STUDIES ON THE ECOLOGY AND BIOLOGY OF BUTTERFISH SCATOPHAGUS ARGUS IN MANDAPAM COASTAL REGION

Thesis submitted for the award of the Degree of

DOCTOR OF PHILOSOPHY

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NOVEMBER 1998

Dedicated to my

beloved parents and

Beloved Family

CERTIFICATE

This is to certify that this thesis entitled **STUDIES ON THE ECOLOGY AND BIOLOGY OF BUTTER FISH *SCATOPHAGUS ARGUS* IN MANDAPAM COASTAL REGION** submitted, by **Mr. V. Gandhi, M.Sc., A.R.S.**, for the degree of Doctor of philosophy in science, to the Madurai Kamaraj University, Madurai, India, is based on the results of studies carried out by him under my guidance and supervision. This thesis or any part thereof has not been submitted elsewhere for any other degree or diploma.

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1. INTRODUCTION

The ocean water covers seven-tenths of the earth's surface with a mean depth of 4000 meters (Colin Nicol, 1960). This tremendous expanse and depth are inhabited by living organisms which are partially exploited for the livelihood of the ever increasing world population. However, the oceans are not evenly populated throughout their extent. The density and total volume of living creatures are the greatest in coastal waters. The food of all animals in the sea is ultimately derived from marine plants including phytoplankton and seaweeds. At present, the growing population of the world is badly in need of food grains and also of animal protein which is rich in fishes.

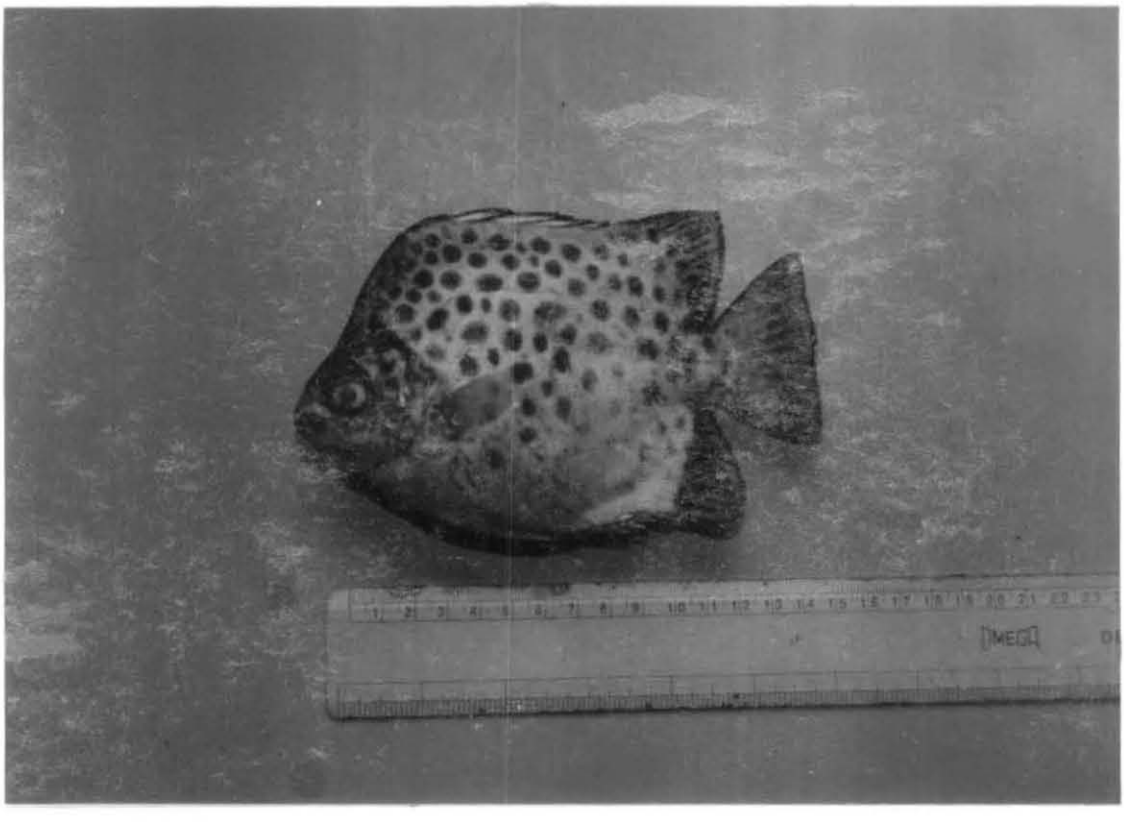
Hindu Religion considers fish as one of the incarnations of God and is called "Matsyavathara" in Sanskrit. Valuable information is available regarding fish, in the great epics of India, in stone carvings and paintings. History of India also has a lot of information on fish, its trade and fisher-folk. Information is also available about salt-fish trade in the West Coast of India which has been carried out as early as in the 18th century. Traditionally fishing has been the principal occupation for the livelihood of a section of the population living along coastal areas.

Early naturalists like Hamilton-Buchannan, Gunther, Day, Alcock, Anderson (CMFRI, 1977) and a number of others carried out numerous studies on Indian aquatic fauna and made valuable contributions to the systematics, distribution and biology of freshwater and marine fishes of the country (CMFRI, 1977). Subsequent workers like Hora, Misra, Trewaves (CMFRI, 1977) and others have added considerable information to the knowledge on the ichthyofauna of India. Certain notable contributions to fishery research were also made by Day, Nicholson, Hornell, Hora and Setna (CMFRI, 1977). In India, not much attention was given to fisheries development aspects in the early part of this century, while other parts of the globe took keen interest to develop fisheries. Only after independence, in the year 1947, steps were taken for organized research and development with the establishment of Central Fisheries Research Institutes for marine and inland fisheries, the Deep Sea Fishing Station and the Central Institute of Fisheries Technology.

Man continues to search for new resources from the sea, especially from the coastal waters where there are still unexploited fishery resources in abundance. By using modern technologies, the existing fishery resources can be utilized for satisfying the requirement nutrient of our population. During the 1940s and 1950s there was not much demand for marine prawns, lobsters, squids, oysters, mussels, crabs and sea-cucumbers and hence were not considered economically important. The poor fishermen themselves did not take them even for their side dish. But

now, these resources play a major role in earning foreign exchange, for the country. They are also in great demand for consumption by the local population, both rich and poor. Similarly, among fin fishes, scats were not considered economically important in the past. However, they have gained much importance now as one of the economically important teleost fishes, not only in India, but also in other countries. They are caught along with other commercially important fishes by trawl nets, shore seines, gill nets, barrier nets and hooks and lines.

The spotted scat *Scatophagus argus* (Plate-1) is also known as leopard pomfret (Mookerjee *et al.*,(1949), butterfish, spotted butterfish, Argus fish, spadefish and spotted spadefish (Barry and Fast, 1988) and spotted scat (Bardach *et al.*, 1972) and is abundant in the coastal waters of India. This fish was not exploited properly during the early part of this centuary because of lack of demand which was attributed to its feeding behaviour. However it is in more demand at present. They are largely consumed by the economically backward fishermen population and also by others because, it is not an expensive fish but at the same time the flesh is of good quality and taste. Large size fishes are transported to inland markets, where they fetch good price just like any other good quality table fish.As this fish is having numerous black spots, it is called `spotted scat'. Since it has black spots on its body, it looks like a leopard and at the same time has the shape of a pomfret. Hence it is also known as `leopard pomfret.' Since its flesh is very soft just



like butter, it is also called as `spotted butterfish'. The body shape of the fish appears like a spade and hence is also known as `spotted spadefish'. It is considered to sing wordless jazz by producing peculiar sounds (Frank, 1979).

The name " **Scatophagus**" is translated as "offal-eater", or "one which eats fecal matter". The name was derived from the finding that scats gathered in harbours and fed on offal and other waste discharges from ships. Scats were also found around sewer outfalls and in waters characterized by high organic waste disposal. However whether scats actually eat offal, or whether they feed on attached algae associated with such discharges, is not known well. The latter has been observed regardless of whether scats are truly coprophagous or not. Many people prefer not to eat this fish because of its reputation as such. The word **"argus"** translated as "thousand eyed, clearly refers to the spots found on all juvenile and large fish (Barry and Fast, 1988).

Scats are not only found in the marine environment, but also are found in other water bodies. The spotted scat, *Scatophagus argus* (Linnaeus) is one of the few teleost species of economic importance that could potentially thrive in tropical brackish-water fish ponds (Bardach *et al.*, 1972, Fast *et al.*, 1989). Scats are abundant in nearshore waters of South and Southeast Asia where they inhabit estuaries, coastal mudflats, mangrove swamps, harbours and upstream rivers. These habitats are characterized by extreme fluctuations in salinity, dissolved oxygen, temperature, tidal movements, river runoff, turbidity and turbu-

lence. The adaptations which allow the scats to live in such ever changing environments endow them with many biological attributes highly desired in a cultured finfish (Barry and Fast, 1988).

The deep, strongly compressed, and green spotted body with a small head, small ctenoid scales, distinct lateral lines, rays and spines are related to particular methods of survival and migration.

Scats are omnivorous which feed on small animal and plant organisms. But their food preference may be filamentous algae for which they have structural adaptations of long and coiled intestine. They feed voraciously on almost anything edible. They grow to a length of 30 cm (12 inches) and to a weight of as much as 1 kg. They are always active but behave in a friendly and peaceful manner towards other species. Their `wobbly' style of swimming make them appear like Angel fishes (Frank, 1979).

Reproduction is by eggs which are fertilized externally after extrusion of milt by males. Eggs and fry are pelagic. Seeds migrate to mangrove swamps, estuaries, lagoons and tidal pools for feeding.

It is a preferred food fish in many parts of South and Southeast Asia and considered as a delicacy in the Philippines (Barry and Fast, 1991). It fetches good price in the market.

Scats as small as 50 gm are almost as highly priced as large specimens (Barry and Fast, 1988).

It is known that wounds inflicted by the spines of scats cause a lot of pain. Hence care should be taken at the time of handling live or dead fishes and also at the time of removing the catch of this fish from nets. All members of the family Scatophagidae are known to have paired poison glands associated with each fin spine (Cameron and Endean, 1970). Careless handling can result in painful punctures, and the pain may last for many hours. However, scats are not aggressive, and they do not actively attempt to inflict wounds. They typically lie flat when handled, but dart away when returned to the water (Barry and Fast, 1992).

Brackishwater fish culture in India became a profitable industry recently and it was largely prompted by the urgent need to increase our much needed protein source and to earn foreign exchange. But, within the last half a centuary, even after the realisation of our potential, it must be said that we have not made adequate progress in harnessing our resources, especially when compared to the great strides this industry has made in the East-asian countries or along the Adriatic coast of the Mediterranean region. Apart from the fertile backwaters of the south-west coast, there are other extensive but less productive salt water lagoons spread along the east coast which altogether are estimated to cover about 3000 hectares. This area can be developed as aquaculture farms. Culturable fish seeds of scats

which are occurring along our coasts can be cultivated. The scats are having excellent qualities such as omnivorous feeding habit, euryhaline nature, hardiness, favourable taste and appearance, good market price and easy availability of seeds. They can be easily cultured like any other fishes.

Sixteen genera consisting of 35 species of fish, including *Scatophagus argus*, are known to occur in the coral reefs of Southeast coast of India, especially in the Gulf of Mannar. They are ornamental in nature and are having heavy demand for aquarium purposes throughout the world.

Scats are also popular aquarium fishes because of their appearance, hardiness, slow growth, and "personable" behaviour (Morgan, 1983). Barry and Fast, (1988) found out from the President of Aquascapes Philippines, a major Philippines tropical fish exporter, that wild-caught scat alone could not fulfill the demand of the world aquarium fish market. *Scatophagus argus* was found to fetch higher price in the United States aquarium trade than in other markets.

Many workers in India have made their valuable contributions to the study of systematics and biology of economically important fishes like oil sardines, mackerel, bombay duck, caranx, tuna, pomfrets, anchovy, polynemids, catfish, ribbonfish, prawns, molluscs and other fishes. But there is no work regarding systematics, biology and ecology of scats in India except a few works on the food of scat and description of the scat. Biochemical

composition of the scat also has not been analysed yet. Despite its high value in aquarium trade, no work has been carried out so far about its maintenance in marine and brackishwater aquaria.

Therefore the aim of the present investigation was to gain more knowledge and offer a comprehensive account of ecology and biology (including food and feeding habits, spawning and larval development and biochemical composition) and information on maintenance of scat, *Scatophagus argus*, in aquaria.

2. AN OVERVIEW OF LITERATURE

Taxonomy

Berg (1940) has classified the scat as a fish that belongs to Phylum: Chordata, Subphylum: Vertebrata, Class: Osteichthyes, Subclass: Actinopterygii, Infraclass: Teleostei, Order: Perciformes, Suborder: Percoidea, Family: Scatophagidae, Genera: *Scatophagus* and *Selenotoca*. Of the two genera, *Scatophagus* is the genus that was studied in the present investigation.

Natural History

Barry and Fast (1988) have given an account on the natural history of the spotted scat (*Scatophagus argus*). As Berg (1940) has pointed out, there are only two genera in this family Scatophagidae. They are *Scatophagus* and *Selenotoca*. Scats are found in harbours, around sewer outfalls, and in waters characterized by high organic waste inflows. Poison glands associated with fin spines are present. Scats are known to have a very wide range of salinity tolerance. Adult scats are primarily herbivorous. Brood stock scats were found in nature during the months of July, September, and October. Fry were found abundant between August and October. The highest number of eggs (807,000) found were from a fish that weighed 497 g.

Record of large size

Generally it is believed that scats can grow upto a size of 30cm (12 inches) in the wild. Khan (1979) reported the occur-

rence of a large sized specimen of *Scatophagus argus* (Linnaeus) measuring 334 mm in length, weighing 1.2 kg from Rajpara landing centre in Gujarat, India.

Description of scats

Many researchers have described the external characters of the scat (*Scatophagus argus*). Munro's (1955) description was that, scats have deep, compressed, angular body with firm skin and small ctenoid scales. Mouth is small with bands of fine teeth in jaws, but not on palate. Rostro-dorsal profile is strongly ascending followed by a deep concavity above the eyes. Colour of the body is blue or greenish gray to dusky brown above, with numerous large round brown spots which may extend on to the soft dorsal. Belly is silvery and fins are pink or Yellowish to brown gray. Total length may reach 12 inches. Scats inhabit estuarine waters and coastal lagoons.

Day (1958) described scats having an eye diameter of 2/7th the length of head. Body is somewhat quadrangular, strongly compressed and dorsal profile is more curved than the abdominal. Opercle is with a weak spine. Teeth are villiform in the jaw. Dorsal spine is strong and caudal fin is fan shaped. Scales are minute. Colour is purplish, becoming white on the abdomen with large round blackish or brownish spots on the body. First dorsal is brownish and the second dorsal is yellowish. The fish attains a size of a foot in length. They occupy Indian ocean, the China sea and the seas around Australia.

Smith (1961) has described scat as having deep, solid, often angular body, with firm skin set with small ctenoid scales. It has a small mouth with bands of fine teeth with none on palate. Gill membranes are narrowly attached to an isthmus. The outer surface of the body has large dark spots.

Carcassion (1977) described its body as olive green, darker above, with numerous irregular large black spots which are larger on the back. Fins and tail are dusky. The fish attains 30 cm in length. It inhabits the seas around India, Ceylon, E.Indies, Philippines, Melanesia and Queensland.

A survey of the fish species found in Australia, New Guinea and Indo-pacific region was reported by Steene (1978). He examined a total of eighty six species, including *Scatophagus* spp., and he also prepared the check list of Scatophagidae (3 species viz *S. argus, S. tetracanthus and S. multifasciatus*).

Caudal skeleton

The caudal skeleton in fish plays a major role in swimming and turning process and has its own value in systematics. Mehta *et al.*, (1989) studied the caudal skeleton in eight perciform fishes (including *Scatophagus argus*) belonging to the families Gobidae, Acanthuroidae and Percoidae and discussed the structure of the caudal fin with ural and preural modifications in relation to swimming habits and importance in taxonomy.

Venom glands in scats

Cameron *et al.*, (1970) stated that all members of the family Scatophagidae have paired poison glands associated with each fin spine.

Method of Capture

There are no special type of nets or devices used exclusively for catching scats (*Scatophagus argus*). They are caught along with other fishes in trawl nets, gill nets, shore seines and barrier nets. The study carried out by Parnichsuke *et al.*, (1988) with artificial fish shelters at the National Institute of coastal Aquaculture, Songkhla (Thailand) indicated that *Scatophagus argus* was one of the six abundant species found. The results indicated that scats were attracted by artificial shelters.

Scat seed resources

Scats normally spawn in coastal waters. The fry, which are black in colour feed on microalgae. They are also commonly found in harbours, estuaries, mangrove swamps, tidal pools and lagoons. They can be collected from these regions for stocking in culture ponds and for ornamental fish trade.

The Kali river estuary, an important estuarine system of Uttara Kannada District of Karnataka has been studied by Nagaraj *et al.*, (1982) for its seed resources, their occurrence, distribution and abundance. The most important seeds available in

plenty, were those of *Scatophagus argus, Penaeus monodon, Mugil cephalus*, edible oyster, mussel and clam. They indicated the scope for exploitation of the seeds for profitable farming in low lying areas, mud flats, and mangrove swamps around Kali Estuary and the potentialities of mariculture in other estuarine systems of the rivers Gangavali, Aghanashini and Sharavathi.

Banada (1983) reported that *Scatophagus argus* were caught in milkfish fry sweeper along with early juvenile milkfish fry. Liu (1985) recorded 112 species of fish larvae and juveniles in the coastal waters of northern and southern Taiwan. His observations on spawning season and distribution indicated that *Scatophagus argus* had a long spawning period of more than three seasons in a year.

Chiu (1991) studied the diurnal depth range of ichthyoplankton in the Kuroshio edge exchange front and found out that the surface water was dominated by *Scatophagus argus* during day time.

Larval Development

Thangaraja *et al.*, (1985) collected larvae of *Scatophagus argus* from Vellar Estuary, Portonovo, India and reared them in the laboratory. Description of different stages was also given. They observed seasonal occurrence of the larvae in relation to salinity and temperature for a period of one year (December 1977 to 1978). The feeding habits of the larvae were observed both under natural and controlled conditions. The results showed

that *Scatophagus argus* was a sturdy fish and would be suitable for aquaculture practices.

Food and feeding habits

Mookerjee *et al.*, (1949) collected various sizes of *Scatophagus argus* during the years 1945 to 1946 from different places in the estuaries of Bengal, like Port Canning, Diamond Harbour, Kolaghat and Basantia. Gut content analysis revealed the presence of unicellular algae, higher plants (*Nitella* and *Chara*), protozoa, sponges, crustaceans, fish scales, sand and mud. Hence they suggested that scats are omnivorous, although it prefers more vegetable food than animal food. As this fish was found in abundance in the lower portion of tidal rivers and in salt water bheris connected to estuaries, they emphasised the need for extensive culture of this fish in ponds and other enclosed water bodies of Lower Bengal.

Datta *et al.*, (1984) studied the food of *Scatophagus argus* inhabiting both fresh and brackish water ponds and reported that it comprised of aquatic macrophytes, phytoplankton, zooplankton and other macro zoobenthos. Qualitative and quantitative analysis of its diet indicated its omnivorous habit. Although this fish is primarily a marine form, it has largely acclimatised itself to brackish water habitat also. Its highly euryhaline nature and wide food choice showed that it could be successfully cultured in freshwater too. Some hydrological parameters of its fresh and brackish water habitats have also been studied to find out its habitat requirements. Gut content analysis of *Scatophagus*

argus (omnivorous) caught in Thailand showed the presence of diatoms, nematodes, rotifers, polychaetes, insects and foraminifera (Monkolprasit, 1994).

Maturation and spawning

There is no information on the spawning biology of scat except the work by Barry and Fast (1992) in the Philippines. They have done a study on the biology of the spotted scat *Scatophagus argus* and found out that it is a herbivorous, euryhaline teleost widely distributed throughout the Indo-Pacific basin. They indicated that it is a valuable brackishwater aquarium fish and also an important foodfish. Length-weight relationship was calculated based on 797 females and 252 males. The sexes could be differentiated by the shape of the head. The largest fish captured was a 1.2 kg female. Reproductive maturation first occurred in females of approximately 150 g size, corresponding to fish estimated to be 7-9 months of age. Male matured at a smaller size than the female. Fecundity was found to be directly proportional to the size of the fish. Data on monthly abundance of mature females and fry suggested that monsoon rain probably triggered spawning in the spotted scat. Observations of spawning behaviour and early juvenile development were also reported.

Temperature tolerance

The effect of temperature on 24 marine fish species of the Gulf of Thailand was studied by Menasveta (1981). The upper

incipient lethal temperature was found to range from 34 to 37.5°C and *Scatophagus argus* had the highest.

Salinity tolerance.

Spotted scats are known to have a wide salinity tolerance. They are found in waters ranging from fresh water (0 ppt salinity) to greater than seawater (≥ 35ppt salinity). Nelson (1984) indicated that spotted scat (*Scatophagus argus* Linnaeus) was a euryhaline teleost widely distributed in near shore waters of the Indo-Pacific Basin.

Induced gonadal maturation and spawning

Castanos *et al.*, (1988) made some preliminary in-vitro observations on the effect of sex steroids and Human Chorionic Gonadotropin (HCG) on the final maturation of oocytes of spotted scat (*Scatophagus argus*). They suggested that neither 17a, 20b - dihydroxyprogesterone (17a,20b) nor 11-deoxycorticosterone (DOC) was responsible for maturation in the spotted scat. Moreover, HCG when administered alone was not an effective hormone for stimulation of maturation in vitro. The combination of HCG and 17,20b was effective in stimulating final maturation in vitro and thus indicated that combined treatment with both a steroid and HCG might be effective in stimulating final maturation and spawning in the spotted scat.

Barry et al., (1988) tested the effect of salinity on sperm motility in the spotted scat (*Scatophagus argus*). There was a

31.6% increase in sperm survival between 10 and 15 ppt salinity. The scat did not spawn in salinities of 10 ppt or less. The spermatozoa remained motile for a longer time in salinities between 25 and 30 ppt. This suggested that the scat might prefer to spawn at salinities within this range. There was also rapid decline in sperm survival at 35 ppt suggesting that the scat might not spawn in sea water.

Barry *et al.*, (1991) did some experiments on gonadal maturation and spermiation in male spotted scat (*Scatophagus argus*). Male scats were treated with synthetic luteinizing hormone-releasing hormone analogue (LHRHa) as a cholesterol based pellet implant. HCG was injected intraperitoneally or intramuscularly and 17a-methyltestosterone (MT) was delivered in cholesterol-based pellets or incorporated into the fish diet. MT alone had no effect on milt production in male scat. However, 35 μg/kg of LHRHa administered through MT incorporated feed induced a significant spermiation response.

Barry *et al.*, (1993) also conducted some experiments on gonadal maturation and spawning induction in female spotted scat. Their investigations focused on the use of the synthetic leuteinizing hormone - releasing hormone analogue, des - Gly^{10}, [D-ALa^{6}] (LHRHa). LHRHa was a highly effective agent for inducing final oocyte maturation, ovulation and spawning in female teleosts. Female scats with oocyte diameters greater than 0.35 mm were given LHRHa. Of the 28 fish tested, LHRHa stimulated both

maturation and spawning in 14 females, but maturation only in the remaining 14.

Culture of scats

Pond culture system

Bardach *et al.*, (1972) indicated that the spotted scat (*Scatophagus argus*) was one of the few teleost species of economic importance and could potentially thrive in tropical brackish-water fish ponds. Terazaki *et al.*, (1980) pointed out that *Scatophagus argus* was one of the predatory fishes found in shrimp culture ponds of Thailand. Biona *et al.*, (1988) observed the production of tiger prawn (*Penaeus monodon*) and spotted scat (*Scatophagus argus*) in polyculture system. Spotted scat grew from an initial weight of 0.41 g to 10.32 g final weight in 6 months. Average weights in the three ponds tested ranged from 7.72 to 14.96 g. Mean survival was 54.8 percent. The yield of scat ranged from 36.7 to 86.2 kg/ha in a period of six months.

Biona *et al.*, (1988) also conducted some experiments on the production of milkfish (*Chanos chanos*) and spotted scat (*Scatophagus argus*) in polyculture system. When grown in polyculture with milkfish, spotted scat did not affect the growth rate or yield of milkfish at a stocking density of 0.53 fish/m². Scat and milkfish stocked at the density of 1.3 and 2.6 fish/m² respectively in polyculture system also, did not affect the growth of milkfish and reached a final standing crop size of 38.5 kg/ha in the case of scat and 422 kg/ha in the case of milkfish.

Biona *et al.*, (1988) also studied the effect of two stocking densities and methyltestosterone feeding on the growth of spotted scat (*Scatophagus argus*) in earthen ponds. Average final weights of scat ranged from 3.33 g for those stocked at a density of 5.76/m² and fed with MT, to 8.39 g for those stocked at 1.15/m² and not fed with MT. At both stocking densities, fish fed with the hormone MT grew slower than the fish that were not fed with MT. MT had a highly significant effect on average scat weight ($P<0.01$, $F = 38.652$, $df = 1896$). Likewise, stocking density had a highly significant effect on average scat size at harvest ($P<0.001$, $F = 405.897$, $df = 1896$). The average weight of scat stocked at 1.15/m² was 7.6g while that of scat stocked at 5.76/m² was 3.78 g indicating lesser weight gain at higher stocking density.

Fast *et al.*, (1989) reported on brackishwater pond culture of the spotted scat (*Scatophagus argus*) in the Philippines. Pond culture of scat was carried out in three separate experiments; (1) monoculture at two stocking densities with and without anabolic hormone added to the feed; (2) polyculture with milkfish (*Chanos chanos*) at two stocking densities without addition of hormone in feed; and (3) polyculture with tiger prawn (*Penaeus monodon*) and with addition of hormone in feed. Average growth of scat was very low in all cases compared to other pond cultured species (milkfish and prawns) and ranged from 2.5 g in 13 weeks for milkfish/scat polyculture, to 10.3 g in 18 weeks for prawn/scat polyculture. Hormone additions to the feed caused a

significant growth reduction in scat. There was also a significant reduction in scat growth at increased stocking densities of 1.3 versus 2.6 scat/m^2 or 1.2 versus 5.8 scat/m^2. The slow growth of spotted scat in ponds would preclude the culture of this fish for commercial purpose. However, pond culture of scat has good potential to meet the needs of the aquarium trade.

Cage culture system

Scats can be cultured not only in pond systems, but also in pen and cage culture systems. Gargantial (1982) carried out studies on different stocking densities, growth rate and types of feeds to be used for culturing fish in floating cages. He has given an account of the cage culture project site in the Bantan River. The species tested included the spade fish *Scatophagus argus* also. The design and construction of floating cages were described together with the stocking of fingerlings and their feeding.

Growth enhancement in scats

Studies on growth rate of scats in culture systems showed that scats were having a slow growth rate. Cruz *et al.*, (1990) used some hormones to promote growth in *Scatophagus argus*. The potential use of 17 alpha - methyltestosterone (MT), estradiol - 17 beta (E sub (2) and/or 3,5,3-triiodo-L-thyronine T sub (3)), as growth promoters for the spotted scat *Scatophagus argus* was evaluated. Fry from the Philippines were fed diet containing

0.01, 1.0, 5.0 and 10.0 ppm T sub (3). There was no effect on growth, feed efficiency and survival after 200 days. Increasing T sub (3) doses resulted in decreasing condition factor and body-tail ratio. Abnormalities were evident at 5.0 and 10.0 ppm T sub (3). In another study, MT of E sub (2) at 10.0 and 20.0 ppm, or at 10. 0 ppm in combination with 5.0 ppm T sub (3), depressed feed consumption and growth in adult scats. Hence there was no anabolic potential exhibited by MT, E sub (2) and/or T sub (3) in the scat.

Tolerance tests in scats

Macahilig *et al.*, (1988) carried out some experiments on temperature, salinity and pH tolerance of spotted scat fry (*Scatophagus argus*). The results of temperature tolerance test indicated that scat fry had a very high upper (41.3°C) tolerance limit. Direct transfer from an acclimation salinity of 25 ppt to salinities ranging from 0 to 40 ppt was tested. At ambient temperature, a mean of 92.5% or more of the scat fry survived for 96 hrs. At 50 ppt salinity, only 30% of the fry survived after 24 hrs while 50% were dead within 3 hrs. At 60 ppt, 100% of the fish died within 6hrs. In the case of pH, all the scat fry survived when they were transferred to waters with a pH of 6, 8 and 10. However, all scat fry died following transfer to water with a pH 4.

Tabanda *et al.*, (1988) investigated the dose-response relationship of 2-phenoxyethanol as a general anesthetic in the

spotted scat (*Scatophagus argus*). 50% of the fish got anesthetized (ED50) at the dose between 0.04 and 0.08 ml/l at a temperature of 27°C. A dose of approximately 0.30 ml/l anesthetized 100% of the fish within 10 minutes and for practical reasons it was the recommended dose for the species when undertaking procedures that required the fish to be placed under short-term anesthesia. No attempt was made to determine the lethal dose (LD50). However fish treated with a dose of 0.64 ml/l for two hours suffered no harmful effects indicating that the therapeutic ratio (LD50/ED50) was greater than 8, an excellent margin of safety.

Mohapatra *et al.*, (1992) acclimatized the marine fish *Scatophagus argus* in freshwater and maintained the fish for about four months, but thereafter the fish died.

Diseases and parasites in scats

Diseases and parasites attack fishes not only in their natural habitats, but also in culture systems.

Galvez (1979) made observations on the viability and resistance of the metacercaria of *Procerovum calderoni* (Trematoda: Heterophydiae) in *Scatophagus argus* (Linn.) in certain media used in fish preparation and its survival in different methods of preservation and cooking. The effect of gamma radiation from Cobalt-60 on survival was also investigated.

Limsuwan *et al.*, (1984) studied the Lymphocystis virus disease of the common spadefish *Scatophagus argus*. They ex-

plained that the external lesions were, raised tumor-like areas of granular or nodular tissues on the skin surface and frequently limited to the fins. Histopathologically, these nodules were composed of enormously hypertrophied connective tissue cells. The disease was observed for about one month and then disappeared. This was the first lymphocystis disease recognized in the common spadefish.

Bilques (1980) described 3 trematodes from three different species of fishes of Karachi coast including *Waretrema piscicola* found on the body of *Scatophagus argus*.

Lio-Po *et al.*, (1988) observed that when spotted scat were initially stocked, they had dermal lesions which probably resulted from handling, during their capture and transport. Mortality was first detected 16 days after stocking and gradually increased over a week's time. The fish had become increasingly lethargic and inactive and many had developed hemorrhagic dermal lesions. The skin of the fish was heavily infested with the crustacean parasite *Caligus* spp. Approximately 20% of the fish had single large isopods in their mouth which almost completely filled the buccal cavity. Smaller isopods were found on the gills. They were manually removed with forceps and the fish were given a Dylox bath in freshwater to remove the *Caligus* spp. They also reported that the infested fish were lethargic and anorectic and they had opaque eyes, hemorrhagic lesions on their bodies and numerous *Caligus* spp., *Trichodina* spp., and *Amyloodinium* spp. were also found.

