Ecobiology and Fisheries of an Economically Important Estuarine Fish, *Sillago sihama* (Forsskal)

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Ecobiology and Fisheries of an Economically Important Estuarine Fish, *Sillago sihama* (Forsskal)

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THIS THESIS IS DEDICATED
TO MY BELOVED
PARENTS AND MY
DAUGHTER, NISREEN

राष्ट्रीय समुद्र विज्ञान संस्थान

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CERTIFICATE

This is to certify that the thesis entitled (Ecobiology and Fisheries of an Economically Important Estuarine Fish, *Sillago sihama* (Forsskal)) submitted by Ebtisam Faisal Saeed Shamsan for the award of the degree of Doctor of Philosophy in Marine Science is based on original studies carried by her under my supervision.

The thesis or any part therefore has not been previously submitted for any degree or diploma in any universities or institutions.

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STATEMENT

As required under the University Ordinance 0.19.8 (vi), I state that the present thesis entitled "**Ecobiology and Fisheries of an Economically Important Estuarine Fish, *Sillago sihama* (Forsskal)**" is my original contribution and the same has not been submitted on any previous occasion. For the best of my knowledge, the present work is the first comprehensive work of its kind from the area mentioned.

The literature related to the problems analyzed and investigated has been appropriately cited. Due acknowledgements has been made wherever facilities and suggestions has been availed of.

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Chapter 1

1.1. Introduction

Aquatic environment provides numerous resources that support human life in different ways. Food remains the basic need of humankind for survival. Organisms of all the trophic levels are available in aquatic system. Those of second, third and higher trophic levels are known to be rich in protein in terms of quantity and quality, particularly in eight essential amino acids required by man (Burton, 1965).That gave the aquatic system its potentiality to produce high quality food which can fulfill human demands. Ever since man realized how to obtain his food from sea, the importance of the seafood increased significantly. Traditionally fish has been cheaper than meat. It is a source of cheap and nutritious food besides being a major foreign exchange earner. Approximately 363,000 million tunes of organic material are produced in the world oceans each year (Weihaupt, 1979) but only a small fraction of this is recovered by way of fisheries for direct consumption.

Out of the entire aquatic organisms that are used as a food, man is interested in the tertiary production (fish in particular) for several reasons. It provides protein-rich food for millions all over the world, which can be expected to help in correcting the state of malnutrition when it is consumed in sufficient quantities. It has other commercial uses as animal food, raw materials (Bond, 1979) and source of drugs and pharmaceuticals (Pandey and Shukla, 2005). Fish oil has more polyunsaturated fatty acids, which is beneficial in lowering the cholesterol level of blood and probably reduces risk of heart attacks (Stansby, 1985). Hence, fish has a very special consideration in human civilization from time immemorial. Growing of the awareness of the fish nutritional values brought it to the fore to be one of the most important diets to be served on table.

The food demands are increasing constantly because the population of the earth is growing all time. To meet this demand we not only required to increase the food production but also use them in a sustainable manner. The exploitation of wild stocks of aquatic organisms has increased considerably to meet this demand. The fish production has reached a plateau and no further increase from coastal water is possible. The scope for increasing fish production from marine sources now lies in the deep sea and far off near fishing areas. As wild populations have been exploited to their maximum limits leading to over fishing, attention naturally turns to fish farming or aquaculture. Such culture can be very efficient way to produce protein food (Odum, 1996).

Fisheries have evolved rather parallel to agricultural farming in the history of human civilization. The world fisheries have changed rapidly during the last few decades. New technology, creation of Exclusive Economic Zone (EEZ) and the1982 UN Convention on the Law Of the Sea (UNCLOS) and other developments have brought about drastic changes in the management of fisheries and resulted in enhanced access and significant expansion of effort and production. From only 20 million tones in 1950s, world fisheries production grew to 112 million tones in 1995 (Ahmed *et al.*, 1999b). Indian total fish production remains around 6.18 million tones (Das and Mishra, 2006)

Modern fisheries science has emerged as a result of a very beautiful blending of many basic sciences such as biology, ecology, hydrology, meteorology, pathology, economics, and commerce and so on. The common aim of these all is the fish as food for humankind (Srivastava, 1999). This need was felt only in the last few decades of the nineteenth century when we started understanding our limitations in the exploitation of the available natural fish resources. Looking at the pressure of unemployment currently faced by many countries of the world, fishery can play an important role in the rural economy. It can provide immense job-potential to unskilled rural population. Indian fisheries sector today provides employment to over 11 million people, directly or indirectly. Another great role is in the alleviation of the suffering of the malnutrition among the poor countries of the world. Fisheries can play important role in this case as well.

A large portion of fish production in the last two decades came from aquaculture and culture based fisheries. According to FAO (1997), in a number of Asian countries such as China, India and Bangladesh, cultured fish and aquatic products represent between 25 % and 50 % of total national fisheries production. Aquaculture today has come to mean controlled production; controls at different levels and various levels or types of manipulation of fin fish in terms of quantity and quality, with reasonable prices. Aquaculture has emerged as a major frontier of fish production in the developing countries both for domestic consumption and for export (Nammalwar, 1997).

Augmentation of finfish production in India can be achieved by carrying out aquaculture on scientific basis such as understanding of the interaction of various environmental parameters in the culture system, influence of water quality: temperature, salinity, pH, dissolved oxygen ...etc on the candidate species cultured, habitat productivity and seed stock availability in space and time. Information on many biological aspects of the fish such as food and feeding habits, reproductive cycle, maturation and spawning period, fecundity, behavior, growth rate, population dynamics and so on are also required to manage wild stock and in the culture practices.

The exploitation of fisheries resources in Indian Ocean has exceeded the natural rate of renewal, resulting in over fishing (Ansari *et al.*, 2006). In such situation, the conservation and fishery management became the need of the hour. Fishery management is the mechanism required to stimulate, control and regulate developmental processes in fisheries; so as to ensure proper and balanced utilization of various fisheries resources and to provide the maximum benefit without causing damage to the resources and the environment (Sivasubramanian, 1999).

Any scientist concerned with any aspect of the fisheries should understand the fish feeding activity, which is the dominant activity of any animal's entire life. This understanding would help to improve the fish catch. Furthermore knowing how food is a limiting factor and how it may be divided among competing animals for culture help to develop a rational method of exploiting a population. Study on the nutritional requirements is also helpful in aquaculture in order to obtain the best growth at least period (Royce, 1972).

Many aspects of the reproductive process are commonly used either to catch the fish easily or to protect them if they are unduly vulnerable. The great fluctuation in the abundance of fish due to failure of the young to survival can also be explained. It is essential and needed prior to the measures adopted for conservation and propagation of a particular fish species. Knowledge of spawning period is one of the most important requisites in fishery management and its rational exploitation. Fecundity of a species is defined as the number of eggs released by an individual fish during a spawning season. It can be used to assess the reproductive potential of a population

Age and growth, length-weight relationship and condition factor data are valuable in describing the general life history of fish. They are more valuable from a management viewpoint, when they can be compared with similar data from other population (Carlander, 1969). Growth varies with sex, age, condition factor and number of biotic and abiotic factors. The main objectives of age and growth determination are, to find out the year classes which support the fishery, to estimate the mortality rate and to assess the recuperation of a given stock under natural or exploited condition (Bal and Rao, 1984).

The biochemical constituents of any fish species denote its nutritional and energy status. The biochemical composition varies from species to species, within the same species and within the same individual. Knowledge on the biochemical changes of the fish is essential for understanding of the metabolism of different populations for providing an estimation of the energy content and for understanding the biochemical circulation of elements.

India is located between 8° 4' and 37° 6' north latitudes, and 67° 7' and 97° 25' east longitudes. It has a coastal line of 8129 km, comprising estuaries, creeks, lagoons, swamps and mudflats, which have to be utilized for culture of different species of shellfish as well as finfish. In addition to prawns the important cultivable species of fin fishes from estuaries, brackish waters, backwaters and coastal waters of India are: Milk fish, *Chanos chanos*, grey mullets, *Mugil cephalus, Liza spp*, pearlspot, *Etroplus suratensis*, Sandwhiting, *S. sihama,* Rabbit fish, *Siganus javus, S.canaliculates,* Sea bream, *Lethrenus spp,* Sea bass, *lates calcarifer*, Grouper, *Epinephelus tauvina*, *E. hexagonatus* and Red snapper, *Lutjanus spp*. Their abundance and seed resource availability in different seasons have been reported (Tampi, 1968).

Goa with about 105 km long coastline has vast resources of marine shellfish and finfish (Ansari, 2004). Fish is a protein rich food and for the state of Goa it assumes special significance as it forms one of the chief components in the diet of 90 % of the population.

The family Sillaginidae (Whitings) is a highly esteemed food fish in Indian waters from Hooghly River in the East Coast to Goa on the West Coast (Sujatha, 1987). Thirty-one species belonging to three genera (two of which are monotypic) are recognized by McKay (1992).Out of these, 11 species of the family Sillaginidae recorded in India. *S. sihama* is the most dominant species. It forms one of the most important fishes, which command high price in different states of the country. It inhabits estuaries and coastal waters, feeding on benthic organisms particularly crustacean and polychaetes. Its euryhalinity, fast growth and seed abundance make it ideal for coastal marine aquaculture (Ramamurthy & Dhulkhed, 1975; Bal and Rao, 1984 and Jayasankar, 1991). Furthermore, in recent past, many experiments conducted in coastal ponds and pens indicated that this species can be successfully cultured along with many suitable species of Milk fish, Grey mullets, Rabbit fishes, Pearl spot and prawns (Ramamurthy *et al.*, 1978; James *et al.*, 1984b; Nammalwar, 1997).

S. sihama is considered a highly esteemed fish in Goa, due to which it commands high price in the local market. Despite its food value, local demand and fast growth no attempt has been made to study the general biology and culture potential of *S. sihama* from Goa waters. For this reason, *S. sihama* was selected to study its ecology, biology and fisheries in one of the main estuaries of Goa (Zuari Estuary).

1.2. Literature review

Several studies have been made on different species of the family Sillaginidae. Celand (1947) studied the economic biology of *S. ciliate* from the Australian waters. Age and rate of growth of *S. sihama* were determined in Japanese waters by Mio (1965). Larvae of *Stolephorus spp.* and *S. sihama* were collected during the survey of larvae and juvenile conducted in the coastal waters off the northwestern of Taiwan by Chan *et al.* (1985). Seasonal changes of the species components of several fishes including *S. sihama* has also been reported from Manpeng Island, Taiwan by Lin *et al.* (2000).

The commonest fish species including *S. sihama* and the ecological role of mangrove ecosystems in the capture fisheries of Gazan creek, Kenya was recorded by Ntiba *et al.* (1993). Study has been conducted by Koike and Inada (1995) in Japan in which the characteristic patterns of different species including *S. sihama* has been reported.

The analysis of bilateral characters of two marine teleosts fishes, *Saurida undosquamis* and *S. sihama* collected from the Red sea coast of Yemen by Al-Hassan and Shwafi, (1997) has been reported. Distribution and variation of eggs and larvae of *S. sihama* were reported from Bohai Sea, China by Jiang *et al.* (1988; 1998). In Philippine *S. sihama* has been reported as the second most abundant species after

Ambassiss spp. (Kato *et al.*, 1996; Kohno *et al.*, 1999). Relative abundance of juveniles and sub adults of finfish including *S. sihama* in Korangi creek, Sindh creek and back waters and Hor lagoon, Pakistan was reported by Ahmed and Abbas (1999); Ahmed *et al.* (1999a); Ayub and Ahmed (2001).

The food and feeding habits and feeding structure of the sandwhiting *S. sihama* and *S. analis* from Srille North Queensland, Australia has been studied by Gunn and Milward (1985). Food and feeding habits and diet of *S. sihama,* a species whose juvenile occur regularly in Kwazulu-Natal estuaries was investigated by Weerts, *et al.* (1997). Reports available on the reproduction of *S. sihama* are very limited. The spawning of *S. sihama* cultivated in the laboratory was studied by Kuma and Nakamura (1978). This record indicated that the spawning may occur in almost equal frequency irrespective of the spawner's size. Total amount of eggs laid during spawning period; however, seems to be dependent primarily on the size or age of female.

Among the family Sillaginidae, *S. sihama* is the most dominant species in Indian waters. This species form minor but commercially important fisheries along the Indian coast. There were no comprehensive studies made on the general biology and fisheries of the Indian sandwhiting *S. sihama* except for few reports.

Estuarine ecosystems are very productive because they receive a high input of nutrients from the river and adjacent land. One of the important roles of the estuaries is to provide a nursery ground for the young ones of many aquatic organisms. A significant contribution has been made on the studies of physico-chemical and biological characteristics of Estuarine ecosystem of Goa, particularly Zuari estuary (Dehadrai, 1970; Bhargava *et al.*, 1973; Parulekar *et al.*, 1973; Parulekar and Dwivedi, 1974; Gangadhara Rao *et al.*, 1976; Rao 1977; Parulekar *et al.*, 1980; De Souza *et al.*, 1981; Qasim and Gupta, 1981; Devassy, 1983; De Souza and Gupta, 1986; Ansari, 1988; Ingole and Parulekar, 1998; Sarma *et al.*, 2001). The Seasonal variability in the physico-chemical features, zooplankton standing stock and faunal composition in the Mandovi-Zuari estuarine system were studied by Padmavati and Goswami (1996). An attempt to evaluate the interrelationship between various parameters and role of salinity and mixing on phytoplankton biomass and diversity, have been made by Krishna Kumari and John (2003).

The earliest attempts on the biology of Indian sandwhiting *S. sihama* around Mandapam and Rameswaram Island in the Gulf of Mannar and Palk Bay have been made by Radhakrishnan (1957). In this study various biological aspects such as relationship of body measurements to total length, age and rate of growth, food and feeding habits, reproduction and fishery and fishing methods were discussed. Krishnamurthy and Kaliyamurthy (1978) have studied the age and growth of *S. sihama* from Pulicat Lake with observations on its biology and fisheries.

Poor information available on the morphometry and interrelationship between various body measurements in *S. sihama.* The available references in this aspect were reported by Radhakrishnan (1957); Jayasankar (1991b) and Reddy (1991).

The importance of the study of food and feeding habits, to evaluate the ecological role of the fish species has been emphasized by many workers. A few scientists have dealt with the aspect of food composition and feeding habits of Sillaginids in India. Chacko *et al.* (1953) studied the food and feeding habits of *S. sihama* in Pulicat Lake; Chacko and Srinivasan (1954) reported the feeding habits of *S. sihama* inhibiting the Vansanthara Estuary. Chacko (1949) gave a detailed account of the food of *S. sihama* in Korapusha Estuary, Kerela. Palekar and Bal (1959) recorded the food and feeding habits of *S. sihama* inhibiting Karwar coast. Krishnamurthy (1969) reported that the polychaete formed the dominant items of the food of *S. sihama* from Pulicat Lake. A study on the food and feeding habits of the sandwhiting *S. sihama* from Nethravati Estuary, by Gowda *et al.* (1988a) revealed that the main food of this fish consists of crustacean and polychaete.

The study of reproductive biology is essential and needed for the conservation and propagation of a particular fish species. There has been very little work carried out on the reproduction of *S. sihama.* Palekar and Bal (1961) studied the maturation, spawning season, fecundity and age at first maturity of the Indian whiting *S. sihama* from Karwar waters. James *et al.* (1976) made an attempt on the induced breeding and cultural possibilities of *S. sihama* in brackish water of south Kanara. Gowda *et al.* (1988b) has been worked on growth, and condition factor and sexuality of *S. sihama*. Studies of the eggs and early larvae of the sandwhiting *S. sihama* from Mandapam waters were carried out by Bensam (1990). Fecundity of sandwhiting *S. sihama* from Karwar waters related to total length, body weight of fish and weight of ovary was recorded by Reddy, (1991). Jayasankar (1991b) reported the Sillaginid fishes of Palk Bay and Gulf of Mannar with an account on the maturation and spawning.

There are only few attempts made on the determination of the age and growth rate of the species *S. sihama* in India. Radhakrishnan (1954; 1957) attempted to study the possibility of age determination by the study of otolith of tropical fish. Reddy and Neelakantan (1992.) used the length frequency distribution to ascertain the age and growth of this species from Karwar waters. Gowda *et al.* (1988b) studied the growth, condition factor and sexuality of Indian sandwhiting *S. sihama*.

Information available on the length-weight relationship and condition factor of *S. sihama* was limited to Gowda *et al.* (1988b), Jayasankar (1991a), and Reddy (1991). Recently, Annappaswamy *et al.* (2004) have studied the length–weight relationship of the sandwhiting *S. sihama* in Mulki estuary, Mangalore.

Studies on the biochemical composition and nutritional values of fishes from Indian waters have been carried out by many workers. The earlier studies dealt with the proximate biochemical composition of several teleost fishes were by Basu and De (1938); Chari (1948); Nair (1965); Parulekar and Pal (1969); Raja (1969). The study was also carried out during recent years (Bumb, 1992; Rattan, 1994; Antony and Antony, 2001; Kosygin *et al.*, 2001; Das and sahu, 2001; Shekhar *et al.* 2004). There is no information available on the biochemical composition of *S. sihama* from Indian coast.

study of the seed resource of the Indian sandwhiting *S. sihama* in Indian waters was made by Mohan (1980); Sudarshan and Neelakantan (1980); James *et al.* (1984a; 1984b); Kaliyamurthy (1984); Ramamohana *et al.* (1984); Bensam (1987) and Reddy and Shanbhogu (1990).

The suitability of *S. sihama* for culture in both brackish and fresh waters was recorded by Ramamurthy and Dhulkhed (1975), James *et al.* (1976), Dhulkhed and Ramamurthy (1977), Kaliyamurthy *et al.* (1977) and Joseph (1980).

Salient features of taxonomic value are mentioned, along with comparison and contrast with similar stages of allied species described. The nature of the seed ground and availability and abundances around Calicut area (Kerela) have been described qualitatively and quantitatively by Lazarus and Nandakumaran (1988). Of cultivable

Planktonic eggs and early larvae of *S. sihama* have been identified from Mandapam, based on similarities in the ripe ovarian eggs as well as other characters; by Bensam (1990).

From the foregoing accounts it is very clear that there is a paucity of detailed information on the fishery biology of *S. sihama* in general and Goa in particular. Considering its food value and preference by the local people a problem on the ecobiology and fisheries of *S. sihama* of Goa coast was selected for the present study. The study was aimed to improve our understanding of different aspects of biological features in relation to ecobiological parameters. Additional information on edibility and nutritional value and culture possibilities of *S. sihama* in the brackish waters of Goa has been discussed.

Objectives:

1. To study the morphometrics relations of an economically important species *S. sihama*.

2. To study the ecobiology of this species, for the fishery management and culture possibilities.

3. To study the dynamics of proximate biochemical constituent to elucidate its nutritional status.

1.3. Systematic Position

Perch- like fishes are all the more typical or less specialized bony fishes. Most have two dorsal fins, which may or may not be united at least basally. The ventral have not more than six rays and are usually, although not always, thoracic. There is no weberian apparatus. All these characters place this fish ....order perciformes

Fins with spines. Ventral thoracic with 1 spine and not more than 5 rays. Caudal rays do not overlap hyporal. Second infraorbital not united with preopercula ....suborder percoidei

Body elongate, slightly compressed, tapering from middle of spinous dorsal fin to head and tail. Head conical, pointed, tapering with small terminal or slightly inferior mouth. Percle with a small, sharp spine; small villiform teeth on roof of mouth restricted to anterior part of vomer, none on palatines. end of upper jaw slides below preorbital bone.

Two separate dorsal fins; the first with 9 to 12 slender spines, its origin above middle of pectoral fin; the second with 1 spine and 16 to 26 rays, its base about twice that of fist dorsal fin. Pelvic fin origin slightly behind origin of pectoral fin; anal fin with two weak spines; caudal emerginate. Lateral line slightly arched; small ctenoid scales covering the body, cheek and top of the head. Swim bladder absent, poorly developed or highly complex, with anterior and lateral extensions and tapered posteriorly to form 1 or 2 slender extensions that project well into the caudal region. Colour is silvery grey or green, sometime with black spots ....family Sillaginidae

1.3.1 Key to genera of Sillaginidáe

Snout and head not depressed; second dorsal spine not elongate; eyes normal, 17 to 22 % of head length; swim bladder present. ....Sillago

Snout and head greatly depressed; second dorsal spine very elongate; eyes small, 3 to 11 of head length, and almost covered by adipose tissue; swim bladder vestigial or absent. ....Sillaginopsis

Snout and head not depressed; second dorsal spine not elongate; eyes normal; swim bladder present, lateral line scales 129-147 ....Sillaginodes

1.3.2 Distinctive characters of species *Sillago sihama*

Body elongated, snout pointed, upper head profile slightly convex; mouth small, terminal, villiform teeth present in jaws and on vomer; 2 or 3 (usually 2) series of scales; on cheeks; a small, sharp spines on opercle; gill rakers on lower limb of first arch 7 to 9. First dorsal fin higher than second and with 11 weak spines; second dorsal fin with 1spine and 20 to 23 soft rays; anal fin with 2 spines and 21 to 23 soft rays. Lateral line with 50 to 84 scales; 5 to 6 scale rows above lateral line and 9 to 10 below the lateral line. Swim bladder with 2 postcoelomic extensions.

Colour: back light brown, lower ventral flanks and belly whitish to silvery, without dark blotches. Both dorsal and caudal fins dusky, other fins pale.

1.3.3. Synonyms

Atherina sihama Forsskal, 1775

Pltycephalus sihama Bloch and Schneide, 1801

Sillago acuta, Cuvier, 1817

Sillago sihama, Ruppell, 1827

Sillago erythraea, Cuvier, 1829

Sillago malabarica, Cantor, 1849

Sillago sihama, Day, 1889

1.3.4. Name

English: Sandwhiting or ladyfish.

Local (Konkani): Muddosi

The name of the species "*sihama*" was given by the Swedish scientist Reter Forsskal, who did the taxonomical classification of animals of Arabia Felix (Happy Arabia, today's Yemen, Red Sea region) and used the Arabic names as a species names. This name was taken from the Arabic word "sahma", which means arrow.

1.3.5. Classification

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Superphylum: Osteichthyes

Class: Actinopterygii

Subclass: Neopterygii

Superorder: Acanthopterygii

Order: Perciformes

Suborder: Percoidei

Family: Sillaginidae

Genus: Sillago

Sepices: sihama

1.4. Geographical Distribution

Most of the species are tropical, but some species occur in the temperate water of southern Australia and northeastern Asia (Hayward, 1997). The family Sillaginidae has a wide distribution in the Indo-Pacific region, (Day, 1889; Weber and Beaufort, 1931; McKay, 1992) reported occurrence of Sillaginids in the western part of the Indo-pacific region from Red sea, to coast of Africa, Madagascar through India to coasts of China, Japan, Philippines, Indo-Australian Archipelago and Australia to

Bougainville islands. Cleland (1947) reported *S. ciliata* from the Australian waters.

S. sihama reported as a new species for Mediterranean, Labenon coast (Mouneimne, 1977) and Turkish water (Guncu *et al.*, 1994). *S. sihama* has also reported in coast of Africa (Ntiba *et al.*, 1993), coasts of China (Jiang *et al.*, 1988), Japan (Koike and Inada, 1995) and Philippines (Kohno *et al.*, 1999). In India all along the west coast and the east coast (Bal and Rao, 1984).

The first report of the family Sillaginidae in Indian waters was by Day (1876). He recorded 3 specie of the genus Sillago: *S. domina*, *S. sihama* and *S. maculata.* Devanesan and Chidambaram (1948) reported the occurrence and distribution of *S. sihama* in Ganjam District, Pukkilipeta, Bimilipatnam, Uppada, Madras, Tranquebar and Sethubavachathram, Mukkur, Pamban and Tuticorin on the east coast and Hosdurg, Cannanore, Valapad, Calicut and Tannur on the west coast of India.

Palekar and Bal (1955) identified 1 more species *S. chandropus* from Karwar waters. Anther species *S. panijus* was recorded from Chilka Lake by Rajan *et al.* (1968). Mckay (1976) reported two genera and five species of the family Sillaginidae from Indian waters with description of a new species *S. vencenti.* Later Dutt and Sujatha (1980) recorded seven species of Sillago from Indian waters: *S. sihama, S. parvisouamis*, *S. macrolepis*, *S. argentifasciata, S. maculata*, *Sillaginopodys chandropus* and *Sillaginopsis panijus*. Dutt and Sujatha (1982; 1984) described two more species of sandwhitings: *S. soringa* and *S. intermedius*.

There are a number of characters involved in the differentiation of species of Sillaginidae. The shape of the swim bladder in the family Sillaginidae is of taxonomic value and help to distinguish between species. As a continuation of occurrence and description reports of family Sillaginidae, Jayasankar (1991) has been reported 6 species of Sillagos: *S. sihama*, *S. indica*, *S. vincenti*, *S. argentifaciata*, *S. soringa* and *Sillaginopodys chandropus* from Palk Bay and Gulf of Mannar. Recently Antony *et al.* (2005) prepared an inventory of the ichthyofauna of mangrove ecosystems. They noted down the guidelines for identification of the families using mangrove ecosystem as breeding, nursery, feeding and hiding grounds. *S. sihama* (family Sillaginidae) was included.

1.5. Habitat

The family Sillaginidae inhabits shallow sandy bottoms of shores and bays, creeks, and estuaries. It is notably absent in oceanic islands and coral reef environments, although at least two species visit sandy reef flats: *S. sihama* and *S. ciliata* (Woodland and Slack Smith, 1963).

Chapter 2

2.1. Introduction

The information on environmental variables that affect the living organisms is vital. Hydrographical studies play an important role in understanding the various biological processes (growth, physiology, reproduction, etc.) and the general productivity of aquatic ecosystem. The physico-chemical parameters such as temperature, salinity, dissolved oxygen and nutrients are of profound biological significance and are used as population indicators (Head, 1985). Temperature and light play an important role in the gonadal gametogenesis, spawning and initiation of gonadal development (Pandey and Shukla, 2005). It is believed that the morphology of fish is determined by genetic and environmental factors, with these being particularly important during the early developmental stages when individuals are influenced by the environment (Ihssen *et al.*, 1981).

Estuaries may have the highest economic values per hectare of many aquatic environments (Costanza *et al.*, 1997). Estuarine ecosystem is characterized by a variable salinity and temperature range of greater than Sea. In tropical estuaries seasonal changes in salinity is obviously greater than in temperature (Blaber, 2000). Tropical and subtropical estuaries represent one of the most exploited ecosystems in the world. In India the estuaries vary from near 30 - 37 psu in salinity of the dry season (Qasim, 2004).The Mandovi - Zuari estuarine systems are tropical estuarine systems and play major role in the economy of Goa.

Some of the early hydrographical and ecobiological work carried out on Goa estuaries are those of Dehadrai (1970); Cherian *et al.* (1975); Gangadhara Rao *et al.* (1976); Rao (1977); De Souza (1977); Qasim and Sen Gupta (1981); De Souza and Sen Gupta (1986); Ansari (1988); Padmavati and Goswami (1996); Ingole and Parulekar (1998). In the view of the importance of environmental condition and hydrographic parameters in fishery biology, it was felt necessary to study the environmental parameters such as temperature, salinity, dissolved oxygen and pH of the study area (Dona Paula in Zuari estuary).

2.2. Study area

Goa is located between 14° 54′ -15° 48′ N latitudes and 73° 41′ - 74° 21′ E longitudes. The two rivers Mandovi and Zuari are joined by Cumbarjua canal, forming major estuarine system in Goa. Mandovi - Zuari estuarine systems are called the lifeline due to their major importance among the seven rivers flowing through the hills and plains of Goa. Geographically, the Mandovi - Zuari River estuaries could be classified as drowned river valley estuaries formed due to the Holocene rise in the sea level (Anon, 1978) .They are rich in living resources such as finfish and shellfish and are used for fishing activity round the year particularly during the monsoon season when the marine fishing is suspended. The minimum wave action in the estuary during monsoon makes it ideal for fishing during this season.

River Zuari originates in the Dighi Ghat in Karnataka. It joins Arabian Sea at its eastern end forming a bay called Mormugao - Dona Paula point after flowing about 67 km (Qasim, 2004). The mouth region of the estuary is rocky and subjected to heavy wave's action while the upstream region is quite narrow (Untawale *et al.*, 1982). Its width at the mouth of the estuary is about 5.9 km while at the upper reaches the width is less than 1 km (Ansari, 1988). The study site was selected at Dona Paula Bay, which is less than two km upstream of the opening of Zuari River in the Arabian Sea (Fig. 2.1.).

2.3. Material and Methods

Water samples were collected from a fixed station at monthly intervals and analyzed for temperature, salinity, dissolved oxygen and pH. The study was carried out during January 2004 - April 2005.

Surface water temperature was measured on the site with a mercury thermometer and the values are expressed as degree centigrade (°C).

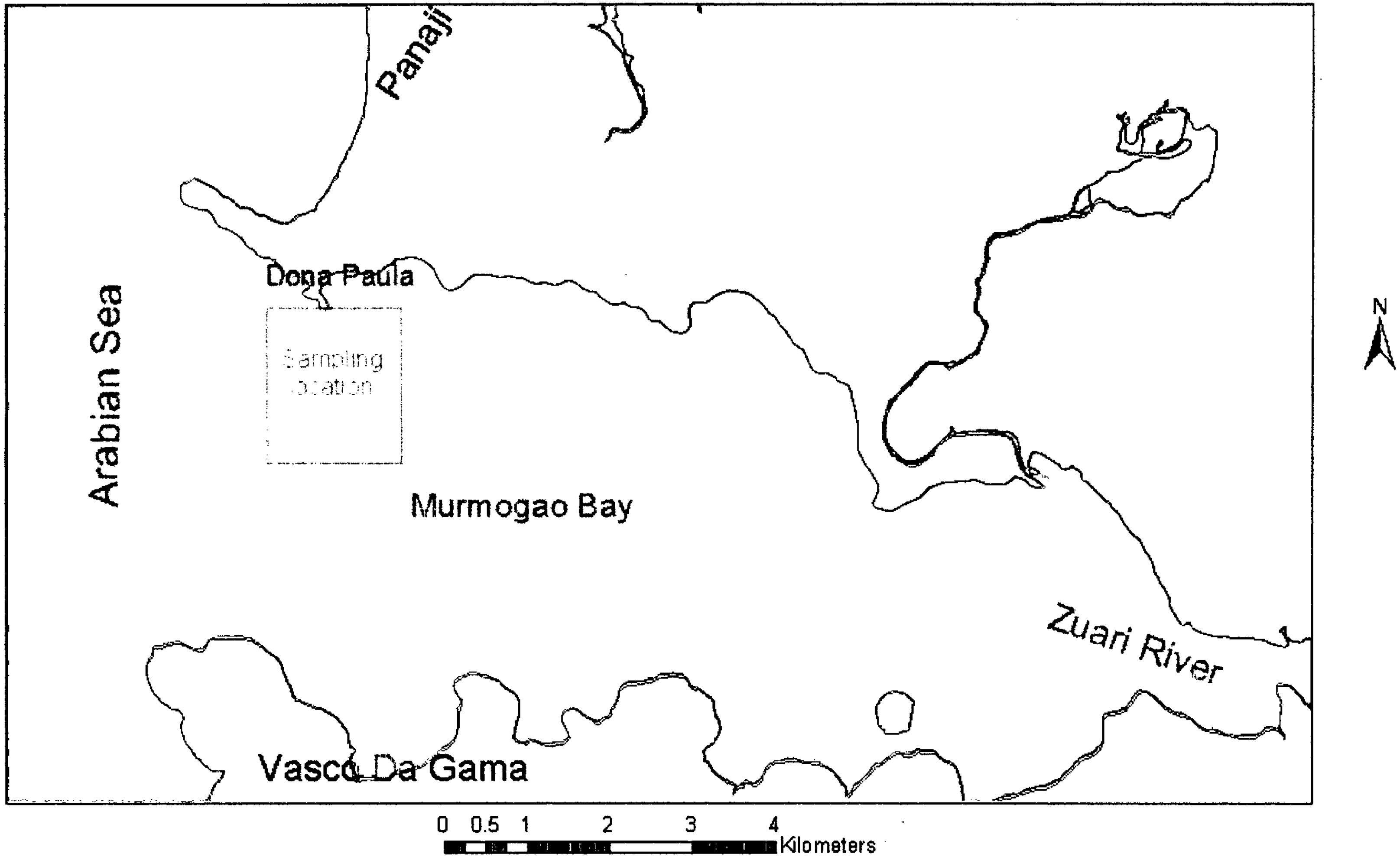


Fig. 2.1. Map showing location of the study area

Salinity was estimated using Guildline "Autosal" model 8400A salinometer (measurement range: 0.005-42 psu), which measure the electrical conductivity ratio of the samples. The readings of the instrument, then converted from conductivity ratio to salinity, which its values are expressed in practical salinity unit (psu).

Dissolved oxygen (DO) was estimated following standard Winkler's method and the values are expressed in mg/ l.

pH was measured immediately in the field using a portable pH meter.

The rainfall and atmospheric temperature data for the period of the study was obtained from the meteorological station, located at NIO.

2.4. Results

Seasonal variability of different environmental features in the estuarine system is chiefly controlled by the regime of the rainfall dividing the year into three distinct seasons: Pre-monsoon (February - May), Monsoon (June - September) and Post-monsoon (October - January). Monthly variations in hydrographical parameters of Zuari estuary (off Dona Paula) are given in Table (2.1.).

Table 2.1. Seasonal variation of different hydrographical and climate parameters during January 2004 – April 2005.

Month/parameter	Water Temperature (°C)	Salinity(PSU)	D.O(mg/l)	pH	Rainfall (mm)	Air Temperature (°C)
Jan	28.2	32.9	3.21	8.34	0	26.1
Feb	29	33	3.52	8.39	0	26.8
Mar	30	34.21	3.91	8.22	0	29.1
Apr	30	34.67	3.98	8.26	0	29.5
May	32.7	34.72	3.91	8.13	164.7	29.5
Jun	26	23.5	4	7.86	601.9	27.8
Jul	24.5	19.01	4.8	7.66	617.3	26.9
Aug	28	26.02	4.54	7.78	476.1	26.8
Sep	29	32.61	3.74	7.8	149.8	26.9
Oct	29	33.1	3.71	8.09	86.2	28.4
Nov	30.5	34.54	3.7	8.09	60	26.7
Dec	26.5	34.64	3.74	8.13	0	26.6
Jan	27	34.63	3.62	7.97	0	25.7
Feb	28	34.76	3.53	7.96	2	26.1
Mar	29.5	35.57	3.45	7.92	0	27.1
Apr	32	35.68	3.92	8.06	45	29.2

2.4.1 Temperature

The surface water temperature fluctuated between 24.5 and 32.7 °C, with an average of 28.8 ± 2.20°C for the whole period. There was a progressive increase in the water temperature from January to May with peak value of 32.7°C in May (Fig. 2.2.). With the onset of monsoon, a sudden fall in temperature (26°C) was observed in June. The temperature remained low during monsoon with minimum value of 24.5 °C in July. A gradual increase in the water temperature noticed at the end of monsoon. The temperature remained high during the rest of the period.

2.4.2 Salinity

Seasonal variation in the salinity of the estuary was very large (Fig. 2.3.). It ranged from 19.01 to 35.7 psu with an average value of 32.09 ± 5.02 psu during the period of observation. In general salinity was high during Pre-monsoon (February - May) reaching 34.7 psu in May. With the onset of monsoon in June the salinity dropped sharply and remained low until August with minimum value of 19.01 psu in July. Salinity began to increase from September onwards.

2.4.3 DO

Seasonal variation in dissolved oxygen concentration during the study period ranged from 3.21 to 4.8 mg/l with an average of 3.83 ± 0.39 mg/l.

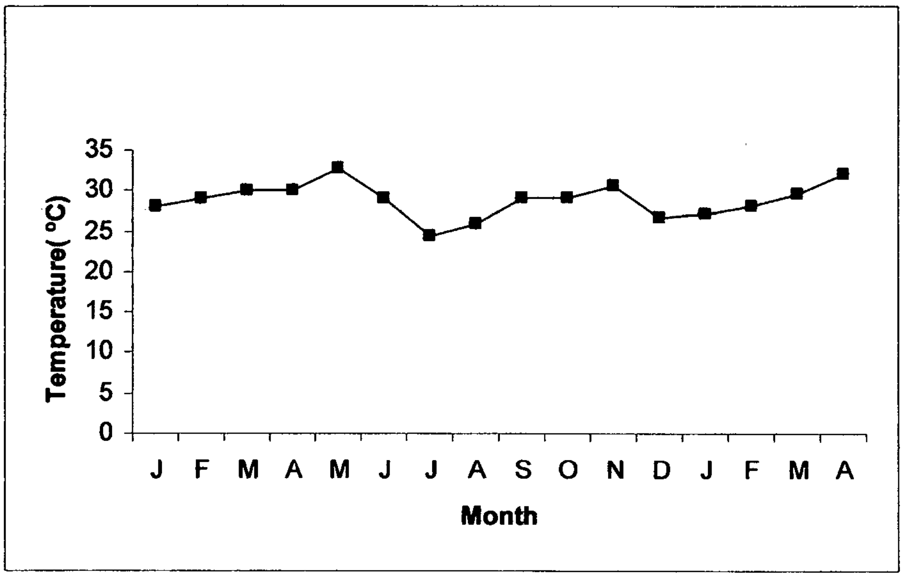


Fig. 2.2. Monthly variation of water Temperature of Zuari Estuary during January 2004 – April 2005.

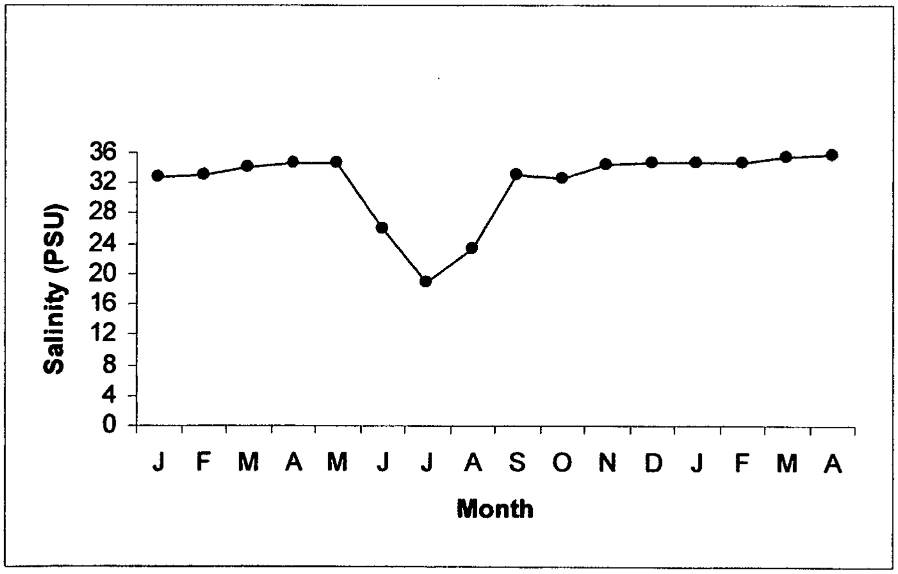


Fig. 2.3. Monthly variation in water dissolved oxygen of Zuari Estuary during January 2004 – April 2005.

The dissolved oxygen values were almost stable (3.21 mg/l - 3.91 mg/l) from January to May (Fig. 2.4.). The values increased during June - August with a maximum value of 4.80 mg/l in July. After September the dissolved oxygen value dropped sharply, reaching to a minimum of 3.74 mg/l. It remained almost stable until December. It is interesting to mention that the annual variation of dissolved oxygen was in contrast with the variation in salinity.

2.4.4 pH

The value varied within a narrow range of 7.66 in July to 8.39 in February with an average value of 8.04 ± 0.21. Comparatively higher pH values were recorded during pre-monsoon (8.13 - 8.39) when the water salinity was high (Fig. 2.5.). During monsoon pH decreased to 7.66 in July coinciding with heaviest rainfall and lowest salinity value. pH began to increase from October onward.

An attempt was made to determine a correlation matrix of the environmental parameters. Positive correlation was observed between temperature and salinity ($r = 0.69$, $P<0.05$) and between pH and salinity ($r = 0.62$, $P<0.05$), while negative correlation was found between dissolved oxygen and salinity ($r = -0.75$, $P<0.05$) and pH and dissolved oxygen ($r = -0.60$, $P<0.05$).

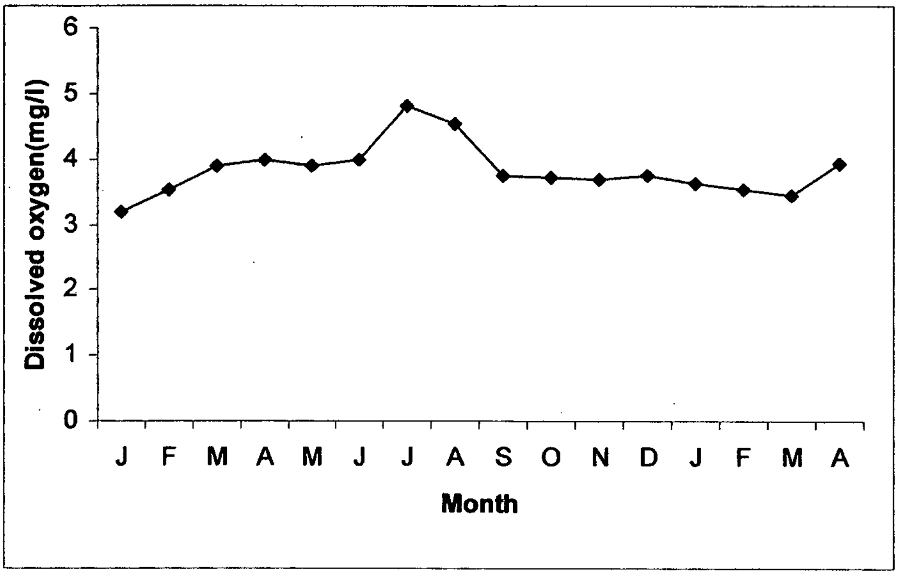


Fig. 2.4. Monthly variation in water dissolved oxygen of Zuari Estuary during January 2004 – April 2005.

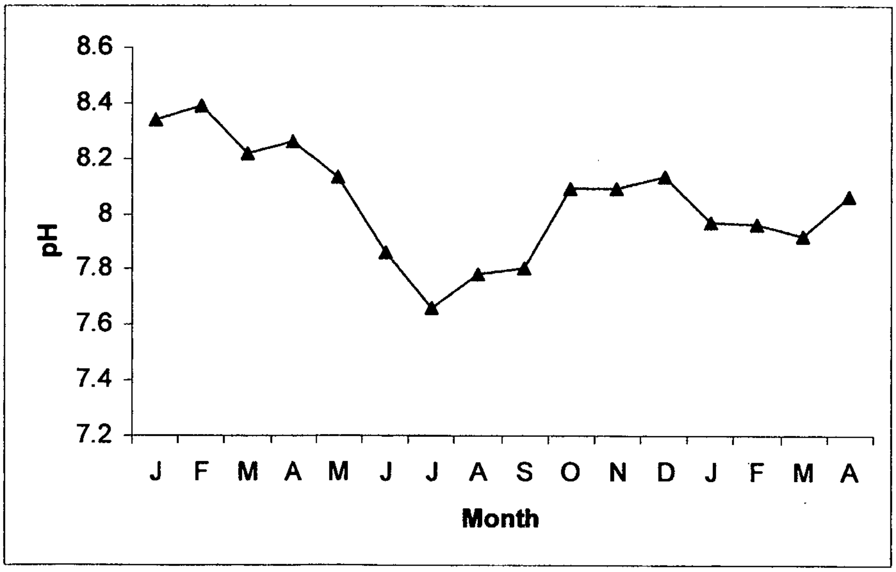


Fig. 2.5. Monthly variation of water pH of Zuari Estuary during January 2004 – April 2005.