Cruz (1988) stated that mass mortality of fry and adults of spotted scat occurred during July and August 1986 in the brackishwater Aquaculture Centre (Philippines). In very sick scats the external gross pathology of the disease was characterised by opaque eyes, hemorrhagic lesions, eroded fins and pale colour. The internal gross pathology was characterised by an empty gut with white mucus-like fluid and spherical pus omentum. Diseased fish did not feed, became lethargic, and often died. The disease was due to infestation of multiple parasites like *Caligus* spp., *Amyloodinium* spp., and *Trichodina* spp.

Natividal *et al.*, (1988) reported that examination of three specimens of spotted scat (*Scatophagus argus*) brood stock, which died during a mass die-off in fish holding tanks, revealed several cyst like structures on their visceral organs. The cysts appeared to be attached to the serosal surface of the intestine. Histological sections of these structures showed that they were visceral xenomas induced by microsporidian parasites. No significant pathological changes were noted in the spleen, liver or kidney of the examined fish. Death was attributed to the combined effects of mechanical and pathophysiological causes. Heavy microsporidian infection may cause inactivation of a substantial proportion of organs affected and lead to mortality.

Pasharawipas *et al.*, (1994) extracted a specific nucleic acid probe (DNA) from purified microsporidian spores derived from infected *Penaeus merguiensis* and *P. monodon* to find out the

intermediate host and to trace the life cycle of the parasite. They found that *Penaeus* spp., were the best intermediate hosts. The extract (DNA) prepared from scats which were along with *Penaeus* spp. in the seawater canals also proved that scats could also be the intermediate hosts of the microsporidian parasite.

Chromosome study in scat

Choudhury *et al.*, (1979) studied the somatic chromosomes from gill epithelia of 6 species of marine fishes including *Scatophagus argus*. *Scatophagus argus* had one pair of biarmed chromosomes in its diploid complement. The interspecific relationship was discussed and the role of pericentric inversion and or centromeric shift was stressed for the origin of karyotypes of *Scatophagus argus* from an ancestral primitive karyotype.

As aquarium fish

According to Morgan (1983), scats are popular aquarium species, because of their appearance, hardiness, slow growth and personable behaviour. Barry and Fast (1988) reported that there was a continuous demand for scats in the tropical aquarium fish markets. Food recommended for aquarium scat included boiled lettuce, steeped oatmeal, common aquarium plant *Nitella* spp., water fleas, worms and insects. Frank (1979) reported that in the aquarium, scats were given live food and also vegetable matter such as algae and soaked porridge of oat meal.

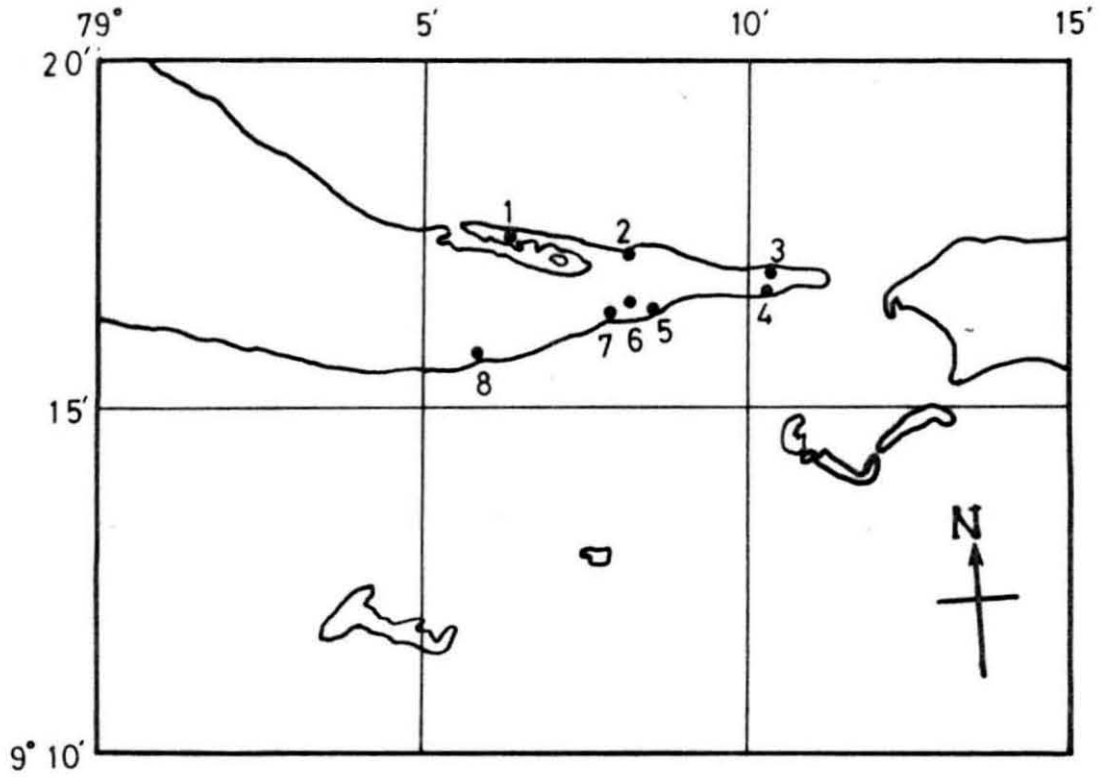
3. MATERIAL AND METHODS

3.1. FIELD COLLECTION

The present study was based on sample specimens of scat, *Scatophagus argus* (Linnaeus), collected from commercial catches brought to the fishing centres located on the Palk Bay and the Gulf of Mannar. They are located in the vicinity of Mandapam (79° 9'E long., 9°16'N lat.) a coastal town on the south east coast of India on a small peninsular extension of the mainland leading to Rameswaram Island (79°19'E long., 9°17'N lat.) (Fig.1). To the north of Mandapam is the Palk Bay and to its south is the Gulf of Mannar. The waters of the two sides meet at Pamban Pass (79°12'E long., 9°17'N lat.) and at Adam's Bridge. The water in the Gulf of Mannar side becomes turbid during May through August due to strong south west monsoon winds and currents. On the other hand the water in the Palk Bay side gets turbid during September through April due to strong North-east monsoon winds and currents. Fishing activities get intensified in the Gulf of Mannar side during north-east monsoon season and in the Palk Bay side during south-west monsoon season.

Sample specimens of spotted scat were collected mainly from different landing centres around Mandapam. These landing centres included INP-Jetty, CMFRI-Jetty, Thonithurai (south), Manoli Island and Pamban (south) in the Gulf of Mannar side and

Figure 1 Location of Mandapam and fish landing centres.



1. Theedai
2. Munaikaadu
3. Thonithurai (North)
4. Thonithurai (South)
5. Mandapam jetty
6. Mandapam
7. Central Marine Fisheries Research Institute
8. Vedalai

Munaikaadu, Theedai, Mandapam (north landing centre) and Thonithurai (north) in the Palk Bay side. The fishing gears used for catching scat were shore seines (ohlai valai), barrier nets (kalamkatti valai), cast nets (veechu valai), gill nets (kanni valai/vidu valai) and trawl nets (madi valai). More details of landing centres, crafts, gears, manpower involved, distance and depth of catch were given in Table 1.

Mostly barrier nets were used for fish catch at Manoli Island. At Mandapam and Pamban, trawl nets were used for the catch. Gill nets, cast nets and shore seines were operated at Munaikaadu and Theedai landing centres. Shore seines and cast nets were used for fishing at Thonithurai on the Palk Bay side. On the otherhand, only cast nets were operated at Thonithurai on the Gulf of Mannar side. Gill nets with small size mesh (10 to 20 mm) were operated near Mandapam jetty on the Gulf of Mannar side and near the Mandapam landing centre on the Palk Bay side.

3.2. DESCRIPTION OF CRAFTS AND GEARS

3.2.1. Crafts

Plank built boats were used to transport nets and the fish catch. The boats were made of planks of country wood and supporting wooden pieces fixed across, like ribs. To prevent leakage of water, pressed cotton pieces were tightly packed in between the planks. Tar coating and painting were given to the outer wall of the boat. The length of the boat was 8 to 10 m and

Table 1 Details of landing centres, crafts, gears, manpower involved, distance and depth of operation.

Landing Centre	Craft	Gear	Manpower involved	Distance from shore (mean)	Depth (mean)
Gulf of Mannar					
1. Manoli Island	Plank built boat	Barrier net (Kalamkatti valai)	10	100 m	1 m
2. Mandapam jetty	-	Gill net (vidu valai/ kanni valai)	3 to 4	20 m	5 m
3. Mandapam south	32/36 footer trawler	Trawl net (madi valai)	5	15 km	15 m
4. Thonithurai (south)	-	Cast net (veechu valai)	1	50 m	0.5 m
5. Pamban south	32/36 footer trawler	Trawl net (madi valai)	5	20 km	25 m
Palk Bay					
1. Munaikaadu/ Theedai	Plank built boat	Shore seine (ohlai valai)	10	800 m	4 m
"	"	Gill net (kanni valai)	2 to 4	1.5 km	6 m
2. Mandapam north	32/36 footer trawler	Trawl net (madi valai)	5	10 km	12 m
"	-	Gill net (vidu valai/ kanni valai)	3 to 4	20 m	2 m
3. Thonithurai (north)	Plank built boat	Shore seine (ohlai valai)	10	800 m	4 m
"	-	Cast net (veechu valai)	1	50 m	0.5 m

the width and height were 1 to 2 m and fitted with 6.5 HP inboard diesel engine.

3.2.2. Barrier net (Kalamkatti valai)

Kalamkatti valai consisted of many pieces of nets. A single piece of net was made up of cotton threads (2 mm diameter). The upper holding rope and lower holding rope were also made up of cotton threads (5 mm diameter). Length and width of the net were 8 to 10 m and 1 m respectively. The mesh size of the net was 2 to 2.5 cm. Required manpower was more than 10.

During low tide times some of the nearshore regions got exposed. There was no water in the exposed area. The exposed area near the shore region was selected in such a way that the exposed area would get 1.25 to 1.50 m depth of water at the time of high tide. Depending upon the size of the exposed area, required number of pieces of nets were connected. The connected nets were buried in the form of a circle into the ground of the exposed area at a depth of 30 cm. The mean distance of operation of this net was 100 m from the shore. At the time of high tide the upper holding ropes of the nets buried under the ground were lifted from the ground and were supported by small sticks (2 cm diameter), measuring 1.5 to 2 m in height to keep the nets erect as a barrier (like a fence), keeping the lower holding ropes of the nets inside the ground. When the water receded again during the next low tide time, the fishes which had entered into the en-

closed area, were caught by the barrier net. The fishes were then captured by scoop nets and also by hand picking. There were two hauls per day during fishing season. This type of net was operated at Manoli Island. The spotted scat, *Scatophagus argus*, was collected from this catch.

3.2.3. Small meshed gill net (vidu valai/kanni valai)

No boat was required for the operation of this net, since this type of net was used close to the shore. The net was a single piece made up of nylon threads (1.5 mm diameter). The upper and lower portions of the net had nylon holding ropes of 5 mm diameter. The length of the net was 15 to 20 m and the width of the net was 1.5 to 2.5 m. The net was operated by 3 to 4 men. It was operated near the shore at a mean distance of 20 m and at a mean depth of 5 m near Mandapam Jetty (Gulf of Mannar) and at a mean distance of 20 m and at a mean depth of 2 m near Mandapam north landing centre (Palk Bay). Two persons used to scare and drive the fish towards the net by splashing the water. In this process the fishes got gilled. There were one or two hauls per day. Most of the sample specimens of scat, *Scatophagus argus*, were collected from such catch.

3.2.4. Trawl net (madi valai)

The operation of trawl net required one mechanised boat and one or two trawl nets. The boat had either fiberglass or wooden body. Most of the trawlers were mainly made up of thick wooden

planks and strong supporting pieces of wooden ribs made of country wood. The length of the boats varied between 32 and 36 feet. All the boats used 80 to 120 HP diesel engines. Winches were used to operate the nets.

The trawl net was bag like, made of 2 mm diameter nylon fibers. The length of the trawl net was 25 m. The width was 2 m at the cod end and 35 m at the mouth portion. The upper portion of the mouth had aluminium floats and the lower portion of the mouth had galvanized iron chains. The two wings of the net had otter boards (one each on either side) to keep the mouth of the net open at the time of operation. The mesh size of the net varied from 20 mm to 200 mm from the cod end to the mouth portion. The two wings of the net were tied with strong nylon ropes of required length. Normally required man power was 5. The net was operated at a mean distance of 15 km and at a mean depth of 15 m in the Gulf of Mannar side and at a mean distance of 10 km and at a mean depth of 12 m in the Palk Bay. The net was operated at a mean distance of 20 km (towards south) and a mean depth of 25 m from Pamban on the Gulf of Mannar side. Generally the trawlers were operated during night hours and some times during the day time. One or two hauls per day were made. Each haul took 2 to 3 hours. Specimens of scat, *Scatophagus argus*, were also collected from these trawl net catches.

3.2.5. Cast net (veechu valai)

This was a 2 to 4 m diameter circular type of net made of nylon threads. It was operated by a single man at a mean distance of 50 m from shore and at a mean depth of 0.50 m. The outer edge of this net had a number of small lead weights which acted as sinkers. The central portion of the net had a long nylon rope of 5 mm diameter which when pulled, closed the net in a conical shape and brought the fish that got entangled. The mesh size was 10 mm and was uniform from the central portion to the edge of the net. Each person could haul a number of fishes in a single fishing day from morning to evening. This net was operated along the Gulf of Mannar and Palk Bay coast. Sample specimens of scat were also collected from this type of net catches.

3.2.6. Shore seine (ohlai valai)

This was operated from a plank built boat of dimensions 9 x 2 x 1 m fitted with 6.5 HP in-board diesel engine. In the operation of one shore seine, a minimum of 10 persons were involved. Shore seine was a bag like net. This was made up of nylon threads of 3 mm diameter. The mesh size of the cod end of the net was 20 mm and it increased to 70 mm towards the mouth portion. The lower portion of the mouth of the net had GI chain, whereas the upper portion of the mouth had plastic floats. The two wing like portions of the net were tied with synthetic nylon ropes of size 20 mm diameter. The length of the ropes varied

depending on the distance of hauling. Additional ropes were also used if needed. To the ropes of the wing portions of the net, palmyrah leaf stripes were tied in order to scare the fish and drive them into the net. One end of the rope of the net was held on the sea shore, while the other end was taken by a plank built boat to a required distance of approximately 0.8 km and a depth of 4 m and then hauled towards the shore. The two ends of the rope were hauled towards the shore simultaneously by 5 persons on each side. The net was operated once a day, mostly during morning hours. The operation of this net also depended on the availability of schools of fish in the area. This net was operated on the Palk Bay side near Munaikaadu and near Thonithurai (north). Sample specimens of scats were also collected from such catches.

3.2.7. Gill net (big size mesh) (kanni valai)

This was operated using a plank built boat by 2 to 4 persons. Each person was having 5 to 7 nets. Each net was connected with each other at the time of operation. All the boats used 6.5 HP in-board diesel engines. The net was made of nylon threads of 2 mm diameter. The upper holding rope of the net had a number of styrofoam floats and the lower holding rope had a number of small stone sinkers. The length of the net was 8 to 10 m and the width/height of the net was 1 to 1.5 m. The mesh size ranged from 20 to 30 mm. Depending upon the requirement, a number of nets were attached in a series and operated at a mean distance of 1.5 km and a mean depth of 6 m near Munaikaadu on the

Palk Bay side. The net was usually operated during early morning hours for a period of 2 to 3 hours.

All the landing centres were visited twice a week for collection of samples. On the day of the visit, all details such as depth at which fishing operations were carried out, direction, distance from shore, number and type of nets operated, number of persons engaged in fishing, number of hauls made, duration of hauls, number of boats operated and meteorological conditions were recorded.

Scats exhibit sexual dimorphism (Plate-2). Sexes can be differentiated by head shape and colouration. The head profile ascends at a constant slope in females and have lighter, olive green colour body, whereas the males have a concave curvature of the head above the eye and darker olive green colour body. Since spotted scats were known to exhibit sexual dimorphism, their sex and natural colouration of the body were also noted in the field itself. Length and weight of the fish were also measured.

3.3. TAXONOMY

During the present investigation, 200 specimens of *S.argus* measuring 51 to 340 mm were collected around Mandapam (Gulf of Mannar and Palk Bay) exclusively for the study of taxonomy (Plate-3). Identification of scat was carried out based on the description of Munro (1955) and Day (1958). Throughout the obser-

Plate - 2 **Sexual dimorphism in scat**

Top **- Male**

Bottom **- Female**


OMEGA

vation period of August 1995 to July 1997, only *S. argus* was recorded. No other species of *Scatophagus* or *Selenotoca* spp. were found. Important morphometric measurements and record of meristic characteristics such as dorsal and anal fin spines, dorsal and anal fin rays, lateral line and transverse fish scales, were made for taxonomic purpose. Specimens in fresh condition only were used for the study. Morphometric measurements and meristic characteristics were recorded, following the method of McKay (1985).

3.3.1. Measurements

Overall length measurements of fish were taken between perpendiculars along the median longitudinal axis of the body, from the snout with mouth closed, by the use of a half meter plastic scale with millimeter divisions. Other than total and standard lengths, measurements were made using vernier calipers. Measurements were taken, to the nearest millimeter. Fish were weighed using a balance, to the nearest 0.1 g, after blotting out water and any adhering matter using dry cotton/cloth. Following measurements were taken into consideration to describe the spotted scat.

1. Total length (TL) : from tip of snout to tip of longest median caudal ray (Ricker and Merriman, 1985).
2. Standard length : from tip of snout to tip of hypural bone (urostyle).
3. Snout length : from tip of upper jaw to front margin of orbit.

4. Eye diameter	: Maximum distance from front margin : to hind margin of eye, along longi- : tudinal axis of body.
5. Head length	: from tip of snout to the farthest tip : of opercular membrane.
6. Pre-dorsal distance	: from tip of snout to a line perpendi- : cular to the origin of spinous dorsal : fin.
7. Pre-anal distance	: from tip of snout to a line perpendi- : dicular to the origin of first anal : spine.
8. Greatest depth of body	: depth at the middle of the body.
9. Pectoral fin length	: Origin of pectoral fin to tip of the : longest pectoral fin ray.
10. Pelvic fin length	: Origin of pelvic fin to tip of the : longest pelvic fin ray.
11. Length of 3rd dorsal spine (longest)	: Origin of 3rd dorsal spine to tip of : the same.
12. Length of 2nd anal spine (longest)	: Origin of 2nd dorsal spine to tip of : the same.
13. Depth of caudal peduncle	: least depth of caudal peduncle

3.3.2. Meristic characters

The number of dorsal fin spines, dorsal fin rays, anal fin spines and anal fin rays were counted. Lateral line scales were counted starting from the upper margin of the operculum to the caudal flexure at the posterior margin of the hypural plate. Transverse scales were counted from the origin of the dorsal fin to the origin of the anal fin.

3.4. MORPHOMETRIC STUDY AND RELATIVE GROWTH OF BODY PARTS

3.4.1. Relationship between standard length and morphometric characters

Two hundred specimens measuring 51 to 340 mm were examined during August 1995 to July 1997. In order to find out the relationship between various morphometric characters and standard length, the general equation (Linear regression) given below was employed.

$$Y = a + bx$$

Where `Y' is dependent variable, `X' is independent variable, `a' is intercept and `b' is slope.

3.5. LENGTH-WEIGHT RELATIONSHIP

To determine the relationship between length and weight, the general equation given below was followed (Le Cren, 1951).

$$\log W = \log a + n \log L$$

Where W = Weight, L = total length and `a' and `n' are constants.

where Log W is dependent variable (Y), Log L is independent variable (X), `n' is regression coefficient or slope and `a' is intercept.

This linear equation was fitted separately for the two sexes, using the data collected during the two years, August 1995 to July 1997, from Mandapam area. For this study, a total of 1,659 fish were used of which 1,141 were females ranging in length from 140 to 300 mm and 518 were males ranging in length

from 120 to 270 mm. 482 young ones (indeterminates) ranging in length from 110 to 117 mm were also taken into account for length weight relationship. Total length was measured from snout to tip of tail in millimeters and weight was taken in grams for each specimen. Specimens with broken tails were not considered. This method was adopted uniformly throughout the study.

3.6. FOOD AND FEEDING HABITS

3.6.1. Gut content analysis

Almost all the studies carried out in the past on food intake of variuos fishes were qualitative and not quantitative (James, 1967). Scientists had described the occurrence of food items found in the digestive tract, usually in the stomach only. This indicated what the fish had eaten and approximately in what proportions, but did not describe how much of each food item has been eaten. The reason for the lack of quantitative work was that it was time consuming. For analysis of food items taken by fishes, methods such as Frequency of occurrence, Numerical occurrence, Dominance, Total volume, Percentage volume, Gravimetric, and Points method have been followed.

Natarajan and Jhingran (1961) indicated that the occurrence method did not take into consideration the quantity of each item of food and similarly the quantitative methods did not emphasise the repeated occurrence of a food item. Thus, individually, either the occurrence method or a quantitative method alone was

not suited for proper analysis of food of fishes. In view of this, an index that took into consideration both the occurrence as well as the quantity of food item which was termed the `Index of preponderance' appeared more suitable. For this purpose, it was considered that the volumetric (displacement) method was an accurate one, of the quantitative methods, to use in conjunction with the occurrence method.

Considering the occurrence as well as the quantity of food item as important, analysis of gut contents of *Scatophagus argus* was carried out by adopting the "Index of preponderance" method (Natarajan and Jhingran, 1961) which was a standard method followed by a number of workers (e.g., Passoupathy and Natarajan, 1986-87; Manikyala Rao and Sreenivasarao, 1991; Vasudevappa and James, 1992; Appanna Sastry, 1993; Sivakami, 1995, 1996 and 1997). This method has been followed by the present author also (Gandhi, 1982) while studying the biometry and biology of *Pennahia aneus* (Bloch). The percentage occurrence of different items of food in different months was determined by summing the total number of occurrence of all items. Since scat is omnivorous, determination of volume of each item of food was easily made by displacement method.

Fish brought from the field to the laboratory was measured and weighed. Since this fish is having compressed body, dissection was made on the lateral side to retrieve its gut contents.

The gut was removed from the body cavity and kept in a glass bowl. It was then opened by teasing with a sharp needle to sort out each food item. Where food components were intact or in an identifiable condition, they were identified upto species level. When the food items were found in mutilated condition, it was possible to identify them only upto genus or family level. A narrow mouth measuring jar was taken and partially filled with a known volume of water. The food item was then added to the water in the measuring jar. The new level of water mark was noted. The difference between the two readings gave the volume of the particular food item. In the same way volume of all the sorted out food items were measured. Then the percentage volume of each food item was determined from the total volume of all the gut contents. The "Index of Preponderance" was calculated using the formula.

$$Ii = \frac{Vi\ Oi}{\Sigma\ (Vi\ Oi)} \times 100$$

where, Vi and Oi represented the percentage volume and percentage occurrence respectively of a particular food item and Ii was the combined "Index". In order to investigate the order of preference of food items taken by different size groups of scat, the fish were grouped into <50 mm, 50 to 100 mm, 100 to 200 mm and >200 mm.

In order to ascertain the condition of stomach during different months, the degree of fullness of the stomach was record-

ed. From this it could be observed how many fish were actively fed and how many fish were poorly fed and in which months. The stomach was considered `full' when it was completely gorged with food, with its wall appearing thin and in some cases even transparent. It was considered `3/4 full' when it was in a partly collapsed condition, in which case the wall was usually thick. Similarly it was classified `1/2 full' or `1/4 full' depending on the relative fullness and the space occupied by the stomach contents. The state of the stomach was termed `little' when the contents occupied anything less than one-fourth the capacity of the full stomach. If the stomach contained practically nothing, they were termed `empty' (James, 1967). In such cases the wall of the stomach having undergone shrinkage, appeared thick with conspicuous inner folds. From the total number of fish examined in a month, the percentage occurrence of the different categories viz.,`full',`3/4 full', `1/2 full', `1/4 full',`little' and `empty' stomach was estimated. Fish stomachs classified as `full', `3/4 full' and `1/2 full' were taken into consideration to have actively fed, whereas fish with `1/4 full' and `little' were taken as poorly fed.

3.7. BIOCHEMICAL COMPOSITION

Fresh scat specimens were collected for biochemical analysis. Specimens of various maturity stages of male and female were utilized for estimating the biochemical composition of liver, muscle and gonads.

Moisture, protein, total carbohydrates and lipid content of the liver, muscle and gonad tissues of specimens of different stages of maturity were estimated. Immature gonads of each sex were collected and their collective weight was taken. The weights of tissues were recorded to the nearest 1.0 mg. Drying of liver, muscle and gonad was carried out in a hot air-oven at 45°C for 24 hours. Then they were powdered and stored in a desiccator, for further analysis. Estimations were done on dry weight basis.

3.7.1. Moisture

Fresh fish were collected from landing centres. Their wet weights were measured to the nearest gram, after removing adhering water using a blotting paper. They were dried in a hot air-oven at 45°C for 24 hours and their dry weights were noted. The difference between wet weight and dry weight was taken as the moisture content.

3.7.2. Estimation of protein

Estimation of protein content of the fish was carried out by Total Kjeldahl Nitrogen Method (TKN). The TKN was estimated by micro Kjeldahl method described by Fels and Veatch (1958).

The fish was dried in a hot air-oven at 45°C overnight. The dried fish tissue was ground well to get a fine powder. Gonads and livers of the fish were also dried separately and their powders were also prepared.

A 50 mg of finely powdered fish tissue was digested with 2.5 ml of concentrated sulphuric acid in the presence of a catalyst mixture (20 g $CuSO_4$., 3 g HgO and 1 gm of selenium powder., part of this mixture was mixed with 20 parts of sodium sulphate) to release all the residual nitrogen. The digested mixture was cooled and diluted with 30 ml distilled water. The solution was thoroughly mixed and transferred to a micro Kjeldahl distillation unit. 10 ml of 40% sodium hydroxide was added and distilled. The green colour distillate (15 ml) was collected in a 100 ml conical flask containing 15 ml of violet coloured boric acid + mixed indicator (200 mg methyl red indicator in 100 ml 95% ethyl alcohol + 100 mg methylene blue in 50 ml 95% ethyl alcohol). This ammonia borate solution (green colour) was titrated against 0.02 N sulphuric acid until it recovered its original violet colour.

Calculation

$$TKN = \frac{(S-B) \times N \times 14 \times 100}{\text{by weight of the sample in g}}$$

Where S = Volume of sulphuric acid for sample in ml

B = Volume of sulphuric acid consumed for blank in ml

N = Normality of sulphuric acid

14 = Equivalent weight of nitrogen

$$\% \text{ of protein} = \frac{(S-B) \times N \times 14 \times 100 \times 6.25}{\text{by weight of the sample in gm.}}$$

6.25 = conversion factor to convert nitrogen into protein value.

To estimate protein values in gonad and liver, the above described method was followed.

3.7.3. Estimation of total carbohydrate

Carbohydrate was estimated by phenol sulphuric acid method (Dubois *et al.*, 1956). 5 mg of dried and powdered fish tissue was taken in 1 ml of distilled water. One ml of 5% phenol and 5 ml of concentrated sulphuric acid (Analar grade) were added to this. Then 4 ml of distilled water was added to make up the volume to 11 ml. It was mixed thoroughly and allowed to cool. The intensity of the colour was read in a spectrophotometer at 450 nm. The amount of carbohydrate present in the sample was calculated from a standard graph which was established using different concentrations of standard glucose.

The same method was followed to determine total carbohydrate in gonad and liver also.

3.7.4. Estimation of total lipid

Lipid concentration in tissues was estimated using the method of Bligh and Dyer (1959). 0.5 gm of fine powdered fish tissue was taken in a test tube and 5 ml of distilled water was added to get a pulp. The pulp was then transferred to a conical flask. 30 ml of chloroform-methanol (1:1) mixture was added to the flask. They were mixed well and kept overnight at room temperature in the dark for complete extraction. The next day, 10 ml

of chloroform and 10 ml of distilled water were added to the flask and centrifuged at 3000 rpm for 10 minutes. After centrifugation, two layers were observed. The lower chloroform layer contained all the lipids. The upper layer containing methanol with water soluble material was discarded. The lower layer was carefully collected free of interphase by sucking out with a fine capillary tube. This chloroform layer was taken in a pre-weighed beaker and evaporated at room temperature of 28°C. After evaporation, the weight of the beaker was determined. The difference in weights gave the weight of the lipid.

To estimate the lipid values in gonad and liver, the above mentioned procedure was followed.

3.7.5. Caloric content

The caloric values for different tissues were calculated using caloric equivalents viz., 5.65 cal/g dry weight for protein, 4.15 cal/g dry weight for carbohydrate and 9.4 cal/g dry weight for lipid (Phillips, 1969). Total caloric content of the three tissues viz., muscle, liver, and gonad was calculated by adding the caloric values of protein, carbohydrate and lipid for each of the seven stages of scat in both male and female. These were then converted to Joules/g using the value 4.186 J/cal.

3.8. REPRODUCTION

3.8.1. Maturation and spawning

Fish samples were taken to the laboratory. Total and standard length of each fish were measured to the nearest millimeter using a half meter plastic scale. Water adhering on to the fish was removed by using a blotting paper. Weight of individual fish was recorded to the nearest 0.1 g. Then each fish was dissected and after observing the colour, position, size and shape of the gonads, they were removed from the body cavity. Weights of ovaries and testes were also taken. Ovaries were preserved in 5% neutral formalin. Examination of preserved ovaries after several weeks revealed no appreciable shrinkage or swelling of ova due to preservation.

3.8.2. Maturity stages

In order to study the maturity of fish and ascertain the spawning season 1,141 females and 518 males were examined. The stages of maturity for males was based on microscopic examination of the gonads. The size, and colour of testis and its extension in the body cavity were noted. The maturity stages of females were determined, based on size of intra-ovarian eggs (Table 2). It was found convenient to classify them into seven stages, corresponding to the stages defined by the International Council for the Exploration of the Sea (Lovern and Wood, 1937) which has been followed by many workers (Gandhi, 1982; Nalluchin-

Table 2 Classification of maturity stages of *Scatophagus argus*

Stages of maturity	Description of intra-ovarian eggs (mm)	Minimum size of intra-ovarian eggs (mm)	Maximum size of intra-ovarian eggs (mm)	Mode of largest groups of eggs (mm)
I	Immature	0.10	0.20	0.12
II	Developing immature and recovering spent	0.26	0.36	0.28
III	Maturing	0.37	0.47	0.39
IV	Mature	0.43	0.58	0.45
V	Advanced Mature	0.59	0.69	0.61
VI	Ripe	0.65	0.75	0.67
VII	Spent	0.26	0.36	0.28
	Residual eggs	0.56	0.72	0.66

nappan and Jayabaskaran, 1991; Madhusoodana Kurup and Samuel, 1991; and Sivakami, 1995).

3.8.3. Ova diameter studies

Ovaries in the I to the VII stages of maturity were used for taking ova diameter measurements. The method used by Clark (1934) which has been adopted by many workers (Gandhi, 1982., Apparao, 1985; 1990; Sriramachandramoorthy, 1991; Madhusoodana Kurup and Samuel, 1991; Nalluchinnappan and Jayabaskeran, 1991 and Shaunsul Hoda and Nallamullah Qureshi, 1993) was followed in the present investigation also. A small portion of the ovary was taken. The eggs were teased and separated by means of a fine needle and spread evenly on a microslide without damaging them. Diameter measurements of atleast 1000 ova from each ovary were taken using a micrometer fitted to a compound microscope, at a known magnification. One micrometer division was found to be equivalent to 0.011 mm. In order to maintain uniformity, the ova were taken from the middle portion of the ovaries of all the fish examined.

3.8.4. Size at first maturity

In order to determine the size of scat at first maturity data on percentage occurrence of gonads in different stages of maturity were analysed in fish collected during August 1995 to July 1997.

3.8.5. Gonado-somatic index

Seasonal fluctuations in the gonads, of both sexes, in relation to the weight of fish was an indication of spawning period and they were recorded during August 1995 to July 1997. The weight of adult males and females and their gonads in different stages in different months were noted. The weight of individual fish was first noted after gently wiping the fish with a blotting paper to remove any adhering water and other materials. The ovaries and testes were then carefully removed from these fish. Both the body weight and gonad weight were measured to the nearest milligram. The percentage of ovary weight in relation to the body weight was defined as the gonadosomatic index and was calculated using the following formula followed by the method of June (1953) and Yuen (1955).

$$GSI = \frac{\text{Weight of gonad (g)}}{\text{Body weight of fish (g)}} \times 100$$

3.8.6. Fecundity

Fecundity of fish is usually determined from the number of ova in the ovary. This varies in different species depending on their spawning habits. Fecundity estimate was made by the method described by Polder and Zijlestra (1959).

The total length and weight of individual fish were taken to the nearest millimeter and milligram respectively, after removing the adhering water using a blotting paper. Then the

paired ovaries were excised and adhering water was removed using a blotting paper. They were weighed to the nearest milligram in fresh condition. A piece of ovary was taken from the middle portion and weighed. The ova in each such piece were teased out in a watch-glass using sharp needles. By this method, it was possible to separate almost all the mature ova except the minute ones, which remained either in groups or attached to bigger ova. Since the aim was to count only the mature ova, this method was found simple and easy to use. Fecundity was calculated using the following formula.

$$\text{Fecundity} = \frac{\text{Weight of ovary (g) x number of ova in sample}}{\text{Weight of sample (g)}}$$

Ovaries from at least 20 specimens were used for fecundity estimation.

3.8.7. Sex Ratio

Scats exhibit sexual dimorphism. Sexes can be differentiated by shape of head and colouration of body. The head profile ascends at a constant slope in females and the body colour is lighter and olive green. On the otherhand, males have a concave curvature of head above the eye and darker olive green colour of body.

During the course of this study, 1,659 specimens of scats were collected and studied. Their sexes were recorded using

external characters of head shape and colouration and also by dissecting and observing the gonads.

3.9. ESTIMATION OF POPULATION GROWTH PARAMETERS

The growth in length was considered to follow the Von Bertalanffy's growth equation:

$$L_t = L\infty \left[1-e^{-k(t-t0)} \right]$$

Where L_t = the length at age t.

$L\infty$ = the asymptotic length,

K = Brody's growth coefficient

t_o = age at which length is zero.

Bhattacharya analysis is a procedure to resolve the length frequency sample into normally distributed components and to estimate thereby mean length and standard deviations for each component. Using the Bhattacharya analysis of the FISAT statistical package (Gayanilo *et al.*, 1995), length frequency data collected during 1995 to 1997 were analysed to estimate the mean lengths. These values were then used for " Mode" Progression and estimation of `L' and `K' by the Gulland-Holt plot method. The relative ages were estimated by the method given by Sparre and Venema (1992). The length thus obtained was used to fit the Von Bertalanffy growth equation in length.

Total instantaneous rate of mortality `Z' was estimated using the "length converted catch curve" method in the FISAT. The

natural mortality rate (M) was estimated using Pauly's empirical equation (Pauly, 1980).

3.10. ECOLOGY

An ecological study of the inshore waters of the Gulf of Mannar and Palk Bay where the scats were found, was carried out from August 1995 to July 1997 for a period of two years from Vedalai to Thonithurai south (Gulf of Mannar), the area between the shore and coral reef beds (Palk Bay) and from Theedai to Thonithurai north (Palk Bay), the area between the shore and coral reef beds. Feeding habits and behaviour of scats were also observed.

Environmental parameters such as atmospheric temperature, water temperature, pH, salinity, dissolved constituents such as oxygen, silicate, phosphate, nitrate and nitrite of surface and bottom waters, photosynthesis and zooplankton volume were determined. Two stations, `A' in the Palk Bay, in front of Theedai and 'B' in the Gulf of Mannar in front of Central Marine Fisheries Research Institute's Regional Centre (Mandapam) were chosen for collection of water samples at a distance of 4 km from the shore. Surface water samples were collected using clean plastic containers whereas bottom water samples were collected using a Nansen water sampler. Standard methods (APHA *et al.*, 1985) were used for the determination of salinity and dissolved oxygen.

Silicate, phosphate, nitrate, nitrite and photosynthesis were estimated following the methods of Parsons *et al.*, (1984).

3.10.1. Temperature

Surface water temperature

Sea water was collected in a plastic container. Soon after the collection of seawater, a mercury bulb thermometer was inserted into the sample and the temperature reading was noted.

Bottom water temperature

For recording bottom temperature, a Reversing thermometer was used.

3.10.2. Salinity

In an Erlenmeyer flask, 50 ml of seawater sample was taken and 2 ml of potassium chromate solution was added. The contents of the flask were titrated against silver nitrate (0.02 N $AgNO_3$) until a persistent red tinge appeared.

Calculation

$$\text{Salinity (ppt)} = \frac{V1}{V2} \times S$$

V1 = Volume of silver nitrate used for titration against standard seawater

V2 = Volume of silver nitrate used for titration against sample seawater

S = Salinity of standard seawater (34.16 ppt)

3.10.3. Dissolved oxygen

Before sampling, a glass stoppered BOD bottle of known volume (100-300 ml) was thoroughly cleaned and rinsed twice with sea water. The sample water was introduced through a long tube into the bottom of the bottle so as to avoid air bubbles while filling.

Two reagents viz., 1 ml of Manganous sulphate solution and 1 ml of alkaline potassium iodide (KI) solution were added immediately to the bottom of the sample in the bottle. The reagents were added with the help of a special syringe pipette for better mixing of the reagents with the sample. Separate pipettes were used for these two reagents. A precipitate appeared. After placing the stopper firmly, the contents of the bottle were shaken well by inverting the bottle repeatedly. Then the precipitate was allowed to settle half way down the bottle. The bottle was kept in a dark box. The sample was analysed within the next 6 hours.

Removing the stopper of the BOD bottle, 1 ml of concentrated sulphuric acid reagent was added and shaken well to dissolve the precipitate. 50 ml of the content was taken in a clean conical flask for titration. The contents of the conical flask was titrated against sodium thiosulphate ($Na_2S_2O_3$ (Ca 0.01N)) solution, within one hour of dissolution of the precipitate, using starch as an indicator. The end point was established with the

disappearance of the dark blue colour.

Calculation

$$\text{Dissolved Oxygen (ml/l)} = CD \times \frac{M \times E \times 1000 \times 0.698 \times V_t}{V_s}$$

CD = Correction for displacement of Oxygen in the sample when reagents were added

$$CD = \frac{\text{Volume of bottle}}{\text{Volume of bottle - Volume of reagents}}$$

M = Molarity of sodium thiosulphate (0.01)
E = Equivalent weight of oxygen = 8
1000 = To express per litre
0.698 = To convert parts per million to ml of oxygen per litre
V_t = Volume of thiosulphate used for titration
V_s = Volume of sample titrated.

3.10.4. Dissolved silicate

10 ml of ammonium molybdate solution was taken in a dry 50 ml graduated cylinder fitted with a glass stopper. 25 ml of seawater sample was pipetted out into the cylinder. After stoppering, the sample was mixed thoroughly by inverting and it was allowed to stand for 10 minutes, but not more than 30 minutes. Then 15 ml of reducing reagent, oxalic acid solution, was added rapidly to make 50 ml and mixed immediately. The solution was allowed to stand for 2-3 hrs to complete the reaction. The extinction coefficient was measured at 810 nm using a 1 cm cell for concentrations > 15 μg-at/l and a 10 cm cell for concentrations < 15 μg - at/l. The measured extinction for the blank (1

or 10 cm cell length) was corrected and reactive silicate was calculated as:

μg-at Si/l = corrected extinction x F

where F is the factor for 1 cm cell length.

$$\mu g\text{-at/l} = F_1 \text{ cm} = \frac{100}{E_S - E_B} \times 28.086$$

This value was multiplied by 28.086 to get the value in mg/l or ppm.

E_S = Extinction of standard

E_B = Extinction of blank

3.10.5. Dissolved phosphate

Seawater samples were filtered to remove plankton. 130 ml polyethylene bottles were rinsed twice with filtered seawater and samples were filled. Samples were analysed as soon as they were collected. 100 ml of sample was taken in a graduated 125 ml Erlenmeyer ? flask. 10 ml of mixed reagent (ammonium molybdate, sulphuric acid, ascorbic acid and potassium antimonyl tartrate) was added to the sample using a syringe-type pipette and mixed at once. After 5 minutes and preferably within the first 2-3 hours, the extinction coefficient at 885 nm was measured using a 10-cm cell against distilled water. The extinction with the reagent blank was used for correction and the phosphate concentration was calculated as:

$$\mu g\text{-at } P/l = \text{corrected extinction} \times F$$

where F is the factor

$$\mu g\text{-at}/l = F = \frac{3.00}{E_S - E_B} \times 30.9738$$

This value was multiplied by 30.9738 to get the value in µg/l or ppb.

3.10.6. Dissolved nitrate

Samples were filtered to remove plankton and analysed immediately. 100 ml of seawater was taken in a 125 ml Erlenmeyer flask. To the sample, 2.0 ml of concentrated ammonium chloride was added. After mixing the solution, about 5 ml was poured onto the top of the Nitrate reduction column (containing cadmium filings coated with metallic copper) and allowed to pass through. The remainder of the sample was added to the column and drained into an Erlenmeyer flask placed under the collection tube. The first 40 ml was collected from the column and discarded. Then 50 ml was collected in an Erlenmeyer flask for analysis. To the 50 ml sample, 1.0 ml of sulfanilamide solution was added from an automatic pipette and mixed well. The reagent was allowed to react for a period of more than 2 minutes, but not exceeding 8 minutes. 1 ml of naphthyl ethylene diamine solution was added and mixed immediately. Between 10 minutes and 2 hours afterwards, the extinction coefficient was measured at a wavelength of 543 nm in a 1-cm cuvette against a distilled water blank. The observed

extinction was corrected with reference to that of the reagent blank and nitrate was calculated.

$$\mu g\text{-at } N/l = \text{corrected extinction} \times F$$

Where F is the factor

$$\mu g\text{-at}/l = F = \frac{20}{E_S} \times 14.0067$$

This value was multiplied by 14.0067 to get the value in µg/l or ppb.

3.10.7. Dissolved nitrite

All glassware were rinsed with the filtered water sample, before use. 50 ml of seawater sample was taken in a 125 ml Enlenmeyer flask. Samples were analysed immediately. To each 50 ml sample, 1.0 ml of sulfanilamide solution was added from an automatic pipette and mixed well. The reagent was allowed to react for more than 2 minutes, but less than 10 minutes to assure a complete reaction. Then 1.0 ml of naphthyl ethylene diamine reagent was added and mixed immediately. Between 10 minutes and 2 hours afterwards, the extinction coefficient of the solution in a 10-cm cuvette at a wavelength of 543 nm was measured. The measured extinction for the reagent blank was used for correction and the nitrite concentration was calculated as:

$$\mu g\text{-at } N/l = \text{corrected extinction} \times F$$

$$\mu g\text{-at}/l = F = \frac{2.00}{E_S} \times 14.0067$$

This value was multiplied by 14.0067 to get the value in µg/l or ppb.

3.10.8. Photosynthesis

Primary productivity studies were carried out using light and dark bottle method. Three 125 ml BOD bottles (2 clear bottles one as Initial oxygen bottle "IB", one as light bottle "LB" and the third one as dark bottle "DB") were washed and taken. They were filled with seawater sample collected at a depth of 1 m. The dark bottle was covered with a black polythene bag and the dark bottle and the light bottle were suspended by means of strings from a buoy at the same depth where the sample of sea-water was collected. Dissolved oxygen in the initial oxygen bottle was fixed at the beginning of the experiment. The LB and DB were allowed to be in the location for a period of 3 hrs., so that photosynthesis and respiration would take place.

After the incubation period, both the bottles were removed and dissolved oxygen in these bottles was determined following Winkler's procedure used for dissolved oxygen estimation.

Primary production was expressed in terms of oxygen evolved or organic material synthesized per unit volume of water per unit time 't'.

Oxygen Evolved :

Let oxygen content of IB in ml/l = X

Let oxygen content of DB in ml/l = Y

Let oxygen content of LB in ml/l = Z

Then

a) Respiratory activity = (X-Y) ml/l/t

b) Gross photosynthetic activity = (Z-Y) ml/l/t

c) Net photosynthetic activity = (Z-X) ml/l/t

3.11. AQUARIUM MAINTENANCE OF SCATS AS ORNAMENTAL FISH

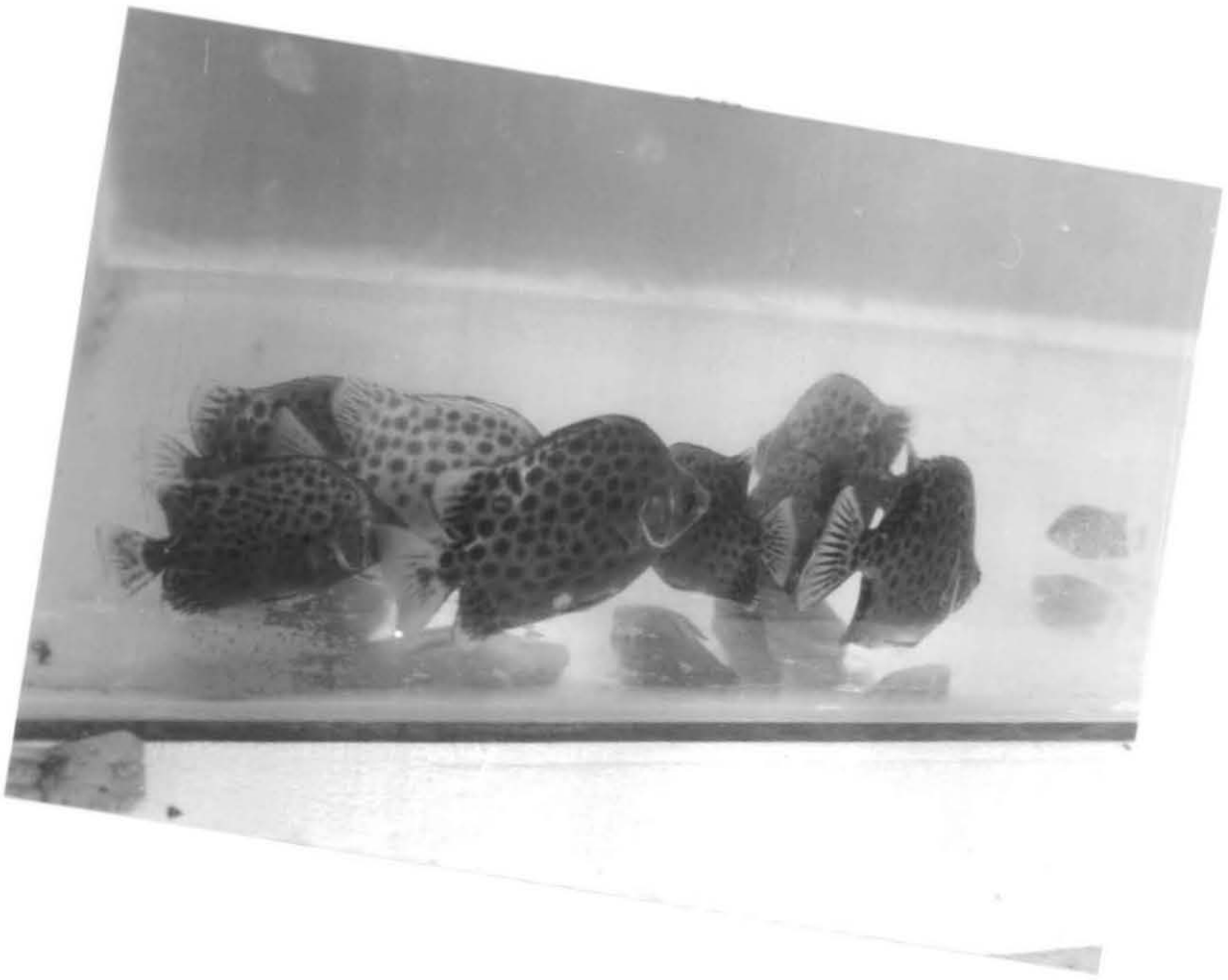
Experiment-I

Generally, in marine aquaria, juveniles of scat are used for ornamental purposes. They can survive for a long time with less quantity of food . They can also survive for a few days without any feed and without any water circulation.

In order to observe the growth rate and survival period, 12 numbers of big size scats, measuring on the average 55 mm in length, were stocked in glass aquarium tanks (Plate-4). The dimensions of the aquarium tank were 4 x 2 x 2 feet. Aquarium tanks were provided with fresh and clean running seawater. Since the tanks were provided with running seawater, aeration was not needed. This experiment was conducted for a period of at least 6 months from July 1996.

The fish were fed once a day during morning hours with minced fresh trash fish which contained 30% protein. The rate of feeding was 10% of mean body weight of stocked scats. Any quan-

Plate - 4 Scat as ornamental fish in aquarium tank



tity of feed left out, was removed with the help of a siphon tube during the same morning to avoid contamination of water. Once a month, length and weight of individual fish were measured and mean length and weight were calculated.

Experiment-II

During the month of February 1997, another experiment was started to observe growth, survival rate, feeding habits and cannibalism among scats. For this experiment, 10 numbers of bigger size scats, measuring a mean total length of 40 mm and 10 numbers of small juvenile fish measuring a mean total length of 10 mm were stocked together in a single aquarium glass tank. Seawater to the tank was provided as done earlier. All the fish were fed with minced trash fish and fresh filamentous algae. The rate of feeding was 10% (5% minced trash fish and 5% filamentous algae) of the mean body weight of the stocked fish. The fish were fed once a day during morning hours. The left out feed was removed during the same morning as mentioned earlier. Once a month, length and weight of individual fish were recorded. Mean length and weight of fish were calculated for every month. This experiment was carried out for a period of at least six months.

3.12. Fry rearing in the aquarium

During the present study, rearing of fry was carried out in glass aquarium tanks kept in the marine aquarium facility of the Central Marine Fisheries Research Institute (CMFRI) at Mandapm. The fry could be collected from the wild, reared in aquarium tanks to prevent natural mortality and then exported to various countries, since the juveniles of scat are in great demand in the world aquarium fish trade. During monsoon season, fry and fingerlings of scat appear in estuaries, lagoons, tidal pools, streams and mangrove swamps and they feed on microorganisms.

During November 1997, fry of scat were collected from the CMFRI's fish farm channel, Mandapam, on the Palk Bay side (India), by using fine mesh bolting silk. Most of the fry were 2.5 mm in size at the time collection. The fry were transported and stocked in glass aquarium tanks. The tanks were provided with running seawater. The inlet and outlet pipes were covered with fine mesh bolting silk to avoid the fry from getting washed away.

The fry were fed with plankton. The food included phytoplankton such as *Cheatoceros* spp., *Skeletonema* spp., *Thalossiosira* spp., *Isocrysis* spp., *Tetraselmis* spp. and *Chlorella* spp. and zooplankton such as rotifers, moina and Artemia nauplii. The food items were freshly collected daily and supplied to the fry.

Observations were made daily. Changes in size of the fry, appearance of organs, formation of pigments, presence of myotomes and number of days taken by the fry to grow from one stage to the next stage were recorded. Samples were collected from the tank and preserved in 5% formaldehyde. Total length of individual fish fry was measured using vernier calipers. Figures were drawn using a camera lucida attached to a research microscope.

4. RESULTS

Taxonomy of the Indian species of *Scatophagus argus*

4.1. DESCRIPTION

Dorsal fin XI, rays 15-17; Anal fin IV, rays 14-15; Caudal fin rays 12-14; Lateral line scales 100-115, TR 80-85. All ctenoid.

Proportional dimensions as percentage of total length were: Head length 22-31%; greatest depth of body 53-65%; tip of snout to origin of spinous dorsal fin 41-53%; tip of snout to origin of anal fin 35-66%; least depth of caudal peduncle 12-14%. As percentage of standard length: Head length 29-39%; greatest depth of body 66-85%; tip of snout to origin of spinous dorsal 54-66%; tip of snout to origin of anal fin 44-87%., least depth of caudal peduncle 16-17%.

Proportional dimensions as percentage of head length were: Length of snout 31-36%; horizontal diameter of the eye 24-25%.

Vertebrae: 11 abdominal, 13 caudal, total 24.

Body: deeply compressed, solid angular body; An obvious curvature above eye on the rostro-dorsal profile of head; Firm skin with minute ctenoid scales in irregular rows; Scales continue upto the soft portion of dorsal, anal and caudal fins and also

on the head and opercle; Small head and mouth; Mouth non-protrusible; Mouth with bands of fine villiform teeth; No teeth on palate; Operculum was irregularly quadrangular with the two upper sides slightly emarginate. Attachment of gill membrane with isthmus was narrow; Dorsal spines were very strong with poison glands and could be differentiated from soft dorsal. Interspinous membrane was strongly notched. Caudal fin was fan like; A distinct lateral line was running parallel to the back profile. A detailed list of description of Scatophagus spp. given by various authors in the past was given in Appendix -1.

4.1.1. Colour

Body was light olive green in colour, darker above, becoming silvery on the abdomen with numerous irregular large round dark brown spots extending on to the fins and tail. The size of the spots was large on the back. Fins were yellowish with light brown markings between rays; Juveniles were olive brown in colour, above the head, and along the back it was bright orange-red in colour.

4.2. MORPHOMETRIC STUDY AND RELATIVE GROWTH OF BODY PARTS

4.2.1. Standard length and morphometric characters

Fourteen characters of each fish were taken for this purpose. The values of a, b, r^2, mean, and standard deviation were

presented in table 3. The relationship between standard length and other characters were given in Figures 2 to 5.

The relationship between standard length and other morphometric characters revealed the following results on growth rates based on the above values. Pre-dorsal length had the fastest growth rate. The slowest growth rate was observed in the pre-anal length and in the pre-orbital length. Pelvic fin length, head length, 3rd. dorsal spine length, pectoral fin length, depth of body, 2nd. anal spine, eye diameter, snout length, inter-orbital space and post-orbital length had growth rates in the descending order of the list.

4.3. LENGTH-WEIGHT RELATIONSHIP

According to Le Cren (1951), the length-weight relationship of fishes was calculated to determine the mathematical relationship between the two variables, length and weight, so that, if one was known, the other could be computed. It was used to measure the variation from the expressed weight for length of individual fish or groups of fish as indication of fatness, general well being, or gonad development.

Le Cren (1951) also pointed out that it was better to fit a general parabolic equation of the form $W = aL^3$ which expressed the relation between the two factors better than the cubic formula ($W = cL^3$) where `W' and `L' represent weight and length of

Table 3 The relationship between standard length and morphometric characters.

S.No.	Characters	a	b	r^2	Mean	Standard deviation
1.	Snout length	2.26	0.0803	84.7	12.29	5.07
2.	Head length	5.63	0.2678	93.60	39.07	16.06
3.	Eye diameter	2.92	0.0570	83.3	10.04	3.63
4.	Pre-orbital length	-3.43	0.1314	96.3	12.97	7.77
5.	Post-orbital length	1.20	0.1429	96.6	19.04	8.44
6.	Inter-orbital space	2.06	0.1389	95.7	19.40	8.27
7.	Pre-dorsal length	8.20	0.4403	96.2	63.17	26.05
8.	Pre-anal length	-3.32	0.5119	63.4	60.60	37.32
9.	Depth of body	3.25	0.6359	92.9	82.64	38.28
10.	Pectoral fin length	4.42	0.1329	80.7	21.01	8.59
11.	Pelvic fin length	5.73	0.2267	87.5	34.04	14.07
12.	3rd. dorsal spine	4.99	0.1781	85.3	27.23	11.19
13.	2nd dorsal spine	3.08	0.0989	86.9	15.43	6.16
14.	Depth at caudal peduncle	1.19	0.1395	96.5	18.61	8.24

a = Intercept; b = Slope; r^2 = Correlation coefficient.