Annual variation in atmospheric temperature during the study period is given in Fig. 2.6. The minimum and maximum atmospheric temperature observed during the study period was 25.8 °C and 29.5 °C, in January and April - May, respectively. Goa has an annual rainfall of about 3453 mm, out of which the maximum is recorded during south - west monsoon (June - September). During the present study, the maximum rainfall was received in June - July (Fig. 2.7.). However, some rain showers were observed in May and October - November during the study period. The total average rainfall during January - December 2004 was 2156 mm with an average of 165.85 mm/month, which is below the average. This happened because Goa received less rain in the year 2004 (2156 mm). Effect of rainfall on the water temperature and salinity is shown in Fig. 2.8. The low values of temperature and salinity recorded during monsoon months coincided with heaviest rainfall. This indicates the direct effect of rainfall on the temperature and salinity.

2.5. Discussion

An extensive work on hydrographical parameters of Mandovi - Zuari estuarine system revealed that the physical, chemical and biological features are adapted to a seasonal rhythm, and the changes are dependent upon the monsoon cycle and the amount of freshwater received in this season. Precipitation and land runoff during monsoon

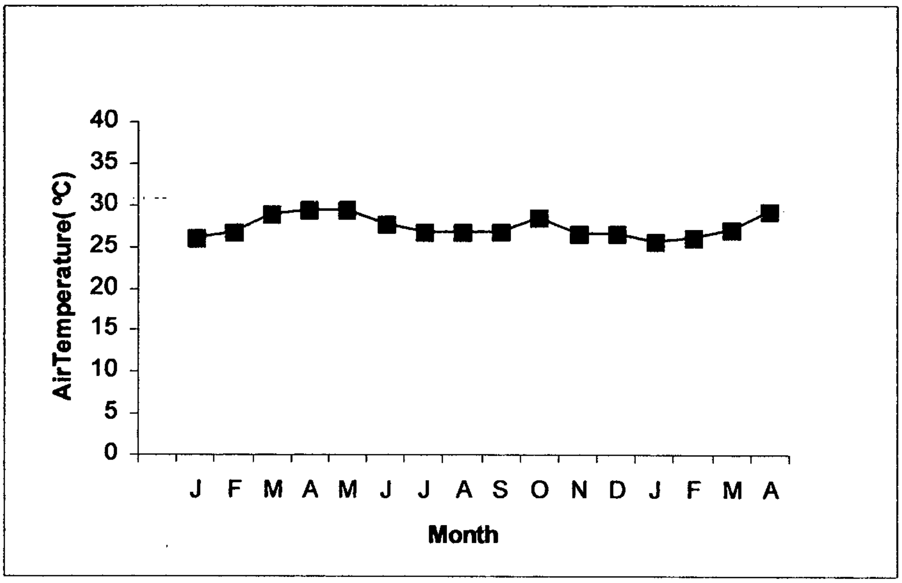


Fig. 2.6. Seasonal changes of Air temperature during January 2004 – April 2005.

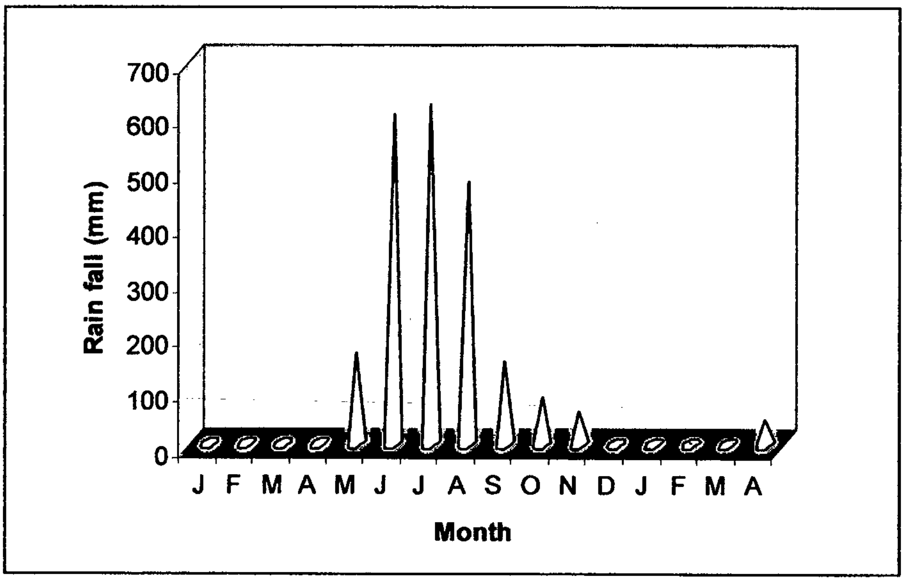


Fig. 2.7. Seasonal changes of rainfall during January 2004 – April 2005 in Goa.

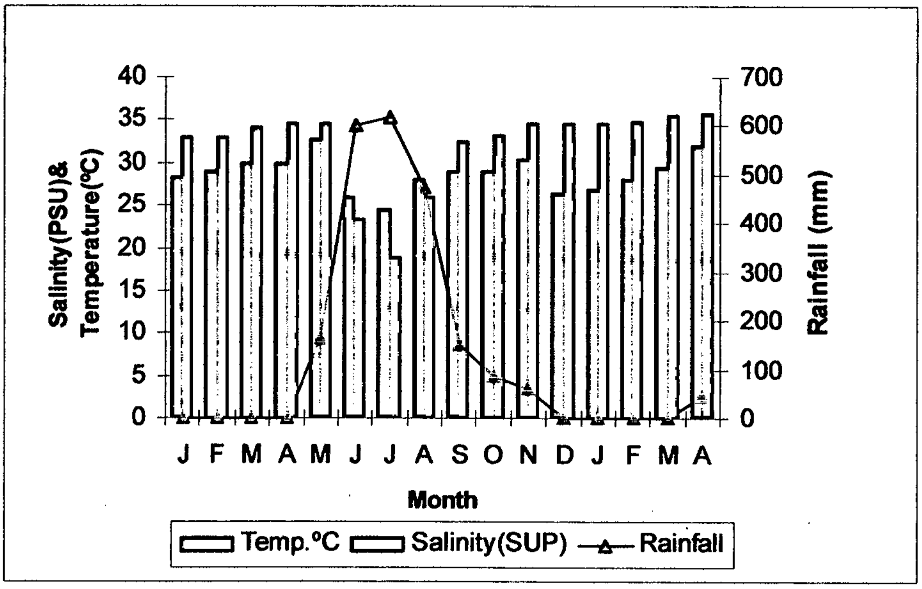


Fig. 2.8. Effect of Rainfall on temperature and salinity of water in Zuari Estuary.

bring about dynamic changes from typically marine to typically brackish water condition in the estuaries (Qasim and Sen Gupta, 1981). That leads to large changes in temperature, salinity, flow pattern, dissolved oxygen and nutrients. The variation in these parameters is known to be lesser in Zuari compared to Mandovi (Padmavati and Goswami, 1996). The changes are however, not significant except in monsoon. Diurnal variations in the physio - chemical conditions in both the Mandovi and Zuari estuaries (Singbal, 1973; 1976) are reported to be controlled by the tides. The water remains well mixed during the pre-monsoon season and gets stratified during monsoon (Qasim and Sen Gupta, 1981). The lighter and less saline water floats at the surface while heavier water remains at the bottom.

In the present study, there was a gradual increase in temperature from January to May and the temperature declined during the monsoon followed by increase in the later months. Similar observations were reported by Dehadrai (1970); Qasim and Sen Gupta (1981) and Rivonker (1991). Temperature was higher during pre-monsoon with peak value in the month of May. This can be attributed to higher atmospheric temperature prevailing at that time. During monsoon the high precipitation and freshwater influx brings cooler water from the upper reaches of the river due to which the water temperature was low at that time.

Salinity is the only factor, which undergoes spectacular change during the year (Qasim, 2004). During the study period, salinity was high and uniform with minute variations except in monsoon. Higher salinity values during major period of study can be attributed to higher temperature. High atmospheric temperature particularly during March - May leads to increasing the rate of evaporation, which in turn increase the salinity values. Heavy clouds reduce the solar radiation decreasing the temperature and rate of evaporation during monsoon. The decrease in salinity can be attributed to heavy precipitation and influx of freshwater from upper reaches of Zuari River during monsoon. Dehadrai and Bhargava (1972) reported similar observations. With the cessation of monsoon, the fresh water flow decreased and the salinity started increasing gradually in the post-monsoon. However, fall in salinity in this estuary during monsoon was not significant. This could be attributed to the thorough mixing of water resulting from intense tidal action and negligible influx of fresh water from the river, which contributes to more saline nature of this area (Cherian *et al.*, 1975). The direct effect of the onset of monsoon can be observed in the rapid decline in salinity of the estuary (Padmavati and Goswami, 1996; Ingole and Parulekar, 1998). Similar trend was reported from Kali estuary in Karwar (Reddy, 1991).

The dissolved oxygen content in the water showed a high level with maximum values in monsoon months. Inverse relationship between dissolved oxygen and salinity was observed from the variation pattern of dissolved oxygen during the study period. Decrease salinity increases the solubility of oxygen in the water, which probably appears to be the main cause for the increase in the concentration of dissolved oxygen during monsoon. This corroborates the earlier findings by Singbal (1976) Qasim and Sen Gupta (1981) and De souza and Sen Gupta (1986). The high values during monsoon are mainly due to precipitation and influx of oxygen rich fresh water from the river runoff.

The pH of the river water is strongly influenced by the terrain through which it flows. The pH of water was slightly alkaline during pre-monsoon and post-monsoon coincided with high values of salinity. Decrease of pH during monsoon can be attributed to decrease in the level of salinity. A positive correlation between the two parameters ($r = 0.62$, $P<0.05$) indicates that pH in brackish water is influenced by the tidal salinity. Low pH values during monsoon have been reported by various workers (Srinivasan and Pillai, 1973; Singbal, 1985; James and Najmuddin, 1986). Low values of pH coincided with high values of dissolved oxygen indicating inverse relationship between pH and dissolved oxygen ($r = -0.060$, $P<0.05$). Such relationship has been observed by Ingole and Parulekar (1998). Nagarajaiah and Gupta (1983) reported similar trend in brackish water pond along Nethravati estuary, Mangalore. pH regulation by soil water interaction besides biological processes in rivers and estuaries was suggested by Sarma *et al.* (2001).

From the above environmental features, the Mandovi-Zuari estuarine system can be classified as a tide-dominated coastal plain estuary (Qasim and Sen Gupta, 1981). During the southwest monsoon the river Zuari gets less diluted than that in Mandovi although the distance of penetration of the salt front during the summer months is almost similar in both rivers. The water is well aerated. The high temperature leads to evaporation and high salinity in summer season.

Chapter 3

3.1. Introduction

Morphological characters that can be seen externally are the ones used to separate the species. Two types of characters e.g.; morphometrics and meristics have been frequently used to delineate stock of fish species (Haddon and Willis, 1995; Murta, 2000; Silva, 2003). Knowledge of fish stock structure is essential for effective fishery management (Grimes *et al.*, 1987; Carvalho and Hauser, 1994; Begg *et al.*, 1999). Despite the advent of biochemical and molecular genetics techniques, studies of morphological variations among populations continue to play an important role in stock identification (Swain and Foote, 1999).

Different populations of the same species living in different geographical areas are known to differ morphologically. Furthermore, the morphometric and meristic characters are highly variables even in the same population depending upon their macro and micro geographical distribution. Morphometric characters have been used to distinguish between stocks of various marine fish population and differentiate intra-specific variations (Ihssen *et al.*, 1981; Winans, 1984).

In early studies (Heincke, 1898), the variation in morphometric characters was assumed to be entirely controlled by genetic factors. However, in recent years the morphology of fish is believed to be determined by genetic and environmental factors (Clayton, 1981; Foote *et al.*, 1989; Robinson and Wilson, 1996; Cabral *et al.*, 2003). Morphometric studies are also commonly used in fishery biology in determining discreteness and relationship among various taxonomic categories.

Some of the earlier studies on the biometrics, morphometrics and racial analyses of the populations of commercially important fishes from Indian waters are those of Pillay (1952; 1957); Radhakrishnan (1957); Rao (1965; 1966) and Vijaya Gupta (1970); Das (1978); Srivastava and Seth (1981) among others.

In spite of the wide distribution of *S. sihama* in Indian waters, the Published work on its morphometry particularly from Goa waters is scanty. Thus, the present investigation on *S. sihama* was made to study the inter relationships of various morphometric characters, their growth rates in relation to total length.

3.2. Material and methods

Sample for the present study were collected during January - April 2005 from Zuari estuary (Dona Paula Bay).Three hundred and fifty specimens of *S. sihama* in the size range 98 - 212 mm total length were examined for body measurements. Specimens with damaged dimension and body parts were left out. Body measurements were recorded carefully in millimeter using a pair of fine dividers. Fifteen morphometric characters have been selected for the study and are shown in Fig. 3.1. They are:

Total length (T.L): The distance from tip of the snout to the tip of longest ray of caudal fin.

Standard length (Std.L): The distance from the tip of the snout to the end of hypural plate.

Head length (H.L): The distance from tip of the snout to the posterior point of opercular membrane.

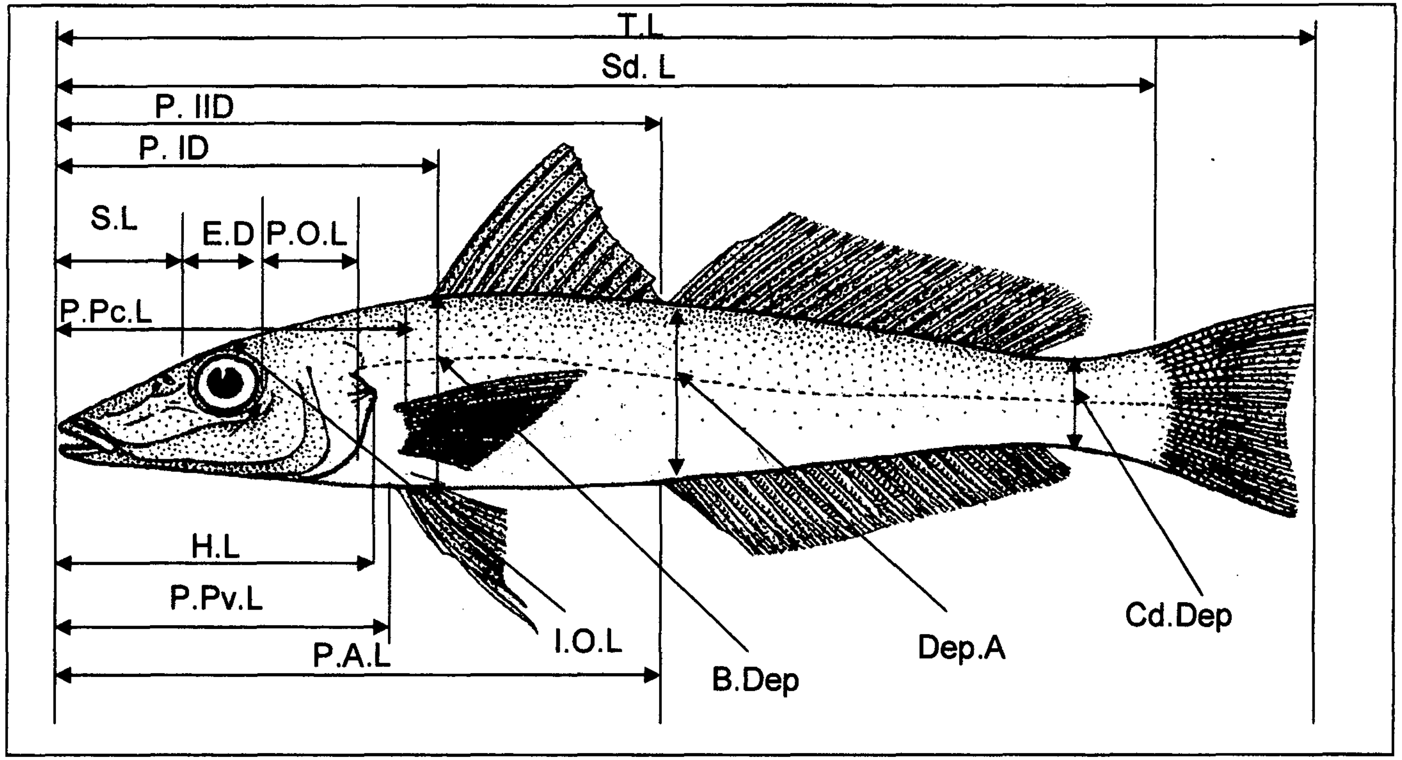
Snout length (S.L): The distance from the tip of upper jaw to the front margin of the orbit.

Post-orbital length (P.O.L): The distance from hind margin of orbit to the tip of opercular membrane.

Inter-orbital length (I.O.L): The distance between the dorsal margins of the eyes.

Eye diameter (E.D): The greatest horizontal distance between the free orbital rims.

Pre-first dorsal fin (P.ID): The distance from the tip of the snout to the anterior end of the first dorsal fin base.



Various morphometric measurement considered in the study:

T.L total length, **Sd.L** standard length, **P.IID** Pre-second dorsal length **P.ID** pre-first dorsal length, **E.D** eye diameter, **P.O.L** post orbital length, **S.L** snout length, **P.Pc.L** pre-pectoral length, **H.L** head length, **P.Pv.L** pre-pelvic length, **P.A.L** pre-anal length, **I.O.L** inter-orbital length, **B.Dep** body depth, **Dep. A** depth through anal, **Cd.Dep** caudal peduncle depth.

Pre-second dorsal fin (P.IID): The distance from the tip of the snout to the anterior end of the second dorsal fin base.

Pre-pectoral length (P.Pc.L): The distance from the tip of the snout to the insertion of the pectoral fin.

Pre-pelvic length (P.Pv.L): The distance from the tip of the snout to the insertion of the pelvic fin.

Pre-anal length (P.A.L): The distance from the tip of the snout to the insertion of the anal fin.

Body depth (B.Dep): The distance from the anterior end of first dorsal fin to the ventral surface of the fish at deepest part.

Depth through anal fin (Dep.A): The distance from the anterior end of second dorsal fin to the anterior end of the anal fin.

Caudal peduncle depth (Cd.Dep): The minimum distance between the dorsal and ventral edges of the caudal peduncle.

In order to determine the degree of association between various variables (measurements) correlation coefficient (r) between these morphometric measurements were calculated. Since there was a significant correlation between total length and the other measurements, all the measurements were taken into consideration to analyze their relationships with total length.

These relationships were estimated on the basis of that "the relationship between two variables may be one of functional dependence of one variable on the other" (Zar, 2006). That is the magnitude of the dependent variable is assumed to be determined by the magnitude of the independent variable. For this purpose, linear regression analysis was applied in case of male and female separately. The statistical relationships between total length and various body characters were derived through the regression equation

$$Y = a + bX$$

Where 'X' denotes total length as independent variable and 'Y' the other dependent variables 'a' and 'b' are constants.

Differences between slopes of various regression lines of male and female were tested using student's t test. The test statistic is:

$$t = \frac{b1 - b2}{Sb1 - b2}$$

Where 'b' is the slope of the regression line, and 'Sb' is the standard error of 'b'.

3.3. Results

The mean with standard error, minimum and maximum values of each measurement were calculated against each character as presented in Table

3.1. The correlation matrix between various measurements is presented in Table 3.2. for male and Table 3.3. for female. Established correlation coefficients (r) showed high positive significant correlation ($P<0.001$) in both the sexes. The highest correlation coefficient was observed between total length and standard length ($r = 0.998$) in male and ($r = 0.999$) in female. The lowest was between postorbital length and eye diameter ($r = 0.889$) in male and ($r = 0.836$) in female.

The results of statistical analysis on morphometric characters are summarized in Table 3.4. Scatter plots of various regression lines are illustrated in Fig. 3.2a-d for male and Fig. 3.3a-d for female. It was found that all the body measurements showed a linear relationship against total length.

Standard length on Total length

The equation derived for standard length and total length was $Y = -6.3971 + 0.9067\ X$ for male and $Y = -5.3507 + 0.8974\ X$ for female. The regression coefficient 'b' was significant ($P<0.001$) with an average rate of 0.91 mm increase standard length in male and 0.90 mm in female per 1 mm of total length. There is a high degree of positive correlation between standard length and total length with 'r' value being 0.998 in male and 0.999 in female.

Table 3.1. Various examined measurements in male and female of *S. sihama*.

Morophometric Measurements	Male			Female		
	Mean ± SE	Minimum	Maximum	Mean ± SE	Minimum	Maximum
T.L	132.75 ± 2.28	98	187	133.45 ± 2.105	101	212
Std.L	113.96 ± 2.07	83	165	114.41 ± 1.89	85	188
H.L	31.39 ± 0.48	24	45	32.22 ± 0.48	25	50
S.L	14.25 ± 0.23	10	21	14.74 ± 0.256	11	24
P.O.L	13.04 ± 0.22	9	18.5	13.46 ± 0.23	10	20
I.O.L	7.21 ± 0.15	5	12	7.26 ± 0.13	5.5	11
E.D	7.50 ± 0.11	6	10	7.63 ± 0.097	6.5	11
P.ID.L	40.30 ± 0.65	28	59	41.31 ± 0.70	29	69
P.IID.L	64.28±1.19	46	92	65.02±1.12	49	107
P.Pc.L	35.84±0.64	26	56	36.59±0.58	27	57
P.Pv.L	37.43±0.62	27	53	38.44±0.62	28	61
P.A.L	63.69±1.17	45	95	64.68±1.16	47	110
Dep.ID	20.30±0.44	13	33	20.61±0.397	16	34
Dep.IID	18.96±0.46	11.5	33	19.20±0.44	13	35
C.PdDep	8.71±0.15	6	13	8.82±0.14	7	13

Table 3.2. Correlation matrix between various morphometric measurements in male of *S. sihama*.

	T.L	Std.L	H.L	S.L	P.O.L	I.O.L	E.D	P.ID.I	P.IID. L	P. Pc.L	P. Pv.L	P.A.L	Dep.ID	Dep.IID	C.PdDep
T.L	1														
Std.L	0.9984	1													
H.L	0.9571	0.9492	1												
S.L	0.9377	0.9277	0.9636	1											
P.O.L	0.9370	0.9275	0.9708	0.9740	1										
I.O.L	0.9589	0.9585	0.9425	0.9296	0.9326	1									
E.D	0.9250	0.9176	0.8999	0.8962	0.8890	0.9140	1								
P.ID.I	0.9562	0.9482	0.9481	0.9431	0.9400	0.9240	0.9131	1							
P.IID. L	0.9940	0.9927	0.9604	0.9489	0.9486	0.9583	0.9274	0.9631	1						
P. Pc.L	0.9629	0.9593	0.9650	0.9552	0.9531	0.9522	0.9049	0.9172	0.9643	1					
P. Pv.L	0.9783	0.9722	0.9734	0.9710	0.9626	0.9521	0.9262	0.9667	0.9809	0.9770	1				
P.A.L	0.9903	0.9892	0.9591	0.9401	0.9423	0.9527	0.9194	0.9526	0.9880	0.9665	0.9765	1			
Dep.ID	0.9583	0.9532	0.9320	0.9366	0.9218	0.9324	0.9236	0.9477	0.9644	0.9242	0.9546	0.9515	1		
Dep.IID	0.9482	0.9406	0.9127	0.9244	0.9139	0.9040	0.9280	0.9370	0.9525	0.9063	0.9453	0.9383	0.9650	1	
C.PdDep	0.9502	0.9462	0.8968	0.9006	0.8953	0.9006	0.9083	0.9059	0.9468	0.9130	0.9308	0.9353	0.9259	0.9380	1

r = 0.314, 105 DF, P < 0.001

Table 3.3. Correlation matrix between various morphometric measurements in female of *S. sihama*.

	T.L	*Std.L*	*H.L*	*S.L*	*P.O.L*	*I.O.L*	*E.D*	*P.ID.I*	*P.IID. L*	*P.Pc.L*	*P. Pv.L*	*P.A.L*	*Dep.ID*	*Dep.IID*	*C.PdDep*
T.L	1														
Std.L	0.9988	1													
H.L	0.9651	0.9600	1												
S.L	0.9555	0.9492	0.9679	1											
P.O.L	0.9338	0.9265	0.9624	0.9666	1										
I.O.L	0.9435	0.9452	0.9233	0.9143	0.9155	1									
E.D	0.9198	0.9229	0.8708	0.8735	0.8358	0.8895	1								
P.ID.I	0.9815	0.9793	0.9703	0.9735	0.9521	0.9439	0.9053	1							
P.IID. L	0.9933	0.9921	0.9672	0.9653	0.9486	0.9481	0.9233	0.9878	1						
P. Pc.L	0.9663	0.9604	0.9798	0.9750	0.9673	0.9373	0.8840	0.9777	0.9718	1					
P. Pv.L	0.9730	0.9694	0.9782	0.9719	0.9652	0.9310	0.8907	0.9742	0.9759	0.9890	1				
P.A.L	0.9888	0.9893	0.9570	0.9558	0.9323	0.9426	0.9234	0.9799	0.9869	0.9685	0.9741	1			
Dep.ID	0.9605	0.9576	0.9154	0.9233	0.8974	0.9276	0.9247	0.9514	0.9620	0.9400	0.9406	0.9531	1		
Dep.IID	0.9601	0.9571	0.9180	0.9266	0.8903	0.8916	0.9167	0.9492	0.9591	0.9360	0.9415	0.9530	0.9697	1	
C.PdDep	0.9270	0.9250	0.8816	0.8749	0.8666	0.8552	0.8799	0.8954	0.9202	0.8851	0.9068	0.9040	0.8963	0.9098	1

$r = 0.324$, 96 DF, $P < 0.001$

Table 3.4. Summery of statistical analysis of male and female of *S. sihama*.

Morphometric measurements (mm)	Male	No= 107		Female	No= 98	
	a	b	r	a	b	r
Std.L	-6.3971	0.9067	0.9984	-5.3507	0.8974	0.9988
H.L	4.6721	0.2013	0.9571	2.9188	0.2196	0.9651
S.L	1.6364	0.095	0.9377	-0.7322	0.1160	0.9555
P.O.L	1.272	0.0887	0.937	0.1737	0.0996	0.9338
I.O.L	-1.3067	0.0642	0.9589	-0.4908	0.0581	0.9435
E.D	1.6411	0.0441	0.925	1.9332	0.0427	0.9198
P.ID.L	3.8917	0.2743	0.9562	-2.1307	0.3255	0.9815
P.IID.L	-4.5639	0.5186	0.994	-5.4519	0.5281	0.9933
P.Pc.L	-5.4735	0.2741	0.9629	0.8617	0.2677	0.9663
P.Pv.L	1.8355	0.2681	0.9783	0.0166	0.2879	0.9730
P.A.L	-3.8179	0.5086	0.9903	-7.7459	0.5428	0.9888
Dep.ID	-4.4198	0.1862	0.9583	-3.6020	0.1815	0.9605
Dep.IID	-6.4499	0.1915	0.9482	-7.6755	0.2014	0.9601
C.PdDep	0.5395	0.0616	0.9502	0.6470	0.0612	0.9270

Head length on Total length

The estimated equation derived was Y = 4.6721 + 0.2013 X for male and Y = 2.9188 + 0.2196 X for female. The regression coefficient 'b' was significant (P <0.001) in both the sexes with an average rate of 0.20 mm increase head length in male and 0.22 mm in female per 1 mm of total length. The degree of association between the two is high and positive with 'r' value being 0.957 in male and 0.965 in female.

Snout length on Total length

The relationship between snout length and total length can be expressed by the equation Y = 1.6364 + 0.095 X and Y = -0.7322 + 0.1160 X for male and female, respectively. From the equation, it is clear that for each 1 mm increase in total length there will be an increase of 0.10 mm and 0.12 mm in snout length in male and female, respectively. The regression coefficient 'b' was significant (P <0.001). There was a high positive correlation between the two variables with 'r' value being 0.938 and 0.956 for male and female, respectively.

Post-orbital length on Total length

The estimated equation was Y = 1.272 + 0.0887 X for male and Y = 0.1737 + 0.0996 X for female. The regression coefficient 'b' was significant (P <0.001) in both the sexes with an average rate of 0.09 mm increase in postorbital length per 1mm of total length in male and 0.10 mm in female. The degree of association between the two is high and positive with 'r' value being 0.937 in male and 0.934 in female.

Inter-orbital length on Total length

The relationship was found to be linear as is clear from the regression equation

Y = -1.3067 + 0.0642 X for male and Y = -0.4908 + 0.0851 X for female, with significant 'b' value (P <0.001) with an average rate of 0.06 mm increase in interorbital length for every 1 mm increase in total length and 0.09 mm in female. Correlation coefficients 'r' was calculated to be 0.959 and 0.944 in male and female, respectively.

Eye diameter on Total length

The linear relationship between the eye diameter and total length may be expressed as Y = 1.6411 + 0.0441 X and Y = 1.9332 + 0.0427 X for male and female, respectively. The 'b' values were found to be significant (P <0.001) in both the male and female with an average rate of 0.04 mm and 0.04 mm increase in eye diameter with 1 mm increase in total length for male and female respectively. High positive correlation was calculated with 'r' values of 0.925 and 0.920 in male and female, respectively.

Pre-first dorsal length on Total length

The estimated equation were Y = 3.8917 + 0.2743 X for male and Y = -2.1307 + 0.3255 X for female. The 'b' values were found to be significant (P <0.001) in both the male and female with an average rate of 0.27 mm and 0.33 mm increase in pre-first dorsal length with 1 mm increase in total length for male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.956 in male and 0.982 in female.

Pre-second dorsal length on Total length

The regression of pre-second dorsal fin on Total length can be written as Y = -4.5639 + 0.5186 X and Y = -5.4519 +0.5281 X with 'r' values of 0.994 and 0.993 for male and female respectively. Significant 'b' values (P <0.001) were found in both the sexes with an average rate of 0.52 mm and increase in pre-second dorsal fin length for every 1 mm increase in total length in male and 0.53 mm in female.

Pre-pectoral length on Total length

The relationship between pre-pectoral fin length and total length was linear with correlation coefficients 'r' 0.963 in male and 0.966 in female. The regression equation can be written as Y = -5.4735 + 0.2741 X and Y = 0.8617 + 0.2677 X in male and female respectively. The regression coefficient 'b' values were found to be significant (P<0.001) with an average rate in both sexes of 0.27 mm increase in pre-pectoral length with 1 mm increase in total length.

Pre-pelvic length on Total length

The estimated equation were Y = 1.8355 + 0.2681 X for male and Y = 0.0166 + 0.2879 X for female. The 'b' values were found to be significant ((P <0.001) in both the male and female with an average rate of 0.27 mm and 0.29 mm increase in pre-pelvic length with 1 mm increase in total length for male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.978 in male and 0.973 in female.

Pre-anal length on Total length

The relationship between pre-anal fin length and total length was linear with correlation coefficients 'r' 0.990 in male and 0.989 in female. The regression equation can be written as Y = -3.8179 + 0.5086 X and Y = -7.7459 + 0.5428 X in male and female, respectively. The regression coefficient 'b' values were found to be significant (P<0.001) with an average rate of 0.51 mm and 0.54 mm increase in pre-anal fin length with 1mm increase in total length.

Depth through first dorsal length on Total length

Depth through first dorsal fin showed a linear relationship with total length, and the estimated equation derived was Y = -4.4198 + 0.1862 X in male and Y = -3.6020 + 0.1815 X in female. The estimated 'b' value was significant ($P<0.001$) in both the sexes. The average rate of the increment of depth through first dorsal length was 0.19 mm and 0.18 mm for every 1 mm increase in total length in male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.958 in male and 0.961 in female.

Depth through second dorsal length on Total length

The linear relationship of depth through second dorsal length with total length is derived by regression equation Y = -6.4499 + 0.1915 X and Y = -7.6755 + 0.2014 X for male and female, respectively. The equation infers that the depth through second dorsal length increases by 0.19 mm in male and 0.20 mm in female for every 1 mm increase in total length. This character showed high positive correlation with total length, with 'r' value 0.948 in male and 0.960 in female.

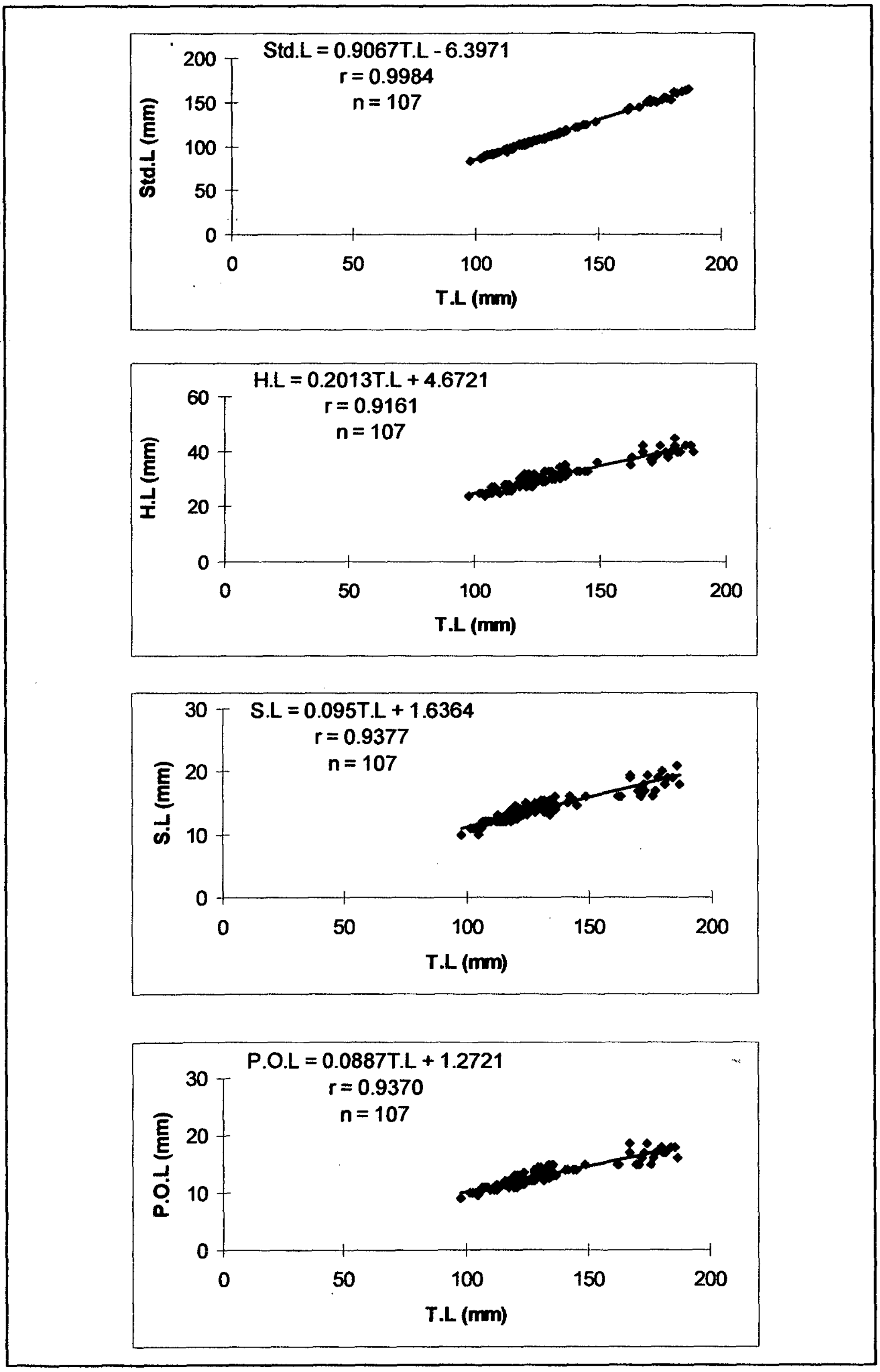


Fig. 3.1a. Relationship between various morphometric measurements and total length in male of *S. sihama*.

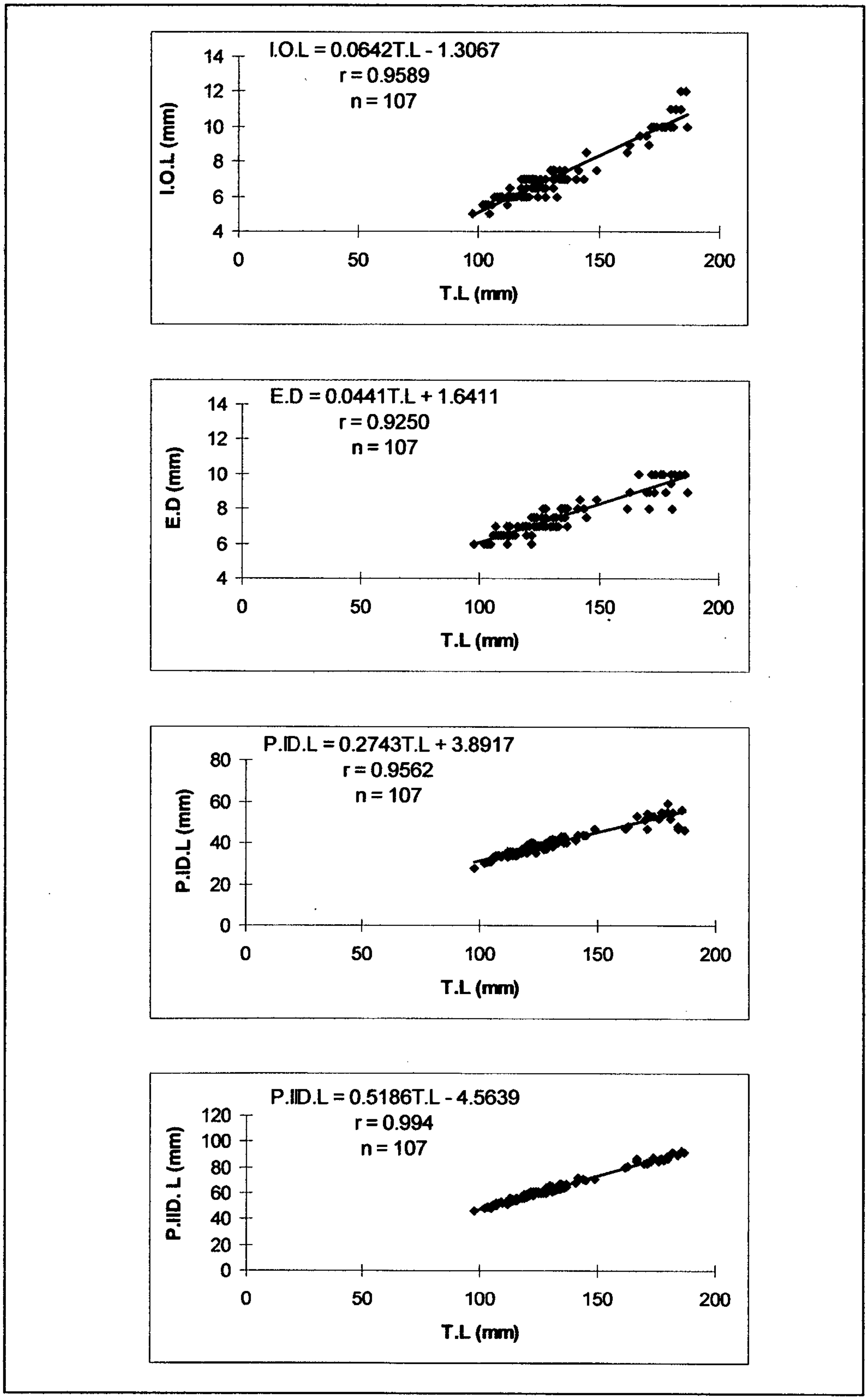


Fig. 3.1b. Relationship between various morphometric measurements and total length in male of *S. sihama*.

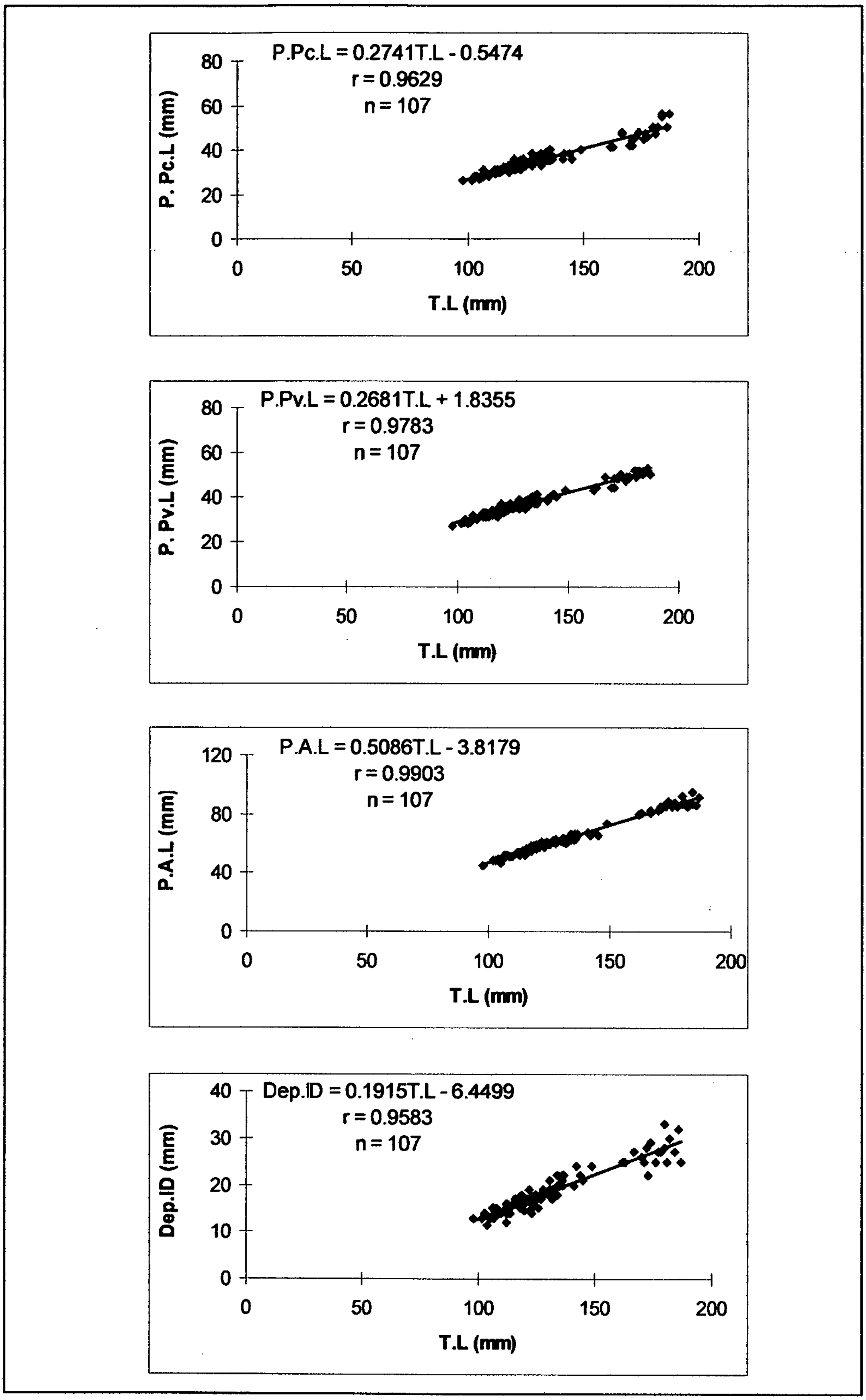


Fig. 3.1c. Relationship between various morphometric measurements and total length in male of *S. sihama*.