Fig.2a Relationship between standard length and snout length

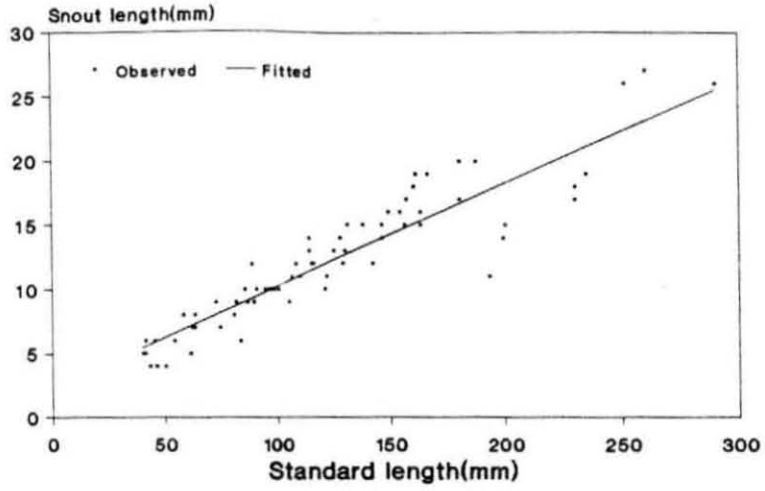


Fig. 2b Relationship between standard length and head length

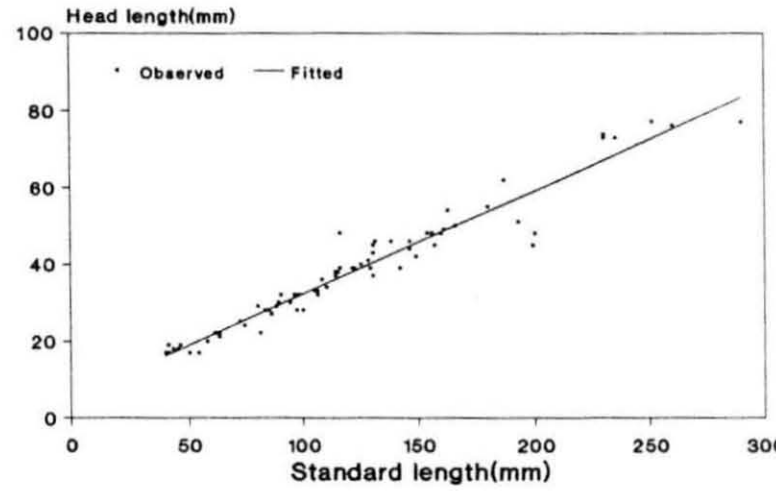


Fig.2c Relationship between standard length and eye diameter

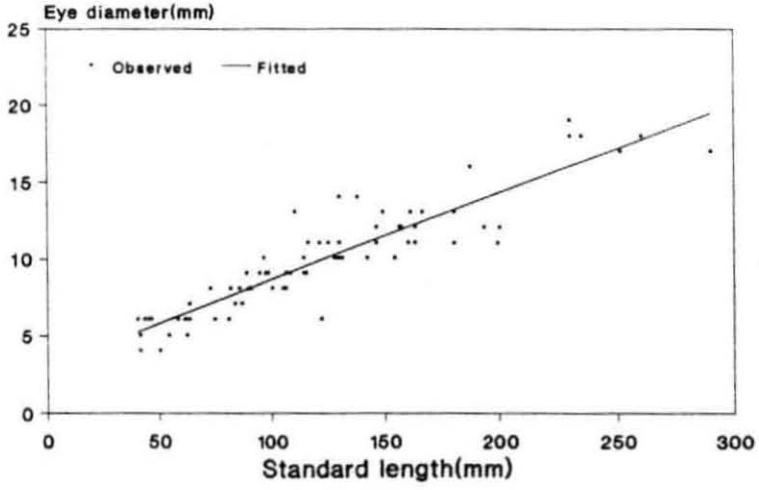


Fig.2d Relationship between standard length and pre-orbital length

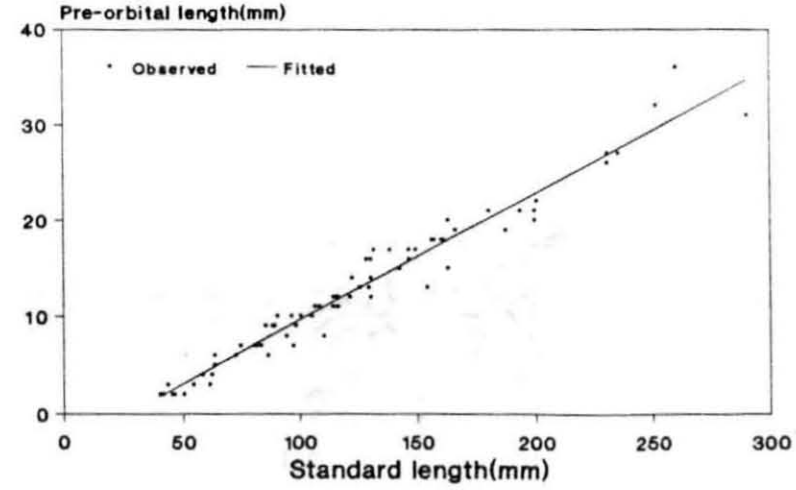


Fig.3a Relationship between standard length and post-orbital length

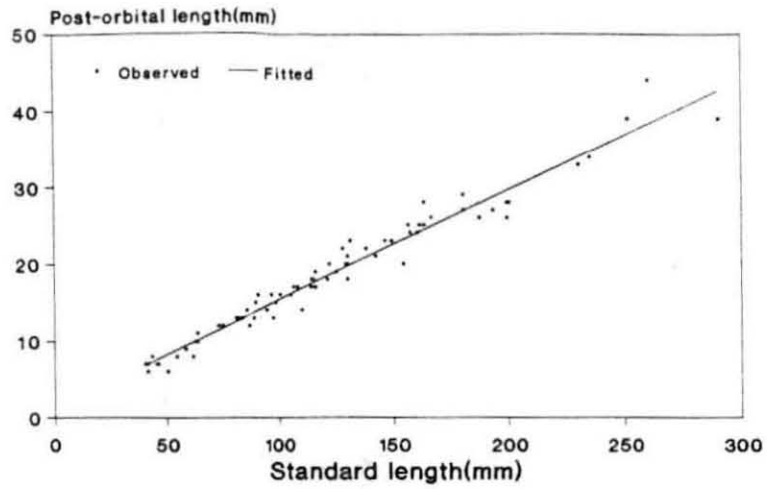


Fig.3b Relationship between standard length and inter-orbital space

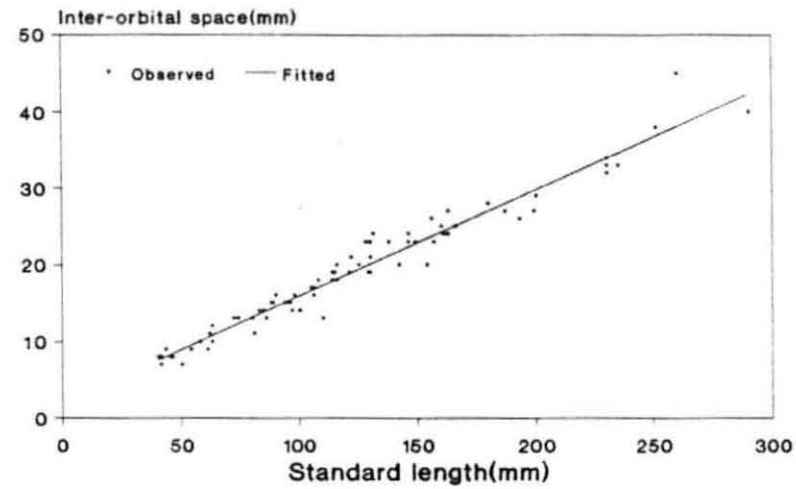


Fig.3c Relationship between standard length and pre-dorsal length

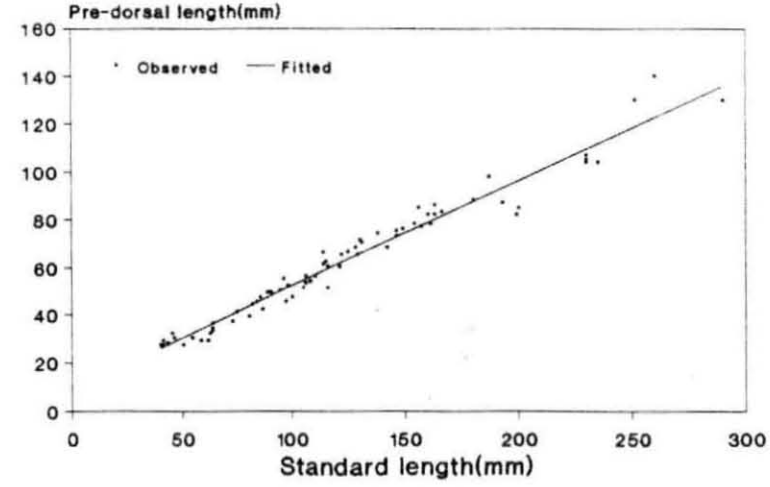


Fig.3d Relationship between standard length and pre-anal length

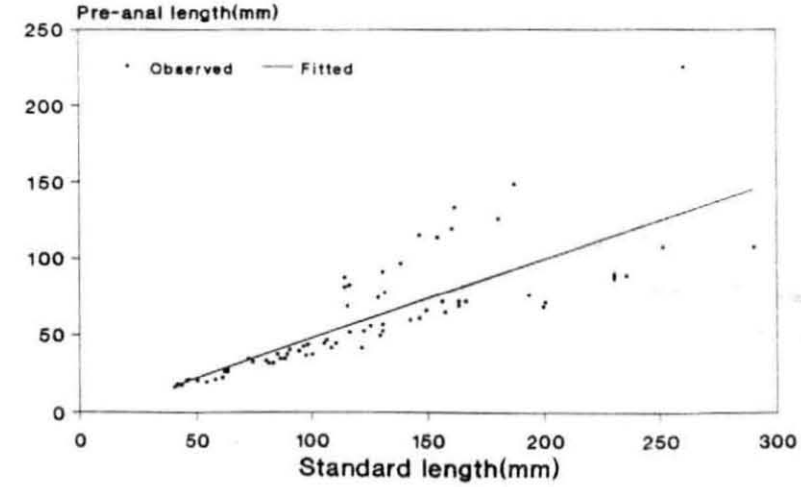


Fig.4a Relationship between standard length and body depth

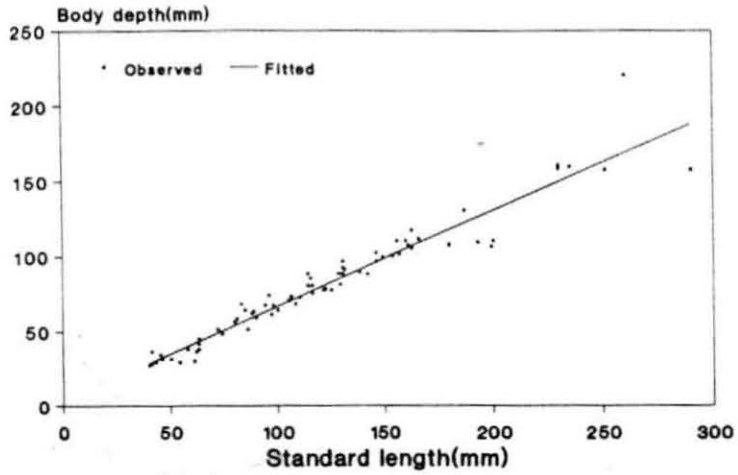


Fig.4b Relationship between standard length and pectoral fin length

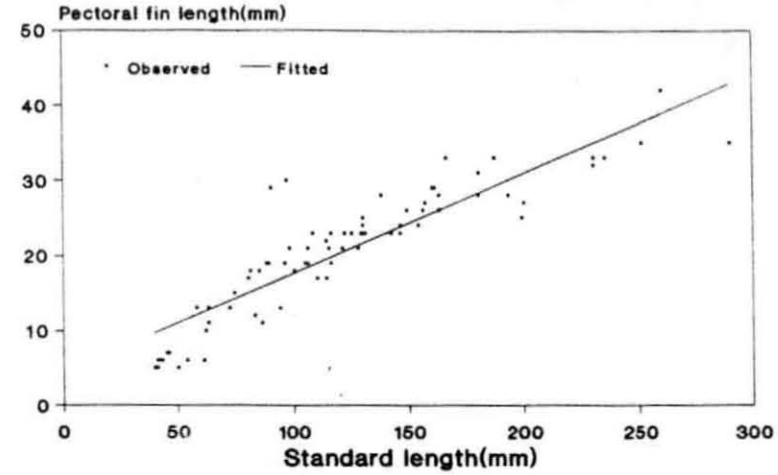


Fig.4c Relationship between standard length and pelvic fin length

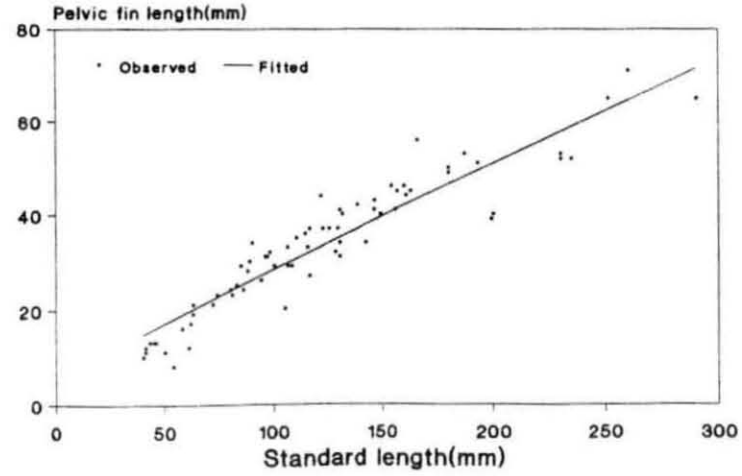


Fig.4d Relationship between standard length and length of 3rd dorsal spine

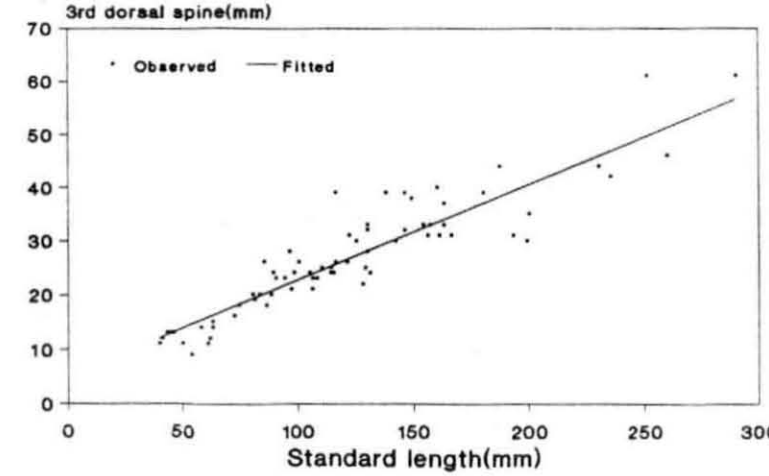


Fig.5a Relationship between standard length and length of 2nd anal spine

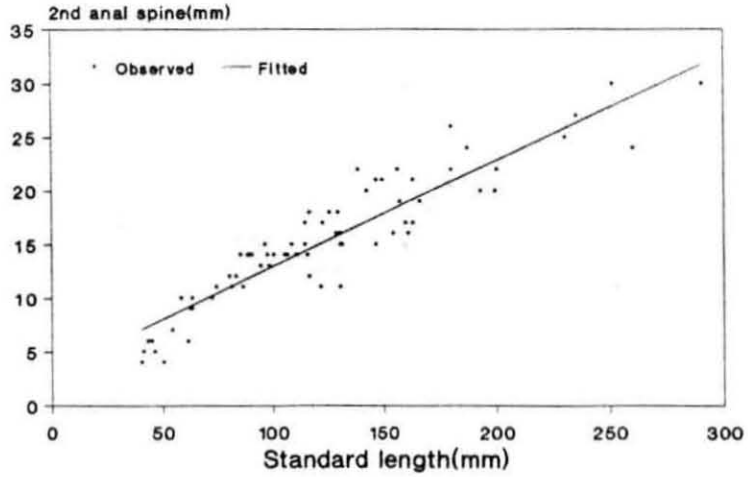
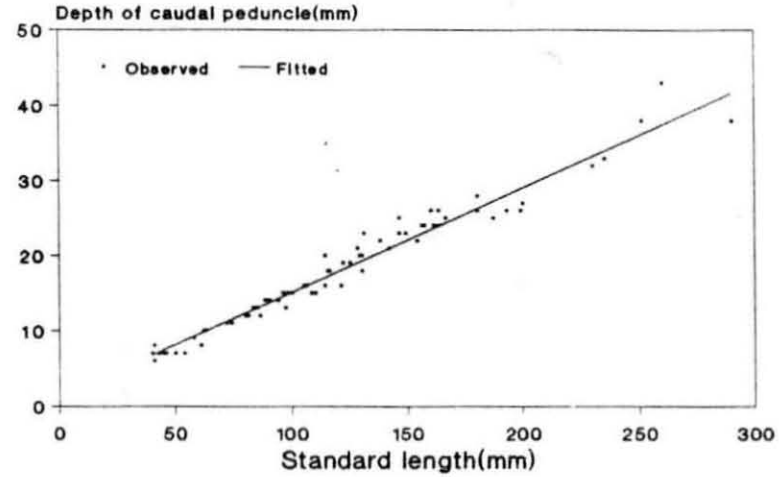


Fig.5b Relationship between standard length and depth of caudal peduncle



fish respectively, `a' a constant equivalent to `c', and `n' a constant to be determined empirically i.e., from the data. The value of the exponent `n' in the parabolic equation usually lay between 2.5 and 4.0 (Hile, 1936; Martin, 1949). Beverton and Holt (1957) stated that important departures from isometric growth (n=3) were rare. Blackburn (1960) reported that in the case of Australian barracuda *Thyrsisrtes atun* (Euphrasen), the value of `n' was considerably below 3.0.

Since the scat had a deep, strongly compressed body, it was decided to fit the general equation $W = aL^n$ for length-weight relationship. The relationship was derived using individual length and weight measurements of 482 indeterminates, 517 males and 1140 females of scat collected during the period from August'95 to July'97.

The values were:

Indeterminates, Weight = 0.0334 x $(\text{Length}^{1.54})$ (±0.056) r^2=69.87

Males, Weight = 0.1369 x $(\text{Length}^{1.38})$ (±0.02) r^2=90.14

Females, Weight = 1.0366 x $(\text{Length}^{1.00})$ (±0.01) r^2=93.60

and were depicted in Figure 6.

Analysis of covariance was carried out (Snedecor and Cochran, 1967) to test the equality of length-weight relationship between males and females. The transformation applied was

$$\log(Y) = a + \log(X)$$

The values were presented in Table-4.

Figure 6b Length-weight relationship in female S.argus

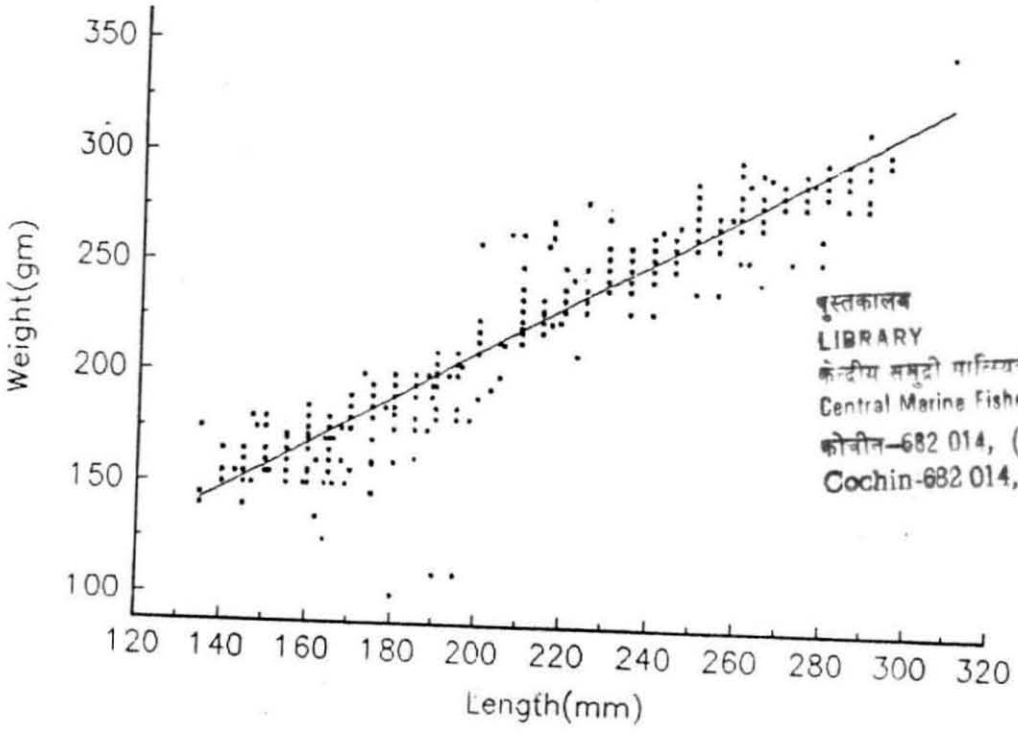


Figure 6a Length-weight relationship in male S.argus

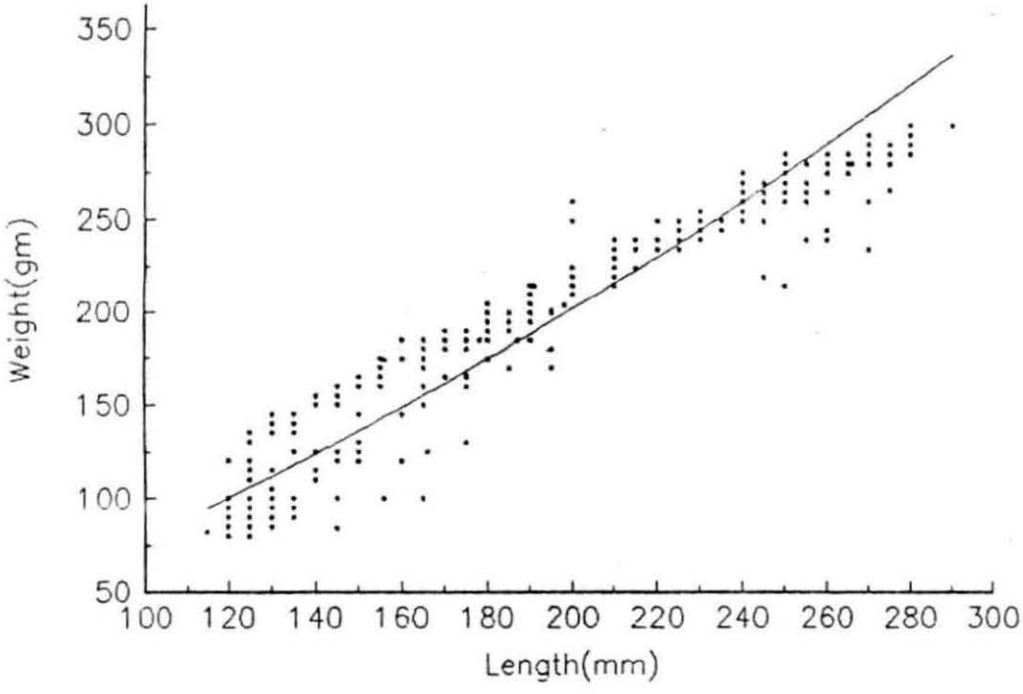


Table 4 Analysis of covariance to test equality of length-weight relationship between sexes.

SOURCE	D.F.	SSX	SP	SSY	b	D.F.	SS	M.S.	F. value
Male	517	37.3692	51.4750	78.6644	1.377	516	7.759	0.01504	
Female	1140	48.1812	48.3228	51.7483	1.003	1139	3.284	0.00288	
Total						1655	11.042	0.00667	
Pooled, W	1657	85.5504	99.7978	130.4127	1.167	1656	13.995	0.00845	
Difference between slopes						1	2.952	2.952	442.47**
Between, B	1	2.0191	4.0586	8.1584					
Within, W + B	1658	87.5694	103.8564	138.5710	1.186	1657	15.399	0.00929	
Between adjusted means						1	1.404	1.404	166.11**

$$\text{Comparison between slopes } F = \frac{2.952}{0.00667} = 442.67$$ (To test equality of 'b' value)

$$\text{Comparison between means } F = \frac{1.404}{0.00845} = 166.11$$ (To test equality of 'a' value)

**** denotes highly insignificant (P < 0.01)**

DF = Degrees of freedom
SSX = Sum of Square in X
SP = Sum of Products in X and Y
SSY = Sum of Square in Y
b = Regression coefficient
MS = Mean Square

4.4. FOOD AND FEEDING HABITS

4.4.1. Qualitative analysis

The main food of the fish consisted of multicellular algae and detritus. The multicellular algae were represented by *Enteromorpha compressa* and *Ulva* spp. The components of detritus were mud, sand, minute broken shells of molluscs, foraminifera and other inorganic matter.

Unicellular algae were represented by *Chaetoceros* spp., *Skeletonema* spp., *Thalossiossira* spp., *Tetraselmis* and *Chlorella* spp. Small fish scales were also found in most of the guts of small and big size fishes. Protozoa occurred occasionally in some guts. Shells of bivalves, sponges, sea-anemones, *Lepas* spp. and foraminiferan shells were also present in the gut contents.

Penaeid prawns were represented by young ones of *Penaeus indicus* and *P. semisulcatus*, whereas other crustaceans were represented by *Metapenaeus* spp., and by caridean prawns of the family Alphaeidae. Copepods were also seen in the gut contents.

4.4.2. Quantitative analysis

Details of percentage occurrence of various food organisms in the gut contents of *Scatophagus argus* in different size groups during the study period from August 1995 to July 1997 were presented in Appendices-2 to 25.

Unicellular algae and detritus were found predominantly in the gut contents of young fish of size <50 mm. Their percentage occurrence was high. Fish scales, protozoa, and copepods were also recorded in the same size group of fishes. The percentage occurrence of copepods was lesser than protozoa. Unicellular algae were also found in the gut contents of fish of size 50 to 100 mm.

Enteromorpha compressa and detritus were the dominant food items in the gut contents of fish of size 50 to 100 mm, 100 to 200 mm and >200 mm. Their percentage occurrence was high in all the size groups. Ulva spp., was recorded in the gut contents of fish of size <100 mm to a lesser extent compared to *E.compressa*.

Sea-anemones, coral polyps, prawns, bivalves, foraminifera, other crustaceans, copepods and lepas were also found in the gut contents of fish of size 50 to 100 mm, 100 to 200 mm and >200 mm throughout the observation period. The percentage occurrence of sponges, sea-anemones, fish scales and coral polyps was higher than that of the other food items such as copepods, alphids and protozoa. Copepods were recorded to a lesser extent during the whole period of observation. Alphids were found only on two occasions during the observation period and that too in the size group >200 mm. Protozoans were totally absent in all the size groups except in the smallest size group of <50 mm.

4.4.3. Selectivity in feeding

From regular observations, it was understood that the diet of *Scatophagus argus* appeared to depend largely on the availability of food items. During the present study, presence of *E.compressa* attached on dead corals, on immersed hard substrata, and on jetties constructed in the sea was recorded. *Ulva* spp. was also recorded from the area of survey. Sponges, sea-anemones, bivalves and lepas were found attached to the above mentioned structures. Food items such as unicellular algae, phytoplankton, copepods and small protozoans were also recorded in the gut contents of juvenile fishes. Pieces of live corals of small size were also recorded. Presence of small prawns, other crustaceans, foraminifera and alphids were also observed during the survey. This study clearly indicated that scats did not exhibit any specific selection of food items.

4.4.4. Condition of stomach

During August 1995, majority of the fish had fed actively (full, 3/4 full and 1/2 full), whereas during September, fish which had fed actively and poorly (1/4 and little) were more or less equal. In October, November 1995 and March 1996, the percentage of fish had that fed actively showed a rise, whereas a steep rise was observed during December 1995, February and May 1996. In January and July 1996, majority of fish were in the

category of poorly fed whereas in April and June 1996, they had fed very actively (Table 5).

During August 1996 and March 1997, the fish had fed actively, whereas during September, October 1996 and February 1997, fish which had fed actively and poorly occurred equally. There was a rise in fish which had fed actively during November 1996 and January 1997. Feeding was very poor in December 1996 and poor in July 1997. During May 1997, the fish had fed actively, whereas in April and June 1997, the feeding activity was very high (Table 5). The present study period from August'95 to July'97 indicated that there was no regular pattern in feeding activity.

4.4.5. Feeding habits

The fish were sometimes observed to have eaten whole organisms. This was obviously governed by the size of the prey. The common food items that were found to have been fed in whole were small prawns, copepods, some phytoplankton, sponges, *E.compressa* and *Ulva* spp. Coral polyps, lepas, sea-anemones and alphids were found as undigested chitinous remains.

Lengthy filamentous algae *E.compressa* were found to have been browsed and swallowed by big fish. Attached organisms such as sea-anemones, small lepas, bivalves and sponges were seen to have been scrapped and swallowed by big fish. Coral polyps were found to have been nibbled by big fish. Prawns, other crustaceans

Table 5 The status of stomach of *S.argus* in terms of fullness as % of total individuals analysed (August 1995 to July 1997).

Condition of stomach	Aug.95	Sep.	Oct.	Nov.	Dec.	Jan.96
No. of Fish	88	91	72	91	57	66
Full	9	7	10	13	16	8
3/4 Full	26	10	25	22	32	9
1/2 Full	22	34	21	27	18	21
1/4 Full	31	19	31	16	14	48
Little	13	31	14	21	21	14
Condition of stomach	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.96**
No. of Fish	56	77	102	107	100	121
Full	14	14	7	39	18	7
3/4 Full	20	27	25	10	21	23
1/2 Full	30	12	44	14	32	10
1/4 Full	13	13	17	18	16	43
Little	23	34	8	19	13	17
Condition of stomach	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.97**
No. of Fish	102	102	102	93	76	100
Full	12	15	18	12	9	12
3/4 Full	11	26	13	28	12	27
1/2 Full	47	10	20	34	18	33
1/4 Full	15	37	42	16	11	19
Little	16	12	8	10	50	9
Condition of stomach	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.97**
No. of Fish	99	84	99	77	94	83
Full	6	29	9	13	12	12
3/4 Full	19	25	19	26	31	20
1/2 Full	25	11	53	14	36	13
1/4 Full	39	23	12	35	16	46
Little	10	13	7	12	5	8

and alphids were seen to have been bitten and swallowed. Detritus, fish scales and foraminiferan shells were found to have been swallowed by big fish.

Protozoa, phytoplankton and copepods were found in small fish which indicated that young fish fed on the surface. Since detritus was also recorded from the gut contents of young fish, it could be inferred that young fish also would have fed at the bottom.

4.5. BIOCHEMICAL CHANGES DURING MATURATION AND SPAWNING

Estimated moisture, protein, carbohydrate and lipid content in muscle, liver and gonad of male and female scats in different stages of maturity (I to VII stages) were presented in Tables 6 & 7. In order to avoid the influence of moisture content on the calculation of biochemical composition of muscle, liver, and gonad, all analyses were carried out on dry weight basis. Each value represented the mean of at least five samples.

4.5.1. Male

The proximate biochemical composition of various tissues of male scat was given in Table-6.

4.5.1.1. Muscle

Moisture content in the muscle varied from 75 ± 0.4 (± S.D) to 77 ± 0.6 (± S.D) % in stages I to VII with the maximum found

Table 6 Moisture (%), protein, lipid and carbohydrate (mg/g) ± S.D. content of muscle, liver and testis of male scat in I to VII stages.

Stages	Moisture	Protein	Lipid	Carbohydrate
		Muscle		
I	76 ± 0.5	594 ± 4	62 ± 0.5	32 ± 0.4
II	76 ± 0.3	583 ± 4	59 ± 0.3	30 ± 0.5
III	76 ± 0.3	567 ± 1	59 ± 0.7	29 ± 0.5
IV	77 ± 0.4	577 ± 2	56 ± 0.2	27 ± 0.4
V	77 ± 0.5	574 ± 4	50 ± 0.2	28 ± 0.1
VI	77 ± 0.6	597 ± 3	64 ± 0.5	30 ± 0.6
VII	75 ± 0.4	600 ± 2	79 ± 0.7	30 ± 0.5
		Liver		
I	72 ± 0.1	527 ± 5	284 ± 3	310 ± 3
II	72 ± 0.2	532 ± 3	277 ± 2	318 ± 1
III	72 ± 0.2	551 ± 0.5	267 ± 1	291 ± 7
IV	74 ± 0.2	507 ± 7	279 ± 2	275 ± 4
V	74 ± 0.2	481 ±12	255 ± 3	258 ± 8
VI	75 ± 0.3	502 ± 8	324 ± 4	299 ±11
VII	73 ± 0.2	542 ± 7	333 ± 5	310 ± 1
		Testis		
I	75 ± 0.4	245 ± 3	346 ± 2	154 ± 1
II	75 ± 0.4	237 ± 2	327 ± 4	137 ± 1
III	74 ± 0.2	244 ± 2	325 ± 4	117 ± 1
IV	75 ± 0.3	262 ± 1	310 ± 1	125 ± 4
V	77 ± 0.4	254 ± 1	287 ± 2	107 ± 2
VI	74 ± 0.4	265 ± 1	340 ± 2	97 ± 1
VII	75 ± 0.2	286 ± 1	363 ± 2	108 ± 1

in stage IV and the minimum seen in stage VII. Protein content ranged between 567 ± 1 (± S.D) and 600 ± 2 (± S.D) mg/g in stages I to VII with the minimum recorded in stage III and the maximum recorded in stage VII. Lipid content varied from 50 ± 0.2 (± S.D) to 79 ± 1 (± S.D) mg/g in stages I to VII with the minimum registered in stage V and the maximum registered in stage VII. The range of carbohydrate content was from 28 ± 0.1 (± S.D) to 32 ± 0.4 (± S.D) mg/g in stage I to VII with the maximum noticed in stage I and the minimum noticed in stage IV.

4.5.1.2. Liver

Moisture content ranged from 72 ± 0.1 (± S.D) to 75 ± 0.3 (± S.D)% in stages I to VII with the maximum recorded in stage VI and the minimum recorded in stage I. The protein content varied from 481 ± 12 (± S.D) to 551 ± 0.5 (± S.D) mg/g in stages I to VII with the maximum observed in stage III and the minimum observed in stage IV. Lipid content varied between 255 ± 3 (± S.D) and 333 ± 5 (± S.D) mg/g in stages I to VII with the minimum found in stage V and the maximum found in stage VII. Carbohydrate content ranged from 258 ± 8 (± S.D) to 318 ± 1 (± S.D) mg/g in stages I to VII with the maximum seen in stage II and the minimum observed in stage V.

4.5.1.3. Testis

The range of moisture content observed was from 74 ± 0.2 (± S.D) to 77 ± 0.7 (± S.D) % in stages I to VII with the minimum

registered in stage III and the maximum registered in stage V. Protein content ranged from 237 ± 2 (± S.D) to 286 ± 2 (± S.D) mg/g in stages I to VII with the minimum noted in stage II and the maximum noted in stage VII. Lipid content ranged between 287 ± 2 (± S.D) and 363 ± 2 (± S.D) mg/g in stages I to VII with the minimum recorded in stage IV and the maximum recorded in stage VII. Carbohydrate content varied from 97 ± 1 (± S.D) to 154 ± 1 (± S.D) mg/g in stages I to VII with the maximum registered in stage I and the minimum registered in stage VI.

4.5.2. Female

The proximate biochemical composition of female scat was given in Table-7.

4.5.2.1. Muscle

Moisture content in the muscle ranged from 74 ± 0.2 (± S.D) to 76 ± 0.3 (± S.D) % in maturity stages I to VII with the minimum seen in stage IV and the maximum observed in stage VII. Protein content of muscle varied between 497 ± 10 (± S.D) and 609 ± 16 (± S.D) mg/g in maturity stages I to VII with the maximum found in stage II and the minimum found in stage VI. Lipid content ranged from 29 ± 1 (± S.D) to 54 ± 1 (± S.D) mg/g in stages I to VII with the maximum found in stage I and the minimum found in stage VI. The range of carbohydrate content was from 19 ± 0.1 (± S.D) to 28 ± 0.5 (± S.D) mg/g in stages I to

Table 7 Moisture (%), protein, lipid and carbohydrate (mg/g) ± S.D. content of muscle, liver and ovary of female scat in I to VII stages.

Stages	Moisture	Protein	Lipid	Carbohydrate
		Muscle		
I	74 ± 0.2	606 ± 24	54 ± 1.0	28 ± 0.5
II	74 ± 0.2	609 ± 16	50 ± 1.0	27 ± 0.1
III	75 ± 0.1	588 ± 90	49 ± 0.2	26 ± 1.0
IV	74 ± 0.2	592 ± 60	46 ± 0.3	25 ± 0.1
V	75 ± 0.1	572 ± 14	39 ± 1.0	23 ± 0.4
VI	75 ± 0.2	497 ± 10	29 ± 1.0	19 ± 0.1
VII	76 ± 0.3	594 ± 60	50 ± 0.1	27 ± 1.0
		Liver		
I	73 ± 0.4	489 ± 70	243 ± 50	188 ± 60
II	71 ± 0.1	461 ± 13	208 ± 90	173 ± 80
III	71 ± 0.1	452 ± 17	179 ± 20	149 ± 30
IV	72 ± 0.3	397 ± 40	151 ± 20	151 ± 20
V	73 ± 0.2	176 ± 10	159 ± 30	140 ± 70
VI	71 ± 0.3	286 ± 10	139 ± 20	132 ± 30
VII	73 ± 0.3	384 ± 30	150 ± 20	156 ± 50
		Ovary		
I	75 ± 0.3	560 ± 3	218 ± 2	65 ± 0.4
II	76 ± 0.2	539 ± 2	236 ± 3	64 ± 0.4
III	76 ± 0.3	547 ± 4	229 ± 2	70 ± 0.5
IV	74 ± 0.2	595 ± 7	239 ± 2	76 ± 0.1
V	75 ± 0.2	458 ± 1	238 ± 1	60 ± 0.4
VI	74 ± 0.2	406 ± 6	242 ± 1	59 ± 0.1
VII	75 ± 0.2	389 ± 2	252 ± 3	71 ± 0.4

VII, with the maximum seen in stage I and the minimum seen in stage VI.

4.5.2.2. Liver

Moisture content of liver was 71 ± 0.1 (± S.D) to 73 ± 0.4 (± S.D) % in stages I to VII with the minimum observed in stage III and the maximum observed in stage V. The range of protein content was from 286 ± 1 (± S.D) to 489 ± 7 (± S.D) mg/g in stages I to VII with the maximum found in stage I and the minimum found in stage VI. Lipid content varied from 139 ± 2 (± S.D) to 243 ± 5 (± S.D) mg/g in stages I to VII with the maximum noticed in stage I and the minimum noticed in stage VI. Carbohydrate ranged between 132 ± 3 (± S.D.) and 188 ± 6 (± S.D.) mg/g in stages I to VII with the maximum seen in stage I and the minimum seen in stage VI.

4.5.2.3. Ovary

The range of moisture content was from 74 ± 0.2 (± S.D) to 76 ± 0.3 (± S.D) % in stages I to VII with the maximum registered in stage III and the minimum registered in stage VI. Protein content ranged from 389 ± 2 (± S.D) to 595 ± 7 (± S.D) mg/g in stages I to VII with the maximum recorded in stage III and the minimum recorded in stage VII. Lipid content ranged from 218 ± 2 (± S.D) to 252 ± 3 (± S.D) mg/g in stages I to VII with the minimum seen in stage I and the maximum found in stage VII. Carbohydrate content varied between 59 ± 0.1 (± S.D) and 76 ± 0.1

(± S.D) mg/g in stages I to VII with the maximum found in stage IV and the minimum found in stage VI.

4.6. CALORIC CONTENT

The total caloric content of oven dried tissues of muscle, liver and gonad in terms of joules for the seven stages of male and female were given in Tables-8 & 9. Each value represented the mean of at least five samples for each stage.

4.6.1. Male

Maximum caloric value of 18,209 joules/g in muscle was noticed in stage VII and minimum caloric value of 16,024 joules/g was found in stage V. Similarly maximum caloric value of 31,299 joules/g in liver was seen in stage VII and minimum caloric value of 25,899 joules/g was recorded in the stage V. In the case of gonad, maximum value of 22,939 joules/g was found in stage VII and minimum caloric value of 19,239 joules/g was noticed in stage V (Table-8).

4.6.2. Female

Maximum caloric value of 16,928 joules/g in muscle was seen in stage I and minimum caloric value of 11,690 joules/g was found in stage II. Similarly maximum caloric value of 24,396 joules/g in liver was recorded in stage I and minimum caloric value of 14,546 joules/g was seen in stage VI. In the gonad, maximum

Table 8 Calculated caloric values of protein, carbohydrate and lipid of muscle, liver and gonad in different stages of maturity of male scat (dry weight basis).

Stages	Tissues	Protein cal/g	Carbohydrate cal/g	Lipid cal/g	Total of P+C+L cal/g	J/g
I	Muscle	3359	132	582	4072	17045
	Liver	2980	1285	2672	6937	29038
	Gonad	1383	640	3252	5275	22081
II	Muscle	3296	126	552	3975	16639
	Liver	3007	1320	2605	6932	29017
	Gonad	1342	568	3073	4983	20859
III	Muscle	3205	119	554	3878	16233
	Liver	3112	1207	2514	6833	28603
	Gonad	1380	485	3051	4915	20574
IV	Muscle	3262	114	528	3904	16342
	Liver	2863	1140	2625	6629	27745
	Gonad	1478	519	2911	4908	20545
V	Muscle	3243	116	470	3829	16024
	Liver	2716	1071	2400	6887	25899
	Gonad	1448	446	2702	4596	19239
VI	Muscle	3371	124	602	4097	17150
	Liver	2839	1242	3047	7128	29838
	Gonad	1498	402	3196	5095	21328
VII	Muscle	3483	127	741	4350	18209
	Liver	3060	1287	3130	7477	31299
	Gonad	1619	446	3415	5480	22939

caloric value of 24,794 joules/g was found in stage IV and minimum caloric value of 20,164 joules/g was noticed in stage VI (Table-9).

4.7. REPRODUCTION

4.7.1. Structure of reproductive organs

4.7.1.1. Ovary

The female reproductive organ of *Scatophagus argus* consisted of a pair of ovaries, oviducts from either side which united to form a common oviduct occupying the ventral position to the swimbladder in the body cavity. The ovary in this species, as in many teleost fishes, was of the cysto-ovarian type and bilobed. The two lobes were separate and of equal size. Each lobe contained a central cavity, the ovocoel, and continued into an oviduct. The oviducts of both lobes of ovary joined to form a common tube which ended in the urinogenital opening.

4.7.1.2. Testis

The male reproductive organ consisted of a pair of elongated testis, vasa deferentia and a common sperm duct. The testis like the ovary, was bilobed and the lobes were of equal size. The two vasa deferentia joined to form a common sperm duct and ended in the urinogenital opening.

Table 9 Calculated caloric values of protein, carbohydrate and lipid of muscle, liver and gonad in different stages of maturity of female scat (dry weight basis).

Stages	Tissues	Protein cal/g	Carbohydrate cal/g	Lipid cal/g	Total of P+C+L cal/g	J/g
I	Muscle	3422	118	505	4044	16928
	Liver	2764	779	2286	5828	24396
	Gonad	3166	269	2053	5488	22973
II	Muscle	3454	110	475	4038	16903
	Liver	2606	718	1959	5283	22115
	Gonad	3048	265	2220	5533	23161
III	Muscle	3325	109	462	3895	16304
	Liver	2528	622	1679	4829	20214
	Gonad	3089	290	2151	5530	23149
IV	Muscle	3343	104	431	3877	16229
	Liver	2244	625	1422	4291	17962
	Gonad	3363	315	2246	5923	24794
V	Muscle	3230	94	363	3686	15434
	Liver	2122	583	1499	4204	17598
	Gonad	2587	247	2252	5086	21290
VI	Muscle	2810	79	271	3160	13228
	Liver	1618	548	1309	3475	14546
	Gonad	2296	245	2276	4817	20164
VII	Muscle	3357	110	469	3937	16480
	Liver	2173	605	1406	4184	17514
	Gonad	2198	294	2361	4853	20315

4.7.2. Maturity stages and ova diameter studies

Classification of maturity stages and ova diameter were given in Table-10.

4.7.2.1. Maturity stages

Stage I-Immature

The ovaries appeared very small and transparent. They occupied less than one third of the body cavity. Ova were not visible to naked eyes and were small and transparent in colour. There was a prominent nucleus, which occupied most of the central region of the ovum. There was no yolk formation. Immature ova were large in numbers and present throughout the year. Diameter of the ova varied between 0.10 and 0.20 mm.

Testes were very slender, thin, and semi-transparent, occupying about the same space as the ovaries.

Stage II- Developing immature and recovering spent

Ovaries were slightly larger and slightly reddish in colour. They occupied one-third of the body cavity. The first batch of eggs got separated from the immature stock. Ova were small, transparent, without yolk and were not visible to naked eyes. The ova diameter varied from 0.26 to 0.36 mm with a mode value of 0.28 mm.

Table 10 Classification of maturity stages of *Scatophagus argus*.

Stages of maturity	Description of the intra-ovarian eggs (mm)	Minimum size of intra-ovarian eggs (mm)	Maximum size of intra-ovarian eggs (mm)	Mode of largest group of eggs (mm)
I	Immature	0.10	0.20	0.12
II	Developing immature and recovering spent	0.26	0.36	0.28
III	Maturing	0.37	0.47	0.39
IV	Mature	0.43	0.58	0.45
V	Advanced Mature	0.59	0.69	0.61
VI	Ripe	0.65	0.75	0.67
VII	Spent	0.26	0.36	0.28
	Residual eggs	0.56	0.72	0.66

Testes were enlarged and whitish in colour and occupied one-third of the body cavity.

Stage III-Maturing

Ovaries were greatly enlarged. They appeared slightly yellowish in colour. The ovarian wall was thick. They occupied about half of the body cavity. Ova were spherical and opaque with deposition of yolk. Ova had granular cytoplasm. Ova were visible to naked eyes. Diameter of the ova ranged from 0.37 to 0.47 mm with a mode value of 0.39 mm.

Testes were well enlarged, flattened and pale white in colour. They occupied lesser space than the ovaries, in the body cavity.

Stage IV-Mature

Ovaries were greatly enlarged and occupied about three fourths of the body cavity. The ovarian wall was thin. The ovaries were yellow in colour and blood vessels were seen. Mature opaque ova, fully laden with yolk were present. Diameter of the ova ranged between 0.43 and 0.58 mm with two mode values of 0.45 mm.

Testes were greatly enlarged, flat and milky-white in appearance and occupied the body cavity as in the case of ovary.

Stage V - Advanced mature

Ovaries were enlarged and occupied the entire body cavity. The ovarian wall became almost transparent. The colour of the ovary was dark yellow. Blood vessels were seen in the ovary. Mature opaque ova, fully laden with yolk were present. Periphery of the ova was transparent. Diameter of the ova varied from 0.59 to 0.69 mm with a mode value of 0.61 mm.

Testes were flat, well-developed and creamy white in colour. When pressed, a small amount of milt oozed out.

Stage VI-Ripe

Ovaries occupied the entire body cavity. They were transparent and the walls became very thin, delicate and rupturable, through which eggs could be seen. Eggs were ripe and transparent with oil-globules and the fish was ready for spawning. Diameter of the ova ranged between 0.65 and 0.75 mm with a mode value of 0.67 mm.

Testes were greatly enlarged with milk-white appearance. When pressed, milt exuded.

Stage VII- Spent

Ovaries were in shrunken condition. They were not fully packed with ova. They were with a few blood patches in fresh condition. They resembled Stage II, but differed from it in the

partly empty, compressed and shrunken appearance. Majority of the ova were small, transparent, and invisible to naked eyes. Scattered amongst them were a few large residual transparent ova visible to naked eyes. Diameter of the small ova ranged from 0.26 to 0.36 mm with a mode value of 0.28 mm, whereas the diameter of the residual ova were 0.56 to 0.72 mm with a mode value of 0.66 mm.

4.7.2.2. Ova diameter studies

The frequency polygons of ova diameter of 1000 ova each measured from ovaries in the I, II, III, IV, V, VI and VII stage of maturity were shown in Figures 7 and 8. In Stage I, majority of the ova were in the size range 0.10 to 0.12 mm and a few of them measured upto 0.20 mm. In Stage II, ova developed from the general egg stock (from the stock of Stage I) had a mode value of 0.28 mm and a maximum size of 0.36 mm. As the ovary passed on from Stage II to III, a second group of ova got separated from the original immature stock. The first group progressed further and showed a mode value of 0.39 mm and the second group had the mode value of 0.28 mm. In the next stage of development (Stage IV), in addition to the immature stock of eggs, the two advanced groups noted in the previous stage were also present. The mode value of 0.28 mm remained the same indicating no growth in this group whereas the mode value of 0.39 mm had progressed further to show a peak value of 0.45 mm. This mature group of eggs which would be spawned in the ensuing spawning

Fig.7a Ova diameter frequency polygon of stage I in *S.argus*

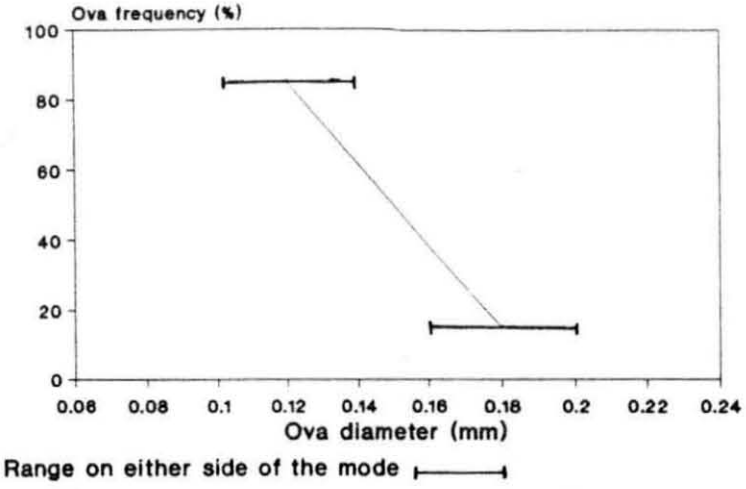


Fig.7b Ova diameter frequency polygon of stage II in *S.argus*

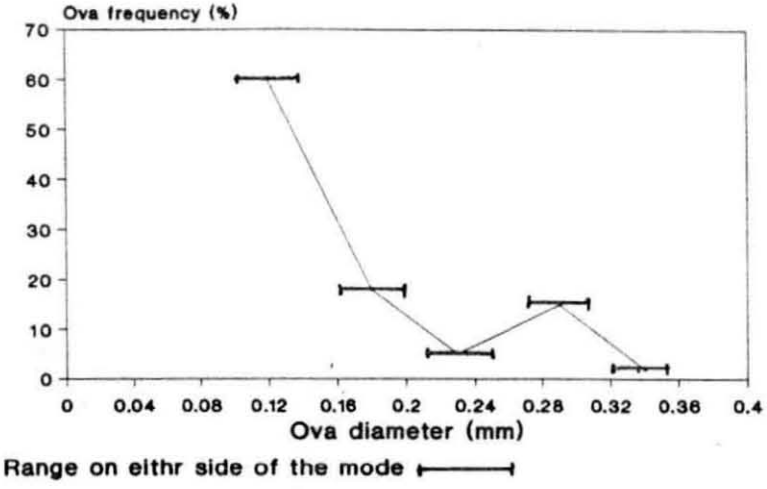


Fig.7c Ova diameter frequency polygon of stage III in *S.argus*

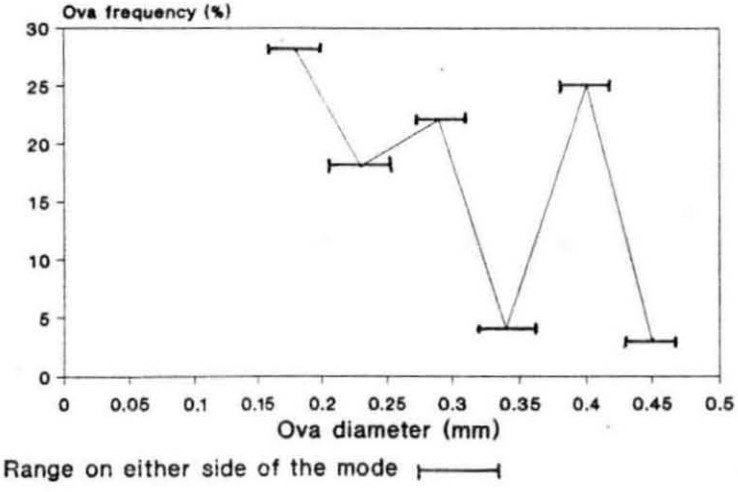


Fig.7d Ova diameter frequency polygon of stage IV in *S.argus*

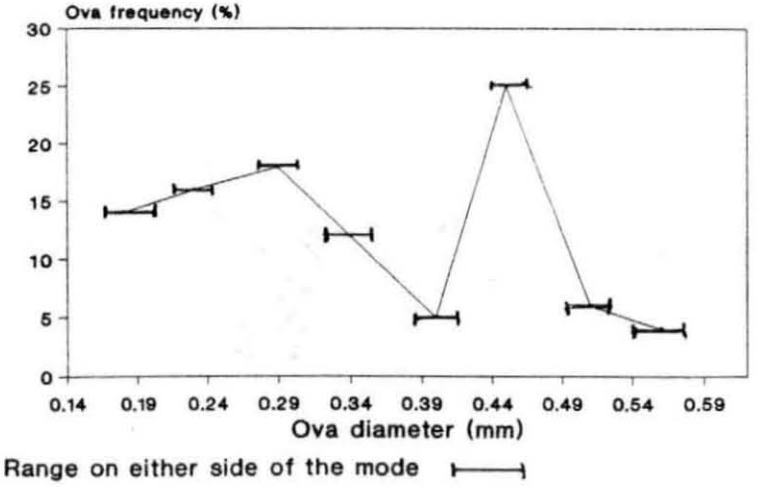


Fig.8a Ova diameter frequency polygon of stage V in *S.argus*

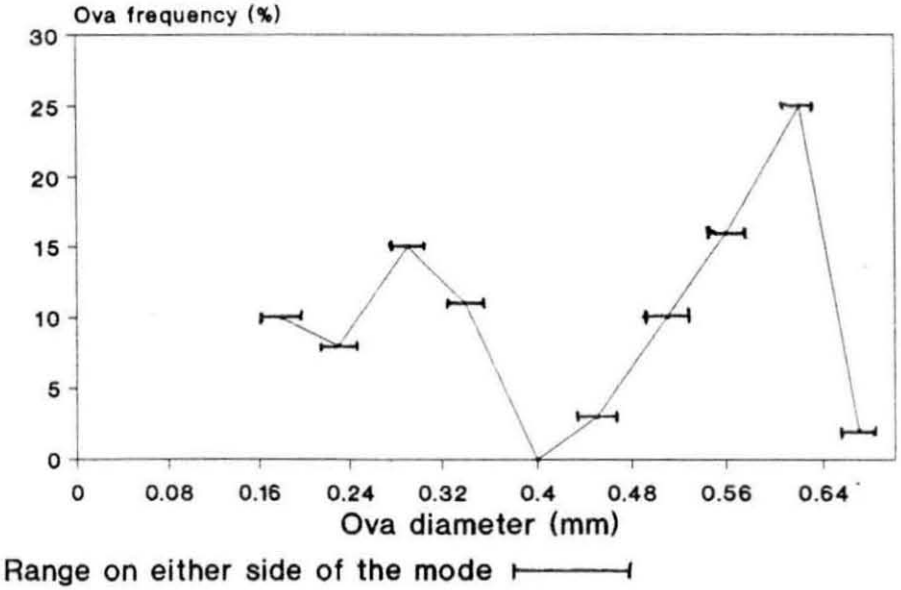


Fig.8b Ova diameter frequency polygon of stage VI in *S.argus*

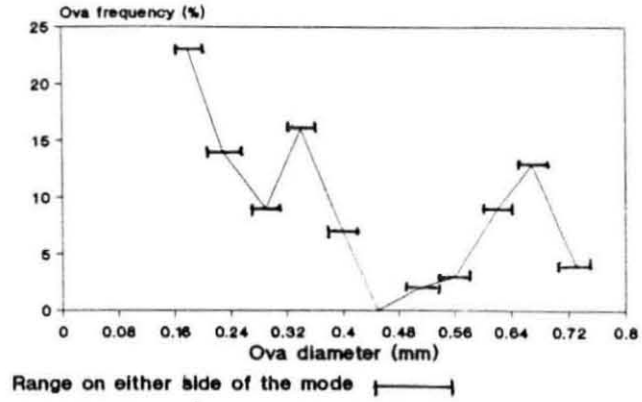
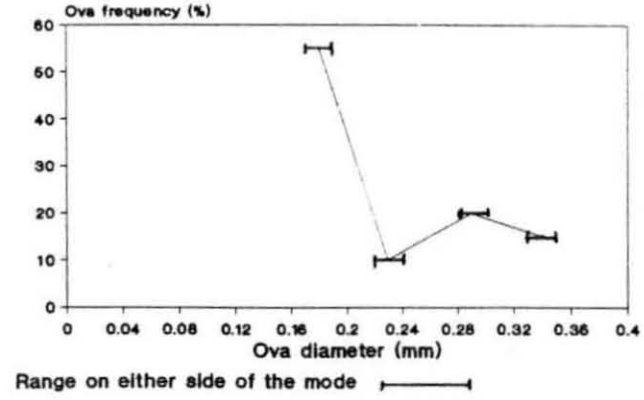
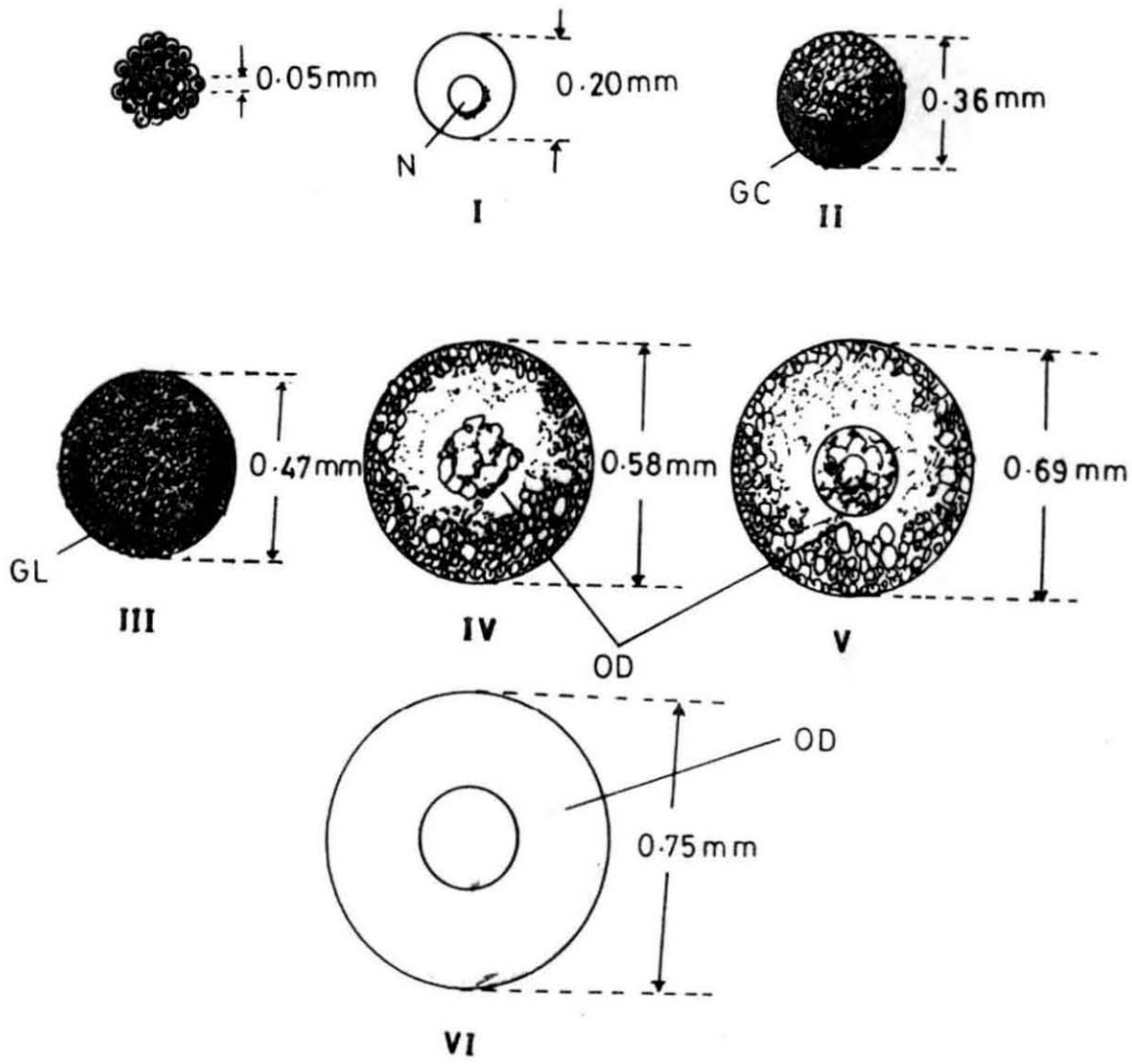


Fig.8c Ova diameter frequency polygon of stage VII in *S.argus*



season, was distinctly separate from the immature and maturing groups of eggs and they could be seen in the frequency curve of this stage (III). Upto this stage, the first group of eggs appeared to grow at a slightly faster rate than the second group. From Stage III to Stage IV, in the maturing group of eggs, there was practically no difference in size, whereas the mature group progressed in size. This trend was reflected more in Stage V, where in the maturing group of eggs stood stationary with a mode value of 0.28 mm. But the mature group shifted from a mode value of 0.45 mm to a mode value of 0.61 mm. The ovary in Stage VI had the largest group of eggs of 0.67 mm which indicated the spawning condition. The second batch of eggs which remained stationary from Stage III with a mode value of 0.28 mm showed little advancement in this stage. From Stage III onwards the first batch of eggs appeared to grow at a much faster rate than the earlier stages, with the result that the first group of eggs was distinctly separate from the second group. The ovary after extrusion of the first group of eggs showed a condition (Stage VII) that represented the spent ovary. The polygon drawn for frequency of ova diameter of this stage resembled Stage II, where, in addition to the two groups of ova typically found in a mature ovary, a few residual eggs were also seen. The first group showed a maximum size of 0.26 mm and the second group varied in size from 0.26 to 0.36 mm. The maximum size of residual eggs was 0.75 mm. The developmental stages of scat ova were given in Figure 9.

Figure 9 Developmental stages of scat ova.



N = Nucleus
GC = Granular cytoplasm
Gl = Globules
OD = Oil droplets

4.7.3. Spawning

Stage I in females and males occurred during August'95 to July'96. High percentage of Stage I was recorded during December to April in females and in male during November to February (Figure 10a). Stage II, in females and males was recorded during August to July the high percentage occurrence in November and December in females and in December, and February to April in males (Figure 10b). Stage III in females and males was observed throughout the period of observation with high percentage in January, February and May in females and in December, February, March and May in males (Figure 10c). During August to July, Stage IV was found in females and males with high percentage in May (Figure 10d). Stage V occurred in females during all the months except during November to March with high percentage occurrence during October and June. Similarly stage V occurred in males throughout the period of observation, except during November to March with high percentage occurrence during October and June (Figure 11a). Stage VI was recorded in females during September to November, June and July with high percentage during September, October, June and July. In males, it was observed during September to November, June and July with high percentage during June and July (Figure 11b). Stage VII was noticed in females during September to November and July with high percentage during November and it occurred in males during September to November and July with high percentage during July (Figure 11c).