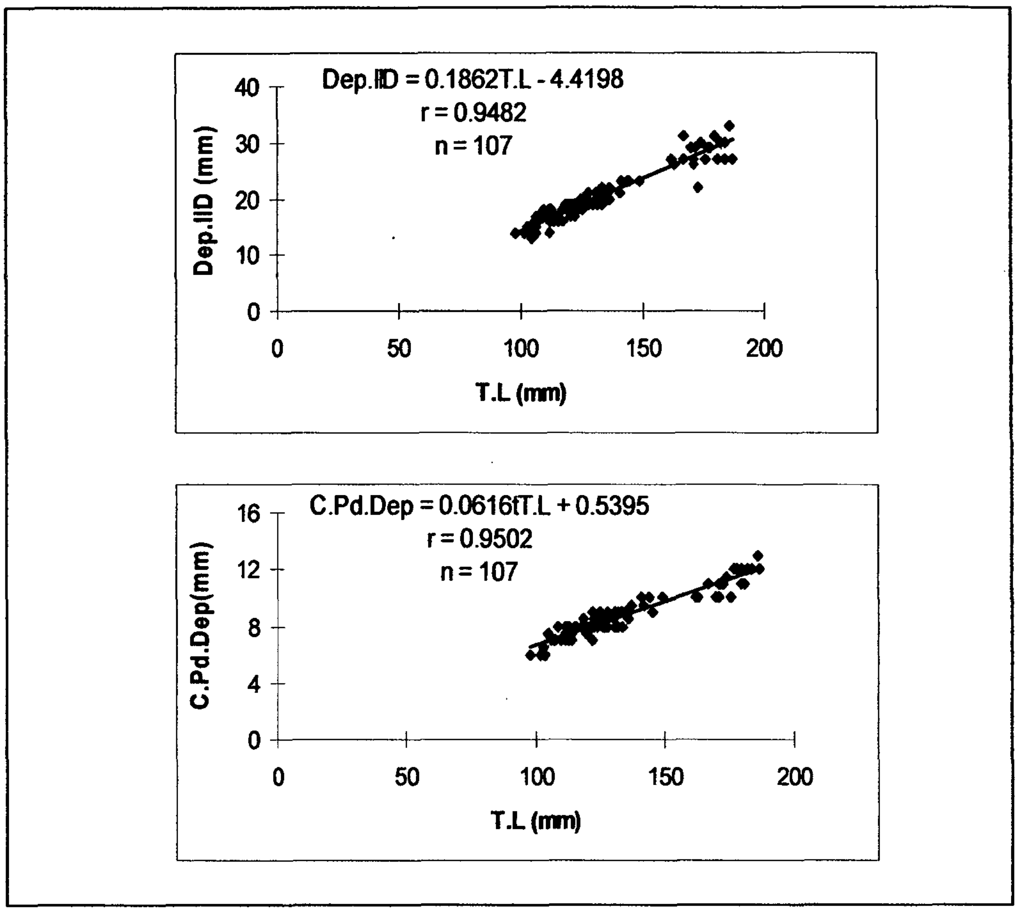


Fig. 3.1d. Relationship between various morphometric measurements and total length in male of *S. sihama*.

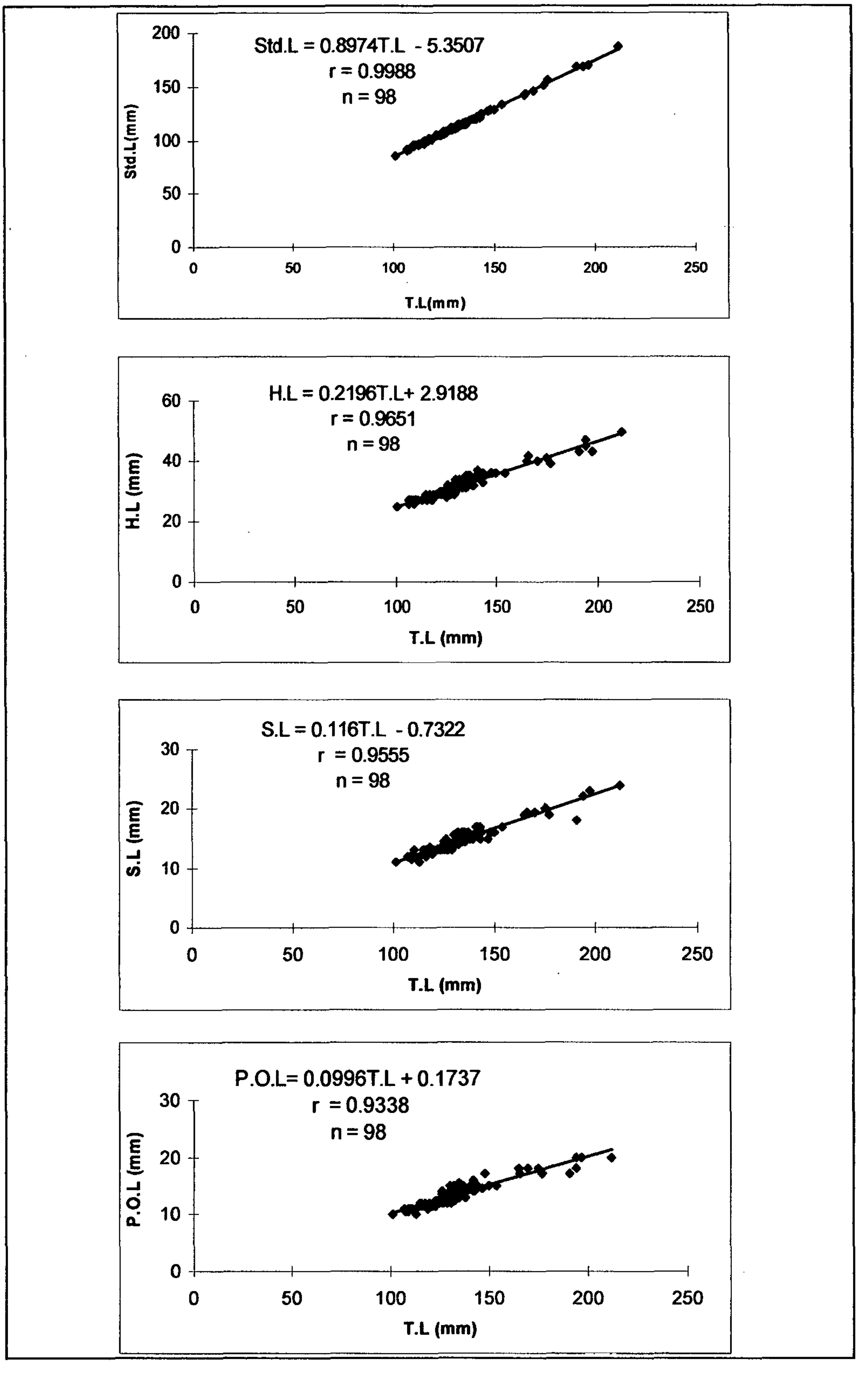


Fig. 3.2a. Relationship between various morphometric measurements and total length in female of *S. sihama.*

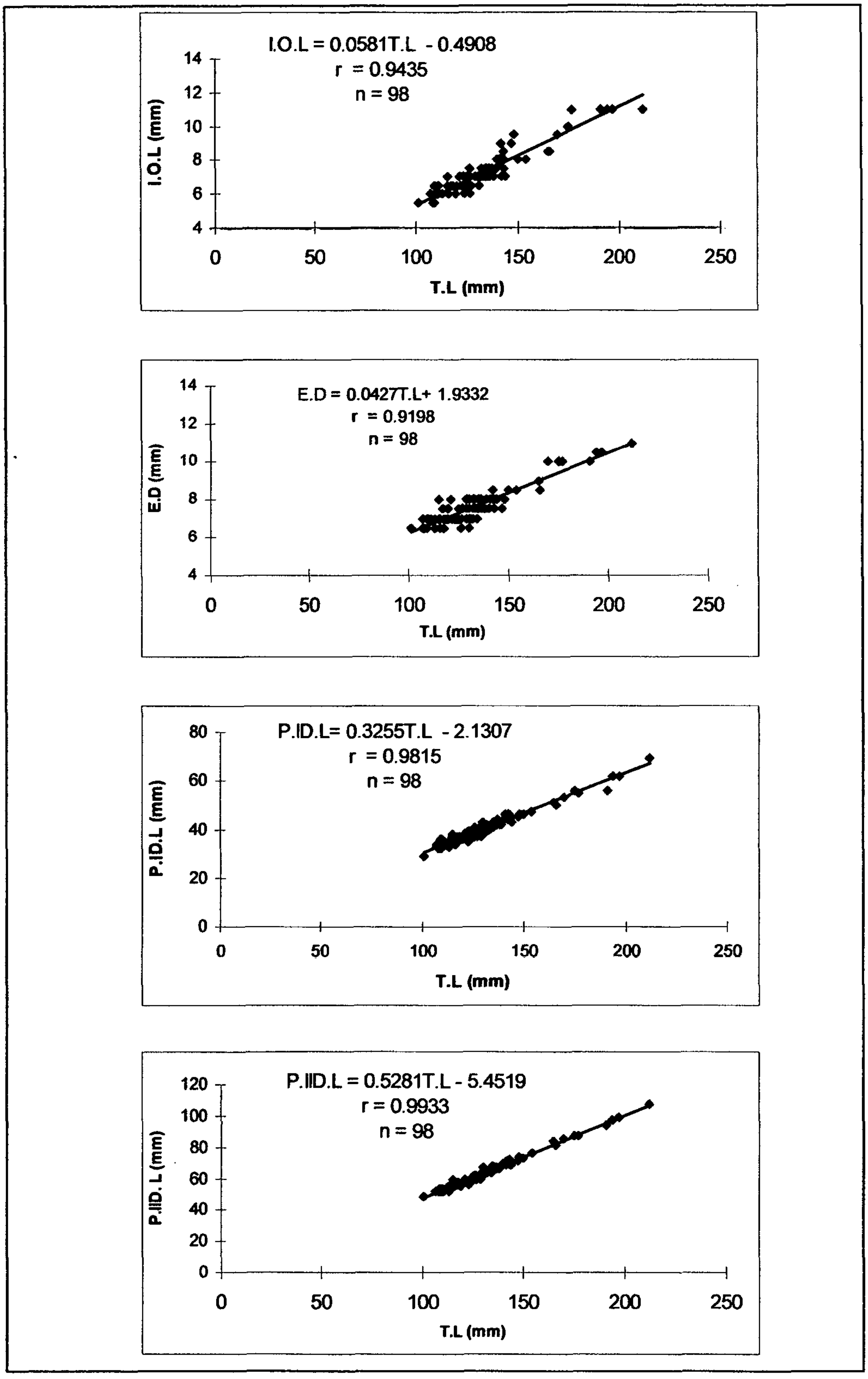


Fig. 3.2b. Relationship between various morphometric measurements and total length in female of *S. sihama*.

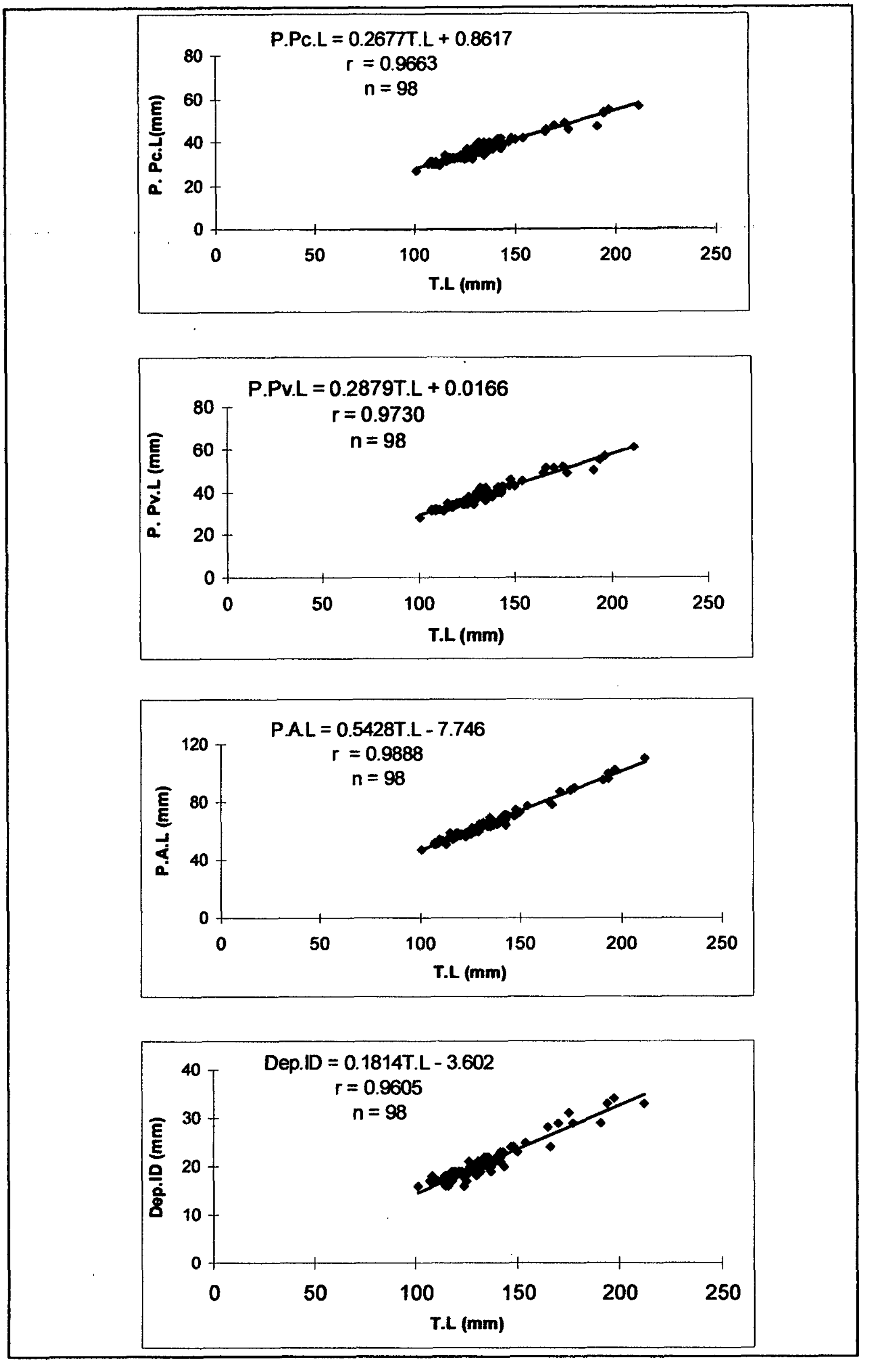


Fig. 3.2c. Relationship between various morphometric measurements and total length in female of *S. sihama*.

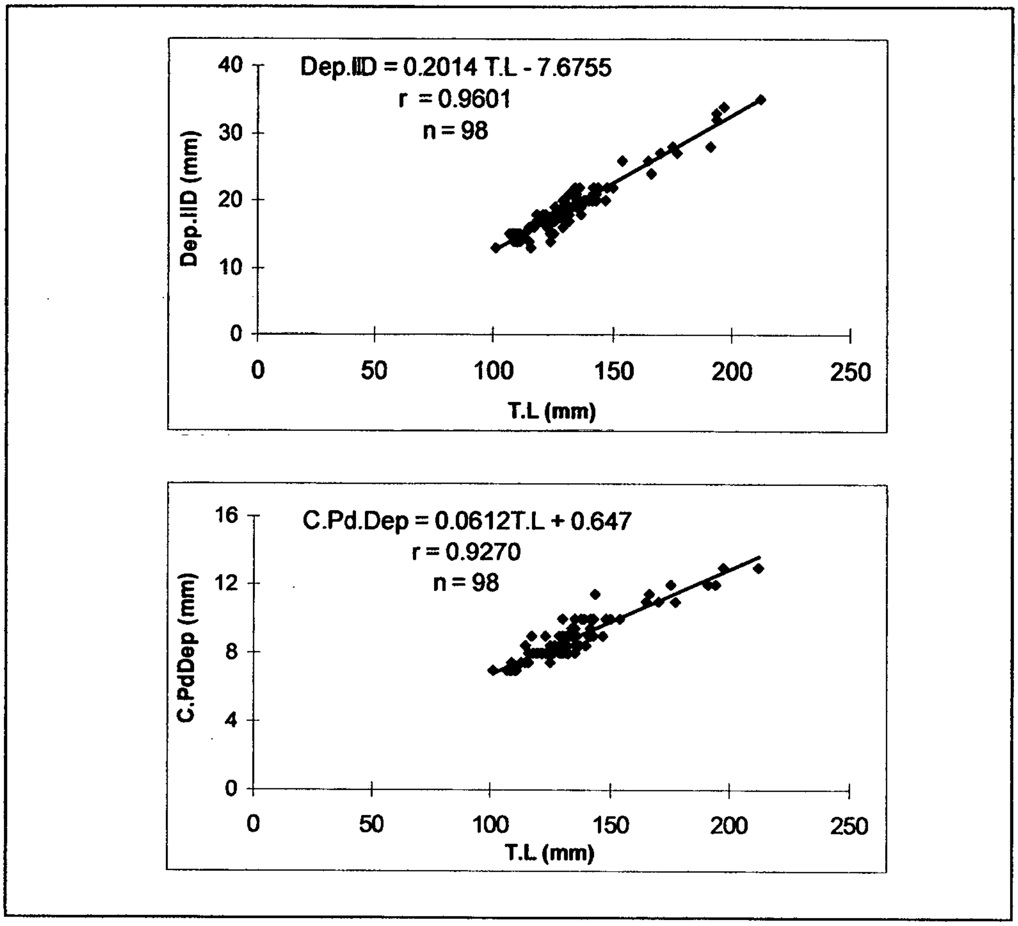


Fig. 3.2d. Relationship between various morphometric measurements and total length in female of *S. sihama*.

Caudal peduncle length on Total length

The regression equation of Caudal peduncle length on total length can be written as Y = 0.5395 + 0.0616 X and Y = 0.6470 + 0.0612 X, for male and female, respectively. The equation suggests linear relationship between the two variables. The significant 'b' value ($P<0.001$) infers that this character increases by 0.06 mm and 0.06 mm per 1 mm increase in total length in male and female, respectively. Like other characters, caudal peduncle length showed high positive correlation with 'r' value 0.950 in male and 00.927 in female.

Difference between slopes of various regression lines of male and female is shown in Table 3.5. Comparisons of slopes estimated in above relationships showed a significant difference between male and female ($P<0.001$) except for the relationship between caudal peduncle depth and total length, which did not show a significant difference between male and female ($P>0.05$).

3.4. Discussion

Analysis of morphometric characters of *S. sihama* in the present study revealed that all the fourteen measure of the external parts of the fish have a linear association with total length. This finding was drawn from the value of correlation coefficient 'r' which was highly significant ($P<0.001$) in all the

Table 3.5. Comparison between regression coefficient in male and female of *S. sinama*.

Morphometric measurements (mm)	Male		Female		t	Significance
	b1	Sb1	b2	Sb2		
Std.L	0.9067	0.0051	0.8974	0.0046	18.574	***
H.L	0.2013	0.0059	0.2196	0.0061	91.509	***
S.L	0.095	0.0034	0.1160	0.0036	104.887	***
P.O.L	0.0887	0.0032	0.0996	0.0039	15.561	***
I.O.L	0.0642	0.0019	0.0581	0.0021	-30.589	***
E.D	0.0441	0.0018	0.0427	0.0019	-14.000	***
P.ID.L	0.2743	0.0082	0.3255	0.0065	-30.118	***
P.IID.L	0.5186	0.0056	0.5281	0.0063	13.571	***
P.Pc.L	0.2741	0.0075	0.2677	0.0073	32.000	***
P.Pv.L	0.2681	0.0056	0.2879	0.0069	15.231	***
P.A.L	0.5086	0.0069	0.5428	0.0084	22.800	***
Dep.ID	0.1862	0.0054	0.1815	0.0053	47.000	***
Dep.IID	0.1915	0.0063	0.2014	0.006	-33.000	***
C.PdDep	0.0616	0.002	0.0612	0.0025	-0.800	NS

(t, 2, 201 DF) = 3.340 *** P<0.001

relationships in male as well as in female. Although the measure related to eye diameter followed by caudal peduncle showed the lower values of correlation coefficient with all the other characters, still their correlation were significant at the same significance level in both the sexes.

Pillay (1952; 1957) has referred to the usefulness of regression analysis and analysis of covariance as employed by Godsil (1948) in racial studied of fishes. The regression analysis in the present study revealed that the growth is taking very similar pattern in both the male and female with slight but significant differences in the values of growth rate of different characters in relation to total length. The highest growth rate is that of standard length 0.9067 mm and 0.8974 mm for male and female respectively, indicating that this character is the fastest growing part of the body. The next faster growing parts are pre-second dorsal length (0.5186 mm), and pre-anal fin length (0.5086 mm). In female the pre-anal fin length is the next most important character (0.5428 mm) followed by pre-second dorsal length (0.5281 mm). Eye diameter was the slowest growing character with growth rate of 0.0441 and 0.0427 in male and female, respectively.

The results of the present study corroborate the findings by Radhakrishnan (1957). He found maximum rate of growth in standard length followed by the body length. The depth of the body through pectoral fin base has the minimum rate of growth in *S. sihama* from Gulf of Mannar and Palk Bay. Similarly, Reddy (1991) studied the relationship between total length and fourteen morphometric characters in *S. sihama* from Karwar waters. He reported that all the morphometric measurement showed a significant association with total length. Moreover, of the fourteen selected characters the maximum rate of growth was noticed in standard length, followed by pre-anal length and snout to second (pre-second dorsal length). The slowest growth was seen in eye diameter followed by, interorbital and postorbital length. These findings are in agreement with the results of the present study.

The most variables ratios are those connected with the eye, and the least variable was the value of body length on total length in five common species of Cynoglossus (Seshappa, 1970). Ramanthan *et al.* (1977) studied the relationship between various body measurements using standard length as a basic character against which regression curves of other variables were drawn. They reported that the total length was the fastest growing character, next to it is the head length and the lowest rate of growth was of the eye diameter comparing to all others. Sharp *et al.* (1978) reported that eye diameter and snout length were the two most important variables, and body length contributed the fourth most important variable. Misra and Carscadden (1978) found that body depth and snout length were the most important variables.

In the present study, linear relationships observed among various parts of body measurements suggest that the growth in length of the fish was isometric. This agrees with findings of Radhakrishnan (1957); Misra and

Choudary (1982); Reddy (1991) and Bumb (1992). On the other hand, Marr (1955) reported non-linear relationship between various body measurements in teleost fishes. Such differences in ratio or proportional growth of body parts may be due to environmental conditions or due to genetic differences (Krumholz and Cavanah, 1968; Das Gupta, 1991).

The simple method for testing hypotheses about equality of two population's regression coefficient 'b' involves the use of student's t test. This test was applied for finding the differences between growth rate of various morphometric characters of male and female. The test showed significant differences between male and female in all the characters except in caudal peduncle depth (Table 3.5).

This study suggests that male and female of *S. sihama* have similar values of growth rate of the examined measurements. Nevertheless, they followed different pattern of growth.

Chapter 4

4.1. Introduction

Fish like any other organisms depends on the energy received from its food to perform its biological processes such as growth, development, reproduction and other metabolic activities. Hence, food is the basis to all function of an individual fish as well as the population. Feeding is one of the main concerns of daily living in fishes, in which fish devotes large portion of its energy searching for food. Detailed data on the diet, feeding ecology and trophic inter-relationship of fishes is fundamental for better understanding of fish life history including growth, breeding, migration (Bal and Rao, 1984) and the functional role of the different fishes within aquatic ecosystem (Blaber, 1997; Wootton, 1998; Hajisamae *et al.*, 2003).

Study of the diet and trophic ecology of the commercially important estuarine fish is also greatly beneficial for fisheries management and conservation (Blaber, 2000). Without knowledge of the food requirements, feeding behaviour pattern, and predator - prey relationships, it is not possible to understand the predicted changes that might result from any natural or anthropogenic intervention.

The same species occupy different habitat may feed on different types of food (Hyndes *et al.*, 1997) or even in the same habitat the diet may vary at different times. The diets of most fish species changes with age and growth. The time and extent of changes in food and feeding habits varies from species to species and often with changes in the life style or habitat (Blaber, 2000).

An extensive work has been done on the food and feeding ecology of many fish species all over the world. Some of the outstanding works in this field are those of Hynes (1950); Maclean (1971); Hyslop (1980); Gunn and Milward (1985); Motta (1988; 1995); Hyndes *et al.* (1997); Shaheen *et al.* (2001) and Hajisamae *et al.* (2003; 2004; 2006).

A number of scientists have also studied various aspects of food and feeding habits of several fish species from Indian waters (Chacko, 1949; Qasim, 1957a; 1957b; Qasim, 1972; Gowda *et al.*, 1988a; Chandru *et al.*, 1988; Reddy, 1991; Serajuddin and Mustafa, 1994; Serajuddin *et al.*, 1998; Rao and Rao, 2002; Serajuddin and Ali, 2005). The present chapter deals with food and feeding of *S. sihama.*

4. 2. Material and methods

Fish samples for the present study were obtained by regular fortnightly sampling from Zuari Estuary during January 2004 to April 2005. The specimens were properly cleaned in the laboratory and the total length, total weight, sex stage of maturity and degree of stomach fullness were recorded. The stomachs were visually classified as gorged, full, ¾ full, ½ full, ¼ full, trace and empty depending upon the degree of fullness and the amount of food contained in them. The stomachs were dissected out and the food was preserved in 5% formaldehyde for further study. The average intensity of feeding was evaluated by points method. Points were assigned as 1.25, 1.0, 0.75, 0.5, 0.25, 0.10 and 0 for gorged, full, ¾ full, ½ full, ¼ full, trace and empty stomachs, respectively (Bapal and Bal, 1950). Fishes with stomachs gorged, full, ¾ full were considered as active feeders, ½ full as moderate feeders and ¼ full and trace full stomachs as poor feeders following the method used by Rao and Rao (2002).

Generally, the stomach is considered for evaluating the food and feeding, however in case of herbivorous fish the alimentary canal is very long and retain most of the food for prolonged period. In the present species the alimentary canal is short; hence the stomach was only considered in this study.

The methods employed for the quantitative and qualitative analysis of stomach contents do not give a complete picture of dietary importance when they singly used. However, when used in combination, such as numerical or frequency occurrence and volumetric or gravimetric, better results are achieved (Srivastava, 1999).

The preliminary analysis of samples revealed that the organisms contained in the stomach reached advanced stage of digestion and was difficult to segregate of different categories of food items, thus it was not possible to adopt any of numerical, gravimetric and volumetric methods separately. Hence, the subjective method of point system (Swynnerton and Worthington, 1940; Hynes, 1950) was followed. The different food categories were assessed by eye and awarded points proportional to its estimated contribution to stomach content and listed under very common, common, frequent, rare and absent. Here consideration was given to the size of the organism. The sum of the points obtained by each food item, for each month, was then converted to percentages, to show the percentage composition of the items, for different months.

Food in relation to size of the fish was also studied by tabulating percentage composition of varying food items against the size groups. Feeding habits were inferred from the nature of food organisms consumed by the fish of various sizes in different months.

Gastro somatic index (Ga.S.I.) was calculated using the method adopted by Desai (1970). For this purpose, the following formula was employed:

$$Ga.S.I. = \frac{weight\ of\ the\ stomach\ contents}{weight\ of\ the\ fish} \times 100$$

4.3. Results

The various food items recorded from the stomach of *S. sihama* during the study period are presented in Fig. 4.1. Generally, the food items found in the examined stomachs were grouped into eight categories namely Crustacean, polychaetes, fish, nematodes, mollusca, sand grains, digested matter, and miscellaneous. The first two groups e.g. Crustacean and polychaetes form the major food items in the stomach, constituting 28.07 % and 22.33 %, respectively of total food composition. However, digested matter was also found in large quantities (19.91 %) followed by sand grains (11.83 %), fish (5.63%), mollusca (3.59 %) and nematodes (2.49 %). The food items found in negligible quantities were collectively put in miscellaneous items. This group included Sipunculid, phytoplankton, filamentous algae, foraminifera, and unidentified matter and occupied about 6.15 % of the food contents.

4.3.1. Monthly variation of food composition

The variation in percentage composition and percentage occurrence of food items in *S. sihama* during different months are shown in Table 4.1., Fig. 4.2. and Table 4.2., respectively. It revealed that percentage composition of different food items varied in different months according to their availability and preference of fish.

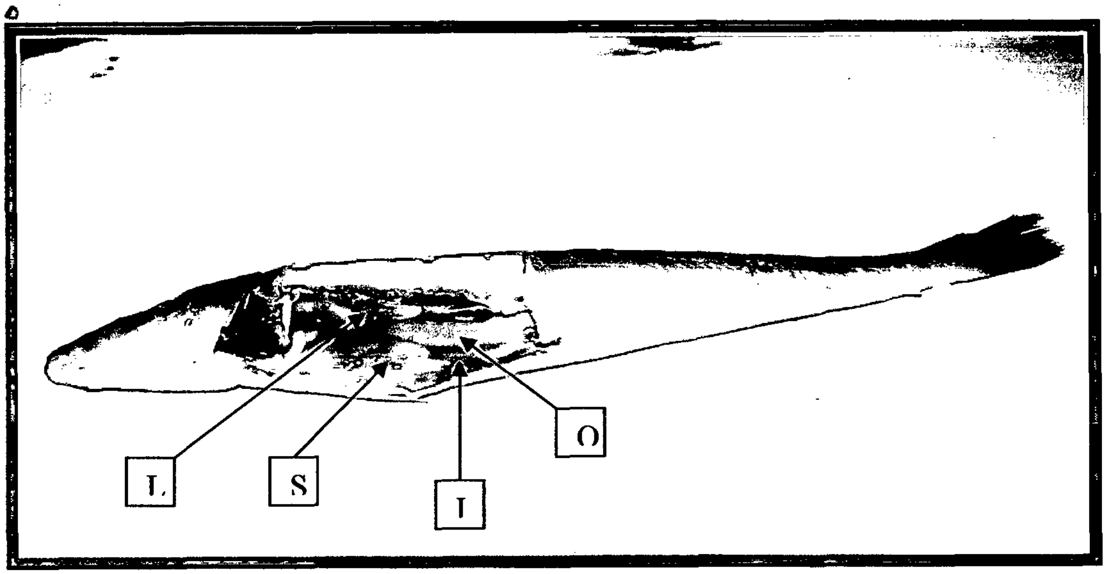


Plate 4.1. Digestive system and Gonads in female of *S. sihama.*
L: Liver; S: Stomach; I: Intestine; O: Ovary.

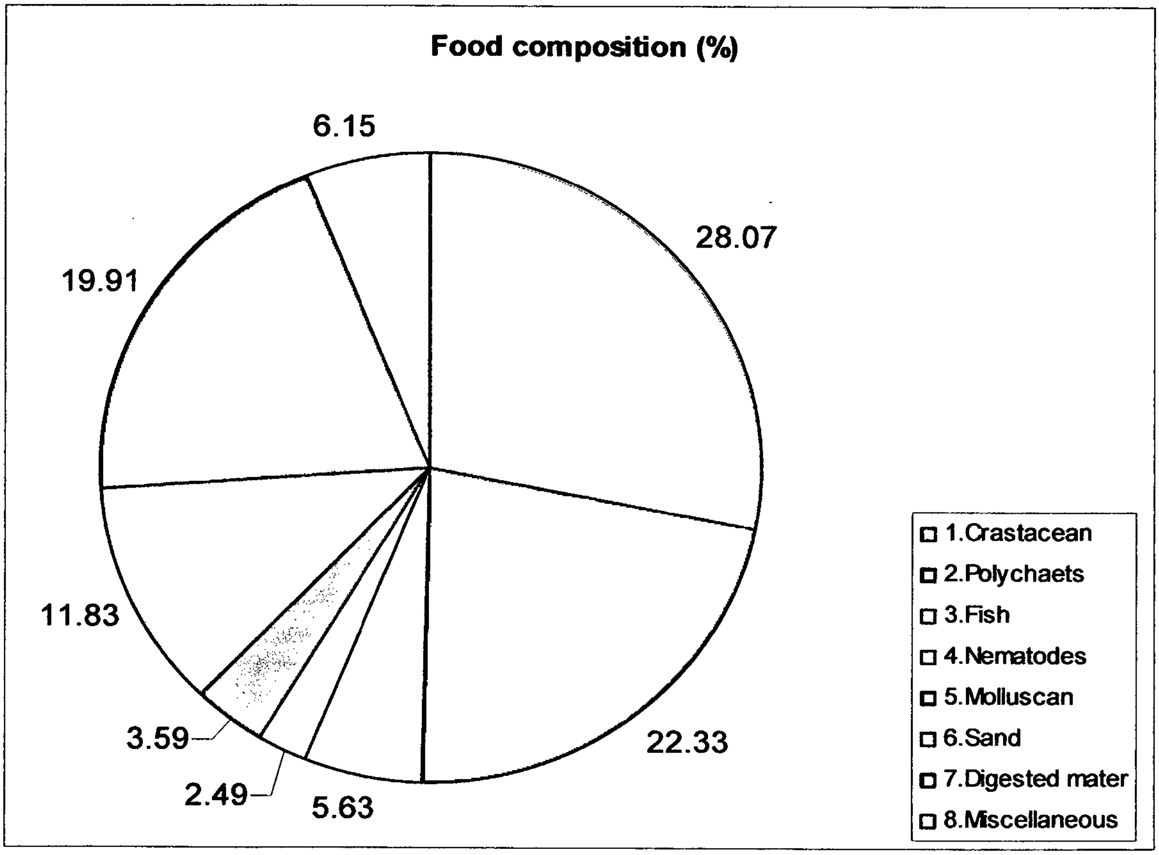


Fig. 4.1. The average percentage of main food items in the stomach of *S. sihama*.

Table 4.1. Various food items in the stomach of *S.sihama* during January 2004 - April2005.

Food item/size group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1.Crustacean																
Crab	5.12	5.41		3.42	12.50		6.67	4.45	8.77			10.13			3.48	
Tannaids	16.17	1.16	3.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36	6.19	9.94	5.72	0.74	0.00
Isopods	13.07	3.11	10.68	0.77	0.76	0.00	0.00	0.00	5.00	0.00	6.32	4.13	8.05	7.61	3.96	0.00
Amphipods	1.63	0.00	0.00	0.31	0.00	0.00	0.00	0.00	2.86	4.72	0.00	0.00	0.00	0.00	0.00	0.00
Small prawn(Penaeid)	0.00	0.00	0.00	0.00	0.00	2.56	1.33	0.00	0.00	0.00	0.00	0.00	4.99	0.00	0.00	0.00
Shrimps	10.58	0.00	13.15	15.19	35.01	1.67	3.33	1.67	0.00	0.00	3.36	2.27	13.78	22.35	0.00	0.00
Mysids	8.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	0.91	0.00	0.00	0.00	1.92
Copepods	0.00	0.00	1.93	0.00	1.50	2.42	0.00	4.76	0.00	0.83	0.00	2.48	0.00	0.00	0.28	4.81
Lucifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.31	0.00	0.00	0.18	0.00
Egg and Larva	0.33	1.21	0.90	0.00	1.87	0.51	0.50	2.72	2.50	6.72	0.51	15.60	0.35	0.07	0.00	1.67
Unident. crustacean	1.05	3.91	4.99	21.28	0.00	0.20	4.67	0.00	6.43	0.42	8.04	0.00	2.30	5.95	3.61	3.57
2.Polychaetes																
Glycera spp	0.00	0.00	2.48	0.70	0.00	0.00	4.67	0.00	0.00	6.55	0.00	0.00	0.00	0.00	5.36	0.00
Scoloplus spp	0.00	7.27	3.31	6.32	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	4.02	4.55	0.00	0.00
Eunicidae family	0.00	0.00	3.64	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00
Spionidae	0.00	0.00	0.00	0.46	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.64	0.00
Poecilochaetus	5.55	11.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.65	4.40	15.55
Nereid	10.49	0.00	0.00	8.40	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	5.50	0.00	2.12	0.00
Unidentifiedpolychaets	2.57	17.07	21.19	12.85	10.27	20.27	12.61	0.00	13.52	4.61	32.63	18.36	17.42	15.15	11.56	10.36
3. Fish																
Fish larvae	0.00	11.32	0.00	0.17	0.00	0.00	9.33	0.00	3.13	0.00	0.00	0.00	7.00	4.65	14.39	0.00
Fish scales	1.16	0.00	1.89	5.40	2.49	0.07	1.00	8.01	5.59	1.22	0.00	2.12	0.50	0.50	0.19	0.00
Fish eggs	0.98	0.00	2.49	1.83	1.66	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.81	0.00	0.00	0.00
4.Nematodes	3.20	0.49	0.00	0.00	1.88	3.76	1.33	0.60	0.00	12.90	10.85	0.00	0.69	1.58	0.32	2.20
5.Molluscan	0.00	2.50	0.76	1.93	3.89	2.36	6.72	0.00	2.01	8.57	11.36	0.00	5.17	0.00	12.16	0.00
6.Sand	8.05	15.71	9.23	3.00	7.90	14.90	13.95	23.83	16.86	7.03	14.61	13.38	8.51	9.91	6.83	15.51
7. Digested matter	11.03	19.00	10.00	10.77	10.40	34.64	18.65	41.19	25.04	40.17	9.07	18.45	8.44	11.04	8.14	42.51
8.Miscellaneous																
Sipunculid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.83	0.00
hytoplankton	0.06	0.08	0.18	0.85	1.21	0.13	0.00	0.76	1.94	0.08	0.21	0.20	0.00	0.10	0.03	0.11
Algae	0.00	0.00	5.98	0.00	3.57	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Foraminifera	0.00	0.00	0.30	0.80	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00
Unidentified items	0.00	0.00	3.83	3.68	5.09	7.83	13.19	12.02	1.60	2.85	0.67	1.29	2.54	5.17	0.94	1.79

Table 4.2. Monthly variation of Percentage Occurrence of food composition during January2004-April2005.

Month	Crustacean	Polychaete	Fish	Nematode	Molluscan	Sand	Digested matter	Miscellaneous
Jan	100.00	85.71	85.71	42.86	0.00	71.43	85.71	14.29
Feb	66.67	44.44	11.11	11.11	22.22	87.50	66.67	0.00
Mar	91.67	66.67	58.33	0.00	8.33	90.91	72.73	16.67
Apr	100.00	76.92	69.23	0.00	30.77	61.54	69.23	15.38
May	68.75	18.75	37.50	6.25	12.50	18.75	37.50	50.00
Jun	18.75	62.50	6.25	12.50	12.50	86.67	53.33	6.25
Jul	37.50	37.50	18.75	6.25	12.50	53.33	53.33	6.25
Aug	38.46	0.00	53.85	15.38	0.00	83.33	58.33	7.69
Sep	50.00	42.86	71.43	0.00	14.29	100.00	64.29	35.70
Oct	26.67	33.33	20.00	33.33	26.67	60.00	66.67	31.25
Nov	71.43	85.71	0.00	42.86	50.00	71.43	42.86	14.29
Dec	83.33	8.33	25.00	0.00	0.00	100.00	72.73	16.67
Jan	90.00	80.00	40.00	0.00	20.00	80.00	60.00	20.00
Feb	86.67	86.67	20.00	13.33	0.00	93.33	80.00	20.00
Mar	43.48	78.26	30.43	4.35	0.00	56.52	39.13	30.43
Apr	37.50	75.00	0.00	12.50	0.00	75.00	75.00	12.50

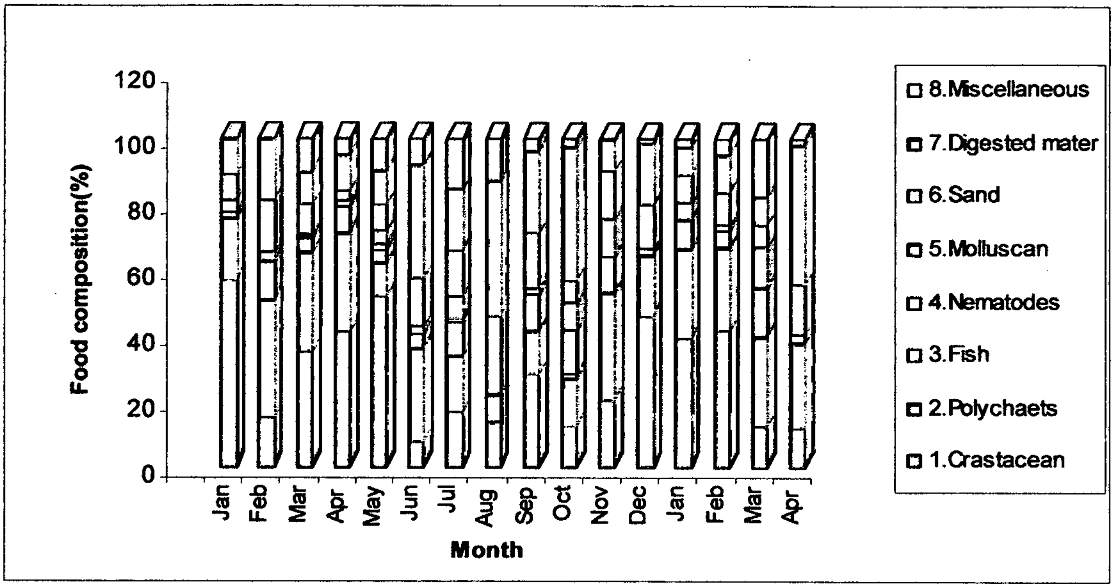


Fig. 4.2. Monthly variation of food composition of *S. sihama*

4.3.1.1. Crustacean

It forms the bulk of the fish diet. The highest percentage recorded was 56.91 % in January followed by 51.64 % in May and, the lowest percentage recorded was 7.16 % in June. In general, crustacean intake was low during June - November. They were recorded in all the months of the year with maximum percentage occurrence (100 %) in January and April 2004. It was represented by the following groups.

Crabs: Juveniles of the crab formed 3.75 % of the annual average food composition. The highest percentage was recorded in the month of May (12.50 %), and the lowest was in April (3.42 %). It was found in the stomach content in the months of January, February, April, May, July - September and December 2004 and March2005.

Tannaids: They represented 2.83 % of the annual average food composition. The percentage composition varied from 0.74 % in March to 16.17 % in January. They were also recorded during November 2004 to March 2005.

Isopods: Isopods contributed 3.97 % to the annual average food composition. They were absent in June - August and October. The maximum percentage of isopods was 13.07 recorded in January and the minimum 0.76 in May.

Amphipods: Amphipods were present in the stomach content in January, April, and September - October with maximum value of 4.72 % in October and minimum 0.31 % in April. They form only 0.59 % of the annual average food composition.

Penaeids: They contributed a small percentage of 0.56 to the annual average food composition. Penaeids were reported in June - July and January. The maximum abundance was 4.99 % in January and the minimum of 1.33 % occurred in July.

Shrimps: Shrimps formed 7.64 % of the crustacean food items. They were absent in January, September - October 2004 and March - April 2005. The maximum percentage (35.01 %) was recorded in May and the minimum (1.47 %) in June.

Mysids: They contributed 0.89 % to the annual average food composition. They were present in January, September, December 2004 and April 2005. The maximum percentage (8.96) was recorded in January and the minimum (0.91 %) in December.

Copepods: They formed 1.19 % of the annual average food composition, The highest percentage was recorded in April 2005 (4.81 %) and the lowest was in March 2005 (0.28 %). They were recorded in March - June, August, October and December 2004 and March - April 2005.

Lucifers: They formed a minute percentage of 0.28 of the annual average food composition. They were recorded in December 2004 and March 2005 forming 4.31 % and 0.18 %, respectively.

Egg and larvae: They contributed 2.22 % to the annual average food composition. They were present in all the months of the year except in April 2004 and March 2005. The maximum percentage 15.60 was recorded in December and the minimum of 0.07 in February.

Unidentified crustacean: Body parts of crustacean of 4.15 % formed the unidentified crustaceans. The highest percentage of this group was recorded in April (21.28) and the lowest in June (0.20).