Fig.10a Percentage occurrence of stage I in male and female *S.argus* during Aug '95 - Jul'96

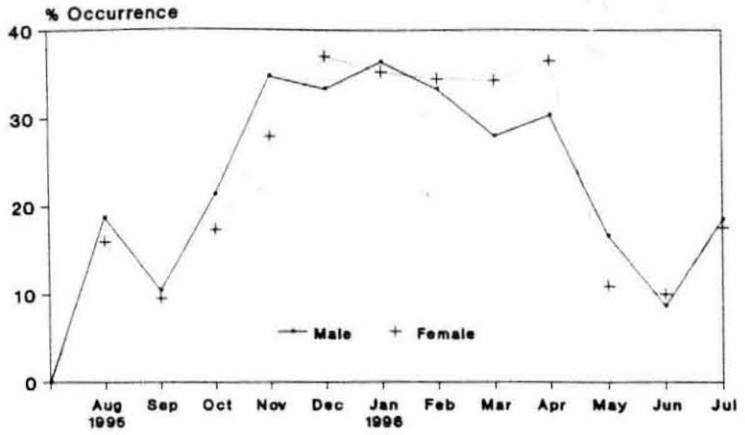


Fig.10b Percentage occurrence of stage II in male and female *S.argus* during Aug'95 - Jul'96

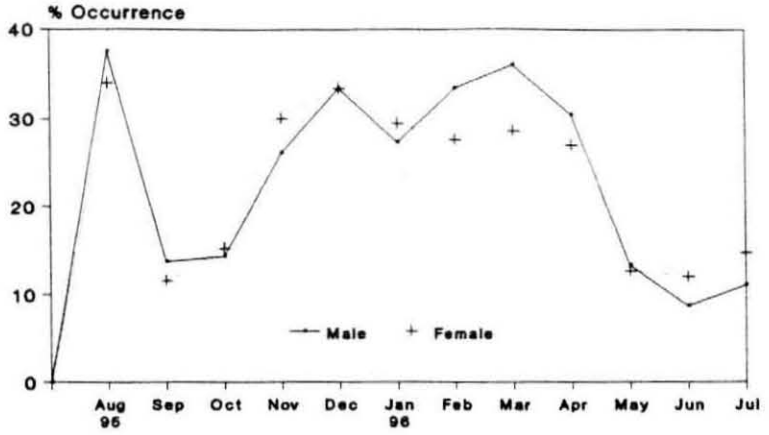


Fig.10c Percentage occurrence of stage III in male and female *S.argus* during Aug'95 - Jul'96

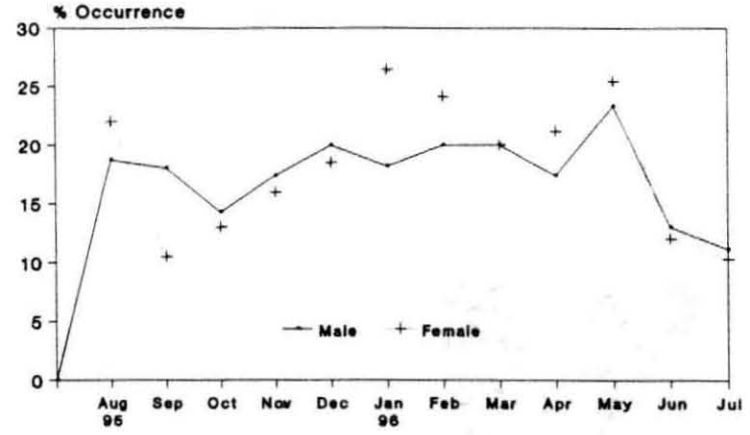


Fig.10d Percentage occurrence of stage IV in male and female *S.argus* during Aug'95 - Jul'96

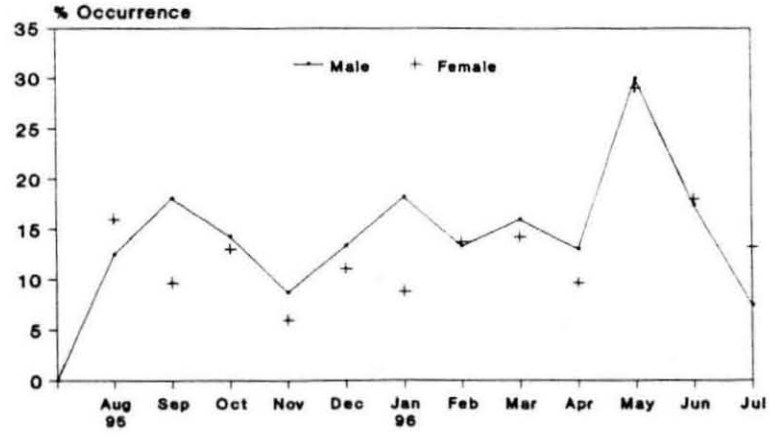


Fig.11a Percentage occurrence of stage V in male and female *S.argus* during Aug'95 - Jul'96

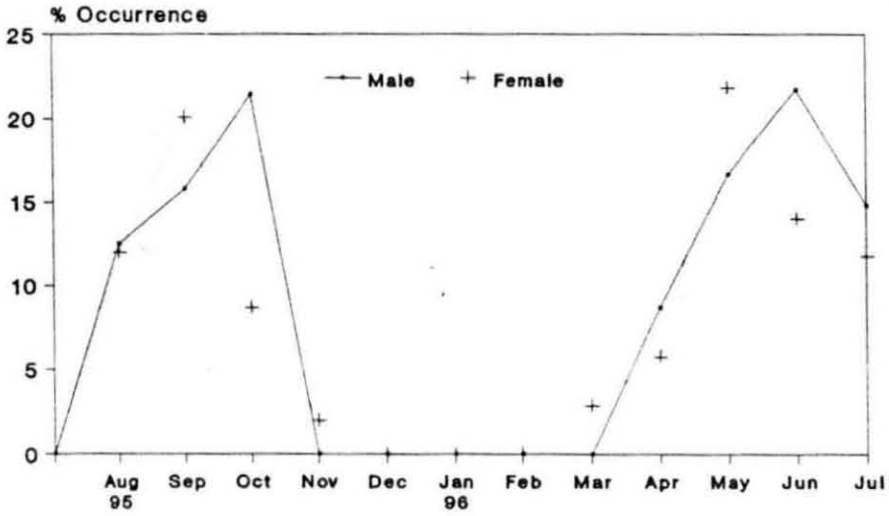


Fig.11b Percentage occurrence of stage VI in male and female *S.argus* during Aug'95 - Jul'96

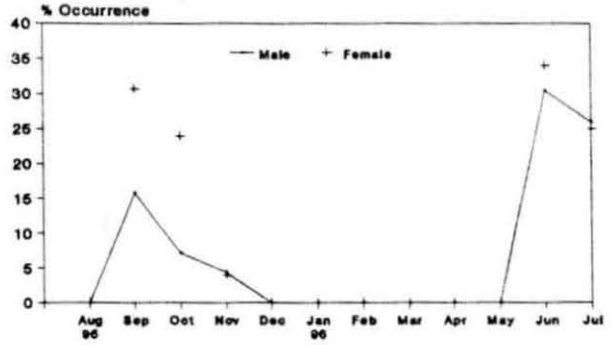
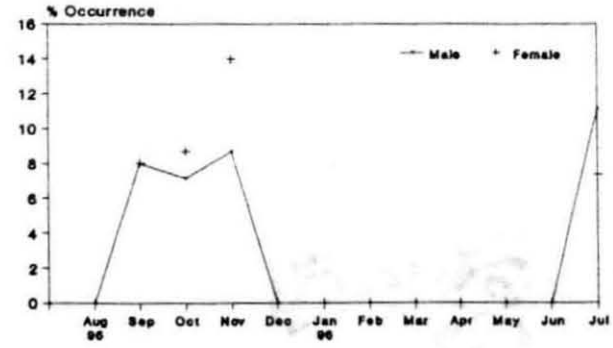


Fig.11c Percentage occurrence of stage VII in male and female *S.argus* during Aug'95 - Jul'96



During August'96 to July'97, Stage I occurred with high percentage occurrence during December to February in females and males (Figure 12a). Stage II was recorded in females and males throughout the year with high percentage occurrence during December to April (Figure 12b). During the period of observation, Stage III appeared in females and males with high percentage during March to May (Figure 12c). Stage IV was recorded in females almost throughout the year except during November, February, August and May with high percentage during August, June and July. In males it was recorded except during November, January to March and May with high percentage observed during June (Figure 12d). Stage V was observed in females during September, October, and May to July with high percentage occurrence during October, June and July. In males it was seen except during August, November, December, February and April with high percentage during October, June and July (Figure 13a). Stage VI was noted in females during September to November and April to July with high percentage occurrence during September, October, June and July. In males it was seen during September to November, April, June and July with high percentage during September, October, June and July (Figure 13b). Stage VII occurred in females during August to November and April to July with high percentage during October and November. In males it occurred except during December to March with high percentage in August and November (Figure 13c). Thus the present study period from August'95 to July'97

Fig.12a Percentage occurrence of stage I in male and female *S.argus* during Aug'96 - Jul'97

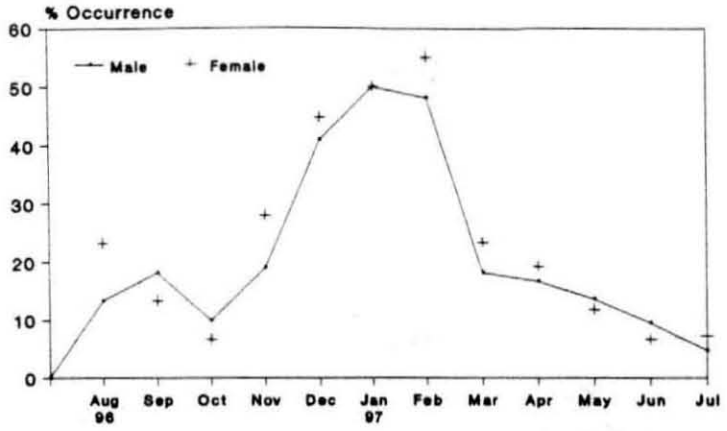


Fig.12b Percentage occurrence of stage II in male and female *S.argus* during Aug'96 - Jul'97

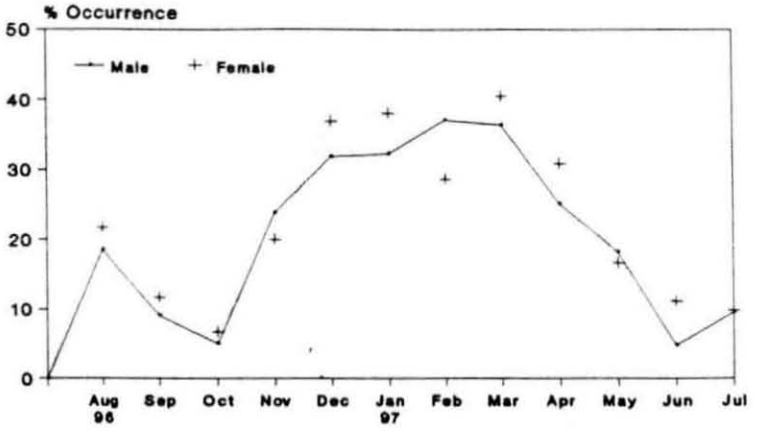


Fig.12c Percentage occurrence of stage III in male and female *S.argus* during Aug'96 - Jul'97

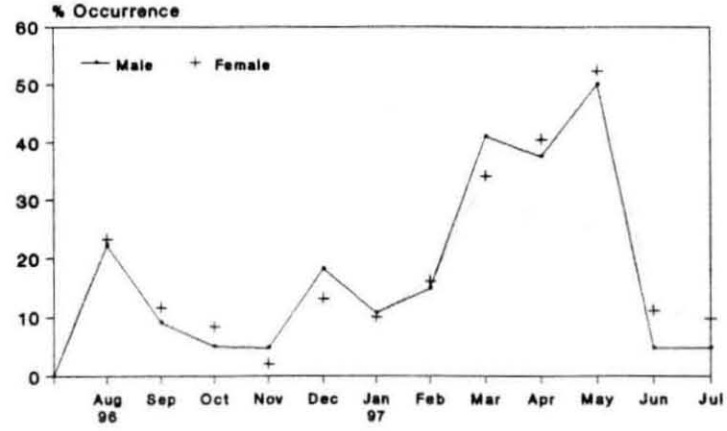


Fig.12d Percentage occurrence of stage IV in male and female *S.argus* during Aug'96 - Jul'97

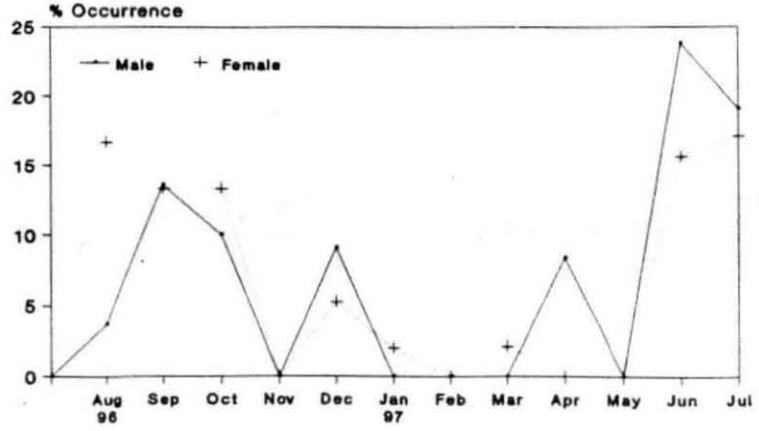


Fig.13a Percentage occurrence of stage V in male and female *S.argus* during Aug'96 - Jul'97

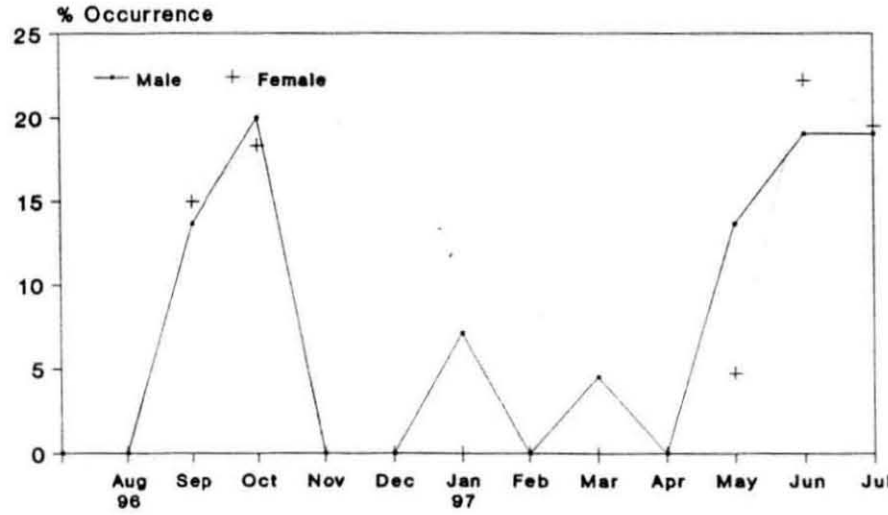


Fig.13b Percentage occurrence of stage VI in male and female *S.argus* during Aug'96 - Jul'97

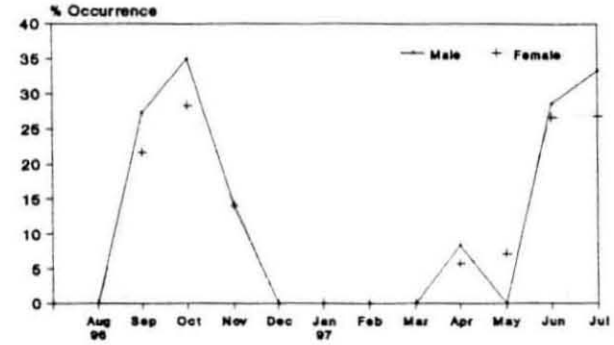
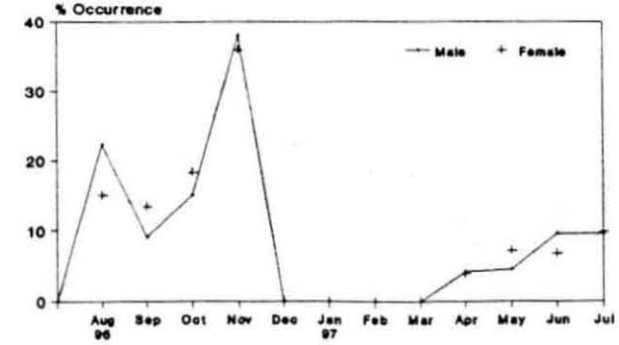


Fig.13c Percentage occurrence of stage VII in male and female *S.argus* during Aug'96 - Jul'97



indicated that there was no regular pattern in the occurrence of maturity stages.

4.7.4. Gonado-somatic index

Monthly mean GSI values of both male and female fishes were calculated and values were given in Figure 14.

Only females measuring above 140 mm and males measuring above 120 mm were taken into account for determining the monthly mean GSI values, since these were the minimum sizes around which both female and male were in mature condition. Observations made during the period from August'95 to July'97, indicated high GSI values during August'95 to October'95, May'96 to July'96, September, October'96 and May to July'97 in females and during August'95 to May'96 in males. Somewhat slightly lesser values were observed during June'96 to July'97 in males.

4.7.5. Size at first maturity

Percentage occurrence of males and females in different stages of maturity in various size groups were given in Tables 11 and 12.

It was clear that 95 % of males reached first maturity stage when they were 120 to 129 mm in length. In the case of females 82 % reached first maturity stage when they were 140 to 149 mm in length.

Figure 14a Trend of Gonado - Somatic Index in Males

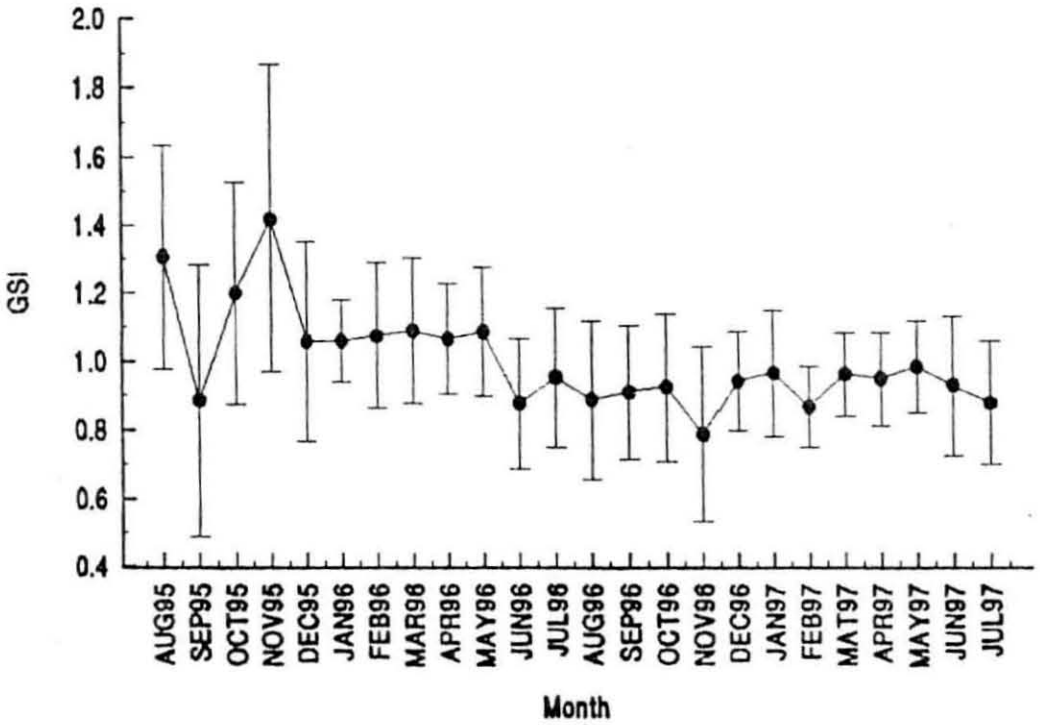


Figure 14b Trend of Gonado - Somatic Index in Females

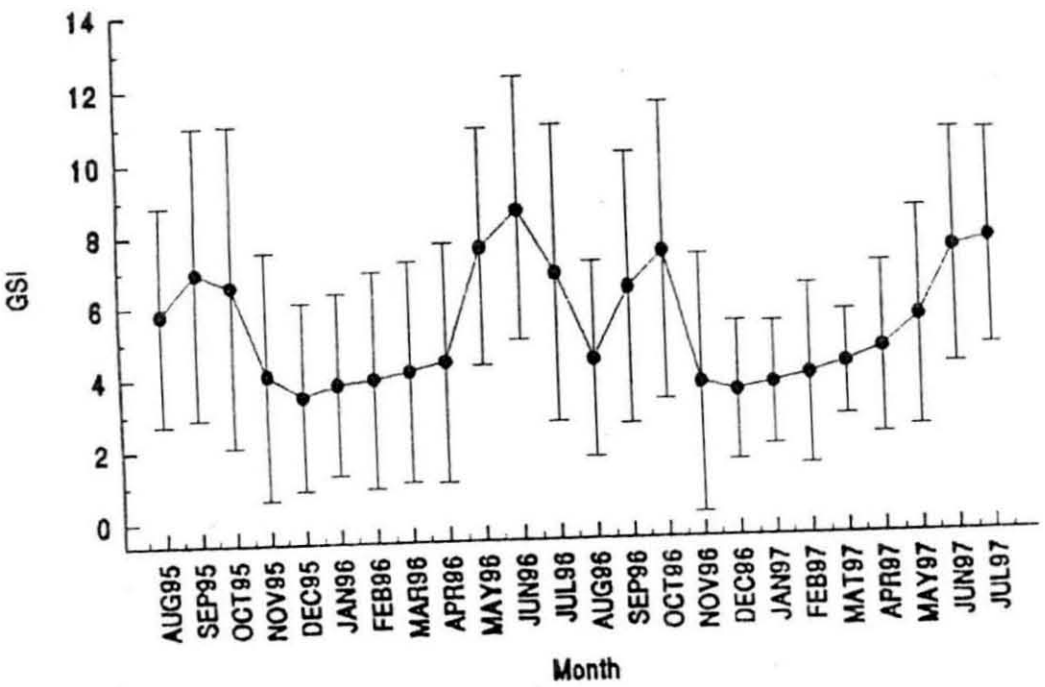


Table 11a Percentage occurrence of males of *Scatophagus argus* in different stages of maturity in various size groups during August 1995 to July 1996.

Size groups (T.L.mm)	No. of fish	Stages of maturity I	II	III	IV	V	VI	VII
120-129	41	90	10	-	-	-	-	-
130-139	18	83	11	6	-	-	-	-
140-149	12	33	67	-	-	-	-	-
150-159	14	7	79	14	-	-	-	-
160-169	10	-	80	20	-	-	-	-
170-179	20	-	55	40	5	-	-	-
180-189	20	-	40	55	-	5	-	-
190-199	21	-	5	52	29	14	-	-
200-209	9	-	-	22	22	44	-	11
210-219	10	-	-	-	80	10	10	-
220-229	9	-	-	-	33	11	33	22
230-239	14	-	-	7	43	14	14	21
240-249	16	-	-	-	31	44	19	6
250-259	6	-	-	-	17	33	17	33
260-269	11	-	-	-	-	9	45	45
270-279	9	-	-	-	33	33	22	11

Table 11b Percentage occurrence of males of *Scatophagus argus* in different stages of maturity in various size groups during August 1996 to July 1997.

Size groups (T.L.mm)	No. of fish	Stages of maturity I	II	III	IV	V	VI	VII
120-129	42	100	-	-	-	-	-	-
130-139	26	92	8	-	-	-	-	-
140-149	9	11	89	-	-	-	-	-
150-159	7	-	100	-	-	-	-	-
160-169	6	-	83	17	-	-	-	-
170-179	28	-	71	29	-	-	-	-
180-189	38	-	39	61	-	-	-	-
190-199	16	-	6	94	-	-	-	-
200-209	3	-	-	67	33	-	-	-
210-219	4	-	-	100	-	-	-	-
220-229	4	-	-	-	100	-	-	-
230-239	6	-	-	-	100	-	-	-
240-249	15	-	-	-	47	53	-	-
250-259	18	-	-	-	6	44	28	22
260-269	19	-	-	-	-	32	32	37
270-279	19	-	-	-	-	-	58	42
280-289	8	-	-	-	-	-	75	25
290-299	5	-	-	-	-	-	40	60

Table 12a Percentage occurrence of females of *Scatophagus argus* in different stages of maturity in various size groups during August 1995 to July 1996.

Size groups (T.L.mm)	No. of fish	Stages of maturity I	II	III	IV	V	VI	VII
140-149	36	97	3	-	-	-	-	-
150-159	67	91	9	-	-	-	-	-
160-169	49	49	43	8	-	-	-	-
170-179	54	2	87	11	-	-	-	-
180-189	77	-	55	43	3	-	-	-
190-199	54	-	2	87	7	2	2	-
200-209	17	-	-	41	29	24	6	-
210-219	31	-	-	10	42	29	7	13
220-229	24	-	-	4	58	13	17	8
230-239	36	-	-	-	64	14	14	8
240-249	25	-	-	-	28	44	12	16
250-259	34	-	-	-	18	21	50	12
260-269	37	-	-	-	5	30	57	8
270-279	7	-	-	-	14	14	14	57
280-289	2	-	-	-	-	50	50	-

Table 12b Percentage occurrence of females of *Scatophagus argus* in different stages of maturity in various size groups during August 1996 to July 1997.

Size groups (T.L.mm)	No. of fish	Stages of maturity I	II	III	IV	V	VI	VII
140-149	9	67	33	-	-	-	-	-
150-159	78	100	-	-	-	-	-	-
160-169	71	80	20	-	-	-	-	-
170-179	68	3	97	-	-	-	-	-
180-189	75	-	64	36	-	-	-	-
190-199	51	-	4	96	-	-	-	-
200-209	19	-	-	100	-	-	-	-
210-219	12	-	-	100	-	-	-	-
220-229	8	-	-	50	50	-	-	-
230-239	13	-	-	-	92	8	-	-
240-249	30	-	-	-	67	27	7	-
250-259	34	-	-	-	18	53	18	12
260-269	37	-	-	-	-	19	32	49
270-279	42	-	-	-	-	17	43	17
280-289	35	-	-	-	-	-	60	40
290-299	10	-	-	-	-	-	70	30

4.7.6. Fecundity

For fecundity estimation, ovaries of 20 fishes in Stage IV or V were taken. Fecundity varied from 115,038 to 153,661 eggs per fish in fish size of total length ranging from 235 (265 g) to 300 mm (350 g).

4.7.6.1. Fecundity and length of fish

In order to find out the relationship between fecundity and total length of fish, fecundity estimates obtained for 20 fish were plotted in a scatter diagram (Figure 15) and a regression line was fitted to the data using the method of least squares. The equation was found to be:

$$Y = 53030.85 + 288.23^{L} \quad (r^2=63.1)$$

where Y = Fecundity

L = Total length of fish in mm.

r^2 = Correlation coefficient.

4.7.6.2. Fecundity and weight of fish

A scatter diagram relating fecundity and weight of fish was plotted in Figure 16a. A regression line was fitted to the data using the method of least squares.

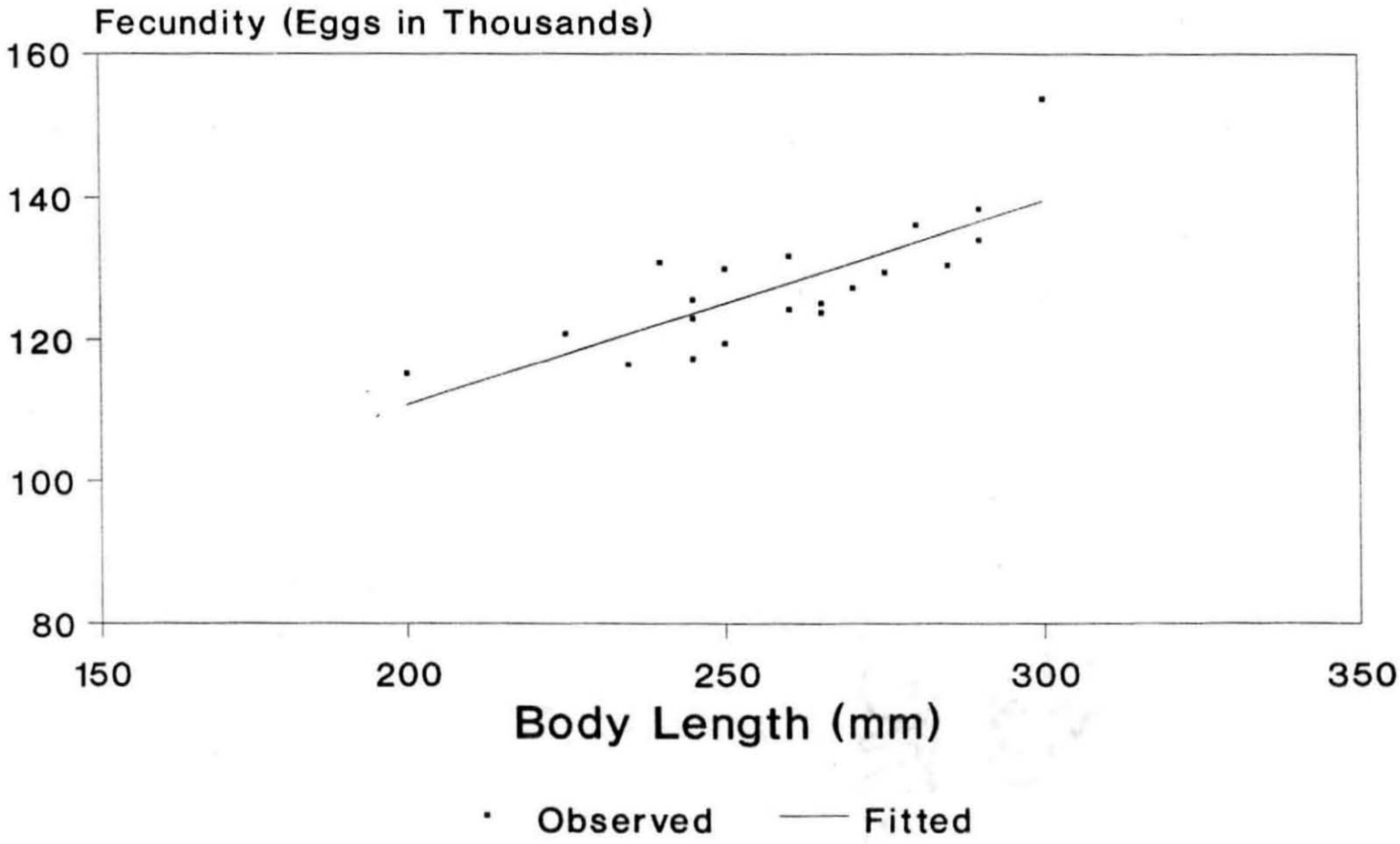
The equation was found to be :

$$Y = -209.255 + 439.620^{W} \quad (r^2=99.9)$$

where Y = Fecundity

W = Weight of fish in g.

Fig.15 Relationship between Fecundity and Total body length of fish



r^2= Correlation coefficient.

4.7.6.3. Fecundity and weight of ovary

A scatter diagram to relate fecundity and weight of ovary was plotted in Figure 16b. A regression line was fitted to the data using the method of least squares:

$Y = -1.7637 + 3080^{W}$ (r^2=99.9)

Y = Fecundity

W = Weight of the ovary in g.

r^2= Correlation coefficient.

4.7.7. Sex ratio

The sex ratio of fish in different months of the observation period were estimated (Table 13). Sexes were distinguished by dissecting and observing the gonads. Fish of size <120 mm could not be identified as male and female and hence were called indeterminates.