4.3.1.2. Polychaetes

Polychaetes formed the second most abundant item in the food of *S. sihama*. They occur in high quantities throughout the year except in August. The maximum percentage occurrence of polychaetes recorded was 85.71 and 86.67 in January 2004 and February 2005, respectively. Different taxa identified belonged to the following groups and families.

Glycera spp: It was varying from 6.55 % in October to 0.70 % in April. It was present in March - April, July and October 2004 with an average percentage of 1.23.

Scoloplus spp: This species constituted from 7.27 % to 2.67 % in February and June, respectively. It occurred during February - April and June 2004 and January - February 2005. It formed 1.76 % of the annual average of food composition.

Eunicidae: Members of this family were found in the stomach of *S. sihama* during March – April 2004 and March 2005, forming only 0.38 % of the annual average of food composition.

Spionidae: Members of this family were found in the stomach of *S. sihama* during March, June 2004 and March 2005, forming only 0.63 % of the annual average of food composition.

Poecilochaetus: Its composition varied from 15.55 % in April to 4.40 % in July 2004. It was consumed in January - February 2004 and February - April 2005 with an average percentage of 2.68.

Nereid : Nereid formed 1.87 % of the annual average of food composition. Nereid worms were recorded during January, April, October 2004, January, and March 2005.

The largest portion of polychaetes forming 13.78 % of the annual food constituents could not be identified. They were recorded round the year except in August and December. The maximum and minimum percentages were 32.63 and 1.57, respectively.

4.3.1.3. Fish

Fish Larvae: Fish larvae were encountered in January - April, July and September. They formed 3.12 % of annual average food composition with maximum percentage of 14.39 recorded in March 2005 and minimum percentage of 0.17 in April 2004.

Fish eggs: This group formed a small portion of the food of *S. sihama*, contributing 0.63 % of total food composition. Its maximum percentage of 2.49 was recorded in March 2004 and the minimum percentage 0.81 in January 2005.

Fish scales: Different types of fish scales were observed in the stomach content of *S. sihama* in most of months except in February and November 2004 and April 2005. The highest percentage was recorded in August (8.01) and the lowest in June (0.07). Fish scales constituted 1.88 % of total food composition.

4.3.1.4. Nematodes

Nematodes were encountered in small quantities in the diet of *S. sihama* (2.49 %). The percentage fluctuated between 12.90 in October 2004 and 0.32 in March 2005. The percentage occurrence of this group was found to be high in January and November 2004 (42.86 %) and low in March

2005 (4.35%). They were absent in March, April and December 2004 and January 2005.

4.3.1.5. Mollusca

Molluscan shells and larvae were found in the stomach content of *S. sihama*. The average contribution was 3.58 % of the food composition. The minimum of 0.76 % in March 2005 and maximum value of 11.36 % was recorded in November 2004. The percentage occurrence analysis revealed that Molluscs were present in most of the months except January, August and December 2004 and February and April 2005. They were recorded in 13.11 % of the total stomach examined.

4.3.1.6. Sand grains

Sand grains were abundant throughout the year. The percentage fluctuated between 3.00 % in April 2004 and 23.83 % in August, with an average of 11.83 % of food composition. Percentage occurrence of sand in the diet of *S. sihama* was 100 % of the examined stomachs in September and December. Sand appeared in 74.36 % of the total examined stomachs during the study period.

4.3.1.7. Digested matter

This group was also found throughout the year. It was fluctuated between 8.14 % in March 2005 and 42.51 % in April 2005, with an average value of

20.47 % of total food composition. Digested matter was present in 62.34 % of total number of stomachs examined. The lowest abundance of 37.50 % noticed in May 2004 and the highest of 85.71 % in January 2004.

4.3.1.8. Miscellaneous

The food items, which form a minute percentage of total food composition or accidentally taken by fish were group under this category. It included Sipunculids, phytoplankton, Algal filaments and Foraminifera contributing 1.75 %, 0.37 %, 0.73 % and 0.09 %, respectively. These items were not present in the stomach regularly. In addition to these items a percentage of 3.91 of food items could not be identified due to advanced state of digestion.

4.3.2. Food composition in relation to size group

The percentage composition and percentage occurrence of various food items in the stomach of *S. sihama* belonging to various size groups are presented in Table 4.3., Fig. 4.3. and Table 4.4.

4.3.2.1. Crustacean

Generally, there was gradual decrease in the occurrence of crustacean in the diet of various size groups of *S. sihama*. The percentage composition ranged from 56.30 % in the size group 75 - 84 mm to 3.38 % in the size

Table 4.3. Food composition in different size groups in *S. sihama*.

Food item/size group	75-84	85-94	95-104	105-114	115-124	125-134	135-144	145-154	155-164	165-174	175-184	185-194	195-204	205-214	215-224	225-234
1.Crustacean																
Crab	0.00	0.00	0.00	2.76	12.86	2.00	1.30	2.14	4.79	0.00	5.33	1.78	0.00	0.00	0.00	0.00
Tannaids	0.00	0.00	0.00	3.37	2.49	2.32	1.86	2.33	5.05	1.51	2.30	0.00	0.00	0.00	0.00	0.00
Isopods	0.00	0.00	0.00	5.20	3.63	7.13	5.59	2.61	3.86	1.65	2.35	1.25	0.00	0.00	0.00	0.00
Amphipods	0.10	0.35	0.00	0.00	0.50	0.00	0.12	0.00	1.56	1.74	0.00	0.00	0.00	0.00	0.00	5.38
Small prawn(Penaeid)	8.70	7.90	0.00	0.00	0.00	1.24	0.07	1.68	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.00
Shrimps	10.25	10.05	25.00	21.30	17.94	9.93	14.87	0.65	6.32	2.17	4.71	0.00	0.00	0.00	0.00	0.00
Mysids	6.52	4.75	4.00	4.83	1.00	0.00	0.47	1.04	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copepods	15.48	12.50	0.00	0.00	0.00	0.17	1.68	0.87	0.31	1.34	0.00	9.50	0.00	0.00	0.00	0.00
Lucifer	6.38	3.90	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.41	0.00	0.00	0.00	0.00	0.00
Egg and Larva	6.50	7.25	0.00	0.00	0.17	4.59	0.24	0.48	0.51	3.59	1.00	0.89	0.00	0.00	16.67	0.00
Unidentified crus.	2.40	7.75	26.85	10.85	0.61	2.74	5.33	10.18	2.08	3.09	2.30	0.63	0.00	0.00	0.00	0.00
2.Polychaetes																
Glycera spp	0.00	0.00	0.00	0.00	7.14	0.93	2.12	1.27	0.00	3.55	0.00	7.81	0.00	0.00	0.00	0.00
Scoloplus spp	0.00	0.00	10.56	0.00	0.00	0.00	1.21	2.12	1.56	3.96	4.02	0.00	0.00	0.00	0.00	0.00
Eunicidae family	0.00	0.00	0.00	0.00	0.00	1.87	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spionidae	0.00	0.00	0.00	0.00	0.86	2.07	2.00	0.00	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00
Poecilochaetus	0.00	0.00	0.00	10.92	1.00	1.06	3.85	2.42	4.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nereid	0.00	15.99	15.65	5.18	0.00	1.45	3.84	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentifiedpolychaets	17.00	2.35		7.46	15.10	12.20	13.42	11.97	13.51	16.34	17.03	6.46	0.00	3.08	30.77	33.78
3.Fish																
Fish Larvae	0.00	0.00	0.56	0.00	2.86	0.00	7.54	7.02	0.00	5.07	8.96	0.00	50.00	0.00	13.85	3.30
Fish scales	0.00	0.00	2.40	0.63	1.22	3.41	0.87	2.41	3.79	1.67	3.33	0.98	0.00	1.67	3.33	1.89
Fish eggs	4.53	4.27	0.00	0.53	0.90	1.01	0.48	1.13	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.Nematodes	0.00	0.00	0.00	0.98	3.41	0.00	0.63	1.60	2.52	4.34	1.38	8.39	0.00	32.50	10.00	0.00
5.Molluscan	0.00	2.87	0.00	1.50	1.05	0.24	1.22	3.41	2.90	1.10	0.00	11.25	0.00	0.00	7.69	52.81
6.Sand	7.55	7.11	3.84	6.37	10.10	15.87	5.90	18.62	12.17	26.01	18.71	8.34	0.00	4.10	10.19	0.34
7.Digested matter	7.12	7.10	10.15	10.94	8.50	27.47	20.38	18.73	23.98	6.99	20.17	13.96	0.00	32.50	7.50	2.50
8.Miscellaneous																
Sipunculid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.05	8.00	19.97	50.00	25.64	0.00	0.00
phytoplankton	0.40	0.00	0.00	0.38	0.56	0.36	0.00	1.09	0.79	0.82	0.00	0.03	0.00	0.15	0.00	0.00
Algae	0.00	0.00	0.00	4.61	0.00	0.00	0.00	0.84	2.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Foraminifera	0.00	0.00	1.00	0.00	0.00	0.13	0.36	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified items	7.07	5.86	0.00	2.20	8.11	2.46	4.64	4.68	3.15	2.88	0.00	0.00	0.00	0.36	0.00	0.00

Table 4.4. Percentage Occurrence of food composition in different size groups.

Month	Crustacean	Polychaete	Fish	Nematode	Molluscan	Sand	Digested matter	Miscellaneous
75- 84	100.00	66.67	33.33	0.00	0.00	33.33	33.33	33.33
85-94	100.00	50	50.00	0.00	50	50	50	0.00
95-104	100.00	75.00	50.00	0.00	0.00	50.00	50.00	0.00
105-114	76.92	46.15	46.15	7.69	15.38	61.54	53.85	15.38
115-124	71.43	57.14	35.71	14.29	14.29	50.00	35.71	21.43
125-134	68.00	68.00	32.00	0.00	4.00	88.00	72.00	20.00
135-144	57.58	54.55	21.21	3.03	6.06	63.64	66.67	18.18
145-154	67.65	50.00	50.00	11.76	17.65	79.41	61.76	20.59
155-164	65.63	59.38	40.63	12.50	15.63	81.25	62.50	15.63
165-174	47.83	52.17	17.39	17.39	21.74	91.30	34.78	17.39
175-184	50.00	50.00	20.00	30.00	0.00	80.00	40.00	20.00
185-194	75.00	100.00	25.00	25.00	25.00	75.00	50.00	32.00
195-204	0.00	0.00	50.00	0.00	0.00	0.00	0.00	50.00
205-214	0.00	33.33	33.33	100.00	0.00	33.33	66.67	33.33
215-224	50.00	50.00	50.00	50.00	50.00	100.00	50.00	50.00
225-234	50.00	50.00	50.00	0.00	100.00	50.00	50.00	50.00

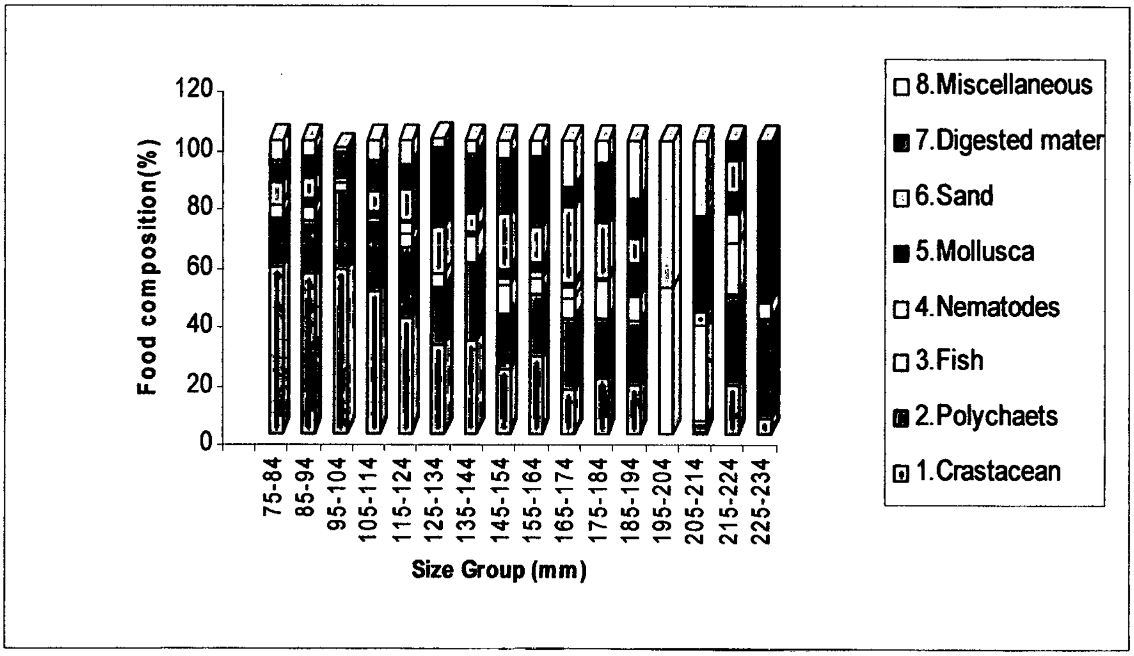


Fig 4.3. Food composition in the stomach of different size groups of *S. sihama*.

group 225 - 234 mm. The percentage occurrence of crustacean was 100 % in the size groups 75 - 84 and 95 - 104 mm followed by gradual decrease in the next higher size groups.

Crabs: Crab juveniles were observed in the diet of fish of size groups 105 - 114 mm to 185 - 194 mm. Their percentage fluctuated between 1.30 in size group 135 - 144 mm to 12.86 in 115 - 124 mm.

Tannaids: Tannaids were present in the fish of size group 105 - 114 mm to 175 - 184 mm. Their abundance varied from 1.51 % in size group 165 – 174 mm to 5.05 % in 155 – 164 mm.

Isopods: This food item was abundant in the diet of fish of size groups 105 - 114 mm to 185 - 194 mm. Its percentage ranged between 1.25 in size group 185 - 194 mm and 7.13 in size group 125 - 134 mm.

Amphipods: Amphipods were recorded in size groups 75 – 84 mm, 85 – 94 mm, 115 – 124 mm, 135 - 144 mm, 155 - 164 mm, and 165 - 174 mm and again in the size group 225 – 234 mm. Its percentage varied from 0.10 in size groups 75 - 84 mm to 5.38 in size group 225 - 234 mm.

Penaeids: Small prawns like Penaeids were found in the fish of size groups 125 – 134 mm, 145 – 154 mm and 185 – 194 mm. The juveniles made their appearance in size groups 75 - 84 to 95 - 104 mm. Penaeids formed 0.07 % of total food composition of size group 135 - 144 mm and 8.70 % in size group 75 - 84 mm.

Shrimps: They were present in the fish of size groups 75 - 84 mm to 175 - 184 mm. They formed 0.65 % - 25.0 % of total food composition in size group 145 - 154 mm and 95 - 104 mm, respectively.

Mysids: They were not recorded with regularity in the sample and therefore did not form the regular food item of the fish. They appeared in the size groups 75 - 84 to 85 - 94 mm, 105 - 114 to 115 - 124 mm and 135 - 144 to155 - 164 mm. The lowest percentage was 0.47 in the size group 135 - 144 mm and highest was 6.52 in size group 75 - 84 mm.

Copepods: Copepods were present in the fish of size groups 75 - 84 to 85 - 94 mm, 125 - 134 mm to 185 - 194 mm and in 175 - 184 mm. Its percentage fluctuated between 0.17 in size group 125 - 134 mm and 15.48 in 75 - 84 mm.

Lucifers: Lucifers formed a very small percentage (0.09 %) of total food, and were observed in the small individuals of size groups 75 - 84 to 85 - 94 mm and in adults of size groups 155 - 164 mm and 175 - 184 mm only.

Eggs and larvae: Different quantities of crustacean eggs and larvae recorded in the stomach of fishes of various size groups from juveniles to adults. The percentage composition of crustacean eggs and larvae fluctuated in different size groups and ranged between 0.17 % in the size group 115 - 124 mm and 16.67 % in the size group 215 - 224 mm.

Unidentified crustacean: There was a good quantity of unidentified crustacean in the fish from size group 95 - 104 mm to 185 - 194 mm. They ranged between 0.61 % in size group 115 – 124 mm and 26.85 % in 95 – 104 mm.

4.3.2.2. Polychaetes:

The percentage of polychaetes as food of fish fluctuated in various size group. It was high (30.77 % & 33.78 %) in the size groups 215 - 224 and 225 - 234 mm, respectively. In the other size group percentage of polychaetes ranged between 3.08 in the size group 205 - 214 mm and 26.44 in the size group 135 - 144 mm. This food item showed maximum percentage occurrence (100 %) in the size group 185 - 194 mm and minimum (33.33 %) in the size group 205 - 214 mm, while the percentage occurrence was 50 % in the size group 175 - 184, 215 - 224, and 225 - 234 mm. Absence of polychaetes in the size group 195 - 204 mm may be due to insufficient number of fish specimens.

Glycera spp: The percentage composition of this species ranged from 0.93 % in the size group 125 - 134 mm to 7.81 % in the size group 185 - 194 mm. Fish of the size group 115 - 124 to 145 - 154 mm recorded this food regularly in the stomach. *Glycera spp* appeared again in the diet of size groups 165 - 174 mm and 185 - 194 mm.

Scoloplus spp: *Scoloplus spp* started appearing in the small fish of size group 95 - 104 mm; it disappeared in the next three groups and again occurred in the size groups 135 - 144 mm to 175 - 184 mm.

Eunicidae: Worms belonging to the family Eunicidae occurred in the size groups 125 - 134 mm and 145 - 154 mm, forming 1.87 % and 0.44 % of food composition, respectively.

Spionidae: Members of this family were present in the food of the size groups 115 – 124 mm to135 - 144 mm and 185 - 194 mm. The lowest percentage recorded was 0.86 % in the size group 115 - 124 mm and the highest 6.25 % in the size group 185 - 194 mm.

Poecilochaetus: This food item was utilized by the size group 105 - 114 mm to 155 - 164 mm as a part of their food. The lowest percentage recorded 1.00 % in the size group 115 - 124 mm and the highest was 4.91% in the size group 155 - 164 mm.

Nereid: Nereid was recorded in the stomach content of size groups 85 - 94 mm to size group 155 - 164 mm. It was one of the important dietary components of small fishes upto 104 mm (17.65 %) and low in the size group 125 - 134 mm (1.45 %).

Unidentified polychaetes: Some body parts of polychaete were recorded in large quantities in all the size groups except in the size groups 95 – 104 and 195 - 204 mm. Its percentage was lowest 2.35 % in size group 85 – 94 mm and highest 33.78 % in size group 225 - 234 mm.

4.3.2.3. Fish:

Fish larvae, scales and eggs were found in a considerable quantity. They were present in high percentage (50 %) of total stomach examined in size group 85 – 94 mm and 49.15 % in size groups 95 – 104 and 105 – 114 mm. This high percentage occurrence could be attributed to the planktonic feeding behaviour.

Fish Larvae: It was recorded in the stomach content of size groups 95 – 104 mm and in115 - 124 mm onwards. The lowest value was recorded in size group 95 - 104 mm and the highest in195 – 204 mm.

scales: It was observed in size groups 95 – 104 mm onwards. The lowest value was recorded in size group105 - 114 mm and the highest in155 –164 mm.

Fish eggs: It was observed in size groups 75 – 84 mm to 155 – 164 mm. Its percentage varied from 0.48 % in 135 - 144 mm to 4.53 % in 75 - 84 mm.

4.3.2.4. Nematodes

Nematode worms were recorded in the stomachs of fish of the size groups 105 - 114 to 115 - 124 mm, 135 - 144 to 185 - 194 mm and 205 - 214 to 215 - 224 mm. They were found in small percentage except in the size group 205 - 214 mm, where they formed 32.50 % of total food composition. The percentage occurrence of Nematodes fluctuated between 3.03 % in size group 135 - 144 mm and 100 % in size group 205 - 214 mm and 225 - 234 mm. They were absent in other size groups.

4.3.2.5. Mollusca

Molluscan shells formed a part of the food items of *S. sihama* during different stages of its life. They were found in the diet of size groups 85 - 94 mm, 105 - 114 to 165 - 174 mm, 185 - 194 mm and 215 - 224 to 225 - 234 mm. The percentage ranged between 0.24 in size group 125 - 134 mm and 11.25 in size group 185 - 194 mm. Their occurrence was 100 % in the size group 225 - 234 mm.

4.3.2.6. Sand grains

The sand grains also formed a part of the stomach content of *S. sihama*. As the fish feed on benthic organisms, it takes some quantities of sand and mud. The lowest was 0.34 % in size group 225 – 234 mm and the highest percentage observed was 26.01 % in size group 165 - 174 mm.

Percentage occurrence revealed that sand grains were found in all size groups.

4.3.2.7. Digested matter

Digested matter was also found in all size groups in comparatively good quantities. The minimum (2.50 %) in the size group 225 - 234 mm and the maximum value of 32.50 % found in the size group 205 - 214 mm. Percentage occurrence of digested matter ranged between 33.33 % in the size group 75 - 84 mm and 72.00 in the size group 125 - 134 mm.

4.3.2.8. Miscellaneous

Sipunculids recorded in the size groups 165 - 174 to 205 - 214 mm. With percentage fluctuated between 8.00 and 50. Its percentage occurrence was 50 % in the size group 195 - 204 mm and 13.04 % in the size group 165 - 174 mm. A very small quantity of phytoplankton particularly diatoms were recorded in all size group except in 85 - 94, 95 - 104, 175 - 184 and 195 - 204 mm. They formed 1.09 % of total food composition in the size group 145 - 154 mm and 0.03 % in the size group 185 - 194 mm. The percentage occurrence was 33.33 % in the size groups 75 - 84 mm and 205 - 214 mm and 6.06 % in the size group 135 - 144 mm.

Presence of algae in the stomach content of *S. sihama* was also poor, restricted to the size group 105 - 114 and 145 - 154 to 165 - 174 mm. The percentage occurrence recorded was 15.38 % in the size group 105 - 114 mm and 2.94 % in the size group 145 - 154 mm. Unidentified organisms were recorded in the size groups 75 - 84 mm, 85 - 94 mm,105 - 114 to 165 - 174 mm and in 205 - 214 mm. Their percentage occurrences varied from 0.36 in the size groups 205 - 214 mm to 7.54 in the size group 115 - 124 mm.

4.3.3. Feeding intensity

4.3.3.1. Stomach condition

Monthly fluctuation in the percentage occurrence of stomachs in different degrees of fullness and feeding condition are given in Table 4.5. Fig. 4. 4.

Month - wise occurrence of actively feeding fishes showed that *S. sihama* fed actively during pre-monsoon (February - May) with peak activity in April. During monsoon, sudden decrease in feeding activity was observed in June. In July, feeding intensity increased followed by decrease in August and remains low (poor) until October. Sharp increase in feeding activity was observed in December and January (Post-monsoon). Month - wise occurrence of empty stomachs showed a wide range of fluctuations from 2.94 % in January to 34.38 % in June. Generally, it was low from January to May, high during June - October and low from December onward coincident with the feeding intensity.

Table 4.5. Monthly variation of stomach condition of *S. sihama*.

Month	No. of fish	Active feeding			Moderate feeding	Poor feeding		
		Gorged	Full	3/4Full	1/2Full	1/4Full	trace	Empty
Jan	34	5.88	29.41	5.88	41.18	5.88	8.82	2.94
Feb	140	8.57	12.86	15.71	24.29	15.71	17.14	5.71
Mar	128	10.94	15.63	17.19	26.56	10.94	14.06	4.69
Apr	48	25.00	16.67	8.33	25.00	16.67	8.33	0.00
May	54	16.67	16.67	12.50	8.33	16.67	25.00	4.17
Jun	64	0.00	6.25	3.13	21.88	12.50	21.88	34.38
Jul	52	3.45	24.14	3.45	17.24	10.34	27.59	13.79
Aug	38	5.26	15.79	5.26	21.05	15.79	10.53	26.32
Sep	94	10.64	12.77	6.38	19.15	25.53	14.89	10.64
Oct	32	0.00	6.25	12.50	37.50	25.00	6.25	12.50
Nov	34	5.88	17.65	35.29	17.65	5.88	11.76	5.88
Dec	28	7.14	7.14	14.29	42.86	7.14	14.29	7.14
Jan.05	32	6.25	25.00	18.75	31.25	18.75	0.00	0.00
Feb	46	8.70	21.74	17.39	21.74	13.04	8.70	8.70
Mar	62	6.45	29.03	29.03	20.97	3.23	6.45	4.84
Apr	14	0.00	14.29	28.57	14.29	14.29	28.57	0.00

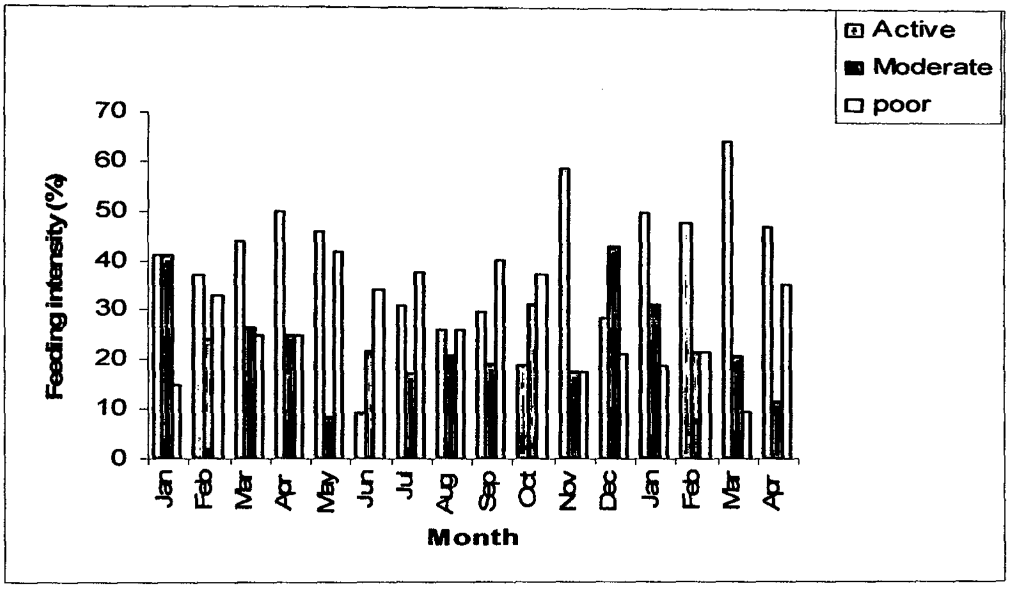


Fig. 4.4. Monthly variation in feeding intensity in *S. sihama*.

Table 4.6. Stomach condition in different size groups of *S. sihama*

Size group(mm)	No. of Fish	Active feeding			Moderate feeding	Poor feeding		
		Gorged	Full	3/4Full	1/2Full	1/4Full	trace	Empty
85-94	2	0.00	0.00	0.00	0.00	0.00	100.00	0.00
95-104	16	12.50	25.00	0.00	0.00	12.50	37.50	12.50
105-114	116	15.87	19.05	15.87	22.22	6.35	11.11	9.52
115-124	124	7.46	17.91	14.93	26.87	8.96	11.94	11.94
125-134	176	11.54	15.38	7.69	23.08	16.67	19.23	6.41
135-144	136	7.35	23.53	10.29	25.00	14.71	10.29	8.82
145-154	108	5.56	11.11	18.52	31.48	9.26	12.96	11.11
155-164	100	8.00	4.00	6.00	32.00	20.00	21.00	9.00
165-174	50	0.00	16.00	32.00	16.00	16.00	14.00	6.00
175-184	20	10.00	10.00	40.00	10.00	10.00	15.00	5.00
185-194	20	0.00	30.00	0.00	10.00	40.00	20.00	0.00
195-204	2	50.00	50.00	0.00	0.00	0.00	0.00	0.00
205-214	20	0.00	0.00	10.00	10.00	70.00	10.00	0.00
215-224	4	0.00	0.00	50.00	0.00	50.00	0.00	0.00
225-234	6	33.33	0.00	33.33	33.33	0.00	0.00	0.00

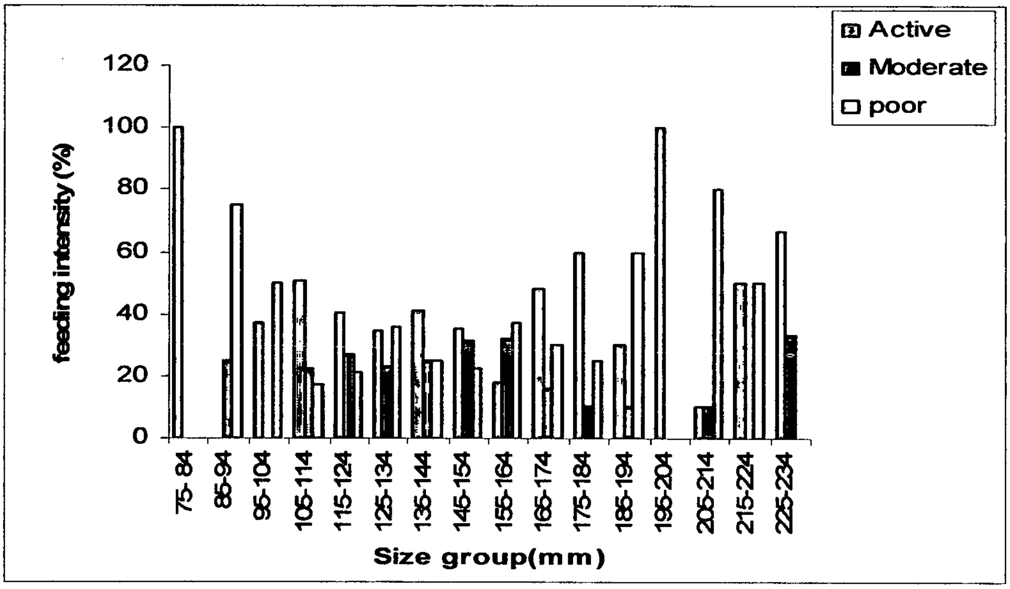


Fig. 4.5. Feeding intensity in different size groups in *S. sihama*.

The feeding intensity in relation to size group based on degree of stomach fullness is shown in Table 4.6., Fig. 4.5. The young individuals in the size group 75 - 84 mm appeared to have fed very actively. There was an obvious decline in the feeding activity in fishes of size group 85 - 94 mm. Above this size group, feeding activity increased with the increase in size reaching the maximum activity in the size group 195 - 204 mm. Moderate activity was recorded in the size group 145 - 154 mm and 215 - 224 mm. Fishes observed to be poorly fed in the size group 155 - 164 mm. Other sharp decreases were observed in the size group 185 - 194 and 205 - 214 mm followed by gradual increase until 225 - 234 mm size group. The percentage occurrence of empty stomachs fluctuated from 3 % in the size group 155 - 164 mm to 15 % in the size group 175 - 184 mm.

4.3.3.2. Gastro Somatic Index (Ga.S.I.)

The Gastro Somatic Index (Ga.S.I.) in different months during the period of this investigation is illustrated in Fig. 4.6. There was an agreement between the monthly variation in gastro somatic index and feeding intensity based on stomach fullness. Monthly average in gastro somatic index varied between 0.89 ± 0.051 in August 2004 and 3.04 ± 0.19 in February 2005. Ga.S.I. was relatively high during pre-monsoon (February - May), low during monsoon until October with minimum value in August. Ga.S.I. increased in November followed by slight decrease in December. However, Ga.S.I. remains high from December onwards.

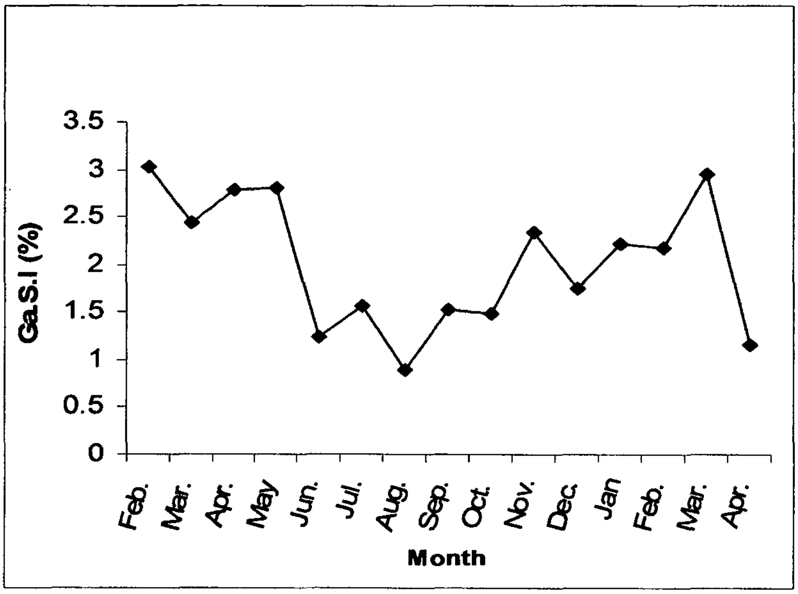


Fig. 4.6. Monthly variation in gastro-somatic index.

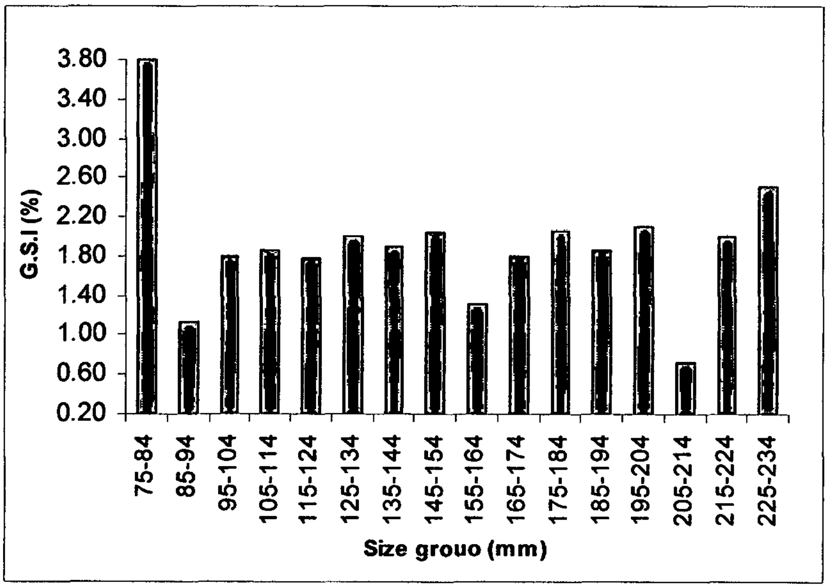


Fig. 4.7. Gastro-somatic index in different size groups.

Ga.S.I in relation to size group is given in Fig. 4.7. Ga.S.I. increased as the fish increased in length, obvious decrease was noticed in the size group 155 - 164 and 205 - 214 mm. It varied between 0.74 % in the size group 205 - 214 mm and 2.51 % in the size group 225 - 234 mm.

4.4. Discussion

4.4.1. Food composition

The length of the intestine of the fish depends upon the feeding habits. Carnivores fishes normally have short and more or less straight intestine. This is because the meat gets digested more easily (Pandey and Shukla, 2005; Serajuddin and Ali, 2005), wherein herbivores fishes the intestine is long and highly coiled because the vegetable food items take more time for digestion. The intermediate condition is found in omnivores. Since, *S. sihama* possesses a relatively short and straight intestine (Plate 4.1.), it can be classified as a carnivores fish.

The analysis of stomach content of *S. sihama* from Zuari estuary revealed that this species consume a variety of food items in this region. Crustacean including crabs and their larvae, tannaids, isopods, amphipods, shrimps, mysids, copepods, lucifers, eggs and larval forms comprised the maximum part of the food of *S. sihama*. Polychaetes formed the second most important item in the food of *S. sihama.* This is in agreement with findings by Gowda *et al.* (1988a) in *S. sihama* and Hyndes *et al.* (1997) in *S. bassensis, S. vittata, S. burrus, S. schomburgkii, S. robusta* and *Sillaginodes punctata*.

Digested and semi digested matter including crustacean appendages and polychaete cilia and organism in an advanced stage of digestion were present and regularly recorded. This category along with sand grains formed a high proportion of stomach content followed by fish larvae. To lesser extents mollusca, nematodes, and other organisms (miscellaneous) also occurred in the stomach of *S. sihama*.

Similar food items were frequently reported in the stomach of *S. sihama* from different regions. They were reported by Radhakrishnan (1957), Gowda *et al.* (1988a), Reddy (1991), Lee (1976), Blaber (1980), Gunn and Milward (1985), McKay (1992), Hyndes *et al.* (1997), Allen *et al.* (2002), Weerts *et al.* (1997), Mohammed *et al.* (2003) and Hajisamae (2006) from India, Taiwan, Australia, South Africa, Iraq and China. Differences in the dominance of different food categories can be attributed to their availability and the habitat where the fish lived at a particular time.

4.4.2. Monthly variation in food composition

Presence of crustacean in the stomach content in different months showed considerable variations with high percentage during January - May and November - December. Among crustacean Shrimps were the most dominant item (7.69 %) followed by Isopods (3.94 %). Crab and its larvae ranked the next dominant item (3.75 %) followed by Tannaids, eggs and larvae and Copepods with percentage values of 2.83, 2.22 and 1.19, respectively. However, Amphipods, small prawns (Penaeid), Mysids and Lucifers were found in small quantities. Among polychaetes Poecilochaetus and Nereid were the most abundant items followed by Scoloplus sp and Glycera sp with percentage of 2.68, 1.87, 1.76 and 1.23 of total food composition, respectively. The monthly variations in the quantity of crustacean and polychaetes in the stomach may be related to seasonal variation in their abundance, age, variation in feeding intensity. The results corroborate the findings by Gowda *et al.* (1988a). Similarly, Rao and Rao (2002) found the dominance of fishes in the diet of *Glossogobius giuris* through out the year, while shrimps and prawns were dominant in July – August. This is perhaps due to the abundant of shrimps and prawns during this period.

Although digested matter came next to polychaetes in their abundance in the stomach, the bulk of this category was consisted of crustacean and polychaetes appendages. Hence, they may not considered as an energetic food.

Fish larvae, Molluscs and Nematodes were found in small but significant fractions in the food of *S. sihama*. Occurrence of Molluscs, Nematodes and Sipunculids, even though in small fractions, they also indicate a bottom feeding tendency.

Occurrence of sand grains throughout the study period with relatively high quantities indicates the bottom feeding habit of *S. sihama* (Blaber, 2000) Sand grains could be taken while fish was burrowing the sand to prey upon benthic animals. Foraminifera and phytoplankton (diatoms) were found in very small fractions in the stomach of few specimens showed that they were probably taken accidentally, along with the sand grains or other items, respectively. Reddy (1991) reported the presence of sand in the stomach of *S. sihama* from Karwar waters. He suggested that sand may be taken accidentally.

4.4.3. Food composition in relation to size group

The ultimate objective of dietary changes is to maximize the energy intake, enhance growth rate and minimize the risk of predation in competing for food with bigger predators (Brown, 1985). The ontogenetic dietary change was distinctive in *S. sihama* in the present study. The diet of fish changed with the increase in size (length). Small fishes are exclusively planktonic feeders subsisting mainly on planktonic forms of crustacean such as Mysids, Shrimp juveniles, calanoid Copepods, Lucifers, crustacean eggs and larvae. Fish eggs, Molluscs larvae and polychaetes are also taken in small proportions. Similar findings were obtained by Hajisamae *et al.* (2006).

The feeding habit gradually changed in fishes above 94 mm total length. Predominance of planktonic food is replaced by benthic food items (polychaetes, crabs, small prawns, Shrimps, Amphipods, Isopods, Tannaids, Molluscs and fish -larvae).

In a similar study Gowda (1988a) reported that crustacean were preferred by fishes of total length 40 - 100 mm, while in fishes larger than 100 mm diet mainly consisted of polychaetes, crustacean, fishes and miscellaneous food items. A complete dietary shift from planktonic feeding in *S. sihama* of less than 91 mm total length to bottom feeding in fishes of over 90 mm has been recorded in Australian waters by Gunn and Milward (1985), Similarly Reddy (1991) observed bottom feeding in larger fishes of *S. sihama* in Indian waters. Weerts *et al.* (1997) noted that fishes less than 60 mm standard length consumed primarily planktonic prey mainly larvacean and copepods, while larger fishes feed on benthic crustacean, polychaetes and bivalves in coast of Africa. Hajisamae *et al.* (2006) reported that dietary ontogenetic change of *S. sihama* was very distinctive where early life stages started feeding mainly on calanoid copepods before shifting to almost entirely benthic predator that feed mainly on polychaetes in Chinese waters.

4.4.4. Feeding habits

While studying the food and feeding habit of *S. sihama* Radhakrishnan (1957) and Gowda *et al.* (1988a) classified the fish as omnivores because of the occurrence of seaweed and phytoplankton in the stomach. In the present investigation occurrence of algal filaments in the stomach of a few of fishes, forming minute proportion of the total food has been observed. More over, they occurred without regularity in different months thus suggesting that algae might have been ingested along with other material accidentally.

According to Moyle and Cech, Jr. (2000), fishes are classified as deteritivores, herbivores, carnivores and omnivores based on the type of food. Within these categories they can be further characterized as euryphagous (eating mixed diet), stenophagous (eating limited assortment of food types) and monophagous (consuming only one sort of food). Thus, *S. sihama* can be classified as euryphagous carnivores, feeding on a wide rangeof food of planktonic and benthic organisms. Many workers (Gunn and milward, 1985; Reddy, 1991; Weerts *et al.*, 1997; Mohammed *et al.*, 2003 and Hajisamae *et al.*, 2006) have also reported Carnivory of *S. sihama*.

While studying the food and feeding habits of other member of the family Sillaginidae, Chandru *et al.*, (1988) reported that *S. vincenti* feeds primarily on polychaetes, small pawns, worms and mollusks. According to him fishes of less than 100 mm length were found to feed mainly on small pawns, whereas, adults showed greater uptake of polychaetes and Planarians. Study of the dietary composition of five *Sillago* species *viz S.*

bassensis, *S. vittata*, *S. burrus*, *S. schomburgkii*, *S. robusta* and *Sillaginodes punctata* showed that crustacean and polychaetes were the taxa most frequently ingested by each of these species (Hyndes *et al.*, 1997). Hajisamae *et al.* (2006) while studying the feeding ecology of *S. sihama* and *S. ingenuua* reported polychaete and other benthic organisms in the gut content and placed them as carnivores as observed in the present study.

4.4.5. Feeding intensity

The results of Ga.S.I. are in agreement with the stomach fullness, in which Ga.S.I. was high in the active feeder individuals and low in the poor feeder. The feeding activity of *S. sihama* was found to be fluctuated with season as well as maturity stages. The intensity of feeding was high during pre-monsoon (February - May). It may be related to food abundance during this season and to predominance of immature and maturing fishes which feed actively.

Distinctive decline in feeding activity during monsoon can be attributed to spawning, which lasts until November as well as to high water turbidity and heavy silt load as reported by Das (1978) in *Mugil cephalus*. Sharp increase in feeding intensity with the onset of post spawning season can be ascribed to occurrence of high number of spent fishes, which feed actively. Moderate feeding observed during post-monsoon in December may be due to occurrence of spent fishes. High values of percentage occurrence of empty stomachs during June - October with peaks in June and September indicates a period of poor feeding activity which also coincide with appearance of more number of mature fishes about to spawn.

In relation to size of fish, the poor feeding activity in the size group 85 - 94 mm could be attributed to the size related dietary shift from planktonic to bottom feeding at this size. While poor feeding intensity in the size group 155 - 164, 185 - 194 and 205 - 214 mm may acts as an indicator of physiological strain of maturity and spawning.

The results of feeding intensity analysis of the present investigation corroborated the results of the previous studies on the same species (Radhakrishnan, 1957; Gowda et al., 1988a; Reddy, 1991). Similar results with different shift timing 81 - 90 to 101 - 110 mm size classes are reported by Reddy (1991). The fact that ontogenetic dietary shifts may be influenced by the abundance and type of prey gives an acceptable reason for such difference. Furthermore, the diet of *S. sihama*, in Richards Bay, Durban Bay and Mlalazi Estuary, in South Africa (Weerts *et al.*, 1997), changes from planktonic prey to benthic crustacean, polychaetes and bivalve siphn tips at different sizes. Fish from Mlalazi Estuary began feeding on benthos at a smaller size than those from Richards Bay and Durban Bay.

The occurrence of poor feeding coincident with peak breeding in other fishes has been reported by Desai (1970), Khan *et al.* (1988), Rao and Rao (1991), Piska *et al.* (1991) Serajuddin and Mustafa (1994) and Serajuddin *et al.*(1998). This confirms the dietary shift in the individual fish as a body requirement in general and *S. sihama* in particular.

Chapter 5

5.1. Introduction

Reproduction is the process by which species are perpetuated. The success of any fish species is ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment (Moyle & Czech, Jr., 2000). Therefore the reproductive strategy as reflected in anatomical, behavioral, physiological, and energetic adaptations is an essential commitment to future generation. It is also a continuous development process throughout ontogeny, requiring energetic, ecological, anatomical, biochemical and endocrinological adaptations. The reproductive behaviour in fishes is remarkably diversified. Most fishes lay a large number of eggs, fertilized in the aquatic environment.

Studies of reproduction and growth of many species indicated that the reproductive cycle of fishes are closely tied to the environmental changes particularly temperature, day length and food supply. These environmental factors have the greatest influence upon the gonadal development initiation and fecundity of the species. The effect of the two former factors on the reproductive cycle of mudsucker *Gillichthys mirabilis*, was demonstrated by (De Vlaming, 1972a; 1972b). Reproductive parameters such as size at first maturity, spawning frequency, fecundity, sex ratio, and recruitment are of great value in fishery prediction and formulation of management measures (Bal and Rao, 1984).

Information on fish reproduction is also important in aquaculture. The availability of quality seeds and the ability to control fish reproduction are limiting factors in the farming of any commercial species. This became an important factor to fulfill the demand of continuity in supply of table fish and fish seeds throughout the year. Sufficient information related to reproductive parameters and developmental biology can only meet this requirements. The successful adoption of induced breeding technique, using pituitary hormone, for a number of important species may play an important role in improving the fish seed supply in aquaculture.

Studies on the reproductive biology of commercially important fishes from Indian waters have been successfully carried out by many authors. Amongst the notable contributions are of Radhakrishnan (1957); Qasim & Qayyum (1963); James (1967); Khan (1972); Qasim (1973); Sreenivasan (1979); Gowda *et.al.* (1988b); Guha & Mukherjee (1991); Jayasankar and Alagarswami (1993); Das Gupta (2002); Doddamani *et al.* (2002) and Manojkumar (2005).

Information available on the reproductive biology of the estuarine fish *S. sihama* from Indian waters, particularly from Goa waters is scanty. Therefore a detailed investigation on various aspects of reproduction was carried out in the present study. This study covered maturity stages, development of ova to maturity, spawning season, gonado somatic index, size at first maturity, sex ratio and fecundity of *S. sihama* from Goa water.

5.2. Material and Methods

Fish samples were collected at fortnightly intervals from Zuari estuary (off Dona Paula) over a period of 15 months (January 2004 - April 2005).The samples were cleaned and the surface moisture was removed using tissue paper in the laboratory. Each fish sample was measured for its total length to the nearest 1 mm and total weight to the nearest 1.0 g. The sex of individual specimen was determined by observing the gonads after dissecting the specimens, as there is no sexual dimorphism in this fish. Maturity stages of each gonad were recorded .The gonads were dissected out and preserved in 5 % formaldehyde for further studies.

5.2.1. Stages of maturity

Stages of maturity of gonads were determined on the basis of morphological appearance (macroscopic observations) in males. Macroscopic as well as microscopic observations were used in case of females, following the standards laid down by international council for exploration of sea (Lovern and Wood, 1937) and given in Jayasankar

(1991b). While macroscopic observations were based on fresh samples, microscopic observations were based on materials preserved in formaldehyde.

5.2.2. Ova development

Intra-ovarian egg diameter was measured using an ocular micrometer with magnification of 0.01 mm to each ocular micrometer division (O.M.D). For the detailed studies of ova, samples from anterior, middle and posterior regions of the ovary were taken in all measurements in the present study. Ova less than 5 μm divisions were not measured since they were present in ovaries of all maturity stages. Ova were grouped into three O.M.D intervals. The ova diameter frequencies from the ovaries of the same maturity stages were pooled and plotted.

5.2.3. Spawning frequency

Frequency of spawning was determined based on the modes of ova diameters in the mature ovaries, following Jayabalan (1986).

5.2.4. Spawning season

Spawning season was determined on the basis of distribution of different maturity stages of male and female during different months.

5.2.5. Gonado Somatic Index (G.S.I.)

G.S.I. was also used to determine the spawning period following the formula given by Qasim (1973):

$$G.S.I. = \frac{Weight\ of\ gonad}{weight\ of\ fish} \times 100$$

The G.S.I. was calculated for both sexes. The average G.S.I. value for each month and size group was also calculated.

5.2.6. Size at first maturity

Fishes belonging to maturity stage III onwards have been considered as mature fish and used for the purpose of calculating the size at first maturity. Data for 15 months were pooled together. The percentage of the mature fish in relation to immature fish in different size-group was determined. The length at which 50 % of fish were mature was considered as length at first maturity (Lm) of both sexes, by the frequency occurrence of different stages of maturity in various size groups.

5.2.7. Sex ratio

Sex ratio was calculated for different months and size groups of the fish. The sex ratio was tested for equality for different months using Chi-square test.

5.2.8. Fecundity

Fecundity was studied by examining 30 mature preserved ovaries. A small portion was cut from the anterior, middle and posterior regions of the ovary and considered as one sample. After recording the weight, the sub samples were teased out and dispersed in a small amount of water. The mature ova were counted and the total number of ova was computed based on the total weight of the ovary using the formula:

$$F = \frac{No\ of\ ova\ in\ the\ sample \times Total\ weight\ of\ ovary}{Weight\ of\ the\ sample} \times 100$$

The relationship between fecundity and total length, total weight and weight of ovary was statistically determined.

5.3. Results

The reproductive strategies of fishes are often reflected in the anatomical differences between sexes. The sexes of most fishes can be easily distinguished by examination of their gonads. Like most of other teleostean, the reproductive glands (testes of males and ovaries of females) of *S. sihama* are typically paired structures. Both the testes and ovaries are suspended by mesenteries across the roof on the sides of the body cavity, in close association with the kidneys. The means of passing sperms from testes and eggs from ovaries are vas deferens and oviducts, respectively. They combine to form a common duct (sperm duct in male and ovarian duct in female), and open to the exterior by a common genital aperture. In general the reproductive organs in *S. sihama* are paired and symmetrical, although cases of asymmetry were also encountered.

5.3.1. Classification of maturity stages

In fishes which are less than 95 mm total length, gonads are minute and translucent; hence sex of such fishes is difficult to be determined. Gonads of adult fishes were classified into five maturity stages based on gonads morphology in male and female, in addition to intra-ovarian ova in female. The classification of maturity stages of *S. sihama* is presented in Table 5.1., Plates 5.1. and 5.2.

5.3.1.1. Maturity stages in Male

Stage I (Immature): Testes are small, thin, and thread-like in shape.

Stage II (Maturing): Testes are semitransparent, dark gray, and extending upto less than ½ of the abdominal cavity. As testes developed they became moderately thick, slightly flattened, and gray-whitish extending upto ½ of the abdominal cavity in the early phases and upto ⅔ of the abdominal cavity in the late phases.

Table 5.1. Classification of different maturity stages in *S. sihama.*

Maturity stage	Description	Mode of ova diameter(mm)	Maximum diameter of ova (mm)
Stage I	Immature	0.05 - 0.08 0.08 - 0.17	0.20
Stage II	Maturing	0.08 - 0.11 0.17 - 0.20 0.29 - 0.32	0.38
Stage III	Mature	0.14 - 0.17 0.23- 0.26 0.29 - 0.32 0.35 - 0.38	0.48
Stage IV	Ripe	0.17 - 0.20 0.23 - 0.26 0.35 - 0.38 0.44 - 0.47	0.64
Stage V	Spent	0.05 - 0.08 0.17 - 0.20	0.44

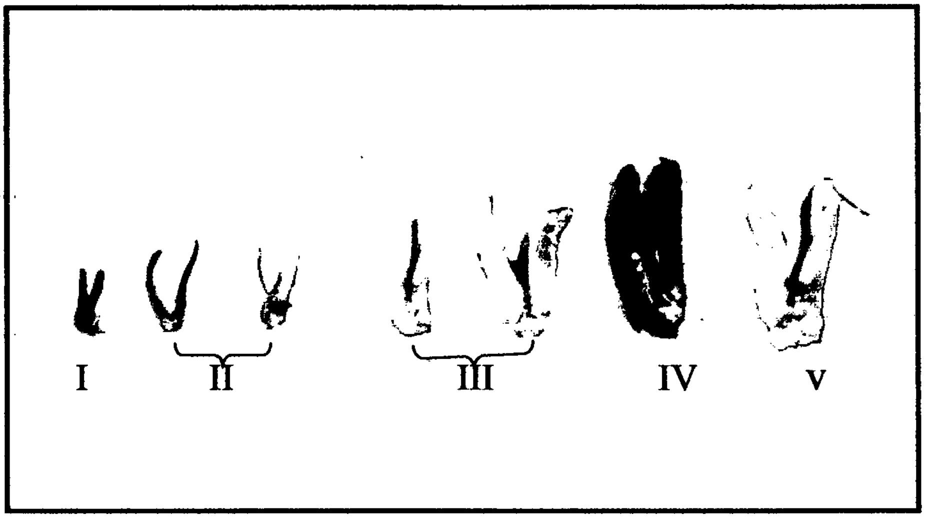


Plate 5.1. Ovary of *S. sihama* in different maturity stages.

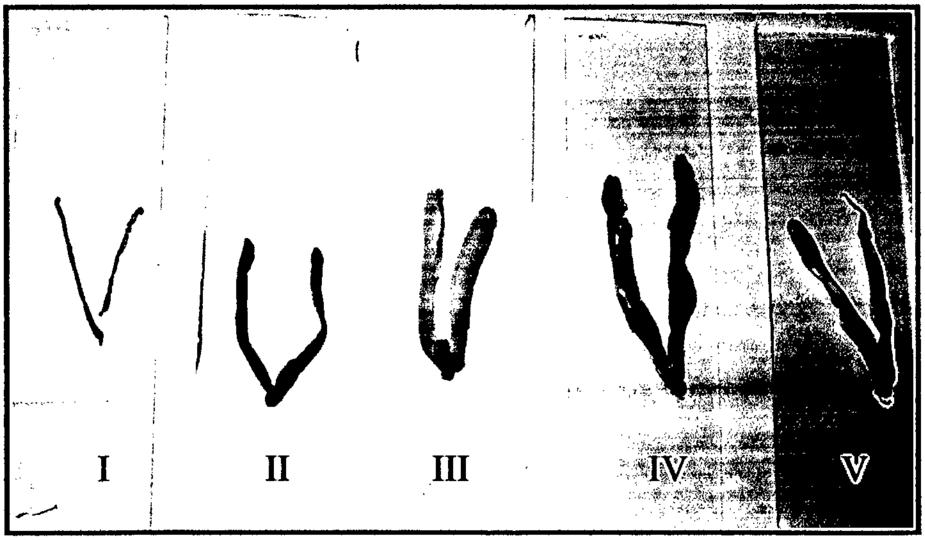


Plate 5.2. Tests of *S. sihama* in different maturity stages.

Stage III (Mature): Testes are large, opaque, well developed and white or ivory in colour. They are ribbon shaped, occupying about ⅔ – ¾ of the body cavity.

Stage IV (Ripe): They look like mature testes thick, flat but more swollen, creamy white, extending in the entire body cavity.

Stage V (Spent): Testes are shrunken, opaque and strap-like. They turned back upto ⅔ body cavity.

5.3.1.2. Maturity stages in Female

Stage I (Immature): Ovaries are small, thin, occupying less than ½ of the abdominal cavity. They are usually translucent pink or glassy. The oocyts are minute (microscopic) resulting in a smooth appearance to the ovary tissue. All the ova are immature with a mode at (0.05 - 0.08 mm).

Stage II (Maturing): The ovaries developed in size to occupy about ½ - ⅔ of the body cavity. They appear as a semi translucent to clear yellow and oval in shape. It showed withdrawal of a batch of ova with a mode at 0.19 mm, another mode at 0.31 mm was representing the maturing ova.

Stage III (Mature): As more oocyts developed and turn opaque, the ovaries turn to pale yellow or apricot colour. The opaque oocyts are visible through the thin gonad wall. At this stage ovaries extending upto more than ¾ of the body cavity. The mature group of ova was well differentiated from immature, maturing groups with mode at 0.37 mm.

Stage IV (Ripe): ovaries are very large and swollen; filling the entire body cavity. Colour is orange with a prominent net work of blood vessels. Granular appearance is an important salient of the ovary at this stage. All the type of ova was observed; well developed ripe ova formed a distinct mode at 0.47 mm.

Stage V (Spent): Soon after completion of spawning activity, the spent ovaries appear flaccid with a prominent blood vessels and reddish yellow in colour. Few oocyts can be seen, whilst yellow- brown bodies may be evident for sometime and are the main feature used to distinguish spent ovary from immature or early maturing ovaries.

Various workers have adopted different types of classification for the intra-ovarian eggs. Hyndes *et al.* (1996) suggested four stages of oocytes in the ovaries of *S. bueeus* and *S. vittata* namely prenuclear, yolk-vesicle, yolk granule oocytes and hydrated eggs. Following this classification the ova could be distinguished in the ovaries of different stages of maturity in the present study are shown in Plate 5.3., and they are:

Pre-nuclear ova (Immature): Transparent ones with a prominent central nucleus. The protoplasm is devoid of any yolk accumulation. The size of

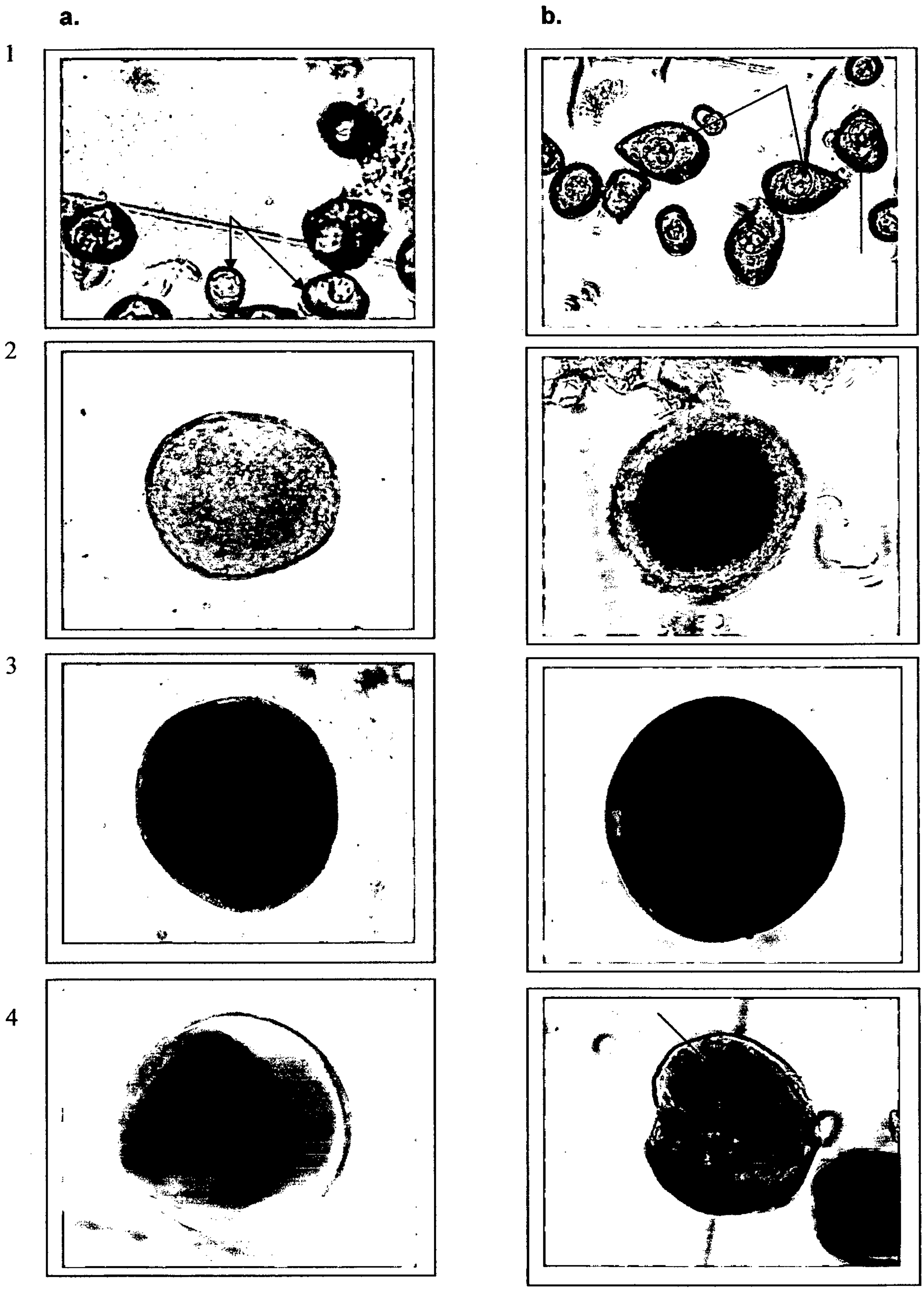


Plate 5.3. Different types of oocytes in the ovary of female *S. sihama:* **a.** (early stage); **b**. (Late stage). 1. Immature ova; 2. Maturing ova; 3.Mature ova & 4.Ripe ova.

ova ranged between 0.02 and 0.05 mm in early stage. With the increase in size upto 0.08 - 0.17 mm, a number of nucleoli can be seen at the periphery of the nucleus. Few ova attain upto 0.20 mm in diameter.

Yolk-vesicle ova (Maturing): Small, opaque in which the yolk deposition just started. Semitransparent area can be made out in the center with partially visible nucleus. The early maturing ova which are not fully yolked, the diameter varies from 0.14 - 0.22 mm. With increase in yolk accumulation the ova became opaque, spherical shape with diameter from 0.22 - 0.35 mm.

Yolk granule ova (Mature): Large, opaque, spherical with slight elongation in some cases. Full yolked and still contained within the follicles. The size ranged between 0.32 - 0.44 mm, upto 0.47 mm in few instances.

Hydrated eggs (Ripe): Fully mature, large, fully or partially transparent which have burst from the follicles. The majority of ova varied in diameter from 0.44 to 0.50 mm, very few instances were found upto 0.62 mm.

5.3.2. Development of ova to maturity

The diameters of ova from representative ovaries of the five maturity stages were measured. The size frequency distribution of ova in the

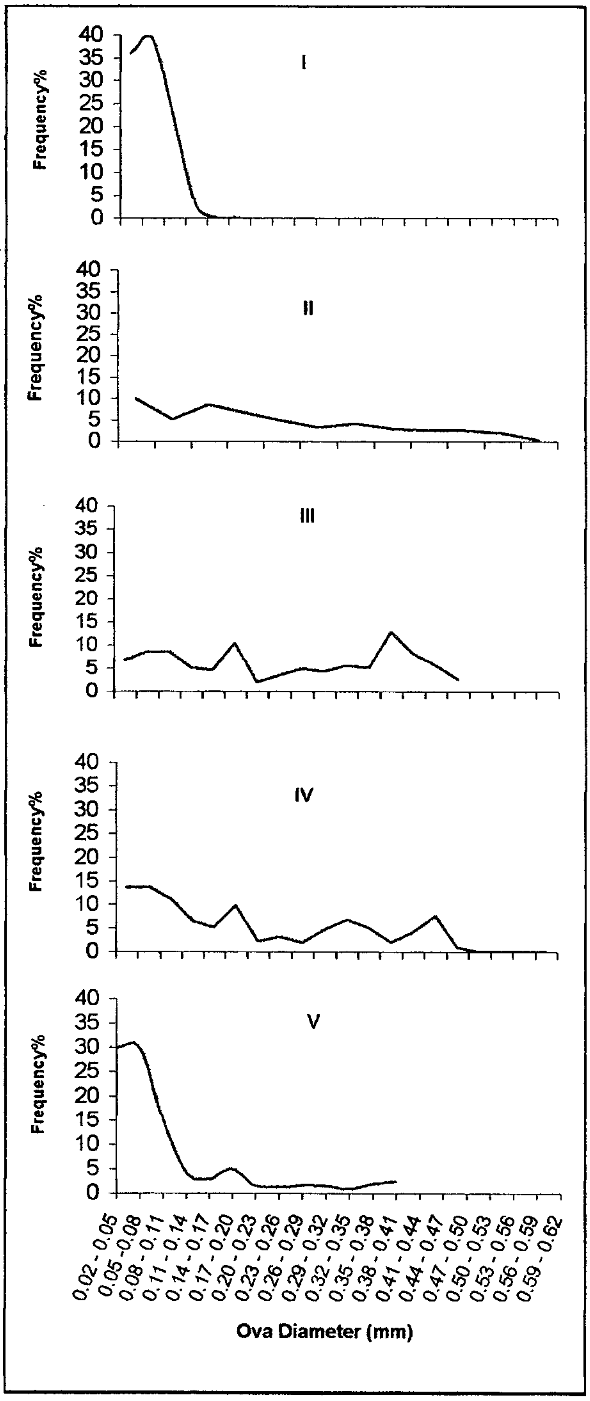


Fig.5.1. Ova diameter fequency polygons of different maturity stages in *S. sihama*.

stages I - V of maturity are shown in Fig. 5.1. The frequency polygons of ova diameters of various maturity stages showed that in stage I (immature ovary), majority of the ova were 0.05 - 0.08 mm (representing the immature stock of ova), and a few ones measured upto 0.20 mm. The immature stock of ova was found in all the subsequent stages. In Stage II (maturing ovary), a batch of ova separated from the general stock forming a mode at 0.08 - 0.11 mm, another distinct mode at 0.17 - 0.20 mm forming the first batch of maturing ova was also formed. In stage III (mature ovary), the first batch of maturing ova which appeared in stage II, developed further and formed a mode at 0.20 - 0.23 mm. In addition a new batch of maturing ova with mode at 0.14 - 0.17 mm made its appearance. At this stage the mature group of ova was well demarcated from maturing and immature ones by a mode at 0.35 - 0.38 mm. Stage IV (ripe ovary), contained all the four stages of ova. The mature group of ova with mode at 0.35 - 0.38 mm, which found in stage III, grew further and reached a mode at 0.44 - 0.47 mm, these ova were ripe and were ready for spawning. In addition to this group, modes at 0.32 - 0.35 mm representing the mature ova, 0.17 - 0.20 mm and a fraction at 0.23 - 0.26 mm were also took place. In stage V (spent ovary), the ripe ova that had been at 0.44 - 0.47 mm in stage IV were already extruded, and there were only immature, maturing and few residual of mature ova. Generally, the maturing and mature ova are passed in succession to advanced maturity stages and fresh batches of maturing ova separated from the immature stock.

5.3.3. Spawning frequency

As can be seen from Fig. 5.1. in an advanced stage of ovary three distinct groups of maturing and mature ova at 0.17 - 0.20, 0.32 - 0.35 and 0.44 - 0.47 mm are separated from the immature ones. As the fish approaches the spawning season, the most advanced group of ova at 0.44 - 0.47 mm were separated distinctly and are released from the follicular chamber, by the time the next group at 0.035 - 0.038 mm are approaching the ripe stage and became ready to release in the same spawning season. The maturing groups of ova which had undergone half the maturation process are also expected to be released in a single spawning season.

5.3.4. Size at first maturity

To determine the size at which the fish attain the first sexual maturity a total of 656 males and 754 females were used. The percentage occurrence of matured individuals was plotted against different size group in male and female and presented in Fig. 5.2. It showed that both sexes became matured at the size group 155 - 164 mm total length (mid point, 159.5 mm). About 90.9 % of the total numbers of males were matured at size 165 - 174 mm; all males were matured at size 175 mm onwards. In female 94.7 % of total number were matured at size 175 - 184 mm and

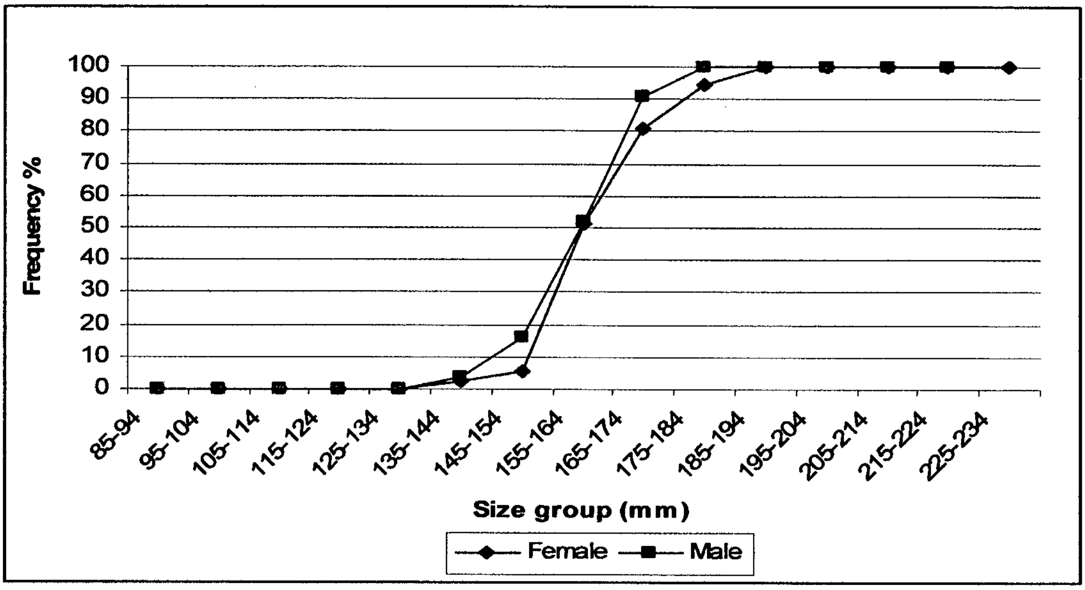


Fig. 5.2. Percentage occurrence of male and female *S. sihama* in different size groups.

from 185 mm onwards all the females were fully matured. The smallest size at which mature specimens were found was 138 mm and 135 mm in male and female, respectively.

5.3.5. Spawning season

Spawning season was determined on the basis of occurrence of different maturity stages of male and female in each month during the period from January 2004 to April 2005. The results are shown in Fig. 5.3. The females in stage III with mature gonads appeared round the year except in March 2004, while females with stage IV gonads were observed during period lasted from June to December and few were found in February. Spent individuals (stage V) were observed in small percentage in March, May, July - August and October. The percentage occurrence of spent gonads was higher by the end of November, sharply increased in December followed by decrease in January. Virtually, fishes with immature (I) and maturing (II) gonads were present all round the year which indicate a protracted breeding behaviour.

Similar trends were also noticed in males. The peak of occurrence of individuals with ripe gonads lasted from September to November. Spent males were found in May, July to January with peak in December.

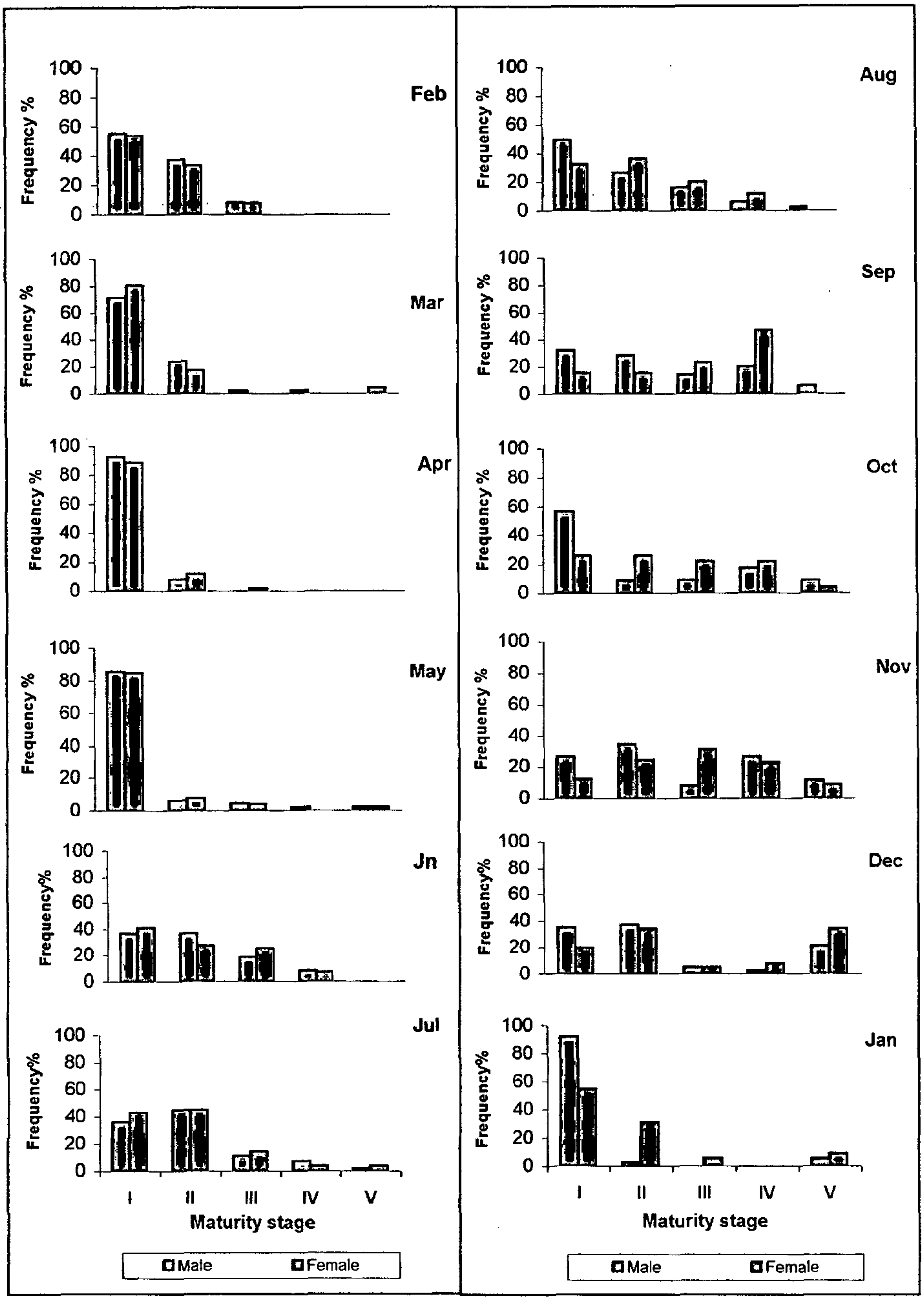


Fig. 5.3. Percentage occurrence of male and female *S. sihama* in different months.

From the above observations it is clear that the major spawning season in *S. sihama* lasts from June to December with peaks spawning activity from September to November.

5.3.6. Gonado Somatic index (G.S.I.)

The monthly G.S.I. of male and female are given in Fig. 5.4. The mean monthly G.S.I. in male fluctuated between 0.10 in April to 1.03 in November and in female from 0.25 in May to 3.76 in September. The values of G.S.I. increased from June to December showing two distinct peaks in September and November in both the sexes. The peak value in G.S.I. coincided with peak spawning period thus showing a close relationship between the two.

5.3.7. Sex ratio

The data on sex ratio is depicted in Table 5.2. The ratio of males to females was found to be 1:1.17. Test of significance of difference revealed that in September and November 2004 and in January - March 2005 the proportions of males and females differ significantly (x^2 = 7.49, $P<0.01$; x^2 = 11.58, $P<0.001$; x^2 = 8.49, $P<0.01$; x^2 = 5.54, $P<0.05$; x^2 = 9.35, $P<0.001$, respectively). In other months the difference was insignificant. The Chi-square test of pooled data did not show any significant difference (x^2 = 3.13, $P > 0.05$).

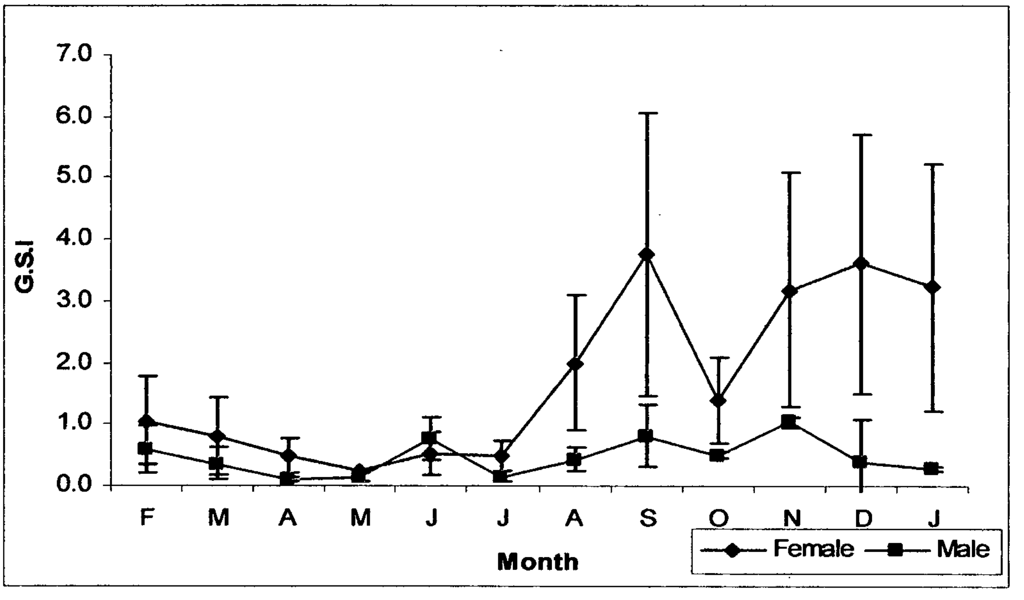


Fig. 5.4. Monthly mean G.S.I. ± SD values of *S. sihama* during February 2004 – January 2005.

Table 5.2. Monthly variation in Sex ratio of *S. sihama* during February 2004 - April 2005.

Month	Total no.	No. of Males	No. of Females	Ratio M : F	X^2
Feb	77	38	39	0.97 : 1	0.01
Mar	98	46	51	0.90 : 1	0.27
Apr	111	51	60	0.85 : 1	0.73
May	101	49	52	0.94 : 1	0.09
Jun	82	38	44	0.86 : 1	0.44
Jul	112	56	56	1.00 : 1	0.00
Aug	99	49	50	0.98 : 1	0.01
Sep	77	50	26	1.92 : 1	7.49**
Oct	50	23	27	0.80 : 1	0.32
Nov	83	26	57	0.46 : 1	11.58***
Dec	84	43	41	1.00 : 1	0.05
Jan	106	38	68	0.56 : 1	8.49**
Feb	104	40	64	0.63 : 1	5.54*
Mar	131	48	83	0.58 : 1	9.35***
Apr	87	51	36	1.4 : 1	2.59

** $P < 0.01$, *** $P < 0.001$ Critical value X^2 3.84, 0.05, 1 DF

Table 5.3. Variation in Sex ratio of different size group.

Size class	Total no.	No. of Males	No. of Females	Ratio M : F	X^2
85-94	3	1	2	0.5 : 1	0.33
95-104	44	27	17	1.59 : 1	2.27
105-114	183	76	107	0.71 : 1	5.25*
115-124	242	132	110	1.20 : 1	2.00
125-134	336	178	158	1.13 : 1	1.19
135-144	203	80	123	0.65 : 1	9.11**
145-154	153	57	96	0.59 : 1	9.94**
155-164	135	54	81	0.67 : 1	5.40*
165-174	70	22	48	0.46 : 1	9.66**
175-184	25	10	15	0.67 : 1	1.00
185-194	12	4	8	0.50 : 1	1.33
195-204	6	2	4	0.50 : 1	0.67
205-214	8	3	5	0.60 : 1	0.50
215-224	5	2	3	0.67 ; 1	0.20
225-234			3		

* P < 0.05, ** P < 0.01, *** P < 0.001 Critical value X^2 3.84, 0.05, 1DF

The data on sex ratio in relation to size group is given in Table 5.3. It suggests that females out numbered males in all the size groups except in 95 - 104, 115 - 124 mm and 125 - 134 mm. The Chi-square test values were found to be significant from 135 - 144 to 165 - 174 mm size groups (x^2 = 5.40, P<0.05; x^2 = 9.94, P<0.01).

5.3.8. Fecundity

Data on observed and calculated number of mature eggs produced by ovaries of different sizes is shown in Table 5.4. The total number of mature eggs varied from 11376 to 103695 in individuals of 150 mm to 342 mm. The mean fecundity value of 30 specimens was 41662 ± 4730.

The relationships between Fecundity and total length, weight of fish and weight of ovary are shown in Fig. 5.5. It showed the best fit by a logarithmic equation as:

$$\text{Log } F = -2.0112 + 2.8971 \text{ Log } L$$

Where F = Fecundity and L = total length of fish.

The fecundity and weight of fish (g) relationship can be expressed in the form of:

Table 5.4. Observed and calculated fecundity of *S. sihama*.

Total length (mm)	Total weight (g)	Ovary weight (g)	Observed fecundity	Calculated Fecundity		
				$F = a L^b$	$F = a W^b$	$F = a O^b$
150	22.11	0.33	15187	19573	16786	11124
153	26.64	0.75	16736	20724	20300	21753
155	27.51	0.29	11376	21515	20977	10010
156	26.73	0.34	14082	21918	20370	11399
157	31.29	0.99	13600	22325	23920	27291
158	25.09	0.55	16749	22738	19096	16884
158	28.39	0.67	17107	22738	21661	19838
160	27.8	0.92	18277	23578	21202	25704
160	29.1	1.46	26476	23578	22214	37484
161	32.56	1.014	24480	24005	24911	27830
162	34.2	1.02	25385	24438	26191	27965
169	36.78	1.23	25461	27609	28208	32586
169	38.52	1.33	32890	27609	29569	34734
170	39.82	1.95	35295	28082	30587	47480
170	38.36	2.41	43192	28082	29444	56449
175	43.82	2.46	46565	30531	33724	57404
181	50.05	1.37	37888	33648	38621	35585
183	45.59	1.74	44863	34732	35114	43260
184	44.45	2.28	41873	35282	34219	53949
187	49.64	1.1	32646	36967	38298	29744
189	50.44	1.7	45666	38119	38928	42446
190	44.54	2.12	46514	38703	34289	50836
194	59.78	1.76	59546	41100	46292	43666
194	54.28	1.66	57720	41100	41953	41629
197	63.43	2.03	63600	42960	49177	49066
212	80.19	3.29	83750	53085	62461	72792
225	72.77	2.22	83336	63025	56572	52786
228	79.58	1.11	73661	65479	61977	29965
286	166.13	3.35	92250	125887	131291	73874
342	257.67	4.46	103695	210839	205421	93331
Average			41662.2	41666	42126	39296

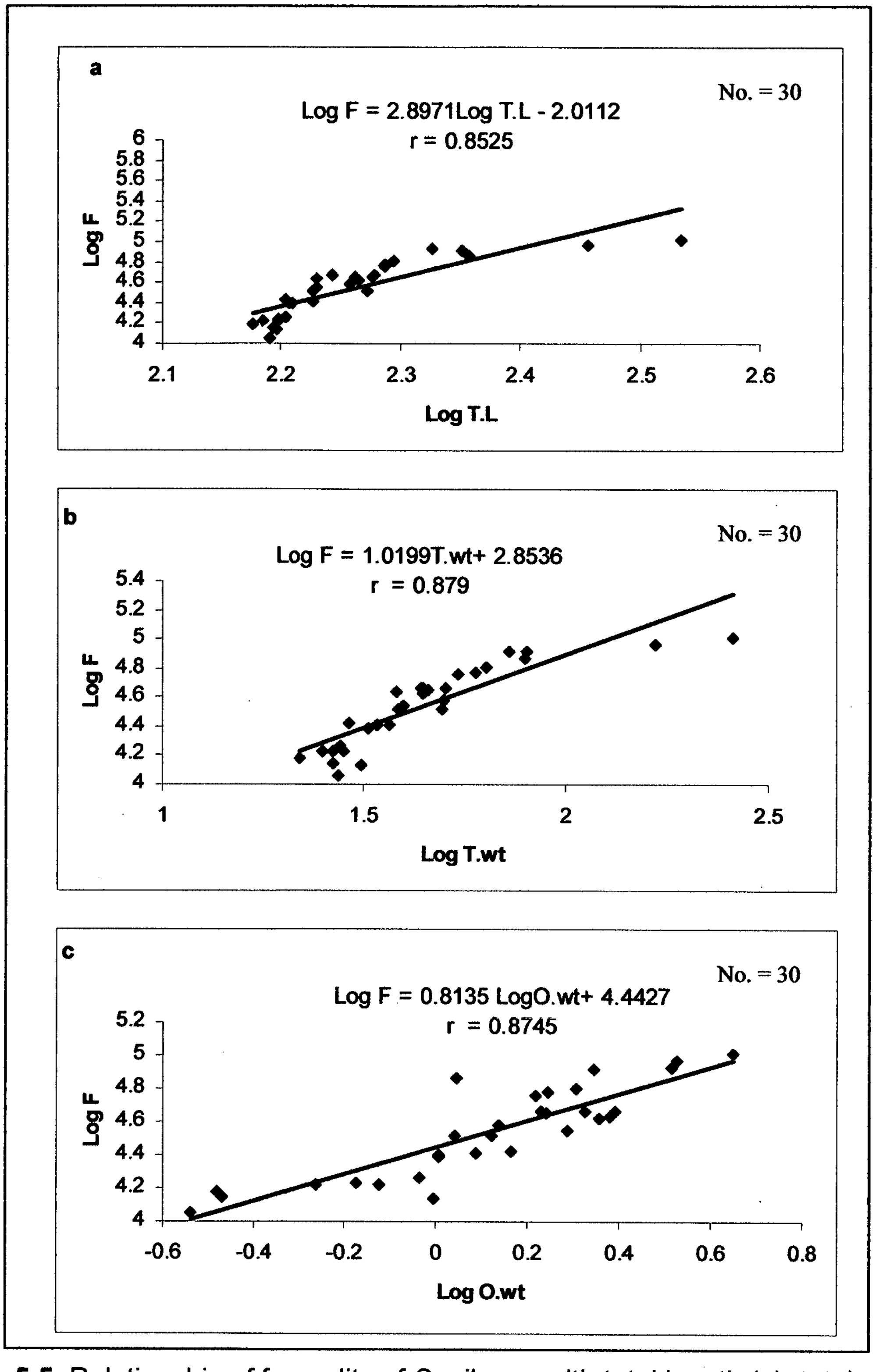


Fig. 5.5. Relationship of fecundity of *S. sihama* with total length (a), total weight (b) and ovary weight (c).

$$\text{Log } F = 2.8536 + 1.0199 \text{ Log } W$$

Where F = Fecundity and W = weight of fish.

The relationship between Fecundity and weight of ovary (g) can be expressed in form of next regression equation:

$$\text{Log } F = 4.4427 + 0.8135 \text{ Log } w$$

Where F = Fecundity and w = weight of ovary.

From the scattered diagrams of relationship between fecundity and total length, weight of fish and weight of ovary, it can be seen that there was linear relationship between fecundity and the three variables. Fecundity increased at the rate of 2.8971, 1.0199 and 0.8135 times of the total length, weight of fish and weight of ovary, respectively. Positive correlation was observed between fecundity and total length, weight of fish and weight of ovary. The correlation coefficient values were $r = 0.7268$, ($P<0.05$); $r = 0.7726$, ($P<0.05$); $r = 0.7648$, ($P<0.05$), respectively.