The females were always outnumbering the males. The percentage occurrence of females and males was given in Figure 17. The percentage of males was considerably low during August'95, October'95 and June'95 compared to the other months of the observation period. They were also in low percentage compared to the percentage of females. High percentage of females occurred during August'96, October'96 and October'97 compared to the

Fig.16a Relationship between Fecundity and Body weight of fish

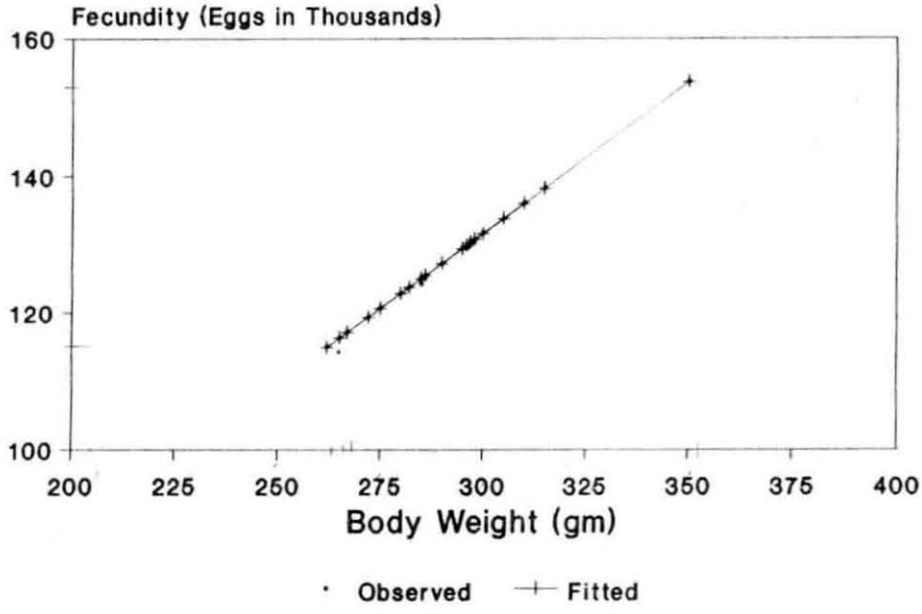


Fig.16b Relationship between Fecundity and Ovary weight of fish

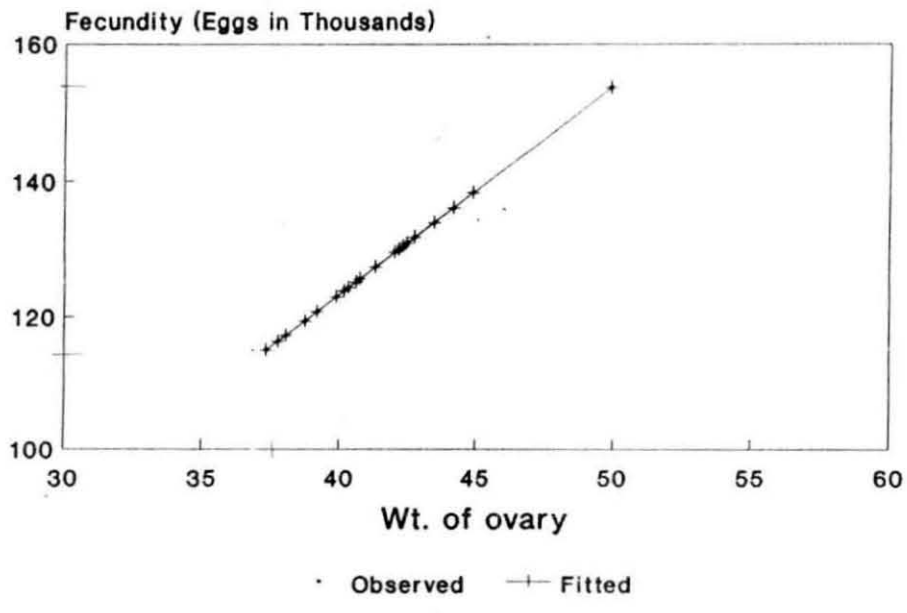


Fig.17 Percentage occurrence of males & females of *S.argus* during august 1995 to July 1997

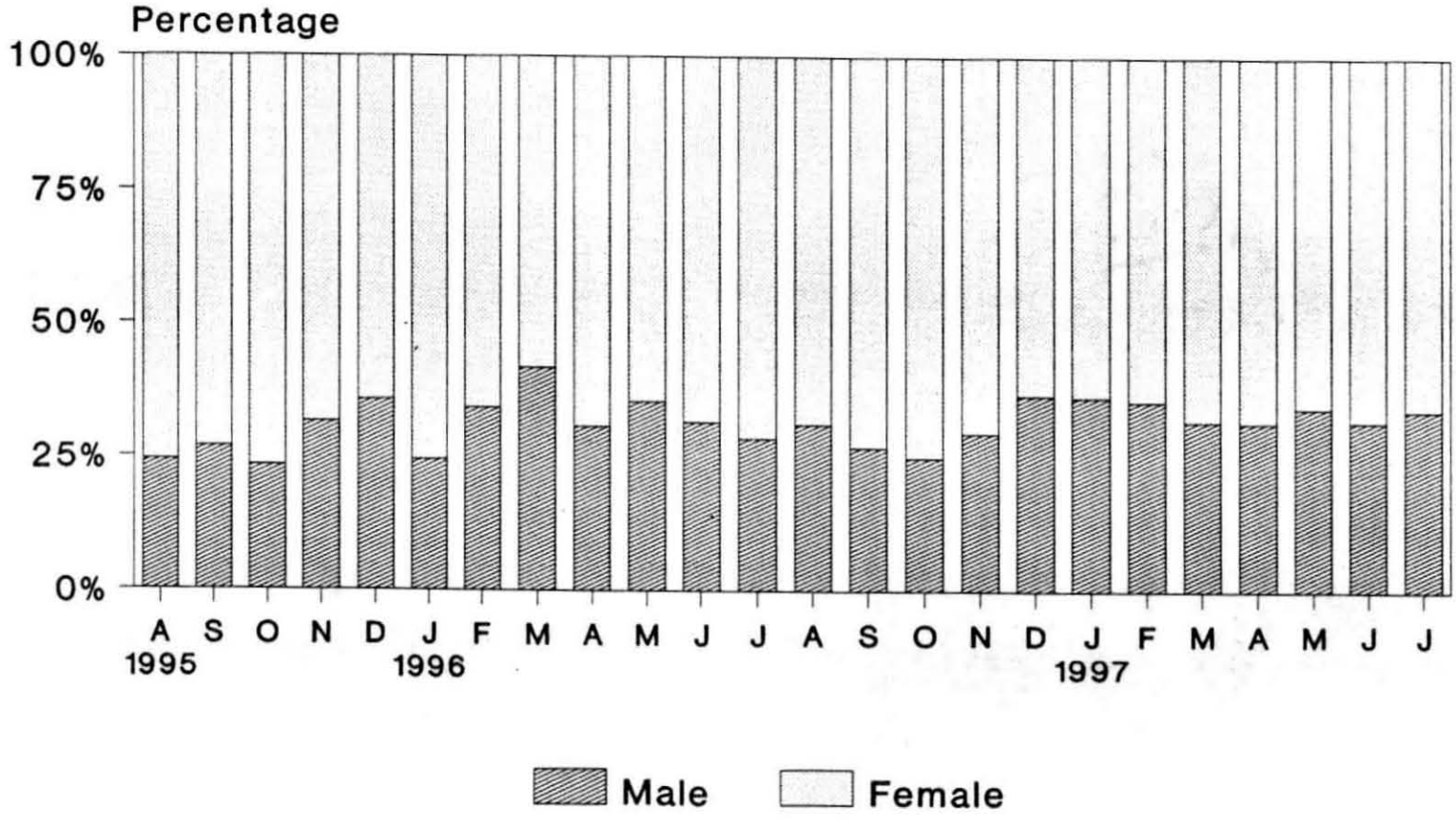


Table 13 Sex ratio of scat during August'95 to July'97

Months	Male	Female	Ratio
August'95	16	50	1:3
September	19	52	1:3
October	14	46	1:3
November	23	50	1:2
December	15	27	1:2
January'96	11	34	1:3
February	15	29	1:2
March	25	35	1:1
April	23	52	1:2
May	30	55	1:2
June	23	50	1:2
July	27	68	1:3
August	27	60	1:2
September	22	60	1:3
October	20	60	1:3
November	21	50	1:2
December	22	38	1:2
January'97	28	49	1:2
February	27	49	1:2
March	22	47	1:2
April	24	52	1:2
May	22	42	1:2
June	21	45	1:2
July	21	41	1:2

other months of the study period. They were also in high percentage compared to the percentage of males.

4.8. POPULATION GROWTH PARAMETERS

The length frequency data collected for 2 years from August'95 to July'97 were used to estimate the mean length of scat the Bhattacharya analysis routine of the FISAT statistical package (Gayanilo *et al.*, 1995). These values were then used for model progression and estimation of $L\infty$ and K by the Gulland-Holt plot method (Figure 18). The relative ages were estimated by the method given by Sparre and Venema (1992). The length at age data thus obtained was used to fit the Von Bertalanffy's growth equation in length (Figure 19) using the above mentioned methods. Growth parameters using the two methods were estimated and the results were presented in Table 14.

The estimated total instantaneous rate of mortality (Z) using the two sets of parameters given in the above table was found to be more or less equal. Similar result was noticed in the estimates of natural mortality (M) also. The rate of exploitation (E) ranged from 21 to 26%.

4.9. ENVIRONMENT AND ECOLOGY OF SCAT

Palk Bay is on the northern side and Gulf of Mannar is on the southern side of Mandapam. The waters of the two sides mixed with each other through the Pamban Pass (Lat 9° 17' N; Long 79°

Figure 18

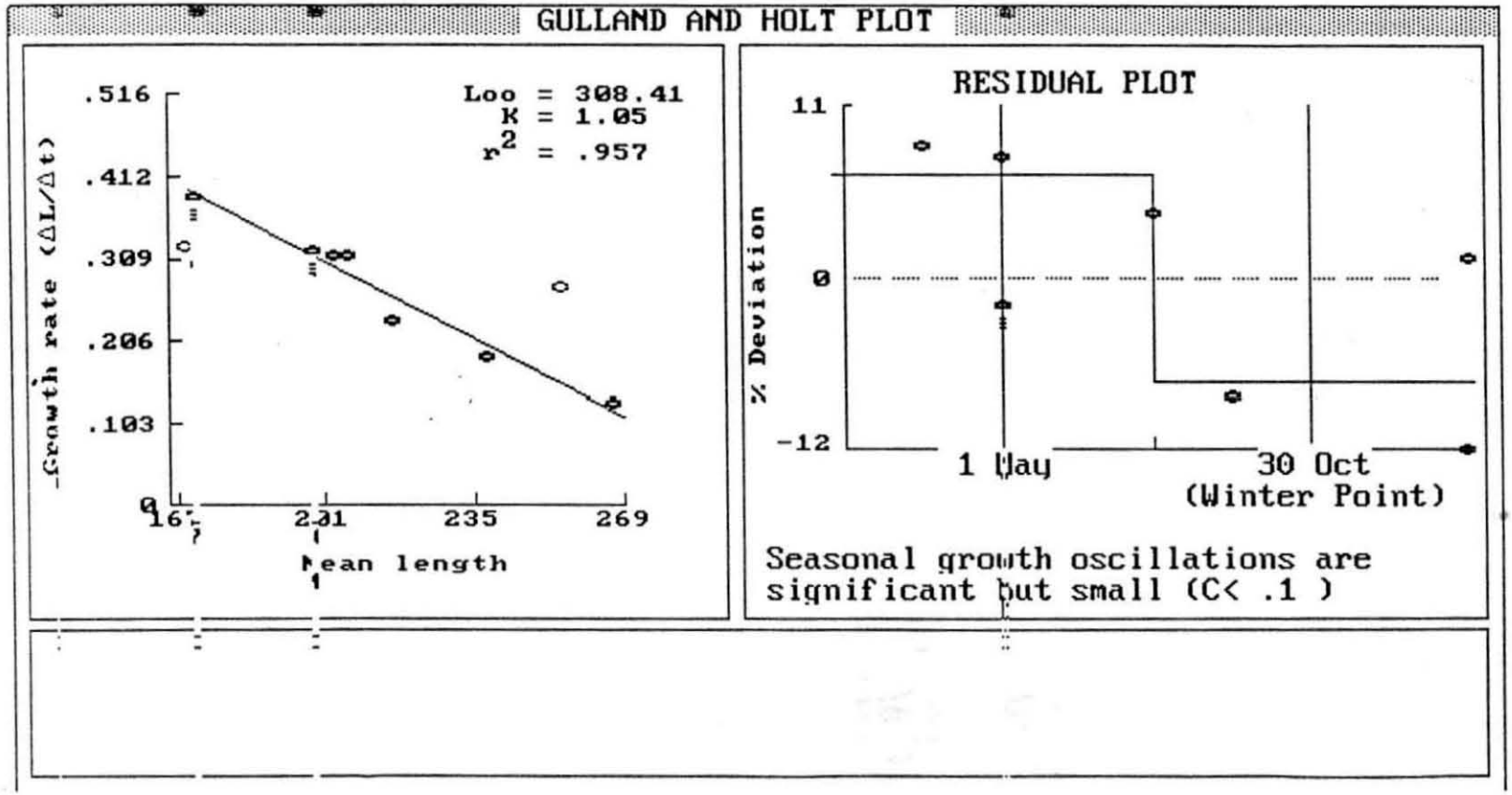

GULLAND AND HOLT PLOT
Loo = 308.41
K = 1.05
r2 = .957
Growth rate (ΔL/Δt)
.516
.412
.309
.206
.103
0
231
235
269
Mean length
RESIDUAL PLOT
11
0
-12
% Deviation
1 May
30 Oct
(Winter Point)
Seasonal growth oscillations are
significant but small (C< .1)

Figure 19

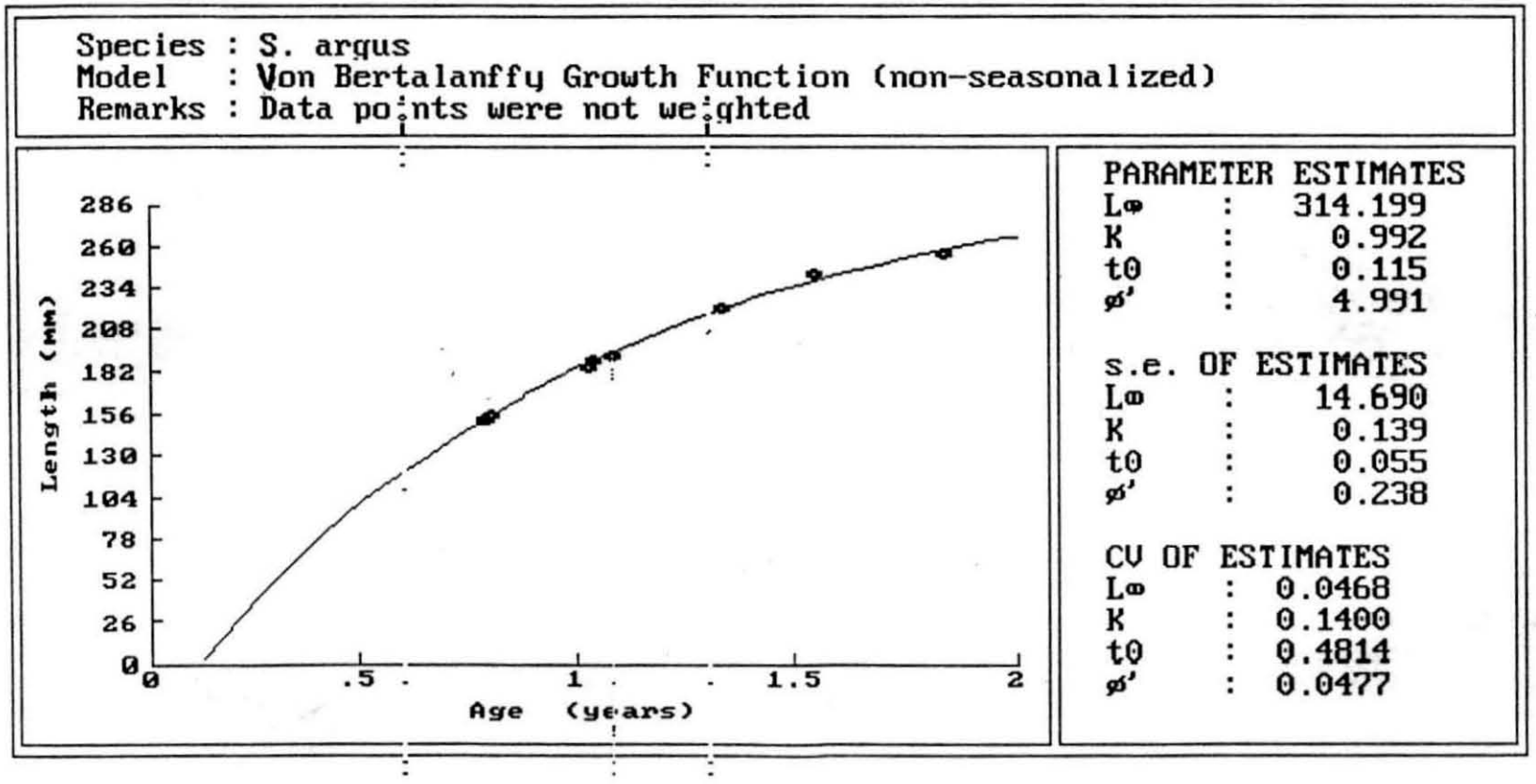

Species : S. argus
Model : Von Bertalanffy Growth Function (non-seasonalized)
Remarks : Data points were not weighted
Length (mm)
286
260
234
208
182
156
130
104
78
52
26
0
0
.5
1
1.5
2
Age (years)
PARAMETER ESTIMATES
L∞ : 314.199
K : 0.992
t0 : 0.115
ø' : 4.991
s.e. OF ESTIMATES
L∞ : 14.690
K : 0.139
t0 : 0.055
ø' : 0.238
CV OF ESTIMATES
L∞ : 0.0468
K : 0.1400
t0 : 0.4814
ø' : 0.0477

Table 14 Estimates of growth parameters, mortality rates and rate of exploitation

	Gulland-Holt	Non-linear Algorithm of FISAT
Growth:		
L (mm)	308	314
K (/yr)	1.05	0.99
t_o	-	0.115
Mortality: (Annual)		
Z	2.32	2.35
M	1.83	1.75
F	0.49	0.6
E (= F/Z)	0.21	0.26

L = length in mm. Z = Instantaneous mortality
K = Year M = Natural mortality
t = time F = Fishing mortality
/yr = per annum E = Exploitation

12' E) and at "Adam's Bridge" between Dhanushkodi on the south-eastern side of India and Thalaimannar on the northwestern side of SriLanka.

Although the region got exposed to both South West and North East monsoons, rainfall during southwest monsoon season was very less. This region got good rainfall during the North East Monsoon months of October through December. During the South West monsoon, the Gulf of Mannar became turbid due to strong winds, which continued upto September. The water in this region got drifted towards the Palk Bay side during May through September. The drift of water created strong currents through the Pamban Pass. During the southwest monsoon season, the water of Palk Bay side was calm. After the onset of the North East monsoon, during October through March, the drift of water was towards the Gulf of Mannar, where it became relatively calm and the water of the Palk Bay side became turbulent. Fishing activities were intense alternately on both sides due to the influence of these factors, (i.e., rainfall and turbid condition of water of the two sides.) during the south west monsoon period of May through September in the Palk Bay and during the North East monsoon period of October through March in the Gulf of Mannar.

From the shore to a distance of 16 km, the depth was 11-13 meters both in the Palk Bay and Gulf of Mannar. The Palk Bay had a much larger shallow area than the Gulf of Mannar. The Gulf of Mannar was more open compared to the Palk Bay, which was a more

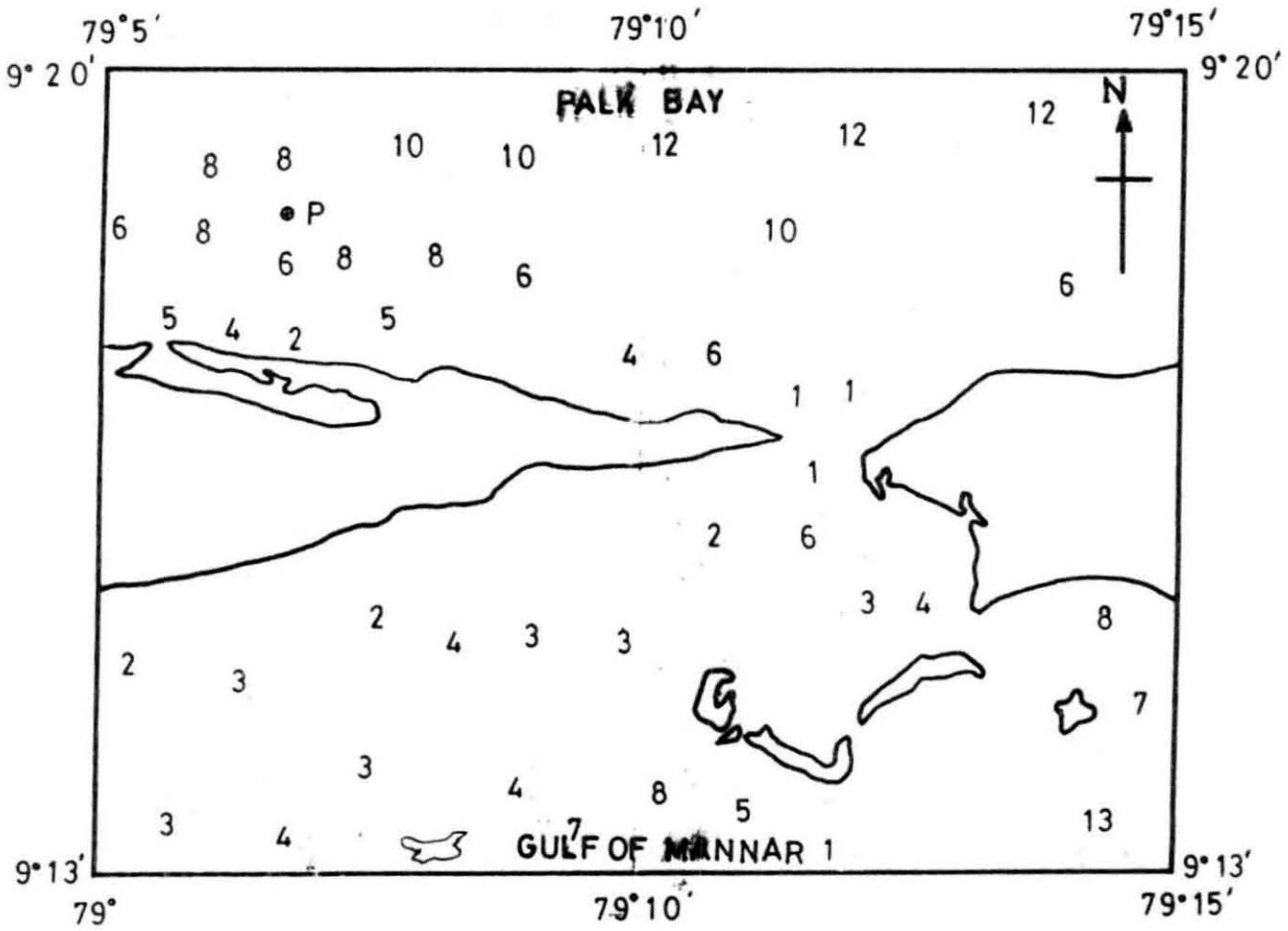
or less land-locked sea (Admiralty chart 68 a). At a distance of 7 km from the mainland of the Gulf of Mannar, Manoliputti and Manoli islands were found situated more or less parallel to the coast. Water between these islands and mainland was more shallow than those outside. Since the Gulf of Mannar was wide open, its water was influenced by the adjacent Indian Ocean also.

Water currents ran towards South (Gulf of Mannar) during October through April, whereas they went towards North (Palk Bay) during May through September. The current flows could be observed from Pamban Pass (near Pamban rail and road bridges) during southwest and northeast monsoon seasons.

4.9.1. Soil condition

Coral reefs were found near Manoli island which was situated in the Gulf of Mannar side. Coral origin was mainly due to the formation of fringing and patch reefs. The depth of seawater between Mandapam shore and coral reef region in the Gulf of Mannar where surveys were conducted, was ½ to 8 m (Figure 20), ?whereas in the Palk Bay, the depth of seawater between Mandapam shore and coral reef region was 1 to 12 m (Figure 20). The bottom was sandy and muddy with intervening rocky patches in the Gulf of Mannar side. On the otherhand, the bottom was more or less muddy in the Palk Bay side. The soil texture differed from shore to deeper region in the Gulf of Mannar side. Near the shore it was coarse sand with broken shells of gastropods, bivalves and fora-

Figure 20. Depth (m) of zones between shore and coral reef regions of Gulf of Mannar and Palk Bay.



minifera and broken pieces of dead corals. Next to this was a region with sand grains of brown colour, a region of fine sand and a region of very fine sand. However, the Palk Bay side was mostly muddy with fine sand.

4.9.2. Gulf of Mannar

4.9.2.1. Flora

Sea grasses such as *Cymodocea rotundata*, *C. serrulata* and *Halophila ovalis* were found. Red algae such as *Hypnea musciformis* and *Spyridia filamentosa*, brown alga *Sargassum tenerrimum*, green alga *Caulerpa racemosa* and Filamentous algae *Enteromorpha compressa* and *Chaetomorpha* spp. were also seen.

4.9.2.2. Fauna

Presence of *Arca* spp., *Meretrix meretrix*, *Donax* spp., Holothurians such as *Holothuria atra*, *H. scabra*, sea urchins, sea fans, sponges like *Siphonochalina* spp., sea anemones like *Stoichactis giganteum*, gastropod *Cerrithidea fluviatilis*, decapods, crabs such as *Portunus pelagicus*, *Thalamita crenata*, *Charybdis cruciata*, *C.annulata* and *Scylla serrata*, prawns such as *Penaeus indicus*, *P.semisulcatus* and *Metapeanus* spp., Isopods such as *Cymodocea* spp., stomatopods such as *Squilla* spp. and amphipods were observed. Sea horses and pipe fishes were noticed. Economically important perches like *Lethrinus* spp., *Epinephelus* spp., *Lutjanus* spp., *Callyodon* spp., *Psammoperca waigiensis*, *Plector-*

hynchus spp., *Theropon* spp. *Teuthis* spp., *Upeneus* spp., *Chiloscyllium indicum*, *Chaetodon* spp., *Scatophagus argus*, *Caranx* spp., *Gerres* spp., and mullets were also recorded. Turtles, seacows and dolphins were also noticed although rarely.

4.9.3. Palk Bay

4.9.3.1. Flora

Filamentous algae like *Chaetomorpha* spp., *Enteromorpha compressa*, sea grasses such as *Cymodocea rotundata* and *Halophila ovalis*, red algae like *Hypnea musciformus*, *Spyridia filamentosa* and *S.ingnis*, brown algae such as *Sargassum tenerrimum*, and green algae like *Caulerpa racemosa* Var. *corynephora*, and *Neomeris annulata* were recorded.

4.9.3.2. Fauna

Oliva spp., *Turritella* spp., *Littorina* spp., *Donax* spp., *Meretrix meretrix*, *Cerrithidea fluviatilis*, *Murex* spp, sea anemones like *Stoichactis giganteum*, sea urchins, seafans, sea horses, pipe fishes, crabs such as *Portunus pelagicus*, *Charybdis annulata*, *Philyra globosa*, *Schizophyrys aspera* and *Menippe rumphii*, prawns *Penaeus indicus*, *P.semisulcatus* and *Metapenaeus* spp., and lobsters *Panulirus* spp, were observed. Economically important perches *Lethrinus* spp., *Epinephelus* spp., *Lutjanus* spp., *Callyodon* spp., *Psammoperca waigiensis*, *Plectorhynchus* spp., *Theropon* spp., *Teuthis* spp., *Upeneus* spp., *Chiloscyllium*

indicum, *Chaetodon* spp., *Caranx* spp., *Gerres* spp. and mullets were also recorded. Turtles, seacows and dolphins were also noticed although rarely.

4.9.4. Hydrological and meteorological features of the area

The Palk Bay and Gulf of Mannar were having some similarity in their hydrological features. At their eastern extremity, the communication of the waters of both regions took place through the **" Pamban Pass"** and **"Adam's Bridge"** between Dhanushkodi and the West coast of SriLanka. This was of significance in having the similarity in hydrological features observed during the monsoon season of the year.

4.9.5. Variations in environmental parameters

Monthly variations in atmospheric temperature, water temperature, salinity, dissolved oxygen and nutrients in the inshore waters of the Gulf Mannar and Palk Bay near Mandapam (South India) were recorded during August 1995 to July 1997.

Atmospheric temperature, surface water and bottom water temperature ranged from 26.0 to 32.2°C; 25.6 to 32.0°C and 25.7 to 32.0°C respectively during August'95 to July'97 in the Gulf of Mannar side. Maximum atmospheric temperature of 32.2°C was noticed during May'97. Maximum surface water temperature of 32.0°C was seen during the same month and maximum bottom water temperature of 32.0°C was found during the same month. Minimum

atmospheric temperature of 26.0°C was seen during December'96. Minimum surface water temperature of 25.6°C was noticed during the same month and minimum bottom water temperature of 25.7°C was recorded during August'96. (Figure 21a).

Atmospheric temperature, surface water and bottom water temperature varied from 25.7 to 33.0°C, 26.2 to 32.0°C and 26.4 to 32.0°C respectively during August'95 to July'97 in the Palk Bay side. Maximum atmospheric temperature of 33.0°C was seen during April'96. Maximum surface water temperature of 32.0°C and maximum bottom water temperature of 32.0°C were noticed during the same period. Minimum atmospheric temperature of 25.7°C was recorded during September'96. Minimum surface water temperature of 26.2°C was found during December'96. Minimum bottom water temperature of 26.4°C was noticed during the same period (Figure 21b).

pH of the surface water ranged from 8.1 to 8.3 and that of the bottom water ranged from 8.0 to 8.6 during August'95 to July'97 in the Gulf of Mannar side. The maximum value of 8.33 in the surface water was seen during September'96 and 8.62 in the bottom water was noticed during April'96. The minimum value of 8.1 in the surface water was recorded during November'96 and 8.03 in the bottom water was recorded during July'96 (Figure 21c).

pH of the surface water varied from 8.0 to 8.8 and that of the bottom water ranged from 8.1 to 8.6 during August'95 to

July'97 in the Palk Bay side. The maximum value of 8.8 in the surface water was found during June'96 and 8.6 in the bottom water was seen during February'96. The minimum value of 8.0 in the surface water was noticed during December'96 and 8.1 in the bottom water was recorded during the same month (Figure 21d).

Salinity of surface water ranged from 29.6 to 36.0 ppt and in the bottom water it ranged from 28.7 to 36.0 ppt during August'95 to July'97 in the Gulf of Mannar side. Maximum salinity value of 36.0 ppt in the surface water was noticed during June'97 and 36.0 ppt was noticed in bottom water during the same period. Minimum salinity value of 29.6 ppt in surface water was found during November'95 and in bottom water 28.8 ppt was seen during May'96 (Figure 22a).

Salinity of surface water varied from 26.3 to 35.4 ppt and in the bottom water it ranged from 26.9 to 35.6 ppt during August'95 to July'97 in the palk Bay side. Maximum salinity value of 35.4 ppt was found in the surface water during May'97 and 35.6 ppt in bottom water was seen during September'96. Minimum salinity value of 26.3 ppt was seen in the surface water during January'97 and 26.9 ppt in the bottom water was found during the same period (Figure 22b).

Dissolved oxygen of surface water ranged from 4.9 to 7.8 ppm and in the bottom water it ranged from 4.7 to 9.7 ppm during August'95 to July'97 in the Gulf of Mannar side. Maximum dissolved

Fig.21a Temperature distribution in the Gulf of Mannar

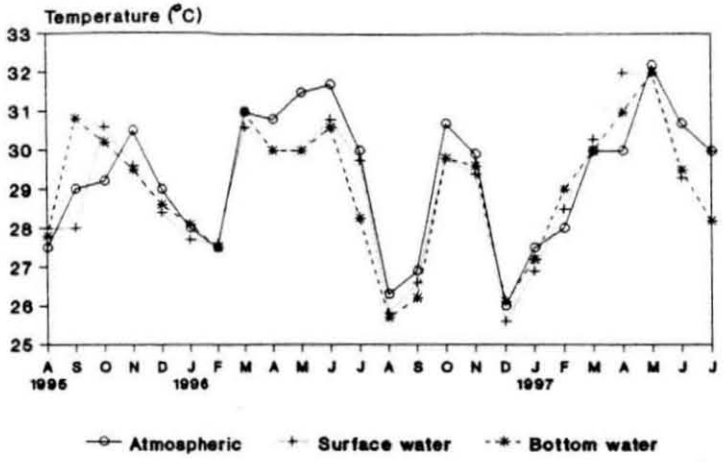


Fig.21b Temperature distribution in the Palk Bay

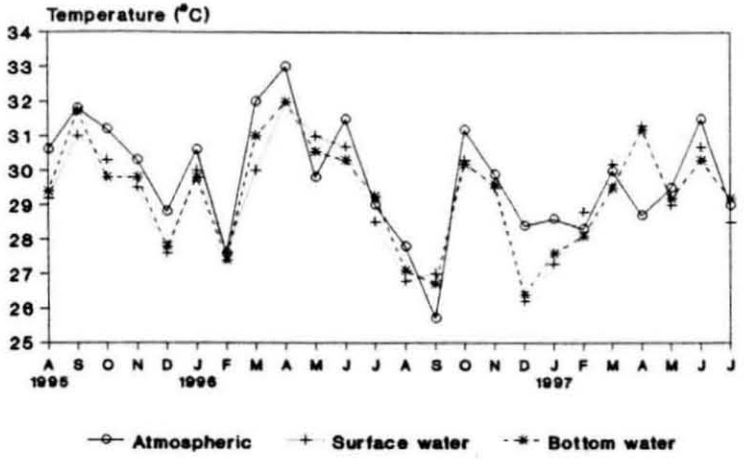


Fig.21c pH distribution in the Gulf of Mannar

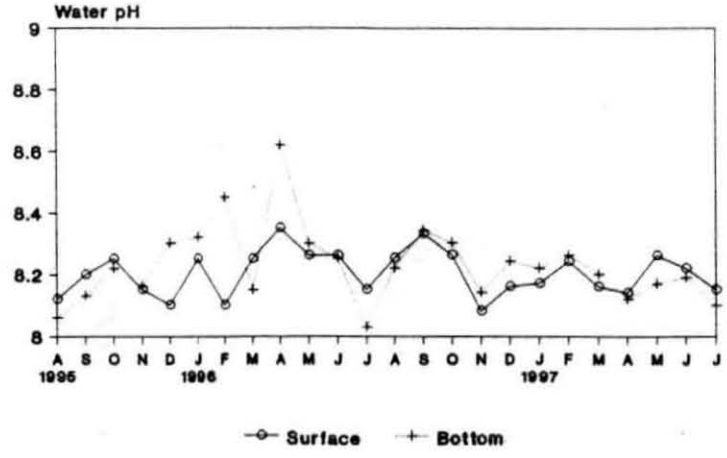
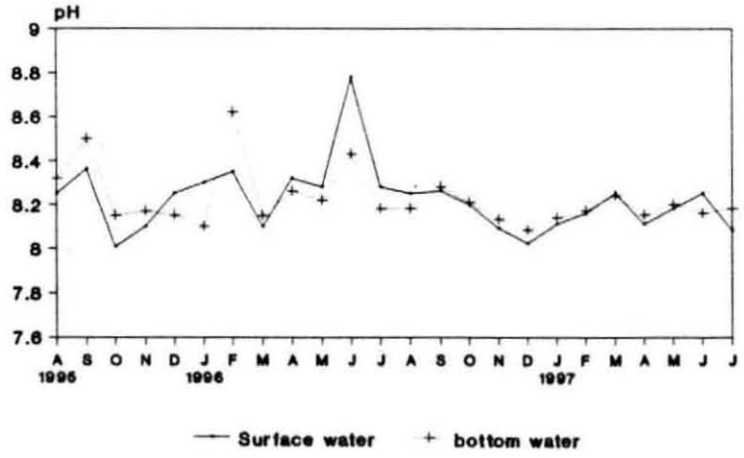


Fig.21d pH distribution in the Palk Bay



oxygen value of 7.8 ppm in the surface water was noticed during January'97 and 9.7 ppm was seen in the bottom water during June'97. Minimum dissolved oxygen value of 4.9 ppm in the surface water was observed during October'95 and 4.7 ppm in the bottom water was found during September'96. (Figure 22c).