5.4. Discussion

5.4.1. Spawning frequency

Presence of three distinct modes of ova in mature ovary besides the immature stock indicates that *S. sihama* from Goa waters spawns more than once in a single spawning season.

The result supports those found out by James *et al.* (1976) and Jayasankar and Alagarswami (1993) on the reproductive of *S. sihama* from south Kanara district and Palk Bay and Gulf of Mannar, respectively. Similar observations were reported in *Trenched sardine*, *Sardinella sirm* (Lazarus, 1990), *S. burrus* and *S. vittata* (Hyndes, 1996), *Gobioides rubicundus* of the Bay of Bengal (Kader *et al.*, 1988), *Etroplus suratensis* of India and Sri Lanka (Pathiratne and Costa, 1984). There are many advantages of multiple spawning. It increases the total number of eggs produce in a single spawning season, spreads the risk of eggs and larval predation over a long period (Blaber, 2000). At the same time it acts to buffer any short-term adverse fluctuation in the abundance of suitable planktonic larval food that may appear in different months.

5.4.2. Spawning season

Coastal or estuarine fishes in the tropics and sub-tropics are mainly serial spawners with a protracted spawning season (Longhurst and Pauly, 1987; Houde, 1989) in contrast to species in temperate regions. The stimuli of the onset of reproduction in any tropical estuarine fishes are less clear than fresh water and tropical reef species. This is perhaps because of the general variety of biotic and abiotic influences of marine, estuarine and freshwater origin that come together in this environment (Blaber, 2000). However, spawning usually occur at a time when environmental conditions are most favorable for larval survival and development. Temperature plays an important role in triggering spawning in tropics.

It is clear from Fig. 5.3. that mature gonads were found throughout the year. However, the percentage frequency of mature gonads was higher during June- December. Spent individual were also noticed in most part of the year and the highest percentage in December. This suggests that *S. sihama* has a prolonged spawning season extending from June to December. The highest spawning activity was observed during September and November in both the sexes. These observations are further supported by. G.S.I. values. In the present study, high values of G.S.I. denoted attainment of peak maturity of gonads. Hence the coincidence of occurrence of stages IIII and IV with high G.S.I. values indicate that the peak spawning takes place during June to December. These observations corroborate the earlier reports of Gowda *et al.* (1988); Jayasankar (1991), and Reddy (1991) in *S. sihama* from Indian water.

5.4.3 Size at first maturity

The size and age at first maturity depends on the nature of the environment in which the population of concern lives (Moyle & Czech, 2000).

Knowledge on the size at first maturity of fish helps to predicts harvestable size of the fish. Hence it has great benefits in fishery as well as aquaculture In the present study it is convenient to consider 155 - 164 mm size group as the size by which both the sexes attain sexual maturity when they are ≥ 2 years old. Slightly different values regarding the size at first maturity *of S. sihama* were observed by others Radhakrishnan (1957) reported first maturity at 130 mm; James *et al.* (1976) at 151 -191 mm; Krishnamurthy and Kaliyamurthy (1978) at 140 - 145 mm and Jayasankar (1991) at 170 – 175 mm. The present observations are very close to the observations made by James *et al.* (1976) and Krishnamurthy and Kaliyamurthy (1978).

Most teleosts are itroparous, means they spawn more than once during their lives. In the present investigation, *S. sihama* attains maturity when it is ≥ 2 years old and the largest specimens found were ≥ 3 years old. This means the species spawn more than once during its life. Hyndes *et al.* (1996) compared the size and age at maturity among sillaginids, and found that *S. burrus* did not live for more than 2 years and never exceeded 4 years age. It attains maturity at the end of its first year at 130 mm length, *S. vittata* reached 2 years of age and some individuals lived for 4 - 7 years. It attains maturity at, size of 130 mm. Comparing with findings of Hyndes and Potter (1996), *S. bassensis* do not reach maturity until the end of its third year of life; by which time it exceeds 200 mm in length, while *S. robusta* grows to a size similar to those of *S. burrus*, but does not reach first maturity until the end of second year of life which is the case with *S. sihama*. The comparison emphasize that the relationship between the size and age at first maturity vary considerably amongst whiting species, distributed in different geographical areas. This could be attributed to habitat variability and environmental factors.

5.4.4. Sex ratio

Sex ratio indicates the proportion of male and female in the population and is expected to be 1:1 in nature. Any deviation from this ratio may indicate the dominance of one sex over the other. This is happens because of differential behaviour of sexes, environmental conditions, fishing, etc. (Bal and Rao, 1984). The monthly distribution of two sexes in *S. sihama* did not show a significant difference in the distribution of both sexes except in September 2004 when males were dominance over females, November 2004 and January – March 2005 when females were dominance over males. However, the overall male: female ratio was 1:1.17. The Chi-square value did not show any significant difference indicating equal distribution of both sexes. Jayasankar (1991) reported a sex ratio of 1:1.1 (male:female) in *S. sihama* from Palk Bay and Gulf of Mannar. Chatterji (1976) reported a ratio of 1:1.4 in major Carp, which did not deviate significantly from the hypothetical distribution.

Comparing with G.S.I. values, it is inferred that during November 2004 and January – February 2005 the G.S.I. was high in female and relatively lower in male. That may indicate higher spawning activity of female at the time of sampling leading to aggregation of females in the spawning ground, while, in September dominance of males may be related to predominance of maturing males of a particular size. Related to size and age, females appeared to be predominant in larger size groups.

5.4.5. Fecundity

Fecundity is the most common measure of reproductive potential in fishes. In order to maintain the position of any species in an environment, it required to reproduce to such an extent that would enable it to counteract all physical and biological hazards such as predation, critical stages of its life history, food supply, etc. (Qasim and Qayyum, 1963).

In general, fecundity increases with the increase in the size of female, which can be expressed by $F = a\ L^b$ (Bagenal, 1978). This means that larger fishes produce considerably more eggs than do smaller fishes. In the case of *S. sihama* the linear relationship between fecundity and total length of the fish suggests that the fecundity increases at the rate of 2.987 times the total length. The linear relationships were also noticed between fecundity and weight of fish and ovary weight. The linearity in such relationships have been also proved by many scientists (Palekar and Bal, 1961; Gowda, 1988b; Jayasankar, 1991; Reddy and Neelakantan, 1991) in *S. sihama*, Chatterji and Ansari (1982) in Dolphin fish *Coryphaena hippurus*, Zacharia and Nataraja (2003) in Threadfin bream, *Nemipterus mesoprion* and Manojkumar (2005) in *Decapterus russelli*.

There is variation in the estimated value of fecundity reported by different workers in *S. sihama*. Radhakrishnan (1957) stated that a fully mature ovary of *S. sihama* produce 14000 eggs, while Palekar and Bal (1961) reported fecundity in the range of 16682 to 166130. The fecundity of *S. sihama* reported by other workers (James *et al.*, 1976; Krishnamurthy and Kaliyamurthy, 1978; Gowda, 1988; Jayasankar, 1991; Reddy and Neelakantan, 1993) were 11304 - 100593, 31678 - 288000, 49862 -1670477, 6956 - 48373 and 20184 - 12045 eggs, respectively. There are many factors that complicate the interpretation of fecundity data. These are fertility, the frequency of spawning, parental care, egg size, population density and environmental factors (Bagenal, 1978).

The present study revealed that *S. sihama* spawn intermittently throughout the year with a wide size range of matured ova in the ripe ovaries. Like most of estuarine fishes the spawning period commence with the beginning of the monsoon season. It attains the sexual maturity at 155 - 164 mm length; produce a large number of eggs as an adaptation to the extreme environment. Total length can be considered as a better indicator of fecundity than weight of fish and weight of ovary in *S. sihama*.

Chapter 6

6.1. Introduction

Typically, growth can be defined as the change in size (length, weight) over time. However, it can energetically, defined as the change in calories stored as somatic and reproductive tissues. The latter definition is useful for understanding the factors that affect growth because of conversion of the ingested food energy into metabolic or growth or excreted energy (Brett and Groves, 1979). Although, most of fish continue to grow throughout their lives, growth is not constant over the years. Consequently, growth has been one of the most intensively studied aspects of fish biology. It is a good indicator of the health of individuals and populations.

The growth rate is an important parameter that influences population dynamics in fishes (Bal and Rao, 1984; Seshappa, 1999). The growth rate is variable because it is greatly dependent on a number of biotic factors such as age, maturity, ingested food quality and quantity and presence of the predators. It is also influenced by abiotic factors, such as temperature, photoperiod, dissolved oxygen and salinity. All these factors interact with each other to influence the growth rate.

Growth is expressed in relation to time, thus it is useful to determine the age of the candidate species. There are two main methods to determine the age of fish e.g. the direct method by rearing the fish in tanks or aquaria or by tagging fishes. The other method is indirect determination of age which is applied in two ways, those are length frequency distribution method and by interpretation of the growth rings on the hard parts.

For species that can be aged, growth is directly determined from size at age or back-calculation from scale readings. In species can not be aged, other methods such as length frequency distribution may be used to estimate the growth rate by treating length as a non – linear measure of biological time (Jennings *et al.*, 2001).

Separation of the complex length frequency distribution for the whole population into cohorts and assign age to them is the aim of estimating growth from length frequency distribution (Jennings, *et al.*, 2001). This method also called as Petersen's length frequency polygon method. In the tropical fishes those breeds over a prolonged period, length frequency distribution is seldom applicable because of the entry of broods into the population several times in a year (Qasim, 1973).

Fortunately, many fishes carry records of time (age) on their hard parts. The hard parts that usually used for age determination are the scales, otolith, vertebral centra, dorsal and pectoral spines operculae, etc. However, the growth rings are known to be more distinct and clear on the otolith than in other structure of the fish. Therefore, they are extensively used to determine the age in fishes (Jennings *et al.*, 2001; David and Pancharatna, 2003). This method of aging is based on the fact that successive rings are formed as the fish grows in age.

Knowledge of a mathematical relationship between the length and the weight of the fish in a given geographical area is a practical index of the condition of fish (Petrakis and Stergiou, 1995). Hence weight of a given fish of known length or length classes can be calculated. A life history and morphological comparison of populations from different regions can be made from length weight relationship (Goncalve *et al.*, 1997). Similarly, calculating standing stock biomass and several other aspects of population dynamics can be estimated using length weight relationship (Morato *et al.*, 2001).

The principle of the length weight relationship is that the weight of the fish increase in relation to increase in its length. Theoretically, it can be described using a power function of the formula $W = a\ L^3$ (Le Cren, 1951) where 'a' and 'b' are constants. In nature, the body proportions of a fish continually change with aging. The form and specific gravity do not remain constant throughout the life history of the fish. Thus, cube law expression does not hold well throughout the life history of the fish (Srivastava, 1999). Hence, a more satisfactory formula to express the length weight relationship is $W = a\ L^b$. The value of 'b' in the equation usually lies between 2.5 and 4. In an isometric growth, the value of 'b' equates 3 for a hypothetical ideal fish, if the value of 'b' is other than 3 the fish grows allometrically (Tesch, 1968).

Condition of fish in general is an expression of relative fatness of fish. The condition factor is expressed as $K = W \times 100 / L^3$. If fish does not undergo the cube law the 'K' value is directly affected by length, age, maturity, feeding intensity and other factors (Gowda, 1984). In order to eliminate the effect of these factors on the 'K' value, Le Cren (1951) suggested the calculation of relative condition factor 'Kn' by the formula $Kn = W / \hat{w}$, where W is the observed weight while $\hat{w}$ denotes the calculated weight.

The knowledge of age and growth of an economically important fish is essential for understanding the age composition of the stocks and the role of various class- years in the fisheries. It is also essential to determine the mortality and survival rate of various year-classes and success of the yearly broods. Accordingly, knowledge of age and growth is of vital importance in the fisheries management.

6.2. Material and methods

Monthly samples were collected from Zuari estuary at Dona Paula point using a shore seine. In addition fishes were also caught by hook and lines during January 2004 - April 2005. Total length and weight of the fishes were recorded to the nearest 1.0 mm and 1.0 g, respectively.

Estimation of age and growth rate in *S. sihama* was carried out using various methods to evaluate the age at corresponding length. Petersen's length frequency polygon method and growth check on otolith were used. The growth parameters were estimated using Von Berttalanfy Growth Equation (VBGE). The condition or well-being of fish was determined by length weight relationship and calculating Relative Condition Factor.

6.2.1. Length frequency distribution (LFD)

When collecting large amount of data it is often convenient to record the data in the form of frequency table. A total number of 1178 specimens were collected during one year (2004) and arranged into size groups with 10 mm intervals. Number of specimens in each size group was recorded and the percentage of their frequency was calculated in each month, separately. Data was pooled and the frequency percentage of each size group was calculated. The frequency polygons were drawn by plotting frequency percentage against size group in different months and for pooled data.

6.2.2. Growth check on Otolith

For the study of growth the otoliths were collected from 81 specimens varying in size from 68 mm to 224 mm. Otoliths were obtained by cutting across on the dorsal sides of the head with a sharp scalpel behind the eyes. The brain with the otic capsules where the otoliths were located became exposed in both sides. As in most fishes, *S. sihama* has three otoliths in each side. The largest otolith (sagitta) was removed from the otic capsule, washed in water, and cleaned from all extraneous tissue. The length of each otolith was measured to the nearest 0.01 mm. Then each otolith was weighed to the nearest 0.001 mg. Otoliths was then ground, immersed in 50 % glycerol and observed under binocular microscope. Reading of the annuli on the otoliths was done following the procedure given by Qasim, (1957). The relationship between total length (TL), otoliths length (OL) and weight (OW) were statistically assessed using regression analysis and calculating the correlation coefficient 'r' (Zar, 2005).

6.2.3. Growth parameters

The growth in *S. sihama* was described using the (VBGE). The equation can be written as:

$$Lt = L\infty \left(1-e^{-K(t-t_0)}\right)$$

Where Lt = length at age t, L∞= asymptotic length (the length of the fish would reach at an infinity age), e = base of the naporian logarithm, K = the growth coefficient (constant), t = age of fish and t_0 is the theoretical age the fish would have at length zero. There are several numbers of equations for determining these parameters, the most followed method is that developed by Ford (1933) and Walford (1946). Graphically, L∞ and t_0

parameters were determined by plotting the Ford - Walford graphs as described in Ricker (1975). The various parameters of VBGE were also calculated following the method given by Bal and Rao (1984). The growth rates were calculated and compared with those obtained by the LFD and checks the growth rings on otolith.

6.2.4. Length - weight relationship (LWR)

A total of 1465 specimen, 676 males and 789 females were utilized for this purpose. The length - weight relationship of male and female was calculated using the parabolic formula and its logarithmic transformation, respectively $W = a + L^b$ (Le Cren, 1951)

$$\text{Log } W = \text{Log } a + b \log L$$

Where W is the weight of fish (g), L denoted the length of fish (mm), 'a' is the intercept and 'b' is the slope, 'a' and 'b' are constants. Significance of difference between the regression coefficients of sexes at 0.05 level was tested using ANCOVA (Snedecor and Cochran, 1967). Depending on the analysis, either combined or separate equation can be derived for the sexes. The't' test was employed to test whether the regression coefficients depart significantly from expected cubic value '3' in both the sexes.

6.2.5. Relative condition factor (Kn)

The relative condition factor was calculated using the formula $Kn = W / \hat{w}$

Where W is the observed weight and $\hat{w}$ is the calculated weight, and was calculated based on the LWR regression equation. Kn was calculated in different months for both the sexes. The average value of each month irrespective of size was considered. The average Kn for each size group was also calculated. Values of Kn were compared with Ga.S.I. and G.S.I. to infer their relation to feeding activity and maturation and spawning if there is any.

6.3. Results

6.3.1. Length frequency distribution (LFD)

The frequency distribution of different size groups in different months is given in Fig. 6.1. It showed monthly size range and modal values. It is clear from the figure that no single mode of size groups could be traced over a period of one year. Hence, attempt was made to condense the data to find the major modes. For this purpose, data was pooled and the results depicted in Fig. 6.2.

As shown in Fig. 6.2. three modes of size groups could be observed. Mode 'a' at 125 - 134 mm length, mode 'b' represented the fishes at 155 - 164 mm and the fishes belonging to size group 205 - 214 mm represented the third mode 'c'. Presence of young fishes throughout the year made it difficult to know the size at which they made their major mode.

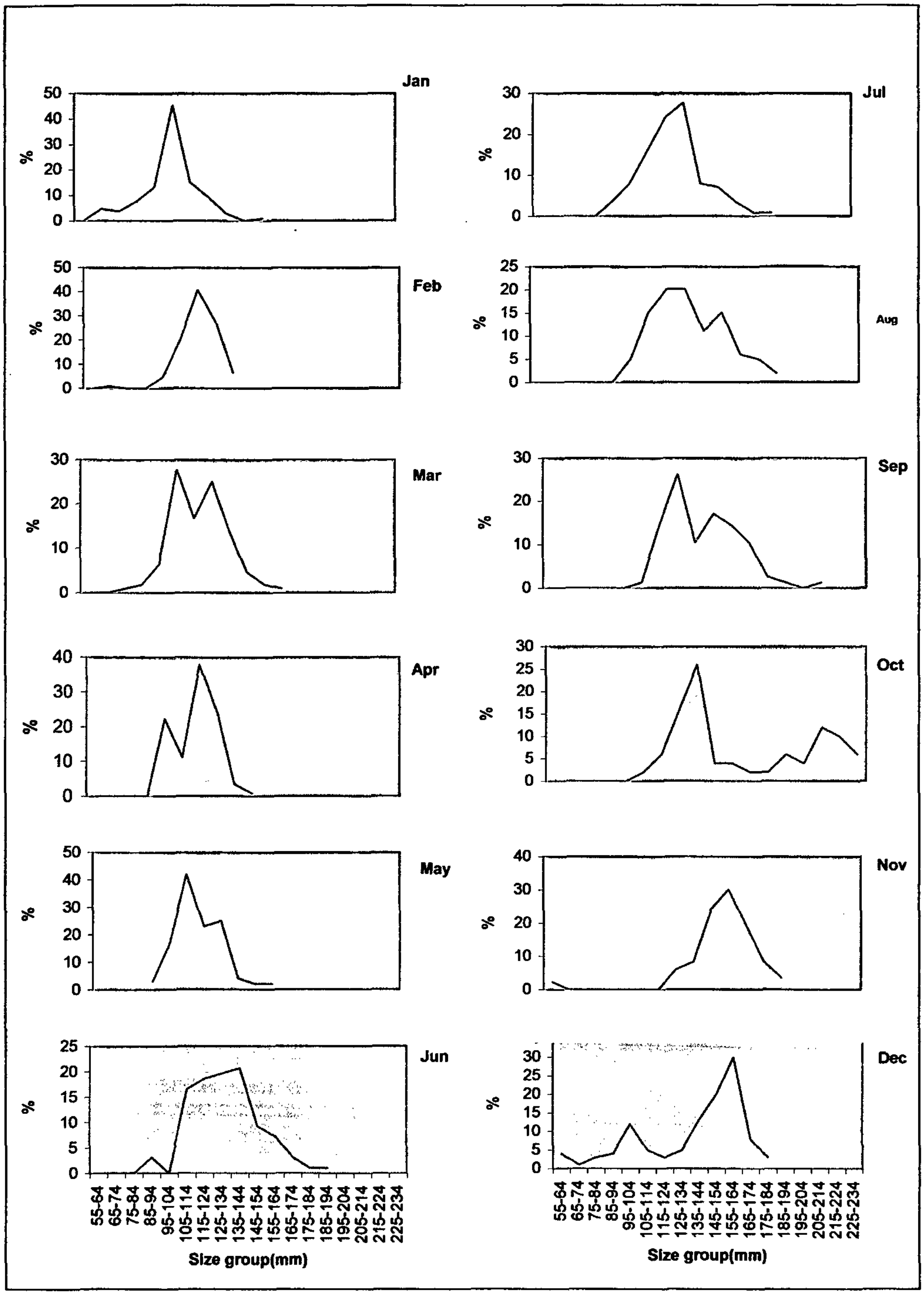


Fig. 6.1. The length frequency distribution of different size groups during January - December 2004.

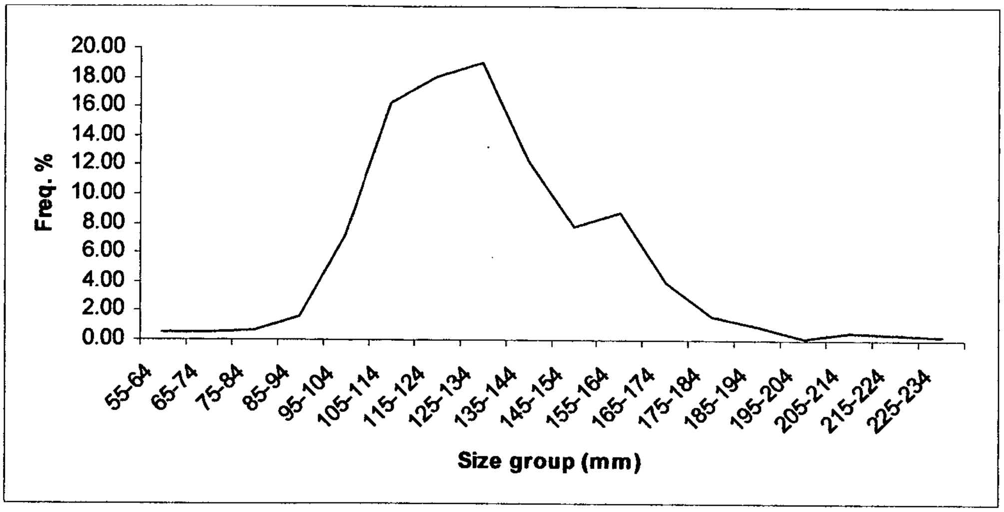


Fig. 6.2. The length frequency distribution (pooled data) during January - December 2004.

Age and growth of these main length groups could not be known directly. So, they have been assigned to different age groups based on otolith studies. The mean length at each age group is given in Table 6.1. The average lengths at various age groups obtained were in close agreement with that obtained by otolith alone. The average lengths were 86.9, 129.2, 166.9 and 202.2 mm at 0+, 1, 2, 3 years, respectively. This also suggests that population of *S. sihama* in Zuari estuary comprise of four year classes.

6.3.2. Growth check on Otolith

Since, it was not possible to determine the age from the LFD data, it was necessary to do by growth check on hard parts. As in other *Sillago spp.* the sagittal otolith of *S. sihama* were elliptical in shape, broad central region and narrow tapering end.

Generally, one-year growth ring (annulus) consists of one summer (wide and opaque) zone and one winter (narrow and translucent) zone. Plate 6.1. The mean length at various age groups e.g. 0+, 1, 2, 3 years is shown in Table 6.2. Plate 6.2 - 6.5. It was inferred that fishes with average length of 88 mm had no rings on their otoliths, while the fishes with an average total length of 130.9 mm had one clear ring on the otolith. The fishes showing two rings were found to have an average length of 168.3 mm.

Table 6.1. Mean length (mm) of *S. sihama* at various age groups.

No Of annuli on Otolith	Size Group (Mean)	Estimates Age	Designation of age group	Growth Rate
None	68-102 (88.0)	Less than one year old	***0+***	
One	108-145 (130.9)	One year old	***1***	42.9
Two	145- 187 (168.3)	Two years old	***2***	37.4
Three	190-224 (199.8)	Three years old	***3***	31.5

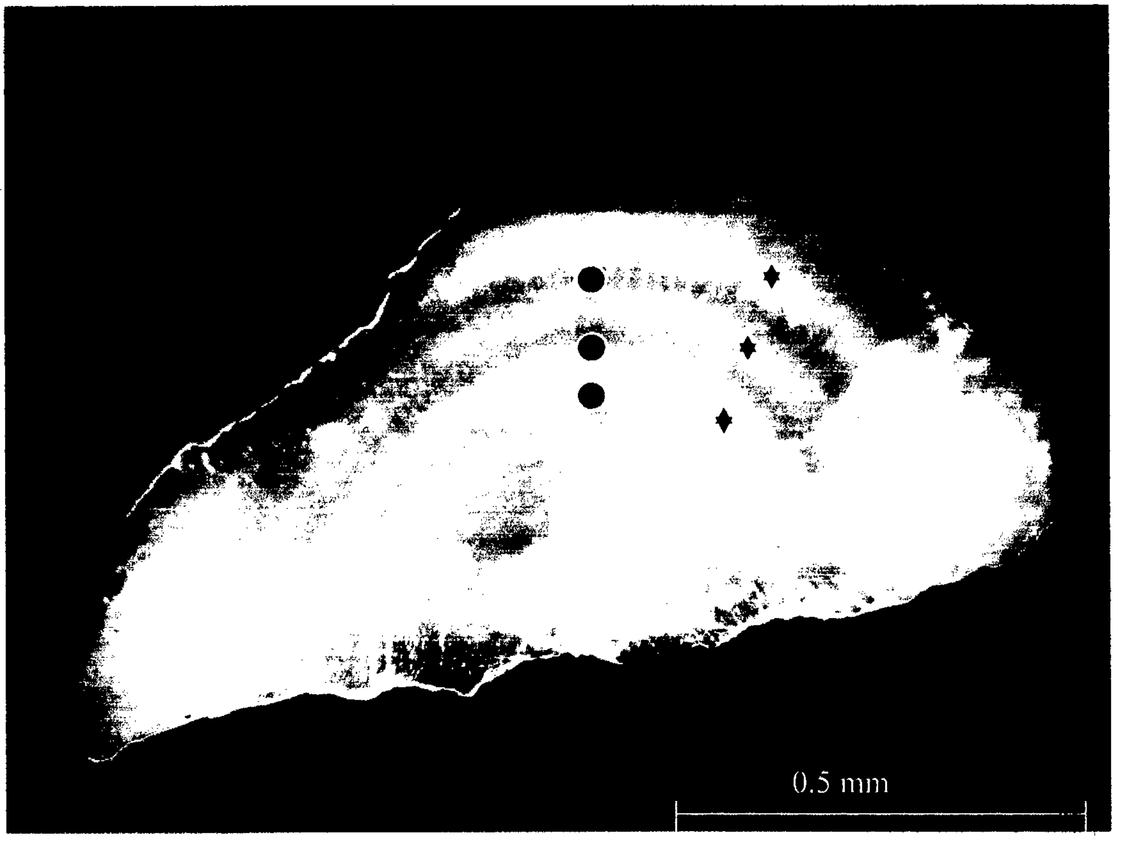


Plate 6.1. Otolith of fish belonging to 3 year group showing decrease the distance between translucent zones with the increase in age.

♦ Opaque Zone. ● Translucent Zone.

Table 6.2. Mean length at different age groups (Model progression analysis) during 2004.

Month	Model progression analysis			
	0+	1	2	3
Jan.2004	65			
Feb.		119.8		
Mar.	100	118.2		
Apr.	100.9	118.0		
May	109.7	130.1		
Jun.	91	139.7	160.7	
Jul.		140.0		
Aug.		138.9	178.4	
Sep.		129.9	160.6	194
Oct.		128.5	183	210.3
Nov.		149.8		
Dec.	55		169	
Mean	86.93	131.28	170.34	202.15
Growth rate		44.35	39.06	31.81

Plate 6.2. Otolith of fish belonging to 0 year group (total length 102 mm).

Plate 6.3. Otolith of fish belonging to 1 year group (total length 133 mm).

Plate 6.4. Otolith of fish belonging to 2 year group (total length 145 mm).

Plate 6.5. Otolith of fish belonging to 3 year group (total length 212 mm).

The mean length of fishes with three growth rings was 199.8 mm. Hence, the average length of *S. sihama* at 0+, 1, 2, 3 years was fixed as 88, 130.9, 168.3 and 199.8 mm, respectively. Split (false) annuli occurred on the age structure causing a problem in age determination is shown in plate 6.6.

The mean values of different otolith measurements in fishes belonging to various size groups are given in Table 6.3. The relationship between total length of the fish and length and weight of the otolith is illustrated in Fig. 6.3. The regression analysis based on least square method revealed that there was a highly significant association between total length of fish and length and weight of the otolith ($r = 0.94$ & 0.93, respectively, $P < 0.001$).The regression equations were given as:

$$Y\ (T.L) = 1.474 + 0.0364\ X\ (O.L)$$

$$Y\ (T.L) = -\ 0.0492 + 0.0006\ X\ (O.W)$$

Where T.L is total length, O.L length of otolith and O.W denoted the weight of otolith.

6.3.3. Growth parameters

Growth in many fishes is widely described using the VBGE model. This model provides an adequate description of growth in many species

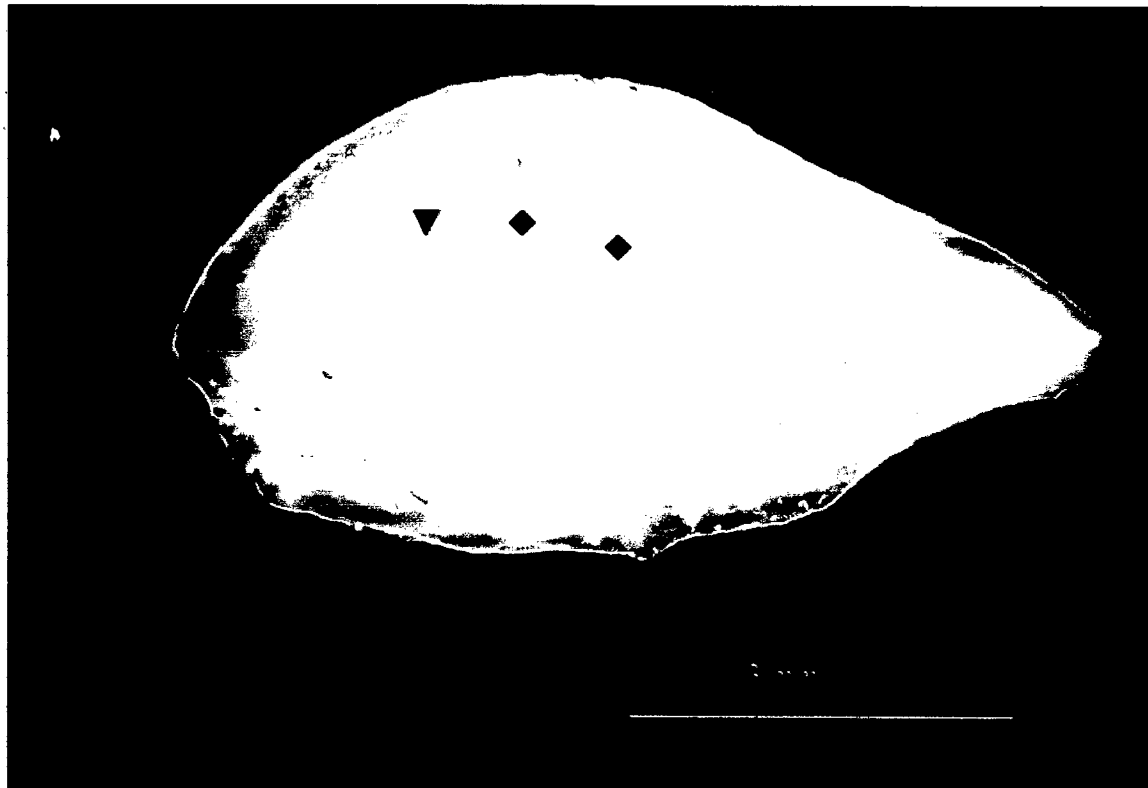


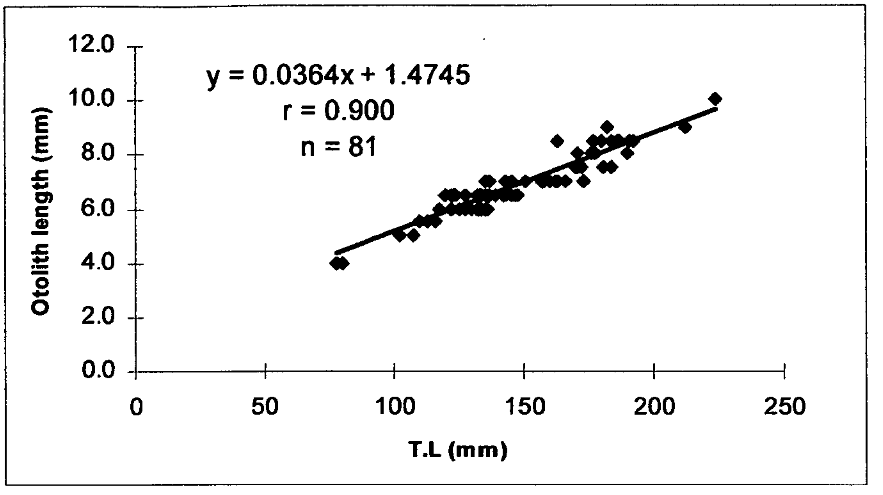
Plate 6.6. Otolith of fish belonging to 1 year group showing true and false rings.

◆ False ring. ▼ True ring.

Table 6.3. Different measurements of Otolith corresponding fish total length in *S.sihama.*

Size group (mm)	T.L Mean	O.L Mean	O.W Mean
75 - 84	79.0	4.0	0.014
85 - 94	-	-	-
95- 104	102.0	5.0	0.017
105 - 114	111.5	5.5	0.022
115 - 124	120.6	6.3	0.029
125 - 134	131.3	6.2	0.032
135 - 144	138.3	6.5	0.036
145 - 154	147.2	6.8	0.039
155 - 164	160.4	7.2	0.051
165 - 174	169.9	7.4	0.052
175 - 184	179.9	8.2	0.068
185 - 194	189.3	8.3	0.072
195 - 204	-	-	-
205 - 214	212.0	9.0	0.085
215 - 224	224.0	10.0	0.11

(a)



(b)

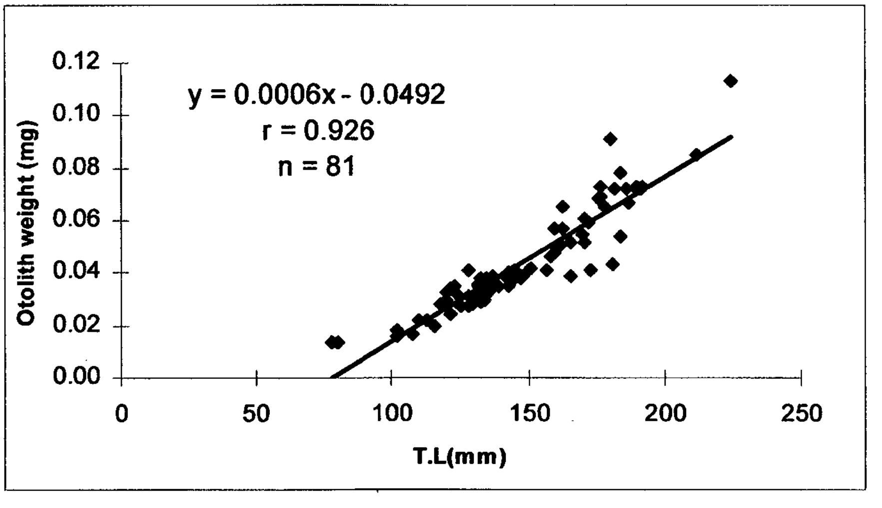


Fig. 6.3. Relationship between total length of the fish and

(a) Length of otolith

(b) Weight of otolith.

(Beverton and Holt, 1957). The growth parameters have been widely compiled and have considerable utility in life history studies. Table 6.4. showed the various parameters of VBGE. The Various parameters were found to be L_∞ = 388 mm and t_0 = -1.60 and k = 0.1526 /year obtained by graphical method (Fig. 6.4.) While L_∞ = 390 mm, t_0 = -1.65 and k = 0.1537 /year by analytical method. By substituting the above values, the VBGE for *S. sihama* can be expressed as:

$$Lt = 388\,[1 - e^{-0.1526\,(t - (-1.6))}]$$ estimated by graphical method

$$Lt = 390[1 - e^{-0.1537\,(t - (-1.65))}]$$ estimated by analytical method

The theoretical length at different ages as calculated by this equation showed a very close agreement with those estimated by otolith method Table 6.5. Subsequently, the growth curve of *S. sihama* is shown in Fig. 6.5.

6.3.4. Length - weight relationship (LWR)

The mathematical relationship between total length and weight of male and female obtained by logarithmic regression equations are as follows:

Male: $\text{Log } W = -5.1691 + 3.0045 \text{ Log } L$

Female: $\text{Log } W = -5.2898 + 3.0633 \text{ Log } L$

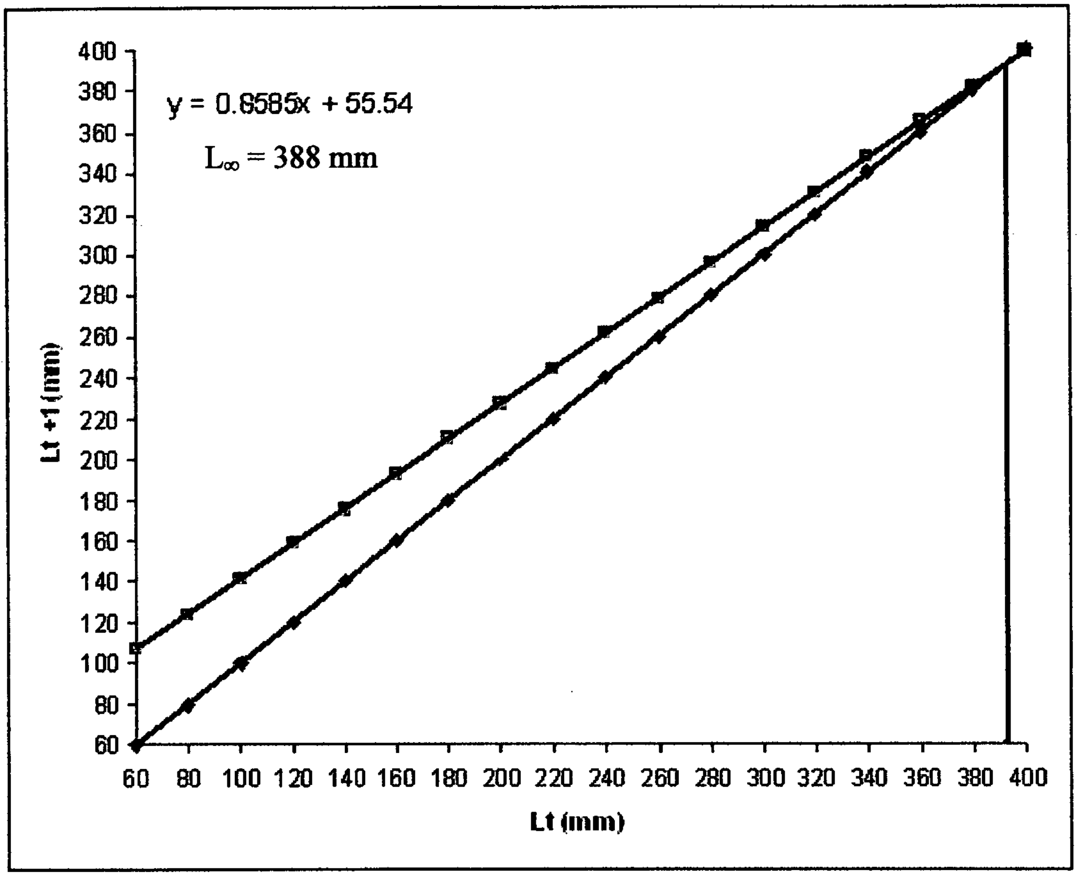
Table 6.4. Calculated length (mm) at age (year) using **VBGE** model.

Age (year)	**$t - t_0$**	**$-K(t-t_0)$**	**$-K(t-t_0)$**	**$1 - e^{-K(t-t0)}$**	**$Lt = L\infty[1-e^{-K(t-t0)}]$**
0+	1.6	-0.24416	0.7833	0.2167	84.1
1	2.6	-0.39676	0.6724	0.3276	127.1
2	3.6	-0.54936	0.5773	0.4227	164.0
3	4.6	-0.70196	0.4956	0.5044	195.7
4	5.6	-0.85456	0.4254	0.5746	222.9
5	6.6	-1.00716	0.3652	0.6348	246.3
6	7.6	-1.15976	0.31356	0.68644	266.3

Table. 6.5. Comparing the mean length of fish at various age groups using different analyses.

Age (year)	**Mean length (mm)**		
	L.F.D.	**Otolith**	**VBGE**
0+	**86.9**	**88**	**84**
1	**131.3**	**130.9**	**127.1**
2	**170.3**	**168.3**	**164**
3	**202.2**	**199.8**	**195.7**

(a)



(b)

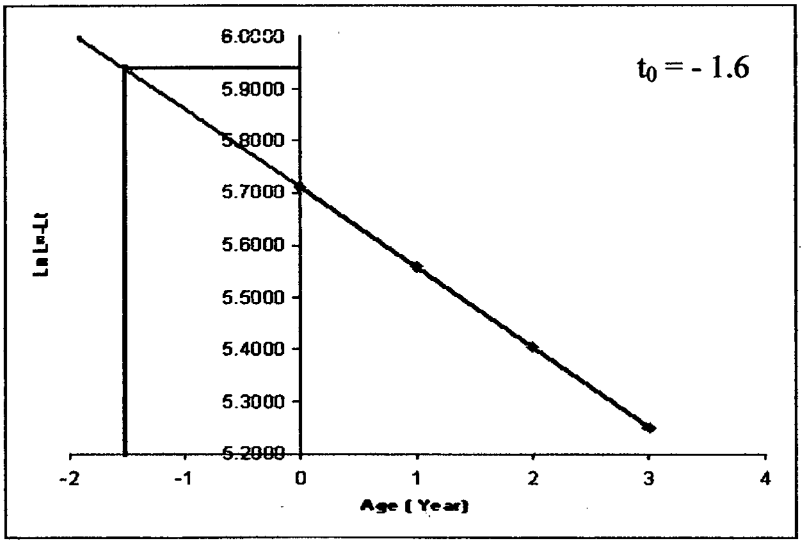


Fig. 6.4. Ford-Wal Ford Graph : (a) L_∞
(b) t_0

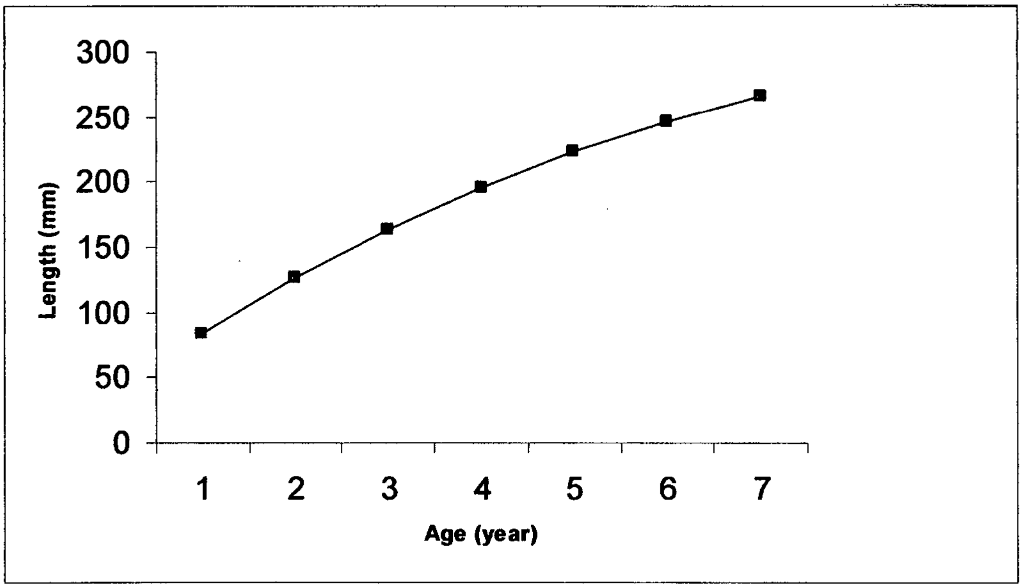


Fig. 6.5. Growth curve derived from VBGE model.

Such relationship was depicted in Fig. 6.6. and 6.7. Their corresponding parabolic equations can be expressed as:

$$\text{Male} \quad : W = 0.00000678\ L^{3.0045}$$

$$\text{Female} : W = 0.00000513\ L^{3.0633}$$

The correlation coefficients 'r' were obtained from the statistical analysis as $r = 0.96$ ($P<0.001$) in case of male and $r = 0.98$ ($P< 0.001$) in female. The results of the analysis of covariance are shown in Table 6.6. It revealed that there was no significant difference ($F = 3.31$, $P>0.05$) in the regression coefficients between male and female. Hence, a common regression for both sexes was calculated, and the common regression equation was expressed as:

$$\text{Log } W = -5.2462 + 3.0420 \text{ Log } L$$

And its parabolic equation is

$$W = 0.00000567\ L^{3.0420}$$

The common relationship was plotted in Fig. 6.8.

Determining the variation of the regression coefficient value 'b' from '3' was tested using '*t*' test, the value of '*t*' for both the sexes were as:

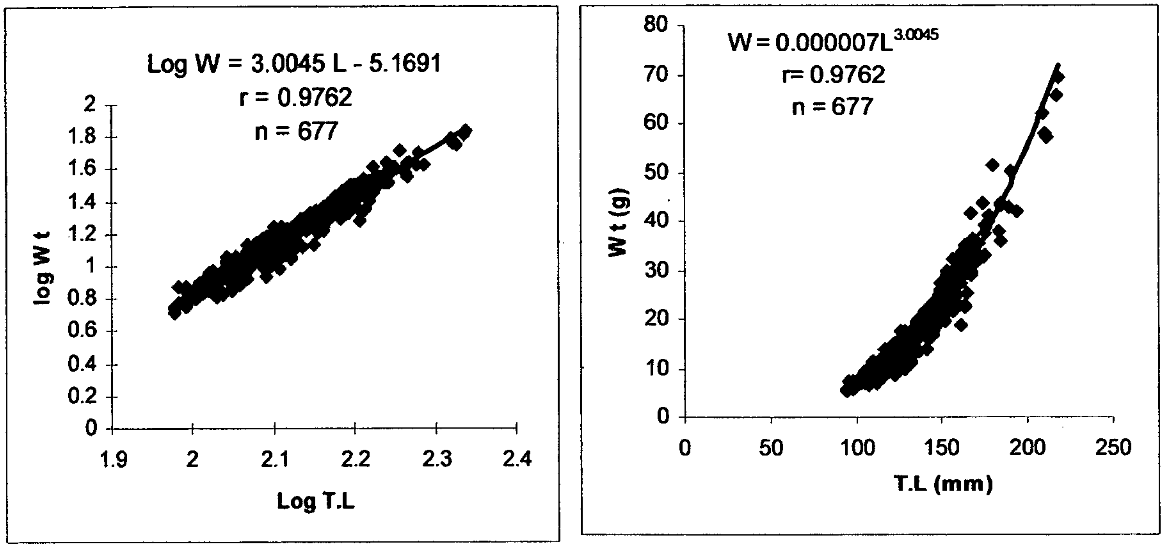


Fig. 6.6. Length – weight relationship in male *S. sihama*.

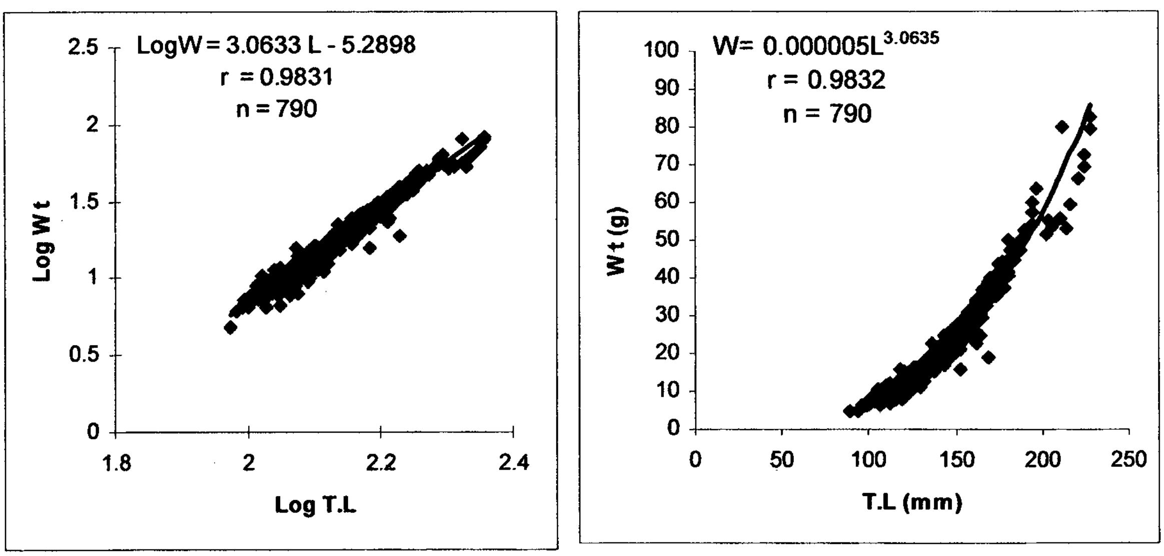


Fig. 6.7. Length – weight relationship in female *S. sihama*.

Table 6.6. Comparison of regression lines of male and female of *Sillago sihama* by ANOCOVA.

Source of variation	Sx^2	Sxy	Sy^2	n	b	Residual	
						SS	DF
Regression (Female)	3.556961	10.8966	34.53245	790	3.06346	1.151154	788
Regression(Male)	2.62423	7.8846	24.8576	677	3.00456	1.16793	675
Pooled Regression						2.31909	1463
Common Regression	6.181192	18.7812	59.3901	1467	3.03400	2.32434	1464

F, 3.31 [0.05(1), 1, ∞] P< 0.025

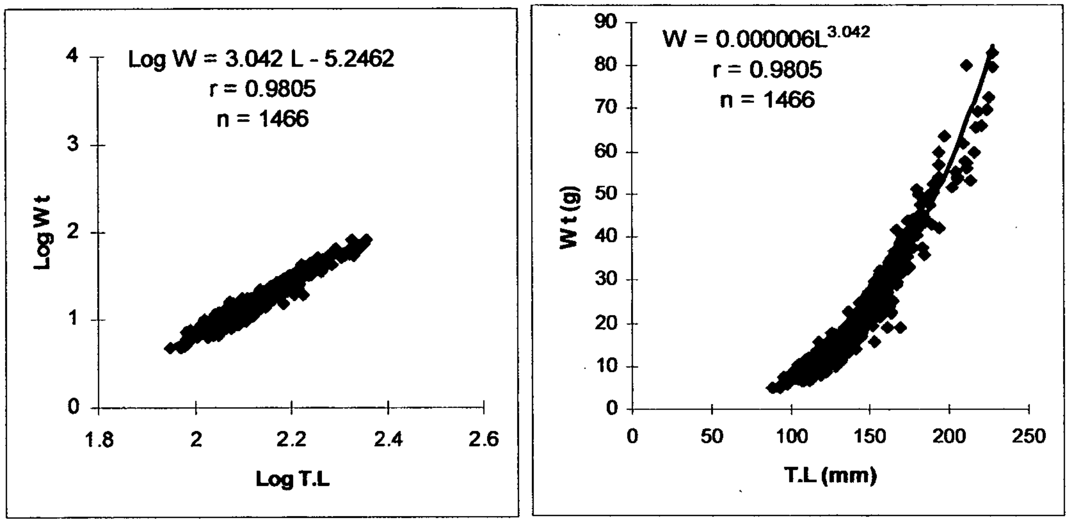


Fig. 6.8. Combined Length – weight relationship in *S. sihama*.

Male: t 0.01 (2), 675 = 0.18 P>0.01 not significant.

Female: t 0.01[(2), 788 = 3.1 P<0.01 . significant.

6.3.5. Relative condition factor (Kn)

The monthly variation of Kn in male and female of *S. sihama* during February 2004 – January 2005 was shown in Fig. 6.9. and 6.10. The fluctuation showed similar trends in both sexes (Fig. 6.9.). In female Kn fluctuated between 0.90 in September to 1.07 in December. The minimum value was reported in September and the maximum in December. In male, the highest value was observed in April and the lowest in September. Generally, Kn values were high during pre-monsoon (February – May) and post-monsoon (November - January) and low during the months of monsoon (July - September) and during October.

Comparing the Kn values with G.S.I. showed that there was no direct correlation between the two variables, while the correlation between Kn values and Ga.S.I. was significant in both sexes (r = 0.58, P = 0.025) male and (r = 0.62, P <0.025) in female. Coincidence of Kn and Ga.S.I. in male and female was depicted in Fig. 6.9. and 6.10., respectively.

The values of Kn at different size groups have been plotted separately for male and female and shown in Fig. 6.11. It showed that Kn remain

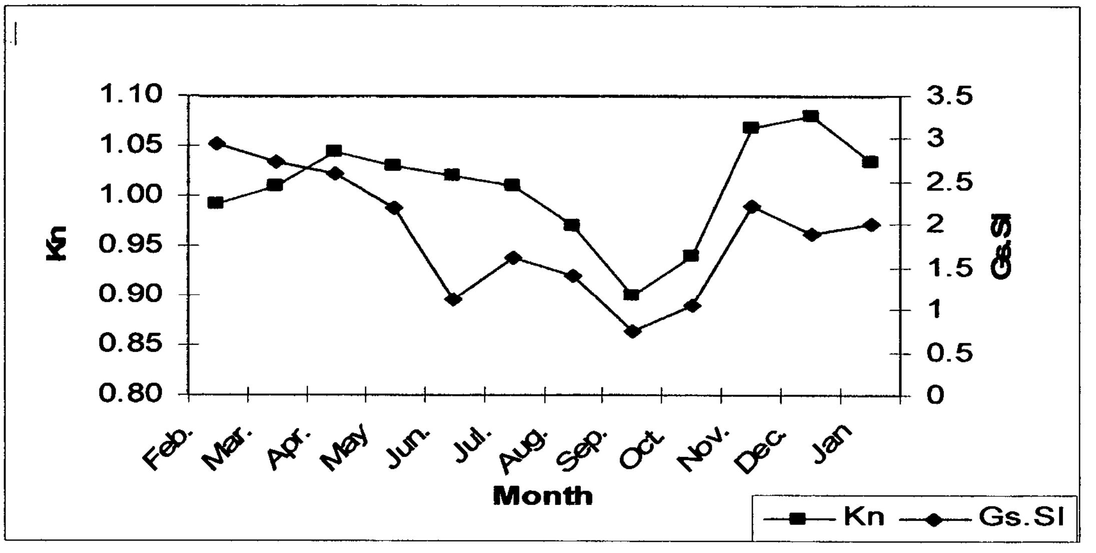


Fig. 6.9. Relative condition factor (Kn) in male *S. sihama.*

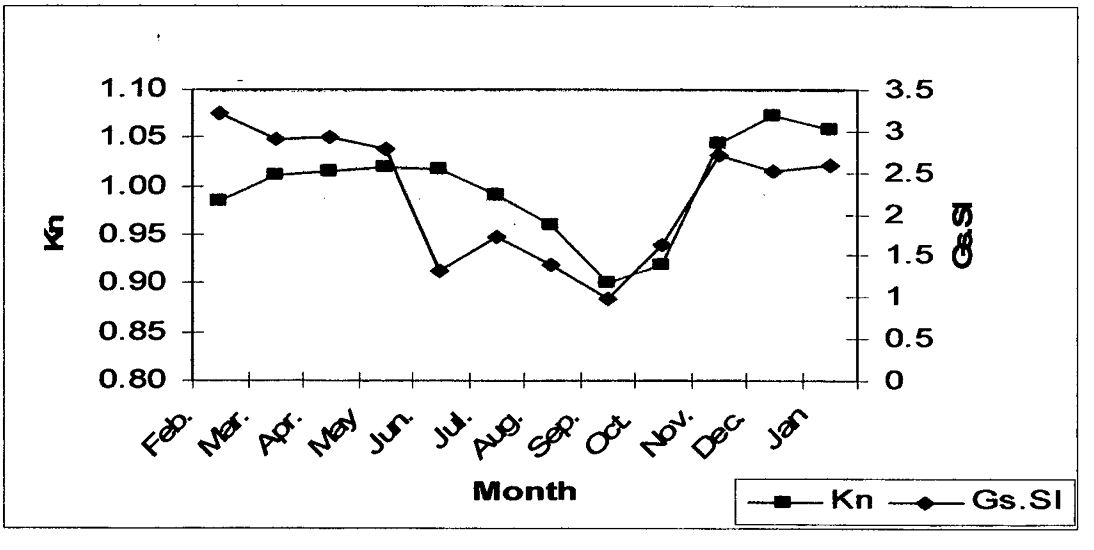


Fig. 6.10. Relative condition factor (Kn) in female *S. sihama.*

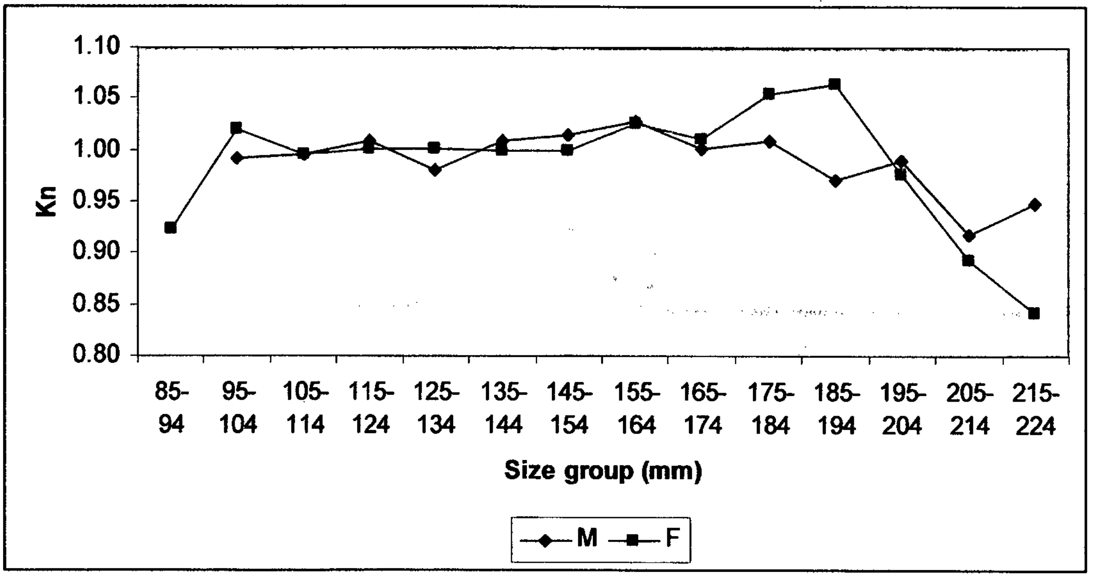


Fig. 6.11. Relative condition factor (Kn) in various size groups.

almost high and stable from size group 95 - 104 mm to 145 - 154 mm, followed by increase in 155 - 164 mm size group in both sexes. From size group 165 - 174 mm there was a gradual increase in Kn until 185 - 194 mm followed by decrease from the size group 195 - 204 mm onwards.

6.4. Discussion

6.4.1. Length frequency distribution (LFD)

As it is clear from Fig. 6.1., the modal progression could not be traced during a period of one year, so the length at age could not directly be predicted from the monthly LFD data. This difficulty in calculating the age and growth from monthly LFD of fish may be because this species has a prolonged spawning period, in which the LFD may not easily indicate the yearly broods.

In the fish that breeds at short intervals over a prolonged period and breeding is non-synchronous in the population, a study of the LFD will not give a proper indication of year classes, because of the entry of broods into the population several times in a year (Qasim, 1973). Therefore, study of LFD was carried out based on pooled data, and the results were more satisfactory. From Fig. 6.2., at least two major modes were observed at 125 - 134 mm length and 155 - 164 mm; one minor mode at 205 - 214 mm was also noticed. Hence, age may be assigned to these modes as 1, 2 and 3 year groups, respectively. Fish at 0-year group was not clearly indicated because they were caught in few numbers and that was probably due to the fishing gear selectivity in which small fishes could not be picked up.

The other attempt of studying the age and growth in *S. sihama* was a combination of LFD data and otolith annual ring count. Based on the counts of the rings on otolith, the age groups arranged as 0+, 1, 2, 3 year and the mean length at each age group was 86.9, 129.2, 166.9 and 202.2 mm, respectively. These results were more accurate than those obtained from direct LFD method. Gowda (1984) has successfully used the combined method in the study of age and growth of *S. sihama* at Mangalore. He reported the presence of four year age group in *S. sihama*, with mean length 155mm (0 year), 205 mm (1 year), 245 mm (2 years) and 275 mm (3 years). The size at different year classes disagree with the observation made in the present study. This could be attributed to variation in environmental conditions.

6.4.2. Growth check on Otolith

Determination of age and growth rate from the study of growth check was based on the assumption that the checks were annual (Qasim, 1957). The annuli are formed of alternative opaque (wide) and translucent (narrow) zones, which accumulate on the otolith. The formation of these zones in the otolith has been attributed to various factors such as seasonal temperature, wet and dry seasons, feeding and reproductive cycles (Beckman and Wilson, 1995). Width of each opaque zone decreases with the increase in age, due to decrease in growth rate. Deviation in age patterns may results from false annuli on the otolith. These annuli tend to be discontinuous, weak and inconsistent with general growth pattern of true ones. They most occur at younger ages.

The present study indicated the presence of fish in four age groups in the population namely 0+, 1, 2 and 3 year groups based on otolith observations. The mean length for the age groups 0+, 1, 2 and 3 was arranged as 88, 130.9, 168.3 and 199.8 mm, respectively. Radhakrishnan (1957) reported the mean length at one to four year age groups as 148, 190, 224 and 240 mm. The variation in size of year classes observed by others could be related to geographical variation and prevailing environmental conditions. Krishnamurthy and Kaliyamurthy (1978) found that the estimated mean length at ages one to five were 60.2, 131.1, 185.4, 227.1 and 265.7 mm respectively. In most recent studies, David and Pancharatna (2003) reported one to four translucent zones and one to five opaque zones on the otolith of *S. indica*.

Work on age and growth of related species from different water systems in the world have been carried out. From Japanese waters, Sulistiono *et al.* (1999) reported that the longevity of specie *S. japonica* was upto 4 years. While the study of age and growth of *S. aeolus* by Rahman and Tachihara

(2005) suggested that the majority of this species die before reaching three years old. From Australian waters, sandwhiting species e.g. *S. vittata* and *S. burrus* rarely exceeded two years of age , though a small number of *S vittata* were caught between four to seven years old (Hyndes *et al.,* 1996; Hyndes and Potter, 1997). However, the present study suggests the longevity of *S. sihama* upto three years old in Zuari estuary. The length and weight of the otolith was observed to be increased with the increase in otolith ring count. Hence, the positive correlation between total length of fish and otolith length and weight suggest that otolith ring count can be used to assess the age of this fish as reported by David and Pancharatna (2003).

6.4.3. Growth parameters

The growth parameters K and L_∞ of the VBGE model are important in fisheries science. The K parameter is closely related to the metabolic rate of fish. A high value of K indicates a high metabolic rate and such fishes mature at early age (t_m) or at a size (L_m) which is large in relation to their asymptotic length L_∞ (Qasim, 1973).

In the present study, the value of L_∞ = 388 mm was relatively high, and the growth coefficient K = 0.15 / year was almost medium. Hyndes and Potter (1997) suggested two categories of growth pattern in *Sillago spp.* from south Western Australia; the first category included fishes characterized by relatively small asymptotic length (<190 mm) and high growth coefficient 'K' (≥1) whereas those in the second category attain relatively large size (L_∞ >300 mm) and have growth coefficient K≤0.5. Accordingly, *S. sihama* from Zuari estuary fall into the second category.

Fishes belonging to the second category attain their sexual maturity at ca. 200 mm, a length reached at the end of the second year life. This is in close agreement with the present study. In *S. sihama,* as in most tropical fishes which have protracted breeding season, almost throughout the year, the entire growth is confined to the pre-maturity phase and has little growth after they become sexually mature. Krishnamurthy and Kaliyamurthy (1978) have calculated L_∞ and K and t_0 values of VBGE in *S. sihama* from Pulicat Lake and the values are 406.82 mm, 0.2226 /year and 0.2745 year, respectively. The growth parameters reported by Gowda (1984) were 532.5 mm , 0.1548 /year and -1.066 year for L_∞, K and t_0 by analytical method and 510.0 mm, 0.1577 /year and -1.09 year by graphical method, respectively. The growth equation was given by Reddy (1994) as $Lt = 519.16\ [1- e^{-0.2179\ (t-\ 0.08909)}]$ obtained by analytical method and $Lt = 508\ [1- e^{-0.211\ (t-\ 0.05)}]$ by graphical method.

6.4.4. Length-weight relationship (LWR)

The regression coefficient of female (3.0633) was found to be higher than in male (3.0045). From this trend, it may be presumed that female gained more weight with the increase in length and subsequently age than male; this difference was not significant as it was revealed from the analysis of covariance [F = 3.3128, 0.05(1), 1, 1464]. Since, there was no significant difference between slopes of regression lines in both sexes. Such result makes it necessary to combine a single regression equation to express the LWR in *S. sihama* from Zuari estuary. Gowda *et al.* (1988) reported that the regression coefficient 'b' does not differ significantly between sexes in *S. sihama* from Mangalore waters, while Jayasankar (1991) and Annappaswamy *et al.* (2004) fount that the 'b' values of male and female differ significantly at 5 % level.

Although the 'b' values were almost equal to the expected value '3' for ideal fish in both the sexes. The't' test clearly showed no departure from cube law in male of *S. sihama* from Zuari estuary. This suggests the isometric growth in male, while the growth was positive allometric in female. Although, the difference between the slopes of the regression of male and female was not significant, it reflects a difference in growth pattern in both the sexes. This difference may be attributed to gonadal development where weights of gonads of females are higher than those of males leading to gaining more weight by female. Dulcic and Karaljevic (1996) stated that the estimated parameters of length weight relationship might differ among seasons and years primarily due to physicochemical characteristics of the environment, sex and maturity stages of a given species. It has been stated that the variation of 'b' is not significant unlike 'a', which may even vary daily Goncalves *et al.* (1997).

The correlation coefficients indicate the degree of association between length and weight of the fish. The high values of correlation coefficients in both sexes revealed that there is perfect relationship between the two variables in this species.

Many workers have worked out the relationship between length and weight of *S. sihama* from Indian waters. Radhakrishnan (1957) reported the relationship between length and weight of *S. sihama* inhabiting Mandapam and Rameswaram waters as $W = 0.11504\ L^{2.8862}$, the 'b' value followed the cube law. Krishnamurthy and Kaliyamurthy (1978), Gowda *et al.* (1988b) and Jayasankar (1991a) observed that the regression coefficient were not significantly different from cube law in *S. sihama* from Pulicat lake, Netravati-Gurupur Estuary and Gulf of Mannar and Palk Bay, respectively. Reddy (1993) reported the same in *S. sihama* from Kali estuary. Annappaswamy *et al.* (2004) also observed that in *S. sihama* from Mulki estuary the regression coefficient was not significantly different from '3' only in female, hence female is following the cube law. Narejo *et al.* (2003) reported a significant difference from cube law in male, female and sexes combined in spiny eel, *Mastacembalus armatus* from Bangladesh waters. From the present observations, it was concluded that the LWR followed cube law only in male of *S. sihama*. However, variation in departure of 'b' value from cube law reported by different authors may be due to difference in the number of samples used for't' test.

While studying the LWR in *S. vincenti* from Parangipettai coastal waters Chandru *et al.* (1988) obtained a LWR equation: log W = -4.8282 + 2.8513 log L. The LWR was also estimated in other species of Sillago. Krishnayya (1963) working on *S. panijus* reported highly significant difference in the regression coefficients of immature and mature fishes which significantly departed from cube law. The LWR of *S. sihama* has also been estimated and reported from different water systems in the world. The 'b' values of *S. sihama* and *S. ciliata* inhabiting the coral reefs, lagoon and mangrove areas of New Caledonia were 3.13 and 3.304, respectively (Letourneur *et al.*, 1998). Harrison (2001) estimated the regression parameters of *S. sihama* as a = 1.075x 10^{-5} and b = 3.029 from South African waters. Taskavak and Bilecenoglu (2001) studied the LWR of *S. sihama* along with other seventeen species from the most important species of the bottom trawl and gill net fisheries in the eastern Mediterranean coast of Turkey. In this study they found that the parabolic equation for the species *S. sihama* was expressed as W = 0.0000014 $L^{3.355}$, with high degree of correlation (r = 0.93).

6.4.5. Relative condition factor (Kn)

The study showed that there was a definite seasonal cycle in the Kn of both sexes of *S. sihama*. The high values of Kn during February - May maybe attributed directly to feeding activity during the summer months (Just prior to the major spawning season in *S. sihama*). Morrow (1951) found that a peak of condition factor is reached at the start of the spawning season in long horn Sculpin, which could be associated with the pre - spawning growth of the gonads.

The gradual decline in Kn from June to October with minimum value in September coincided with the peak spawning season, may be due to decline in feeding intensity by the spawner fishes. By November - December the Kn value started increasing, coinciding with the increase in the number of the spent fishes. This may be related to the increase in the feeding intensity of the spent fishes to rebuild their body's reserves. This resulted in sharp increase of Kn at the end of spawning and during post spawning period. It has been pointed out by several authors that the condition of fishes is influenced to a varying extent by several factors. Baragi and James (1980) found it difficult to explain the changes in condition of the Sciaenid *Johneops osseus* based on the intake of food and sexual cycle. He suggested that this could depend on several other unknown factors. Seasonal variation of Kn is influences by the gonadal development, feeding activity and several other factors (Gowda, 1984; Doddamani *et al.,* 2001)

In the present investigation, comparing monthly variation of Kn with Gastro and Gonado somatic indices revealed a significant correlation between Kn and Gastro somatic index in both the sexes. This suggests that feeding intensity may be the main but not the only factor responsible for the monthly variation in Kn in *S. sihama*. It seems that there is an interrelation between feeding intensity and reproduction and these two factors are the most important that influence the Kn. These findings corroborate observations by Qasim (1957) in *Centronotus gunnellus* and Das (1978) in *Mugil cephalus.*

In relation to size, the fishes of the size groups 95 - 104 to 145 - 154 mm comprised mostly of immature and maturing have high Kn values. This is expected because of high feeding intensity in these size groups. The first sharp increase of Kn at 155 - 164 mm length in both sexes may reflect the length at first maturity. The gradual rise in Kn values from group165 - 174 mm to group 185 - 194 mm followed by decrease in larger fishes due probably to the gain in weight of recovering fishes. The increase in Kn values after the size group 165 - 174 mm is more rapid in female than in male, thus indicating the possibility of the fact that recovery after spawning has more marked effect on Kn of the female than male fish. David and Pancharatna (2003) studied K and Kn in *S indica*. They reported that the gradual decrease in the fish condition after the size at first maturity may be due to decline in feeding activity in response to commencement of spawning period. They also reported decrease in K and Kn with the increase in length and age suggesting that juveniles have a better condition factor than adults.

The above observations revealed that the population of *S. sihama* from Zuari estuary comprising of four year groups. The mean length at different year groups estimated by LFD and using VBGE are in close agreement with those estimated by count rings on otolith indicating the validity of otolith in age determination in tropical fishes. *S. sihama* in this area following an isometric growth pattern in male only. Feeding activity and reproduction cycle are the main factors influence the condition of the species.

Chapter 7

7.1. Introduction

On a global scale, fish and fish products are the most important source of protein in the human diet. This protein is relatively of high digestibility compared to other protein source. It comprises of all the ten essential amino acids in desirable quantity for human consumption. All these properties brings the fish flesh to be in the same class as chicken protein and are superior to milk, beef protein and egg albumen (Srivastava, 1999).

In general, the biochemical composition of the whole body indicates the fish quality. Therefore, proximate biochemical composition of a species helps to assess its nutritional and edible value in terms of energy units compared to other species. Variation of biochemical composition of fish flesh may also occur within same species depending upon the fishing ground, fishing season, age and sex of the individual and reproductive status. The spawning cycle and food supply are the main factors responsible for this variation (Love *et al.*, 1980).

An increasing amount of evidences suggest that due to its high content of polyunsaturated fatty acid fish flesh and fish oil are beneficial in reducing the serum cholesterol (Stansby, 1985). In addition to that, the special type of fatty acid, omega-3 polyunsaturated fatty acid, recognized as an important drug to prevent a number of coronary heart diseases (Edirisinghe, 1998). It is recommended by cardiologists to use generous quantities of fish in food to obtain adequate protein without taking in excessive fatty acids and lipids (Dyerberg, 1986; Kinsella, 1991). The nutrition experts and people who are interested in caloric content of the food for weight control also require information on biochemical composition of the diet.

Although several studies deal with the proximate composition of biochemical components of many commercially important fishes (Parulekar, 1964; Nair, 1965; Raja, 1969; Qasim, 1972; Ramaiyan *et al.*, 1976; Sivakami *et al.*, 1986; Sinha and Pal, 1990; Das and Sahu, 2001), but no work on similar lines has been carried out in *S. sihama* particularly from Goa waters. Therefore, the present study was undertaken to elucidate the dynamics of biochemical composition of muscle of *S. sihama* with reference to season and size.

7.2. Material and methods

Samples of *S. sihama* were collected from Zuari estuary (Dona Paula) during the period of January 2004 to April 2005.The specimens were properly cleaned in the laboratory and the total length, total weight, and sex were determined. Based on their total length, fishes were arranged into size groups. Gonads and general viscera were removed and preserved in 5 % formaldehyde for further study. Body muscle samples (free from skin and scales) from four to six specimens were pooled together and used for the analysis of biochemical components every month. Similarly, a composite sample of fish representing different size groups was taken to study the dynamic of biochemical constituents in this tissue. Estimation of the moisture content was carried out by drying the pre-weighed wet samples at 60 °C until a constant weight was obtained. The difference in weight was calculated and expressed as percentage moisture content of the sample. Percentage was calculated by the following formula.

$$Moisture\% = \frac{Wet\ weight\ of\ tissue - Dry\ weight\ of\ tissue}{Wet\ weight\ of\ tissue} \times 100$$

The dried samples were finely powdered using mortar and pestle and stored in desiccator for further analysis.

Lipid was estimated by the method of Folch *et al.* (1957). Ten mg of dried sample was homogenized in 10 ml of chloroform-methanol mixture (2/1 v/v). The homogenate was centrifuged at 2000 rpm. The supernatant then washed with 0.9% saline solution (KCl) to remove the non-lipid contaminants and allowed to separate .The upper phase was discarded by siphoning. The lower phase was allowed to dry in an oven and the weight was taken. The lipid content was expressed as Percentage by the following formula.

$$Lipid\,\% = \frac{Weight\ of\ lipid\,(mg)}{Weight\ of\ sample\,(mg)} \times 100$$

Protein was estimated following the method of Lowry *et al.* (1951). To a 10 mg of sample 1 ml of 1N NaOH was added for protein extraction in water bath for 30 minutes. Thereafter, it was cooled at room temperature and neutralized with 1 ml of 1N HCL. The extracted sample was centrifuged at 2000 rpm for 10 minutes, and an aliquot of the sample (1 ml) was further diluted with distilled water (1/9 v/v). From the diluted sample, 1 ml was taken and treated with 2.5 ml of mixed reagent (carbonate – tartrate – copper) and 0.5 ml of 1N Folin's reagent. After 30 minutes, sample absorbency was read at 750 nm using spectrophotometer. The results were expressed as percentage.

Total Carbohydrate was estimated by the phenol sulphuric acid method (Dubois *et al.*, 1956). Sample of dried tissue (10 mg) was treated with 2 ml of 80 % sulphuric acid and was allowed to digest for about 20 - 21 hours at room temperature. Two ml of 5 % phenol reagent followed by 5 ml of concentrated sulphuric acid were added to the digested sample and was allowed to cool. Absorbency was measured at 490 nm. The concentrations were expressed as percentage. All the values of biochemical components were expressed as percentage dry weight basis.

Caloric content was calculated by multiplying the concentration of various components with conversion factors 4.15, 9.4, and 5.65 for carbohydrate, lipid and protein, respectively, (Phillips, 1969). The caloric values were expressed as calories per gram (cal/ gm) on dry weight basis. All the estimations were done in triplicate and mean values were calculated.

7.3. Results

Both, seasonal and size wise variation in biochemical components are tabulated in Table 7.1., Fig. 7.1. – 7.4. and Table 7.2., Fig. 7.5. – 7.8, respectively. Moisture forms the major component of the biochemical composition with an annual average value of 77.8 % ± 1.033 throughout the investigation period. The seasonal variation was in the range of 76.2 - 79.6 %.The moisture content was observed to be high from January to March (79.3 % - 79.1 %) followed by gradual decline until June (76.9 %). It was steady during July - September after which moisture content increased until November followed by sharp decline to reach its minimum value in December 2004 (76.2 %) (Fig. 7.1.). Related to size of the fish, there was a slight fluctuation in moisture content. The value was low in the size group 85 – 94 mm and fluctuated within a very narrow range from the size group 95 - 104 mm to the size group 145 - 154 mm, followed by increase in the size group 155 - 164 mm. In the size group 165 - 174 mm moisture content was decreased followed by gradual increase until the

Table 7.1. Seasonal variation in the biochemical components of the muscle of *S. sihama*.

Month/compos	Moisture %	Lipids %	Lipids cal/ g dry wt.	Carbohydrate %	Carbohydrate cal/ g dry wt.	Protein %	Protein cal/ g dry wt.	Total Caloric value (cal/ g)
Jan	79.32	3.20	300.80	0.46	19.09	19.21	1085.33	1405.22
Feb	79.27	2.25	211.50	0.58	24.07	19.13	1080.66	1316.23
Mar	79.08	2.65	241.27	0.52	21.58	22.80	1288.28	1551.13
Apr	78.47	3.05	286.70	0.57	23.66	23.19	1310.44	1620.80
May	77.91	4.19	393.86	0.35	14.48	22.38	1264.37	1672.71
Jun	76.99	4.07	378.74	0.54	22.53	24.73	1397.34	1798.61
Jul	77.04	3.79	356.73	0.44	18.47	21.65	1222.96	1598.16
Aug	78.09	3.12	292.97	0.56	21.08	22.63	1278.36	1592.41
Sep	78.20	2.94	276.26	0.63	26.23	23.89	1349.51	1652.00
Oct	78.70	2.69	249.53	0.54	22.41	24.27	1371.09	1643.03
Nov	79.40	2.16	202.10	0.48	20.09	24.96	1410.17	1632.35
Dec	76.20	3.04	286.23	0.44	18.43	21.23	1199.63	1504.29
Jan	77.43	3.00	246.75	0.53	19.30	22.67	1280.70	1546.74
Feb	77.06	3.76	353.84	0.58	24.07	22.97	1297.61	1675.52
Mar	76.62	3.87	363.47	0.62	25.65	20.46	1155.89	1545.01
Apr	76.70	2.83	280.12	0.59	24.61	23.73	1340.77	1645.50

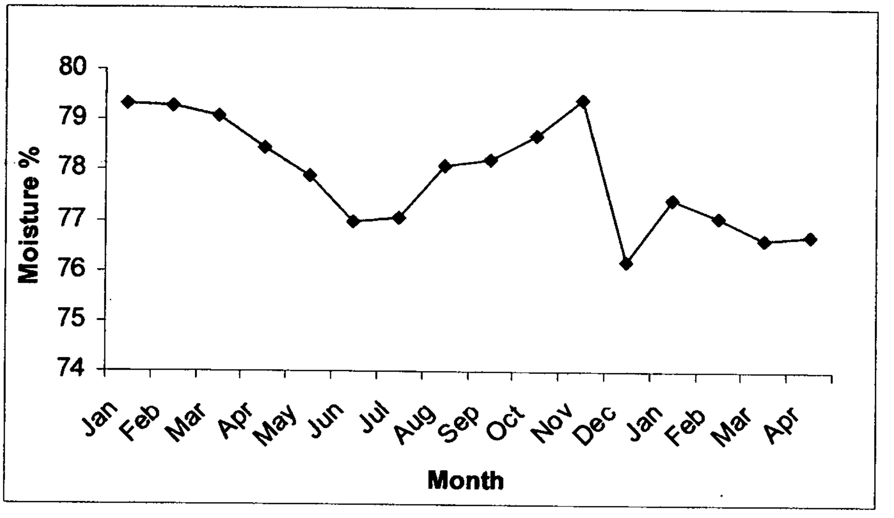


Fig. 7.1. Monthly variation of Moisture content in *S. sihama*.

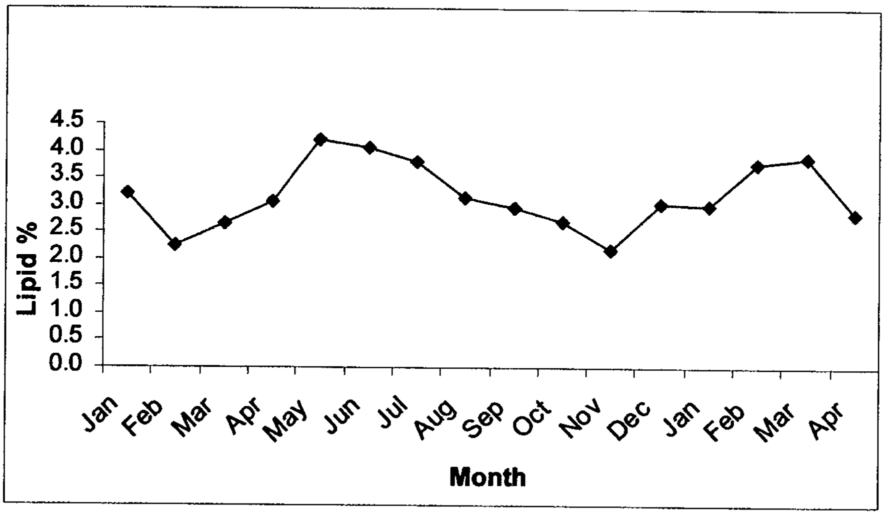


Fig. 7.2. Monthly variation of Lipid content in *S. sihama*.

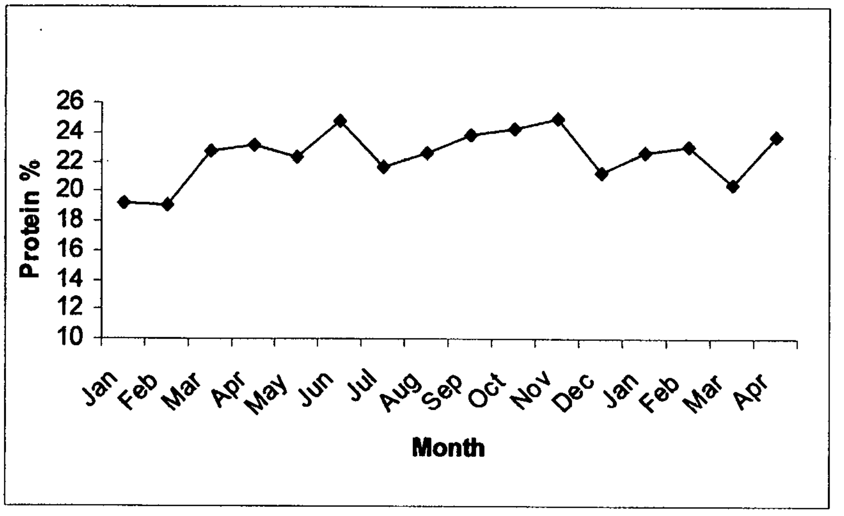


Fig. 7.3. Monthly variation of protein content in *S. sihama*.

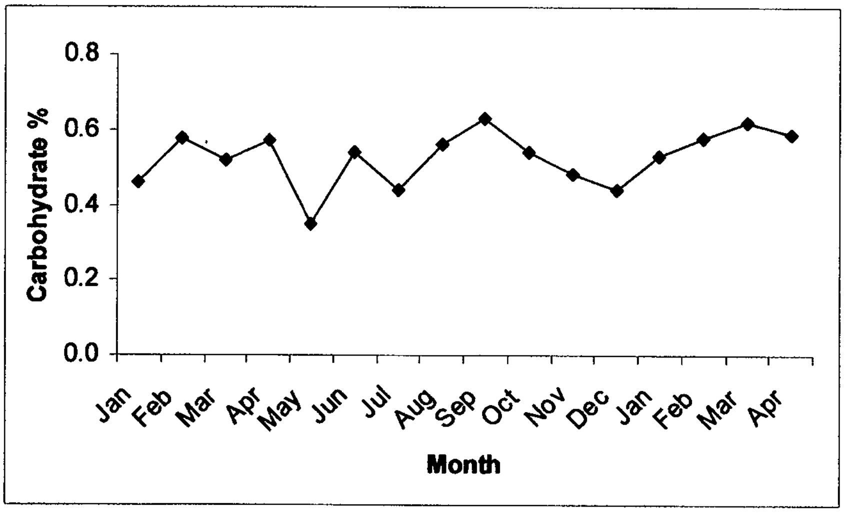


Fig. 7.4. Monthly variation of carbohydrate content in *S. sihama*.

size group 205 - 214 mm. There after the moisture content was decreased (Fig. 7.5.). The moisture content was independent of size class as no coincident pattern was noticed.

Seasonal variation of Lipid content ranged between 4.2 % in August and 2.2 % in November (Fig. 7.2.). The average value was about 3.2 % ± 0.615 indicating that this species is moderate fat fish. The percentage of lipid content showed a low values during January - April, followed by sharp increase in May - June just prior to spawning season. Thereafter, gradual decline was observed to reach its lowest value in November, after which the value increased. Lowest value coincided with peak spawning season. Inverse relationship between lipid and moisture content was observed from the negative correlation between the two constituents ($r = -0.6$, $P<0.05$). Lipid content in relation to size group showed a slight fluctuation (Fig. 7.6.). High value was recorded in the size group 85 – 94 mm followed by decrease in the next size group, 95 -104 mm. Thereafter, gradual increase in lipid content was observed until the size group 145 - 154 mm. Sharp decrease was observed in the size group 155 - 164 mm, which coincided with the first maturity, followed by increase in the next size group 165 – 174 mm. Thereafter, lipid content decreased and showed low values in 205 – 214 mm and 225 - 234mm size groups. No consistent pattern was discernible in relation to the size of the fish.

Table 7.2. Changes in the biochemical components of the muscle of *S. sihama* in different size groups.

Size group/ Composition	Moisture %	Lipids		Carbohydrate		Protein		Caloric value Total cal/ g
		%	cal/ g dry wt	%	cal/ g dry wt	%	cal/ g dry wt	
85-94	75.95	3.75	352.50	0.71	29.40	17.78	1004.85	1386.75
95-104	77.07	2.99	262.26	0.54	22.59	13.84	782.07	1066.91
105-114	77.54	3.24	310.72	0.50	20.94	16.98	959.36	1291.01
115-124	77.32	3.25	305.97	0.53	21.81	16.96	958.19	1285.97
125-134	77.57	3.01	283.96	0.51	21.12	14.45	816.47	1121.55
135-144	77.46	3.89	347.92	0.53	20.25	17.58	993.18	1361.35
145-154	77.21	3.46	323.22	0.49	20.50	21.02	1187.39	1531.10
155-164	77.88	3.11	298.06	0.49	20.52	13.09	739.49	1058.07
165-174	77.07	3.70	333.23	0.52	21.56	17.96	1014.76	1369.55
175-184	77.80	2.99	279.31	0.53	21.85	14.96	845.05	1146.21
185-194	77.63	2.93	275.42	0.48	20.00	16.11	910.37	1205.79
195-204	77.80	2.55	239.70	0.40	16.76	16.02	905.12	1161.58
205-214	78.38	2.25	211.50	0.46	19.21	18.50	1045.09	1275.79
215-224	77.71	2.65	249.10	0.38	15.85	15.31	864.88	1129.83
225-234	77.24	1.60	150.40	0.43	17.97	18.15	1025.26	1193.63

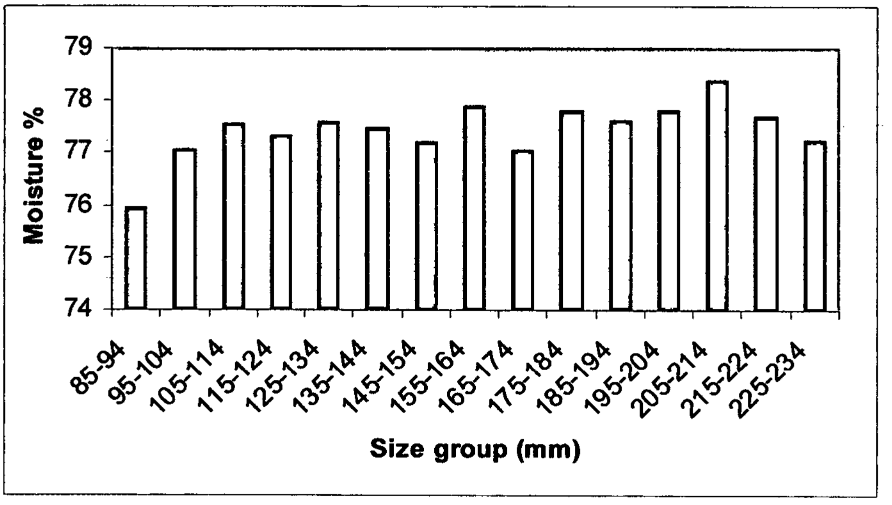


Fig. 7.5. Moisture content in different size groups of *S. sihama*.

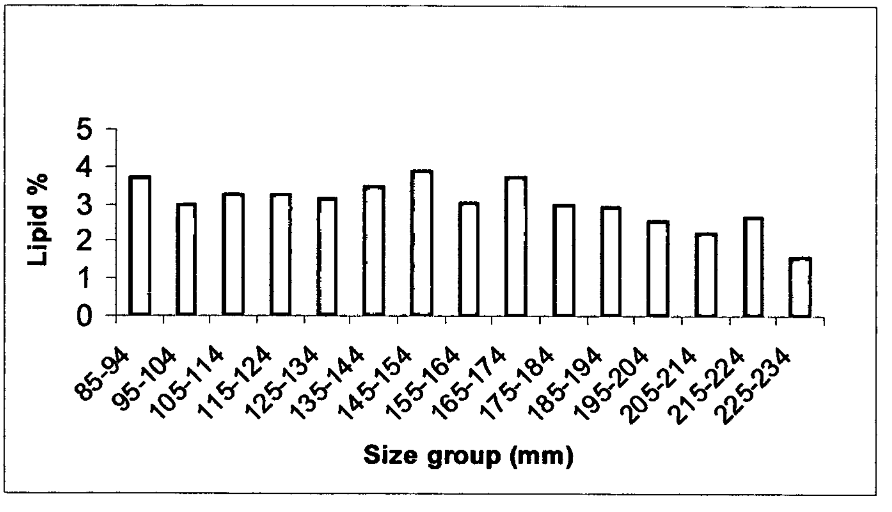


Fig. 7.6. Lipid content in different size groups of *S. sihama*.

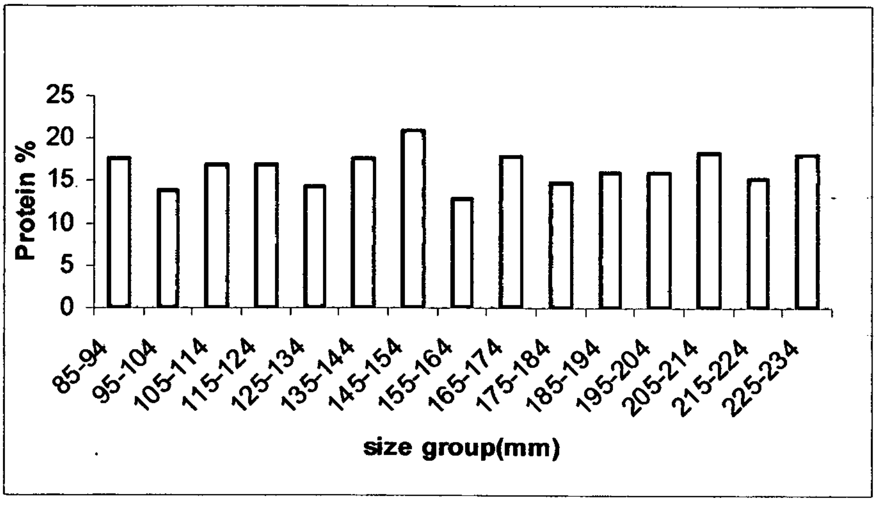


Fig. 7.7. Protein content in different size groups of *S. sihama*.

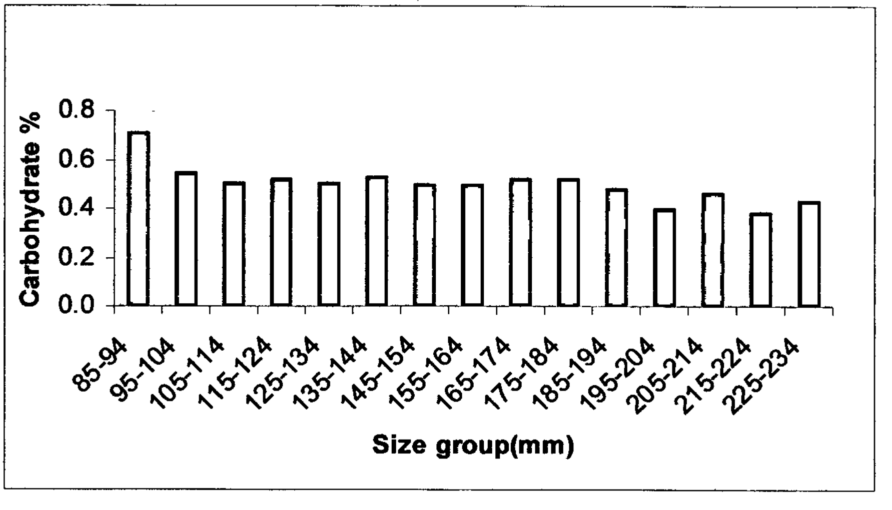


Fig. 7.8. Carbohydrate in different size groups of *S. sihama*.

As shown in Table 7.2. & Fig. 7.3., protein content of *S. sihama* varied from 19.13 to 24.96 %. The average value was calculated to be 22.49 % ± 1.772. There was a gradual increase from January to June followed by slight decrease in July. From August to November, protein values were obviously increased to reach the maximum value (24.96 %) in November. Another decline was recorded in December - February. The lowest value was recorded in February while the highest was in November. Protein content was fluctuating with the growth in size of the fish and did not show a distinct pattern. The highest value was recorded in the size group 145 – 154 mm and the lowest value in the size group155 - 164 mm (Fig. 7.7.).

Carbohydrate occurs in a very minute quantity in the fish tissues. In the present study, it varies between 0.35 % and 0.63 % with an average value of 0.53 % ± 0.075. Monthly variation shown that carbohydrate fluctuated between 0.46 and 0.57 % from January to April followed by a sudden fall to 0.35 % in May. Abrupt increase was observed in June (0.54 %) to September (0.63 %) with slight decrease in July. Thereafter, there was a decline in carbohydrate values until December (0.44 %). The lowest value was recorded in May 2004 and the highest in September 2004 (Fig. 7.4.). Percentage of carbohydrate with reference to size group was stable and did not show a specific pattern (Fig. 7.8.).The results may therefore summarized that there was a similarity, observed between the carbohydrate content and protein content, in which both the constituents have lower values synchronized with the post-spawning and early maturation phases.

Average total caloric value of the biochemical components that utilized as energy sources *viz* Lipids, protein and carbohydrates were calculated as 1285.65 ± 59.09 cal/ g,1270.81± 100.16 cal/ g and 21 .61 ± 3.16 cal/ g on dry weight basis, respectively. Monthly variation of total caloric values is given in Fig. 7.9. Total caloric value observed during the study period ranged between 1316.23 cal/ g and 1798.61 cal/ g. Caloric value increased from February (lowest value) to June (highest values) (Fig. 7.9.). It remained stable from July to November with slight decrease in December followed by gradual increase. Total caloric value in different size group is shown in Fig. 7.10. Positive correlation was observed between the caloric value and the lipid content ($r = 0.456$, $P < 0.05$). The caloric value showed highly significant correlation with the protein content ($r = 0.856$, $P < 0.001$) (Table 7.3.).

7.4. Discussion

The chemical composition of marine organisms comes quite close to that of land animals. The principle constituents are water (66 – 84 %), protein (15 – 24 %), lipids (0.1 – 22 %), minerals (0.8 – 2 %) and sugar in very minute quantity (0.3%) at maximum value in fishes (Jacquot, 1961).

Table7. 3. Correlation matrix between the biochemical constituents and caloric content.

	%Moisture	*% Lipid*	*% Carbohydrate*	*% Protein*	*Total cal / g*
%Moisture	1				
% Lipid	-0.6**	1			
% Carbohydrate	-0.04922	-0.2493	1		
% Protein	-0.05258	-0.05957	0.135462	1	
Total cal/ g	-0.36046	0.455916	0.02469	0.85592***	1

** $P < 0.01$ *** $P < 0.001$

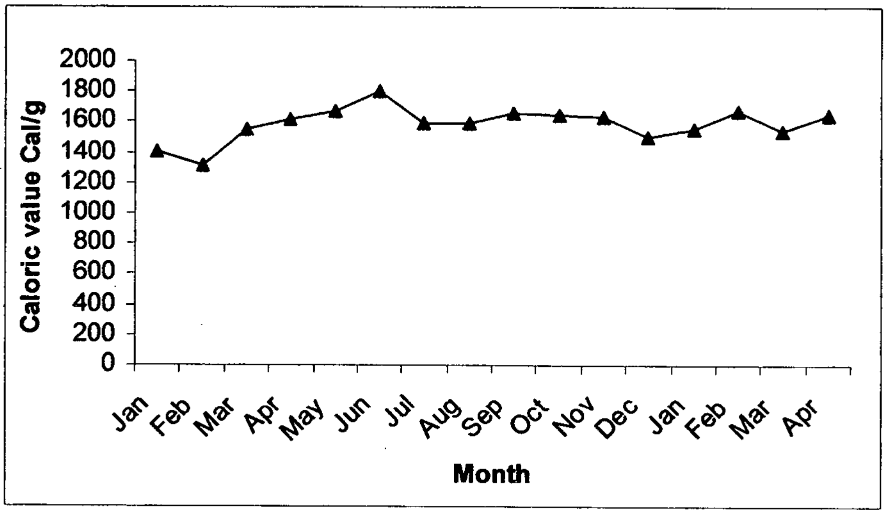


Fig. 7.9. Monthly variation in total caloric content.

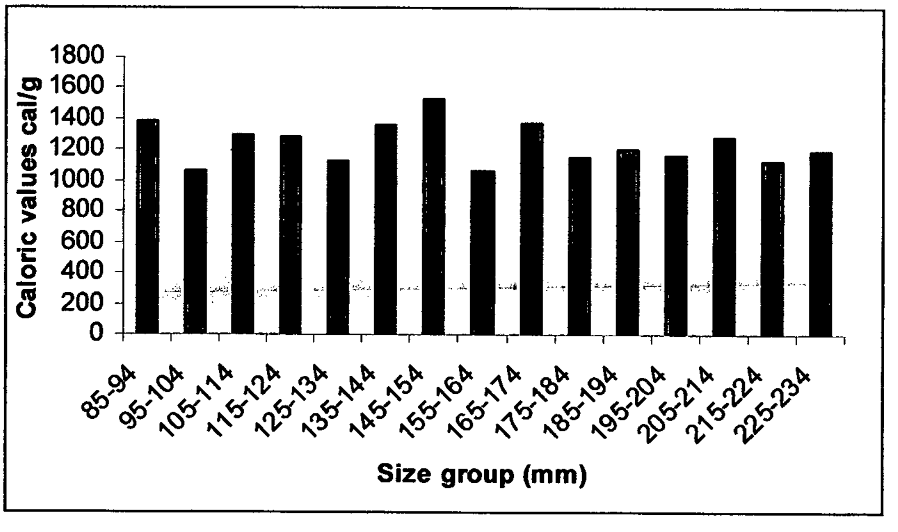


Fig. 7.10. Total caloric value in different size groups.

In the present investigation, the main constituents of the muscles of *S. sihama* were estimated to be 76.19 - 79.57 %, 19.13 - 24.96 %, 2.16 - 4.19 % and 0.3 - 0.6 % for moisture content, protein, lipids and carbohydrates, respectively. Depending upon the level of lipids in the fish muscles, fishes are classified into three categories e.g. fat fish with more than 8 % average fat content, average fat fish with fat content vary between 1 % and 8 % and lean fish with fat content less than 1 % (Srivastava, 1999). Accordingly, *S. sihama* having an average 3.16 % fat content falls into the second category (average fat fish).

The significance of the seasonal variation in biochemical constituents is complex and it is almost impossible to distinguish between the effects of many factors, which influence the biochemistry of the fish. In fishes, the biochemical content is related to maturation of gonads and the food supply (Jacquot, 1961; Medford and Mackay, 1978). The biochemical constituents are also influenced by metabolism mobility of the fish and geographical area (Stansby, 1962). Marked changes were observed in the biochemical composition of the muscle of *S. sihama* during different seasons of the year, which may be the result of the processes mentioned above.

Seasonal variation in the moisture content of the body muscles of *S. sihama* showed decrease in the moisture content from January - May which coincided with the increase in water salinity. However, with the onset of monsoon, the moisture content values increased from July until October, with the advancement in maturation and spawning activity.

The moisture was inversely related to lipid content in the present study. The inverse relationship has also been reported in marine fishes such as *Mugil cephalus* (Das, 1978); *Sarda sarda* (Zaboukas, 2006) and freshwater fishes *Mystus seenghala* (Jafri, 1968) and *Ophicephalus punctatus* (Jafri and Khawaja, 1968). Ramaiyan *et al.* (1978) reported that generally when oil content is high the moisture content is low in *Septipinna taty*, whereas, Shekhar *et al.* (2004) reported that moisture content did not significantly differ according to season in *Labeo rohita*, and was low when other constituents (Lipid, protein and carbohydrate) were high. The moisture content was high during monsoon and part of post-monsoon when the lipid content was low. That can be ascribed to similar rapid fall in lipid content during spawning season.

It has been reported by Das (1978) that high values of moisture content in *Mugil cephalus* could be due to the decline in food intake during the monsoon months when the water would be highly turbid and heavily silt loaded. Similarly, in the present study high moisture was reported during the second half of monsoon season. The results of the present study revealed that changes in moisture content in the muscle of *S. sihama* could be attributed to changes in lipid level directly and to spawning and feeding intensity indirectly.

Fat have a special importance to the animal body, which are primarily a source of energy in the diet. They offer higher calories percentage energy (9.5) than that offer by protein and carbohydrate (4 each). Fats also pad to keep different body organs in place. Moreover, fats give the diet its particular flavors.

Seasonal differences in the availability of food and changes in the reproduction cycle have considerable effect on the tissue biochemistry of the fish, particularly fat (Bumb, 1992). Fishes like other animals, store fat in their muscle for the supply of energy during starvation and reproductive phases. The greatest concentrations of fat may be found at the end of prolific feeding in summer and the least in winter (Love, 1980). Intensive feeding in *Ambassis commersoni* coincides with the occurrence of high fat content in the muscle of fish (Bumb, 1992).

Intensive feeding in *S. sihama* in January and April - May (pre-spawning) coincided with relatively high values of lipids. With the commencing of spawning season in June, feeding activity also decreased until October. There was a parallel decrease in the muscle lipid during same period. This could be attributed to less food intake. Richard (1997) suggested that during starvation the source of energy is lipid and carbohydrate in fishes.

A rise in the fat content of mackerel muscles before spawning followed by a fall after spawning was observed by Chidambaram *et al.* (1952). Reduction in the lipid content during the spawning season has been recorded in *Bregmaceros mclellandi* (Parulekar and Bal, 1969), *Mugil cephalus* (Das, 1978) and *Ambassis commersoni* (Bumb, 1992). The fat content of common carp reached the lowest level in the spent stage, indicating its utilization in spawning activity (Masurkar and Pai, 1979).

Changes in the muscle fat were not well marked with the growth of the fish. The lipid content showed a gradual increase with the increase in length until the size group 145 - 154 mm, which showed the maximum lipid content value. Sudden decline in the next group 155 - 164 mm may correspond to first maturity. While, low values in very large sized indicates that beyond a certain size range the fish becomes leaner. This agrees with the findings of Sekharan (1950). Such distribution of lipids in the muscles of *S. sihama* suggests that the energy demands during the growth are not met by the muscle fat. Higher fat and protein were observed in ripe and gravid fish where a low level of fat and protein was recorded in spent and young fish (Bhuyan *et al.*, 2003).

Protein was the most dominant biochemical constituent in the muscle of *S. sihama*. Protein values were observed to increase from July to November when maximum numbers of mature fishes were found. Decline in protein content in December and remain almost low until February, coincided with post-spawning period. Parulekar (1964) reported maximum protein content in the spawning specimens and the minimum associated with the spent and early maturation phases. Protein content can be correlated with the phases of maturity and spawning (Parulekar and Bal, 1969). Accordingly, protein content goes on increasing with the advancement in maturity. Similar elucidation in *Mugil cephalus* was suggested by Das (1978). He noticed that high values of protein coincided with the spawning season when the gonads were ripe and the decline coincided with post spawning period. In the present study, it seems that fish was utilizing fat as a main source of energy, sparing protein for bodybuilding. This was corroborated by findings recorded by Phillips *et al.* (1966). They found that carbohydrates were utilized for energy by trout and thus spared protein for protein purposes in the body. Protein is not an efficient energy source for fish. It will be used for energy if the available energy from other sources (lipid and carbohydrates) is insufficient (Phillips, 1969). Rattan (1994) suggested that protein and visceral lipid resources may be utilize in the pre-spawning period and the muscle reserve in the post - spawning period in *Etroplus suratensis*. Therefore, the sequence of mobilization of endogenous source of energy could be the possible reason of high level of lipid content in the mature spawners.

Van Bohemen and Lambert (1980) that the highest protein content in pre-spawning stage might be due to its ready supply suggested it by the liver. Medford and Mackay (1978) showed that muscle protein and lipid of northern pike, *Esox lucius* were high before spawning and low after spawning. This could be attributed to the fact that these constituent might have been utilized for spawning and gonadal development. While studying the biochemical composition of *Cyprinus carpio* Sivakami *et al.* (1986) had found that protein for germ building was mobilized from the muscle especially in stages I to IV of maturity. Changes in the protein content during spawning season may occur due to changes in the endocrine system that monitors supply of nutrients to gonads from all parts of body including liver and muscles (Sinha and Pal, 1990; Jyotsna *et al.*, 1995).

Protein cycle and lipid cycle of muscle in *S. sihama* were more or less inversely related. It seems that there is an alternative uses of the energy sources (lipids and protein) in *S. sihama*. Jafri (1968) also noticed such relationship in *Mystus seenghala*. The protein cycle in muscle does not seem to be influenced greatly by feeding intensity. Heavy feeding during summer (pre-monsoon) and low feeding during post-monsoon showed no corresponding decrease or increase in protein in *S. sihama*. Similar findings were reported by Bumb (1992) in *Ambassis commersoni*, in which she observed that protein does not show any relationship with intensity of feeding. Bernard (1976) reported that hepatic and extra-hepatic and glycogen stores serves for metabolic needs during food shortage, while body protein is conserved. Similarly, Norman (1980) suggested that in snakehead, protein catabolism is reducing with the onset of starvation.

Rattan (1994) reported that moisture content and protein gradually decreased in mature male and ripe female, which corresponds to the cessation of feeding in the mature and ripe stages.

Carbohydrates formed a minor percentage of the total composition of the muscle. The low values of carbohydrates recorded in the present study could be because glycogen in many marine animals does not contribute much to the reserves in the body (Jayasree *et al.*, 1994). Ramaiyan *et al.* (1976) reported similar findings in 11 species of Clupeids. Vijayakumaran (1979) stated that carbohydrate plays a minor part in energy reserves of *Ambassis gymnoccephalus* and depletion due to spawning is negligible. Phillips *et al.* (1966) reported that carbohydrates are utilized for energy in trout, thus sparing protein for building of the body.

There are two types of food energy e.g. heat, which is useful for the maintenance of body temperature and free energy that used for body metabolism. However, the food energy including both the types is express as heat. The unit used to express the food energy in nutrition studies is calorie (cal) or kilogram calorie (Kcal). Variation pattern observed in caloric values indicates a direct association between lipid content and high degree of association between protein content and caloric value. The highest caloric value was recorded in the size group 145 – 154 mm when they are ≥ two years old just prior to first maturity. The value decreased in the next size group 155 – 164 mm (size at first maturity). This indicated that the fish starts utilizing the endogenous source of energy for gonads building.

The study of the proximate composition of *S. sihama* revealed that it is rich in protein and average in lipid content. Variation in biochemical composition in present study seems to be governed by spawning cycle and feeding activity.

Chapter 8

8.1. Introduction

Fish has been a major commodity in trade for more than thousand years and seafood has significantly influenced the living conditions of coastal people all over the world. Fishing and fisheries contribute more than any other animal production activity to protein intake in most of the developing regions of the world. India has an extensive coastline of about 8129 km, comprising estuaries, lakes, lagoons, swamps, and mudflats extending between 8° 4' and 37° 6' north latitudes, and 67° 7' and 97° 25' east longitudes.

Indian Ocean occupies an area of 20.8 % of the world ocean; it yields only about 8.2 % of the total global fish catch (Pandey and Shukla, 2005). In addition, India is blessed with vast inland water resources in the form of rivers, estuaries and mangrove wetlands. The total fish catch of India for 2004 was 6,399,390 tones in which production from inland water was more than 50 %.

Sillaginids or sandwhitings are highly esteemed food fishes in Indian waters from Hoogly River in the east coast to Goa in the west coast (Sujatha, 1987). Among Sillaginids occurred in Indian waters, *S. sihama* is commercially the most important. Fishing for *S. sihama* is carried out all round the year with peak during the months of monsoon (June – September), when the sea fishing is suspended.

Although Goa is the smallest maritime state of India, it contributes about 3 % of the total marine fish catch in the country (John, 2006). The total fish production of Goa was 101 thousand tones in 2005. *S. sihama* forms a minor but important fishery from both marine and inland waters in Goa. The species is locally referred to as *"Muddoshi"*. Although, it is a highly esteemed fish by the medium and rich classes due to which it commands high price, it is available in small quantities during different seasons in the market.

Although, traditional culture of marine finfish has been practiced in Goa, these are known to be used for traditional culture of two major cultivable groups, namely Milkfish *Chanos chanos* and Grey mullets *Mugil cephalus* (Nammalwar, 1997).

In the view of its importance in the fishery and absence of any published information on the fishery of this species from this area, the present study was undertaken. The data used have been collected from Directorate of Fisheries, Government of Goa, Panaji.

8.2. Fishing Methods

In India, large varieties of crafts and gears have been designed for marine and inland fishing. The fishing methods used for *S. sihama* are the same that commonly operated in estuaries and backwaters. The main types of gear commonly used in the Mandovi - Zuari estuarine system and inshore waters for the capture of this species are Hook and line, stake net, Gill net and shore seines. Accidentally they are also caught during trawling. Slight modification has been made to these gears to suit local condition.

8.2.1. Hook and Line

This is the ancient method for catching fishes. The principle of line fishing is to offer a bait to entice the fish. The gear consists of a string made of nylon and cotton firmly tied with a small hook at the end. The free end of the line is attached with long bamboo stick (2 - 5 meter long). The baits used (clams meat, shrimp and Nereid worms) are fixed on the hook. The hook having bait remains in the water and the bamboo stick is held in hand. This method used to capture *S. sihama* in Mandovi - Zuari estuarine system and also in inshore waters of Goa throughout the year.

8.2.2. Shore seines

Shore or beach seines are generally used during the monsoon months when fishing in deeper areas is not possible due to changes in weather condition. This gear is small shore seine consisting of some pieces of rectangular nets joined together. It is operated from the beach to surround a small area of the inshore waters. As the fish trapped in the encircled regions, the net is then dragged on the shore. It is used throughout the year especially during monsoon seasons in estuaries and inshore waters.

8.2.3. Gill nets

These nets are locally referred to as "*Kantai*". These are wall-like nets of various sizes and meshes. It is made of number of pieces of variable lengths joined together. Floats are attached to the net to keep it vertical and straight. Capture is, however, more successful in the night due to invisibility of the nets. Gill nets are operated close to the mouth of the estuary. During monsoon season, bigger sized fishes of the species are caught in large numbers by these nets as the mesh size is sufficient to catch the larger fish.

8.2.4. Stake net

Stake net is set depending upon the tidal direction. The gear has conical netting and is made of nylon twine. The net also consists of a scare line tide to the stake with coconut leaves for driving the fish into the net. While the head robe is tide to the stake, lead sinkers are attached at the base of the net. Generally, bamboo poles are used as stakes. The gear is operated at a depth of about 4 - 5 meters and the net is set facing direction of the tide. Once the gear is set an area of about ¾ to 1 km is encircled by the scare line using a dug out canoe. Then the scare line is slowly brought towards the net to direct the fishes into the net. Later, the net is hauled vertically and catch is removed.

8.3. Age and Size composition

The commercial catches of *S. sihama* ranged from 85 to 234 mm in total length from Zuari estuary through out the year. The predominant size groups in the catches ranged between 120 and 170 mm length. Only small numbers of fishes measuring upto 225 mm were found in the catches.

Comparing with age determination data, the catches comprised of one to two year groups. The largest size group upto 225 mm and at about three years old forms only a small portion of the catch. The later group was caught during monsoon months. From the above trends, it was found that fishes of size ranged from 120 to 170 mm when they are almost one to two years old and are the predominant in the catches of *S. sihama* in Goa.

8.4. Productions of *Sillago sihama*

Although *S. sihama* forms one of the economically important species of fishes from Goa coast, its contribution is minor in both marine and inland catches. The importance of *S. sihama* as food fish is perhaps under estimated because in many areas they are taken by small-scale fishermen using seine net and hook-and-line in large quantities and do not necessarily enter records of commercial catches (McKay, 1992).

The percentage contribution of *S. sihama* in the total fish catch of Goa during the period from 1997 to 2005 is given in Table 8.1. and the annual fluctuation of its catch is shown in Fig. 8.1.

Goa has one of the most productive fishing grounds along the west coast of India. These grounds provide several commercially important species of finfish as well as shellfish. The total fish catch of Goa fluctuating between 60075 metric tones and 103091 metric tones during 1997 - 2005 with an average of 76815.67 metric tones. During 1997 to 2005, the catch of *S. sihama* increased from 42 metric tones (0.05 % of total catch) in 1997 to 190 metric tones (0.27 %) in 2001, with an average of 106.56 metric tones (0.14 %). The fluctuation in the annual catch of *S. sihama* may be attributed to multi-fishing. Comparing with the total catch *S. sihama* has a poor landing during the period 1997 - 2005, despite its economic importance.

Table 8.2. shows the production of *S. sihama* from marine and inland waters of Goa during 1997- 2005. It is clear from table that the landing of *S. sihama* from marine water fluctuated between 5 metric tones in 2003 to 55 metric tones in 1998. While the Catches of *S. sihama* from inland

Table 8.1. Percentage contributions of *S. sihama* of the total fish catch of Goa during 1997 – 2005.

Sr.No	Year	Marine catch (M. Tonnes)	Inland catch (M.Tonnes)	Total
1	**1997**	10	32	42
2	**1998**	55	106	161
3	**1999**	13	72	85
4	**2000**	15	107	122
5	**2001**	17	173	190
6	**2002**	8	77	85
7	**2003**	5	70	75
8	**2004**	15	74	89
9	**2005**	27	83	110

Table 8.2. Production of *S. sihama* from Goa waters during 1997 – 2005.

Sr.No	Year	S. sihama catch (M.Tonnes)	Total catch (M.Tonnes)	%
1	***1997***	42	91277	0.05
2	***1998***	161	67236	0.24
3	***1999***	85	60075	0.14
4	***2000***	122	64563	0.19
5	***2001***	190	69386	0.27
6	***2002***	85	67563	0.13
7	***2003***	75	83756	0.09
8	***2004***	89	84394	0.11
9	***2005***	110	103091	0.11

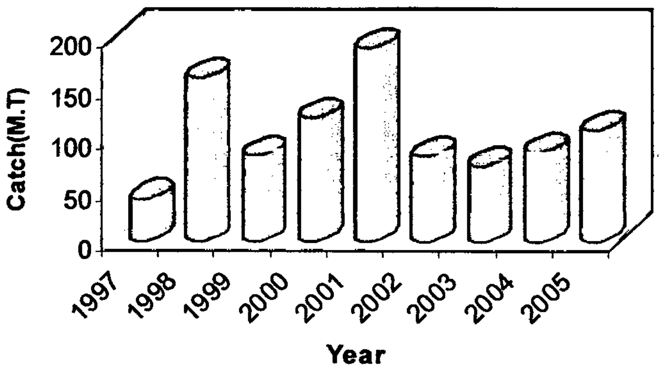


Fig. 8.1. Total catch of *S. sihama* from Goa waters during 1997 – 2005.

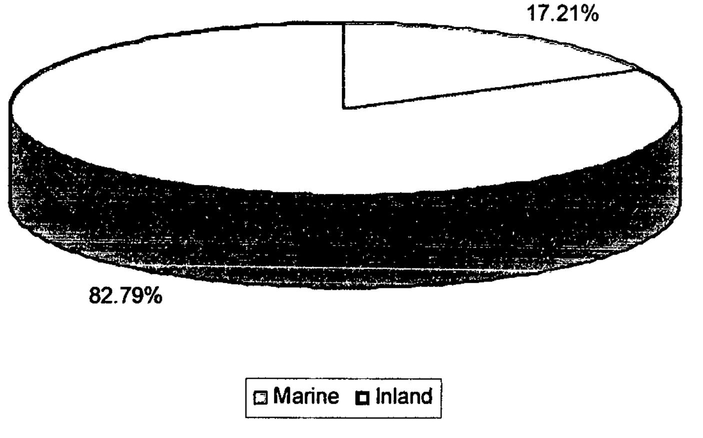


Fig. 8.2. Average percentage contribution of *S. sihama* from marine and inland waters of Goa during 1997 – 2005.

water fluctuated between 32 metric tones in 1997 and 173 tones in 2001. This indicates that the catch of *S. sihama* from inland waters was better than that from marine (Fig. 8.2.).

8.5. Culture Possibilities

Aquatic animals including fishes hold a greater productive potential than terrestrial animals for many reasons. The most important reasons are the body temperature, which is near that of their environment, and the body density is similar to habitat (Parker, 2002). With these two properties, the energy required to regulate the body temperature and that to over come gravity can be directed towards growth. This can enhance the growth rate. Another important feature of aquatic animals is that they inhabit multidimensional environment, where different species inhabit different space and position within the water body. This expands the aquaculture options at one site. In addition, the efficient food conversion increases the nutritional values of the animal.

Choosing a fish species for aquaculture is important for successful culture (Parker, 2002). The candidate species should have a number of features for successful culture, these are:

- Reproductive habits must be understood.
- The fish should produce massive quantities and occur frequently.

- Egg and larvae requirements, a stable supply of seed must be available.

- The next factor to consider is the nutritional needs and feeding habits.

- Adaptability to crowding.

- Disease resistance.

- Market demand.

S. sihama possesses most of the features of a candidate species mentioned above. In the recent past, *S. sihama* has been considered for culture in both freshwater and saltwater systems (Dhulkhed and Ramamurthy, 1977; Kaliyamurthy, 1979; James *et al.*, 1976, 1984a, 1984c; Alagarswami, 1990). It has a prolonged spawning season, spawns more than once in a single spawning season, having high egg production. Hence, the seed are available throughout the year. Earlier workers have reported the abundance and seed resources availability in different seasons and regions. Small-sized Juveniles of *S. sihama* have been observed in the Gulf of Mannar and the Palk Bay during rainy season (Radahakrishna, 1957 and James *et al.*, 1984d), from the south Kanara coast (Ramamurthy and Dhulkhed, 1975), from Gangoli estuary (Jemes *et al.*, 1976). Fry of *S. sihama* were obtained in the surf region of the sea at

Calicut during January- February and October (Mohan, 1980). Post-larvae and Juveniles of *S. sihama* were available in good quantities throughout the year in the Pulical Lake (Ramamurthy *et al.*, 1978; Ramamurthy, 1985; Roa *et al.*, 1984) and in Palk Bay (James *et al.*, 1984). They were also reported in the fishery resource of Uttara Kanada District (Reddy and Shanbhogue, 1990). In Goa waters, it is available in large number in the inshore waters in all the months (Ansari *et al.*, 2006). Thus, it seems that the seasonal abundance of the seeds of *S. sihama* may be similar in both east and west coasts of India with slight variation in the peak months of abundance.

S. sihama feeds on a wide range of food items, which can be supplied directly from the environment. Being a non-predatory, it can be cultured in a poly culture system along with other species. Some experiments were carried out on the poly culture. At Mangalore *S. sihama* was cultured with *Chanos Chanos*, *Liza macrolepis*, *and Penaeus indicus*, and the growth rate of 10.6 mm, 57.4 mm, 28.2 mm, respectively, were recorded. At Tuticorin *Chanos chanos*, *Valamugil seheli* and *S. sihama* were kept in pen culture, and the average monthly growth increment recorded were 22.7 mm, 26.9 mm and 16.8 mm, respectively. Rabbit fishes, groupers and sandwhiting *S. sihama* were cultured in a cage culture (James *et al.*, 1984b). The average monthly growth rate for *S. sihama* was 10 mm. The results of these experiments are encouraging.

Considering the biological information available of *S. sihama* and its ability to withstand very wide range of salinity (Bal and Rao, 1984), *S. sihama* is suitable for culture in both the brackish water and fresh waters.

Owing to the natural abundance of the seeds of *S. sihama* and its demand in the local market, culture of the species should be attempted on a large scale in Goa waters. This will increase the yield and generate employment opportunities for the fishermen communities.

Summary

Goa with about 105 km long coastline has vast resources of marine shellfish and finfish. Fish is a protein rich food and for the state of Goa it assumes special significance as it forms one of the chief components in the diet of about 90% of the population (Ansari, 2004). *S. sihama* is a highly esteemed fish, due to which it commands high price in the local market. It forms a minor but important fishery from both marine and inland waters in Goa.

In view of its importance in the fishery and absence of any published information on its eco-biology and fisheries from Goa coast, the present study was undertaken for a period of sixteen months from January 2004 to April 2005. The highlights of the results are as follows:

Environmental parameters

Seasonal variation of the major hydrographical parameters such as temperature, salinity, dissolved oxygen and pH of Zuari Estuary were recorded during the study period. The study revealed that southwest monsoon rain and land drainage seem to play an important role in changing the physico-chemical parameters of the estuarine waters.

The temperature and salinity values were low during monsoon than during pre and post-monsoon seasons. Rainfall has a direct effect on the temperature and salinity. In contrast to salinity, dissolved oxygen values increased during monsoon months. Higher values of pH were recorded during pre-monsoon and post-monsoon, and low during monsoon coincident with the decrease in salinity.

Morphometrics

Interrelationships between morphometric measurements of *S. sihama* were statistically analyzed. Fourteen parameters were used and regression equations for each were formulated to evaluate the growth rates of different body measurements in relation to total length. The equations describing these relationships in male and female, respectively, are

Standard length	Y= -6.3971 + 0.9067 X,	Y = -5.3507 + 0.8974 X
Head length	Y= 4.6721 + 0.2013 X,	Y= 2.9188 + 0.2196 X
Snout length	Y= 1.6364 + 0.095 X,	Y= -0.7322 + 0.1160 X
Postorbital length	Y= 0.1737 + 0.0996 X,	Y= 1.272 + 0.0887 X
Interorbital length	Y= -1.3067 + 0.0642 X,	Y= -0.4908 + 0.0851 X
Eye diameter	Y= 1.6411 + 0.0441 X,	Y= 1.9332 + 0.0427 X
Pre first dorsal fin	Y = 3.8917 + 0.2743 X,	Y = -2.1307 + 0.3255 X
Pre second dorsal fin	Y = -4.5639 + 0.5186 X,	Y = -5.4519 +0.5281 X

Pre pectoral length	$Y = -5.4735 + 0.2741 X$,	$Y = 0.8617 + 0.2677 X$
Pre pelvic length	$Y = 1.8355 + 0.2681 X$,	$Y = 0.0166 + 0.2879 X$
Pre anal length	$Y = -3.8179 + 0.5086 X$,	$Y = -7.7459 + 0.5428 X$
Body depth	$Y = -4.4198 + 0.1862 X$,	$Y = -3.6020 + 0.1815 X$
Depth through anal fin	$Y = -6.4499 +0.1915 X$,	$Y = -7.6755 + 0.2014 X$
Caudal peduncle depth	$Y = 0.5395 + 0.0616 X$,	$Y = 0.6470 + 0.0612 X$,

(X represents total length and Y the other variables)

Of the fourteen morphometric characters examined the maximum growth rate in relation to total length was noticed in standard length and the minimum was observed in eye diameter. Established correlation coefficients (r) showed high positive significant correlation (P<0.001) in both the sexes. The highest correlation coefficient was observed between total length and standard length (r = 0.998) in male and (r = 0.999) in female. The lowest was between postorbital length and eye diameter (r = 0.889) in male and (r = 0.836) in female. Comparisons of slopes estimated in above relationships showed significant differences between male and female (P<0.001) except for the relationship between caudal peduncle length and total length.

Food and Feeding habits

According to type of food *S. sihama* can be classified as euryphagous carnivores, feeding on a wide range of planktonic and benthic organisms. The monthly percentage composition of food revealed that *S. sihama* feeds mainly on crustacean, polychaete, fish larvae and mollusca.

The ontogenetic dietary change was distinctive in *S. sihama* in the present study. Small fishes are exclusively planktonic feeders subsisting mainly on small crustacean, crustacean eggs and larvae, fish eggs, molluscs larvae and polychaetes. The planktonic prey in the diet of *S. sihama* is gradually decline in fishes above 94 mm total length and being replaced by benthic food items (polychaetes, crabs, small prawns, Shrimps, Amphipods, Isopods, Tannaids, Molluscs and fish larvae).

The feeding activity of *S. sihama* fluctuated with season as well as maturity stages. The intensity of feeding was high during pre-spawning (March - May) and post-spawning seasons (January - February), low during spawning season (June - December).

Reproduction

Maturity stages were classified based on the macroscopic appearance of gonads and microscopic study of the intra-ovarian eggs in female. Accordingly, five maturity stages were recognized in *S. sihama.* They are immature, maturing, mature, ripe and spent.

The ova diameter studied indicate the gradual continuous maturation processes in the species. Presence of more than one mode of ova within a wide size range in the matured ovaries revealed that *S. sihama* spawn intermittently throughout the year with a peak in September - November. The percentage frequency of mature gonads also suggests that this species has a prolonged spawning season extending from June to December with highest spawning activity during September to December in both the sexes.

In the present study, the smallest size at which mature specimens were found was 138 mm and 135 mm in male and female, respectively; while the 50 % maturity was found to be at 155 - 164 mm size group. Hence, 155 - 164 mm was considered as the size at which both the sexes attain sexual maturity when they are ≥ 2 years old.

The sex ratio of the population shows that the sexes are equally distributed with a ratio of 1: 1.13 of male : female.

The fecundity values were found to vary from 11,376 to 103,695 in specimens ranging between 150 mm to 342 mm with mean fecundity value of 42,575. Relationships between fecundity and other parameters such as total length of fish, weight of fish and weight of gonads were statistically analyzed. Fecundity showed significant linear relationship with the three parameters with high degree of association being 0.73, 0.77 and 0.76, respectively.

Age and growth

Age of the fish was determined by growth check on hard parts (otolith). The determination made on the basis that successive rings are formed as the fish grows in age. The mean length of *S. sihama* at various age groups e.g. 0+, 1, 2, 3 years was estimated as 88, 130.9, 168.3 and 199.8 mm, respectively. The relationship between total length of the fish and length and weight of the otolith revealed that there was a highly significant association between total length of fish and length and weight of the otolith ($r = 0.94$ & 0.93) ($P<0.001$), the regression equations were given as:

$$Y\ (T.L) = 1.474 + 0.0364\ X\ (O.L)$$

$$Y\ (T.L) = -\ 0.0492 + 0.0006\ X\ (O.W).$$

Since, it was not possible to determine the age directly from the length frequency data, it was done based on the data of otolith study. The average lengths were 86.9, 129.2, 166.9 and 202.2 mm at 0+, 1, 2, 3 years, respectively.

The growth parameters were determined by VBGE model based on the otolith study data. The growth equations derived by analytical and graphical methods are:

$L_t = 390[1- e^{-0.1537\,(t-(-1.65))}]$ & $L_t = 388\,[1- e^{-0.1526\,(t-(-1.6))}]$, respectively.

There was a close agreement between the mean length at various age groups and growth rate derived by the three methods. This suggests the validity of otolith in age determination of tropical fishes.

The length-weight relationship separately for male and female was found to be as:

$$\text{Male} \quad : \text{Log } W = -5.1691 + 3.0045 \text{ Log } L$$

$$\text{Female} : \text{Log } W = -5.2898 + 3.0633 \text{ Log } L$$

The correlation coefficients 'r' were obtained from the statistical analysis as ($r = 0.96$, $P<0.001$) in case of male and ($r = 0.98$, $P<0.001$) in female indicating perfect relationship between the two parameters in both sexes. Since, there was no significant difference between the slopes "b" of the two regressions, a common regression for both sexes was calculated as:

$$\text{Log } W = -5.2462 + 3.0420 \text{ Log } L$$

Variation of the regression coefficient value 'b' from cube law using '*t*' test revealed that although the "b" value was almost equal to 3 in both sexes, female showed significant departure from 3. This suggests that only male of S. *sihama* inhabiting this area is following the cube law showing isometric growth pattern.

The pattern of fluctuation of relative condition factor during different months of the year seems to be similar in both sexes of *S. sihama*. This pattern was found to simulate the pattern of the gastro somatic index. Although feeding intensity showed a positive correlation with Kn values, the fluctuation in Kn of both the sexes could not be attributed to feeding intensity or reproductive cycle alone. It seems that there is an interrelation between feeding intensity and reproduction and these two factors are the most important factors influencing the Kn *S. sihama*.

Biochemical composition

Seasonal variation in the biochemical composition of the muscle of *S. sihama* were studied and the average values of the major components were 77.8 ± 1.03 % moisture content, 3.2 ± 0.62 % lipids, 22.49 ± 1.77 % protein and 0.53 ± 0.07 % carbohydrate. The results indicate inverse relationship between moisture content and lipids. The protein content goes on increasing during the spawning season when the lipid content decreases, suggesting that there is an alternative use of protein and lipid as energy source in this species. Variation in biochemical composition in the present study seems to be governed by spawning cycle and feeding activity.

Fishery and Culture possibilities

S. sihama forms about 0.14 % Of the total fish catch of Goa. It forms a minor but economically important fishery in Goa. Although, it is highly esteemed by the medium and high classes in Goan society, *S. sihama* is present in the local market in a limited quantity. The catches comprised of two to three year groups (120 - 170 mm length). Hook and line, gill net, small shore seine and stake net are the main gears used for the capture of this species in the estuarine, inshore and backwaters.

Study of different aspects of the ecology and biology of *S. Sihama* indicates the suitability of this species for culture in both the brackish water and fresh waters.

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