Dissolved oxygen of surface water varied from 4.3 to 8.4 ppm and in the bottom water it ranged from 4.9 to 8.6 ppm during August'95 to July'97 in the Palk Bay side. Maximum dissolved oxygen value of 8.4 ppm in the surface water was seen during August'95 and 8.6 ppm was found in the bottom water during May'96. Minimum dissolved oxygen value of 4.3 ppm in the surface water was noticed during April'96 and 4.9 ppm was recorded in the bottom water during May'97 (Figure 22d).

Dissolved phosphate of surface water ranged from 0.93 to 10.69 ppb and in the bottom water it varied from 0.9 to 10.68 ppb during August'95 to July'97 in the Gulf of Mannar side. Maximum dissolved phosphate value of 10.69 ppb in the surface water was observed during November'96 and 10.68 ppb was noticed in the bottom water during February'97. Minimum dissolved phosphate value of 0.9 ppb was seen in both the surface water and the bottom water during September'95 (Figure 23a).

Dissolved phosphate of surface water varied from 1.55 to 14.09 ppb and in the bottom water it ranged from 0.93 to 12.23 ppb during August'95 to July'97 in the Palk Bay side. Maximum

Fig.22a Distribution of Salinity in the Gulf of Mannar

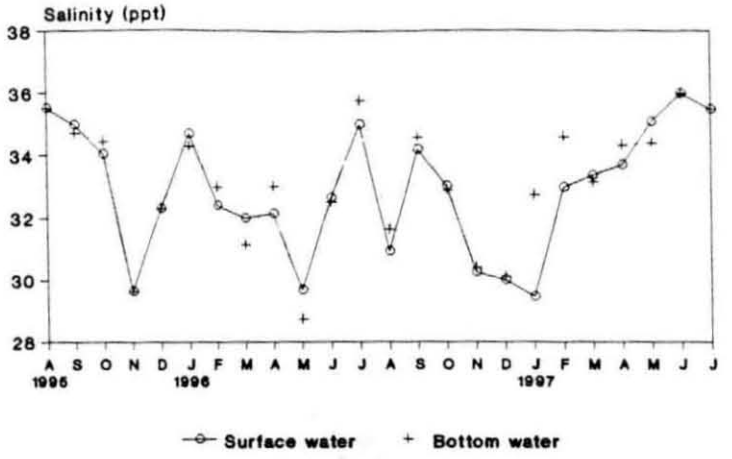


Fig.22b Distribution of Salinity in the Palk Bay

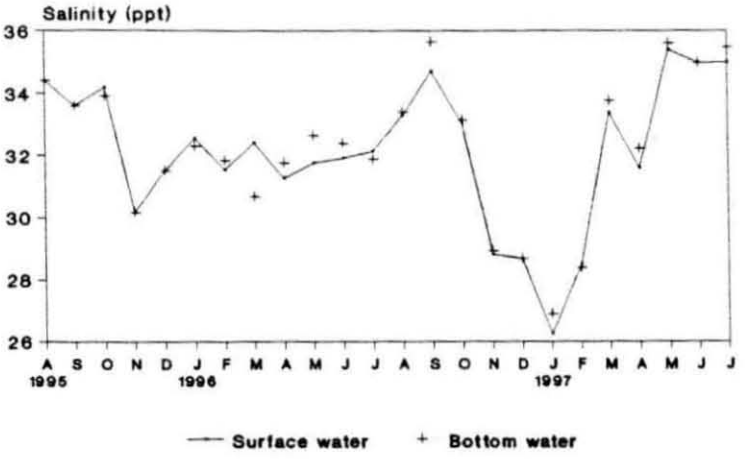


Fig.22c Distribution of Dissolved Oxygen in the Gulf of Mannar

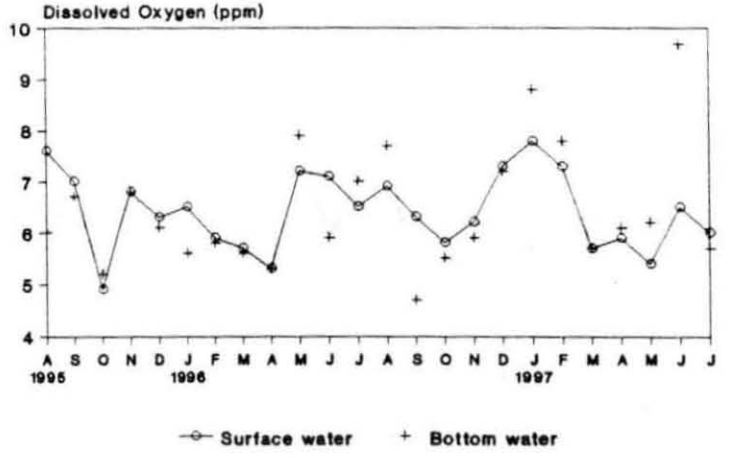
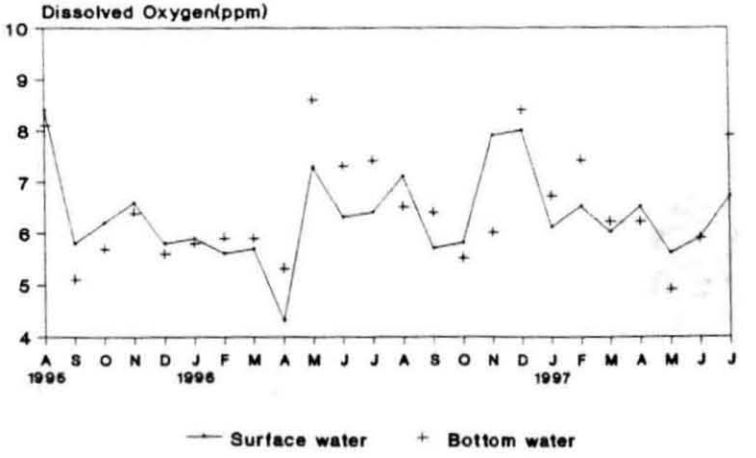


Fig.22d Distribution of Dissolved Oxygen in the Palk Bay



dissolved phosphate value of 14.09 ppb in the surface water was found during January'97 and 12.23 ppb was recorded in the bottom water during the same period. Minimum dissolved phosphate value of 1.55 ppb in the surface water was seen during September to December'95 and January to March'96 and 0.93 ppb was noticed in the bottom water during September'95 (Figure 23b).

Dissolved silicate of surface water ranged from 0.04 to 1.19 ppm and in the bottom water it ranged from 0.04 to 0.99 ppm during August'95 to July'97 in the Gulf of Mannar side. Maximum dissolved silicate value of 1.19 ppm in the surface water was found during April'96 and 0.99 ppm was seen in the bottom water during the same period. Minimum dissolved silicate value of 0.04 ppm in the surface water was recorded during May'97 and the same was found in the bottom water during the same period (Figure 23c).

Dissolved silicate of surface water varied from 0.08 to 0.62 ppm and in the bottom water it ranged from 0.08 to 1.22 ppm during August'95 to July'97 in the Palk Bay side. Maximum dissolved silicate value of 0.62 ppm in the surface water was recorded during June'96 and 1.22 ppm was seen in the bottom water during May'96. Minimum dissolved silicate value of 0.08 ppm in the surface water was found during September'95 and the same value was seen in the bottom water during the same period (Figure 23d).

Fig.23a Distribution of Dissolved Phosphate in the Gulf of Mannar

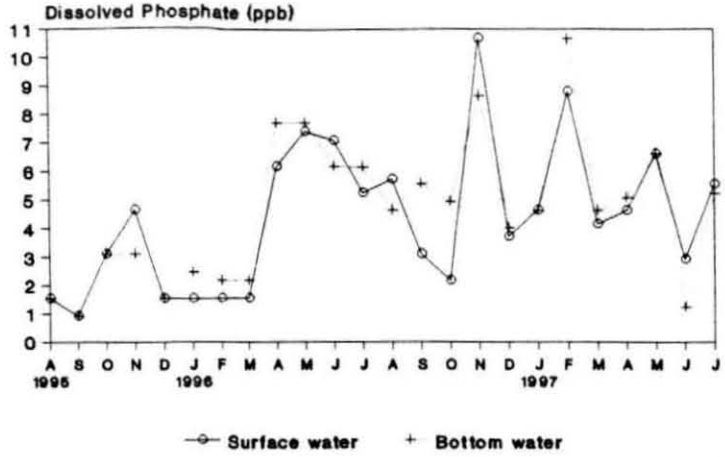


Fig.23b Distribution of Dissolved phosphate in the Palk Bay

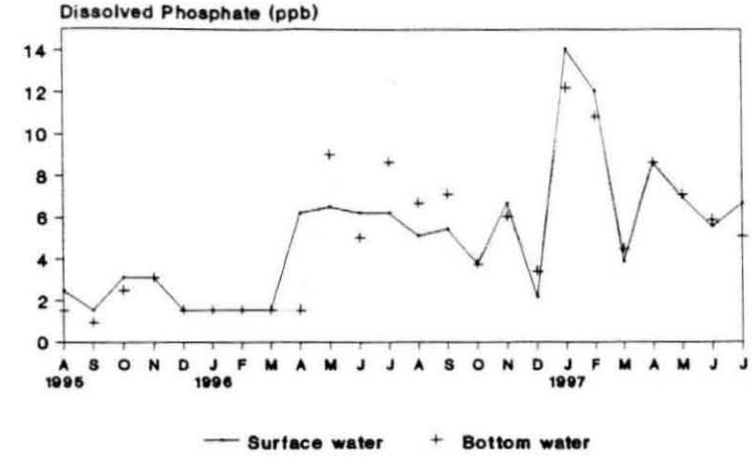


Fig.23c Distribution of Dissolved Silicate in the Gulf of Mannar

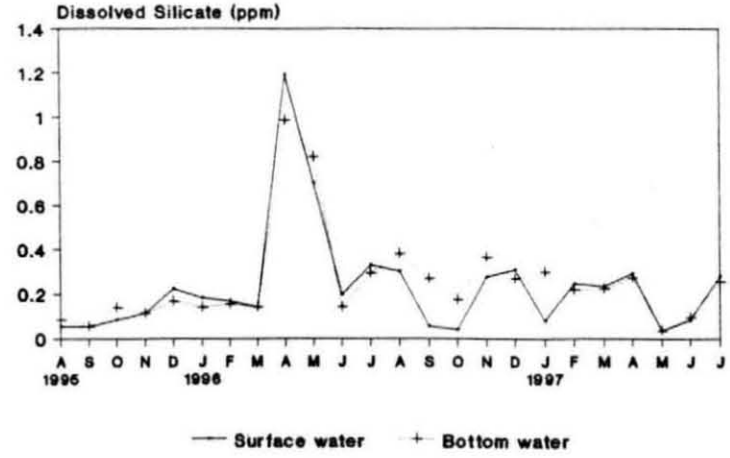
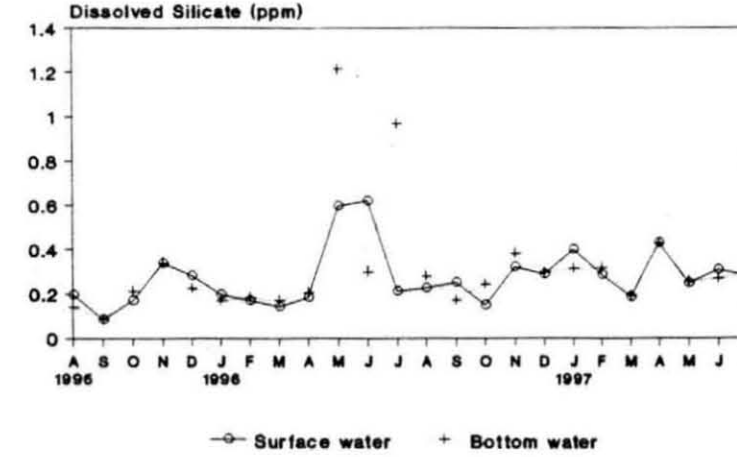


Fig.23d Distribution of Dissolved Silicate in the Palk Bay



Dissolved nitrate of surface water ranged from 10.51 to 89.29 ppb and in the bottom water it ranged from 10.55 to 95.52 ppb during August'95 to July'97 in the Gulf of Mannar side. Maximum dissolved nitrate value of 89.29 ppb in the surface water was recorded during May'96 and 95.52 ppb in the bottom water was found during the same period. Minimum dissolved nitrate value of 10.51 ppb in the surface water was seen during January'96 and 10.55 ppb in the bottom water was noticed during October'96 (Figure 24a).

Dissolved nitrate of surface water varied from 10.51 to 64.43 ppb and in the bottom water it varied from 10.51 to 55.05 ppb during August'95 to July'97 in the Palk Bay side. Maximum dissolved nitrate value of 64.43 ppb in the surface water was seen during May'96 and 55.05 ppb in the bottom water was found during the same period. Minimum dissolved nitrate value of 10.51 ppb in the surface water was noticed during January'96 and in the bottom water the same value was seen during March'96 (Figure 24b).

Dissolved nitrite of surface water ranged from 0.14 to 3.43 ppb and in the bottom water it ranged from 0.14 to 3.57 ppb during August'95 to July'97 in the Gulf of Mannar side. Maximum dissolved nitrite value of 3.43 ppb in the surface water was recorded during February'97 and 3.57 ppb in the bottom water was seen during the same period. Minimum dissolved nitrite value of

0.14 ppb in the surface water was noticed during August, October, and December'95 and May'96 and in the bottom water the same value was noticed during August, October, and December'95, and March, April and June'96 (Figure 24c).

Dissolved nitrite of surface water ranged from 0.14 to 5.04 ppb and in the bottom water it ranged from 0.14 to 4.41 ppb during August'95 to July'97 in the Palk Bay side. Maximum dissolved nitrite value of 5.04 ppb in the surface water was seen during July'96 and 4.41 ppb in the bottom water was found during January'97. Minimum dissolved nitrite value of 0.14 ppb in the surface water was noticed during April, and December'95, January and June'96 and the same value in the bottom water was recorded during December'95 to February'96 and June'96 (Figure 24d).

Gross photosynthesis ranged from 22.04 to 165.37 mg $C/m^3/hr$ and net photosynthesis ranged from 8.82 to 79.15 mg $C/m^3/hr$ during August'95 to July'97 in the Gulf of Mannar side. The maximum gross photosynthesis value of 165.37 mg $C/m^3/hr$ was seen during February'96 and 79.15 mg $C/m^3/hr$ of net photosynthesis was found during March'97. The minimum gross photosynthesis value of 22.04 mg $C/m^3/hr$ was noticed during May'96 and 8.82 mg $C/m^3/hr$ of net photosynthesis was recorded during the same period (Figure 25a).

Gross photosynthesis ranged from 33.58 to 160.33 mg $C/m^3/hr$ and net photosynthesis ranged from 10.18 to 146.96 mg $C/m^3/hr$

Fig.24a Distribution of Dissolved Nitrate in the Gulf of Mannar

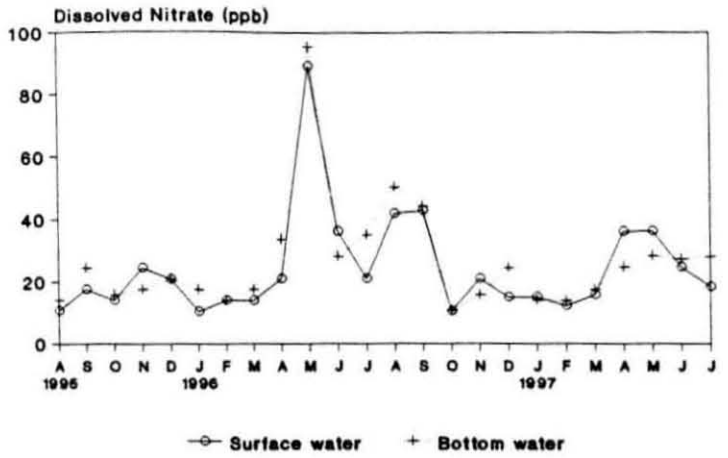


Fig.24b Distribution of Dissolved Nitrate in the Palk Bay

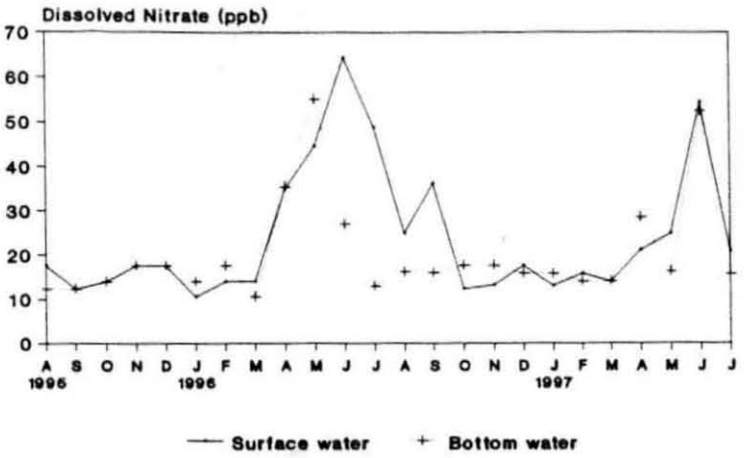


Fig.24c Distribution of Dissolved Nitrite in the Gulf of Mannar

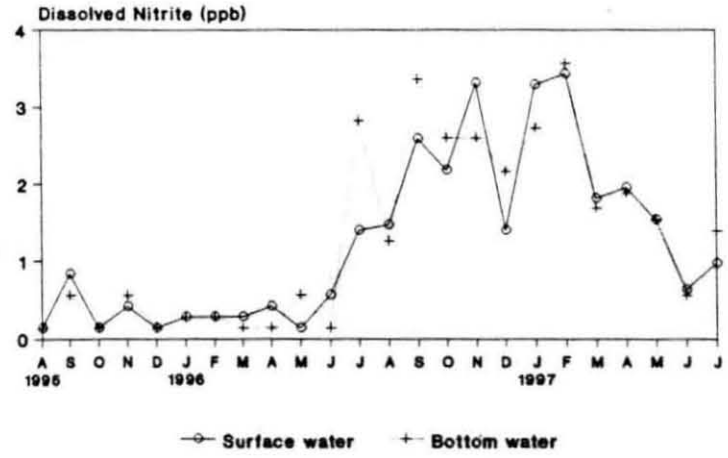
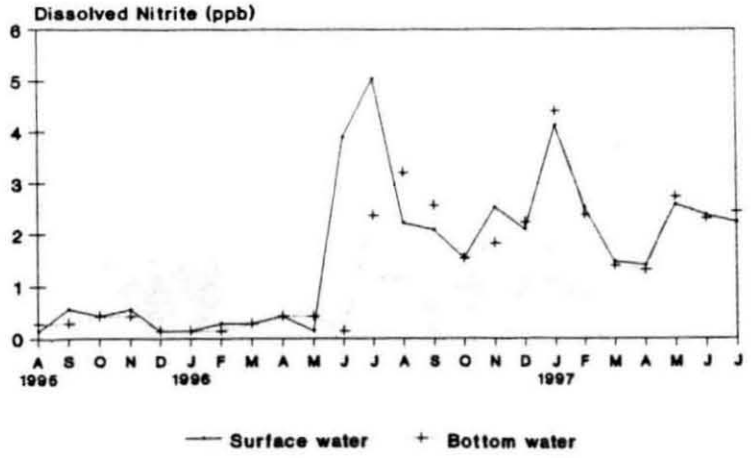


Fig.24d Distribution of Dissolved Nitrite in the Palk Bay



during August'95 to July'97 in the Palk Bay side. The maximum gross photosynthesis value of 160.33 mg $C/m^3/hr$ was seen during February'96 and 146.96 mg $C/m^3/hr$ of net photosynthesis was found during the same period. The minimum gross photosynthesis value 33.58 mg $C/m^3/hr$ was noticed during October'95 and 10.18 mg $C/m^3/hr$ of net photosynthesis was recorded during November'95 (Figure 25b).

The quantity of zooplankton ranged between 2.50 and 8.20 ml/l during August'95 to July'97 in the Gulf of Mannar side. The maximum value of 8.20 ml/l was seen during November'95 and the minimum value of 2.50 ml/l was found during January'97 (Figure 25c). It ranged from 3.30 to 6.90 ml/l during August'95 to July'97 in the Palk Bay side. The maximum value of 6.90 ml/l was noticed during May'97 and the minimum value of 3.30 ml/l was found during July'96 (Figure 25d).

4.10. SPOTTED SCAT AS AN ORNAMENTAL FISH IN THE AQUARIUM

Mean length and mean weight were recorded once a month. The mean length noted during February'96 to August'96 ranged from 52 ± 9.8 mm to 98 ± 10.6 mm whereas the mean weight ranged between 32 ± 6 g and 66 ± 6.8 g for the same period (Table 15). Higher length increment (10 mm) and higher weight increment (7 g) were recorded during March'96. Lesser length increment (4 mm) and lesser weight increment (3 g) were observed in August'96. Length and weight increments decreased, when the fish attained larger

Fig.25a Distribution of Gross and Net Photosynthesis in the Gulf of Mannar

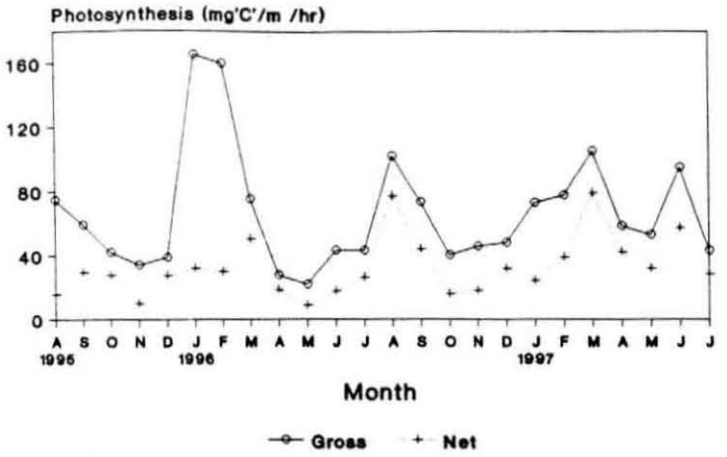


Fig.25b Distribution of Gross and Net Photosynthesis in the Palk Bay

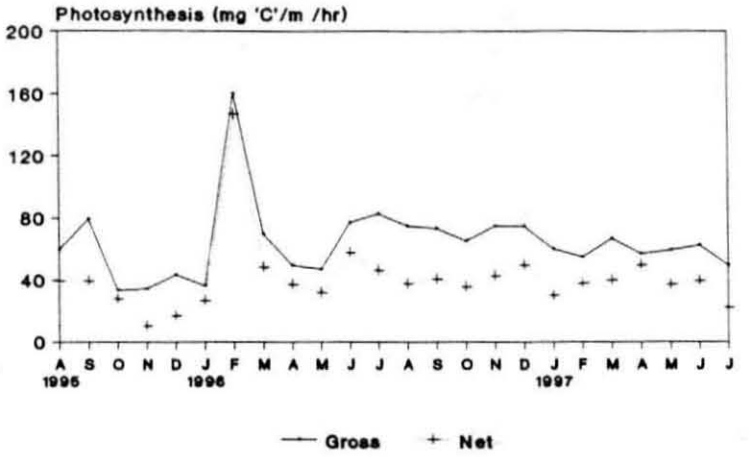


Fig.25c Distribution of Zooplankton in the Gulf of Mannar

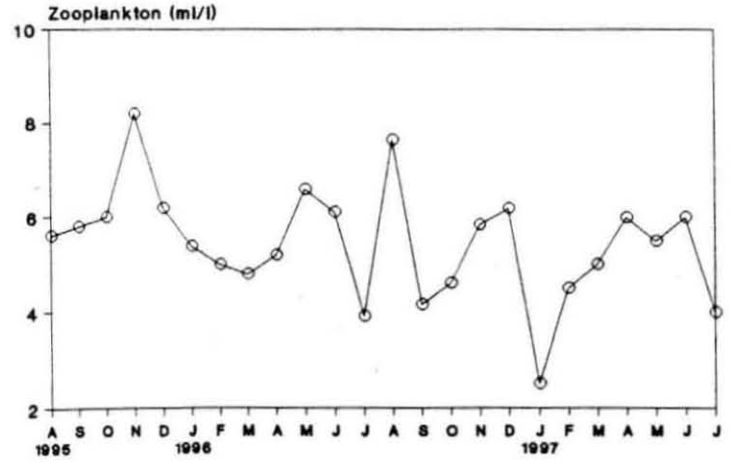


Fig.25d Distribution of Zooplankton in the Palk Bay

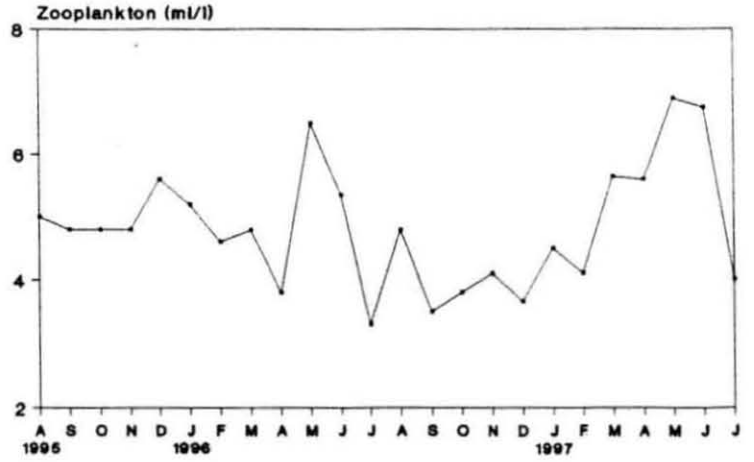


Table 15 Length and Weight of scat maintained in the aquarium during February '96 to August '96.

Month	Length in mm Mean ± S.D	Weight in g Mean ± S.D
February'96	52 ± 9.8	32 ± 6.0
March	62 ± 9.8	39 ± 6.0
April	71 ± 10.1	46 ± 6.1
May	78 ± 9.7	52 ± 6.1
June	86 ± 9.8	57 ± 6.3
July	94 ± 10.1	63 ± 5.0
August'96	98 ± 10.6	66 ± 6.8

size. It was also observed that the fish freely accepted minced trash fish supplied throughout the experiment.

In the second experiment where adults and juveniles were stocked together, there was no cannibalism observed. The fish appeared very active and were nice to look at as one of good quality aquarium fishes. They used to move as a group and swam to the surface as well as to the bottom exhibiting sloping movements. They were not aggressive. At the time of feeding, they were friendly and took the food without chasing one another. However, they consumed the food voraciously. At the time of feeding, they came to the surface of the water, whenever they saw food. If one of the fishes of the group started to move or get out of place, others followed suit immediately. The grouping of fish was aesthetically pleasing to see compared to seeing a single fish. The brown spots on their light or dark olive green colour of deep, strongly compressed body exhibited a look similar that of butterfly fishes.

When they were fed with only minced trash fish (throughout the first experiment), they confined only to that type of food. When they were fed with filamentous algae *Enteromorpha compreesa* and minced trash fish (throughout the second experiment), both juveniles and adult fishes fed freely on both types of feed.

Since there was no cannibalism, juveniles and adult scats could be kept and maintained in the same tank which would exhibit

an aesthetic look because juveniles and adults moved in separate groups. It was also observed that growth increments of this fish, in both experiments decreased when the fishes attained larger size. It was also confirmed that scats were omnivorous since they took both types of feed (minced trash fish and filamentous algae) which were provided during the second experiment. 100 % survival rate was also observed in both the experiments.

4.11. FRY REARING IN THE AQUARIUM

Development of scat from fry to juvenile was given in Figure 26.

4.11.1. Fry 2.5 mm (Figure 26A)

The total length of fry was 2.5 mm at the time of collection from the wild. Body was more or less oval shaped and transparent in colour with a terminal mouth. The dorsal and anal fin folds had appeared; but there was no spines and rays. Both dorsal and anal fin folds extended upto the caudal fin fold. Fry were transparent in colour. Caudal fin fold was round in shape and transparent in colour. Faint indication of rays was seen in the caudal fin fold. Pectoral fin fold appeared slightly and was transparent in colour. Myotomes were seen in the post-anal region. However, there were no myotomes in the pre-anal region. Pigment spots started to appear near the eyes and continued upto the anal region. Pigment spots were also observed near the

lateral lines. Eye balls appeared bright and bluish and iris was jet black in colour.

4.11.2. Fry 3.5 mm (Figure 26B)

The fry took 3 days to reach a size of 3.5 mm from 2.5 mm. Compared to the earlier stage, the body was slightly bigger in size. Its body was transparent and the pigmentation was clear. Further pigmentation started below the dorsals. The dorsal had soft spines and rays, whereas the anal had only rays. In this stage ventral fin fold started to appear.

4.11.3. Fry 5.5 mm (Figure 26C)

The fry reached 5.5 mm in length from the size of 3.5 mm after 6 days. The body was somewhat elongated. The dorsal and anal fins were with clearly formed spines and rays, whereas the caudal, pectoral and pelvic fins were with clearly formed rays only. Pigment spots appeared in several parts of the body. There were spines in the operculum. Six numbers of branchiostegal rays were also observed.

4.11.4. Fry 11 mm (Tholichthys fry) (Figure 26D)

The fish took 17 days to grow from 5.5 mm to 11 mm as tholicthys fry, with unique features of having bony plates on head. The body was deeply compressed laterally. There were no scales on the body. Minute vermiform teeth started to appear on both the jaws. The skin was rough with thick pigmentation spread through-

out the body. The head was covered with bony plates. One of these bony plates, dorsal to the eye, had a posteriorly oriented projection forming spiny horns on either side of the head. The bony plates disappeared slowly, as the tholichthys fry reached the juvenile stage. Fins developed well. The dorsal and anal spines were prominent.

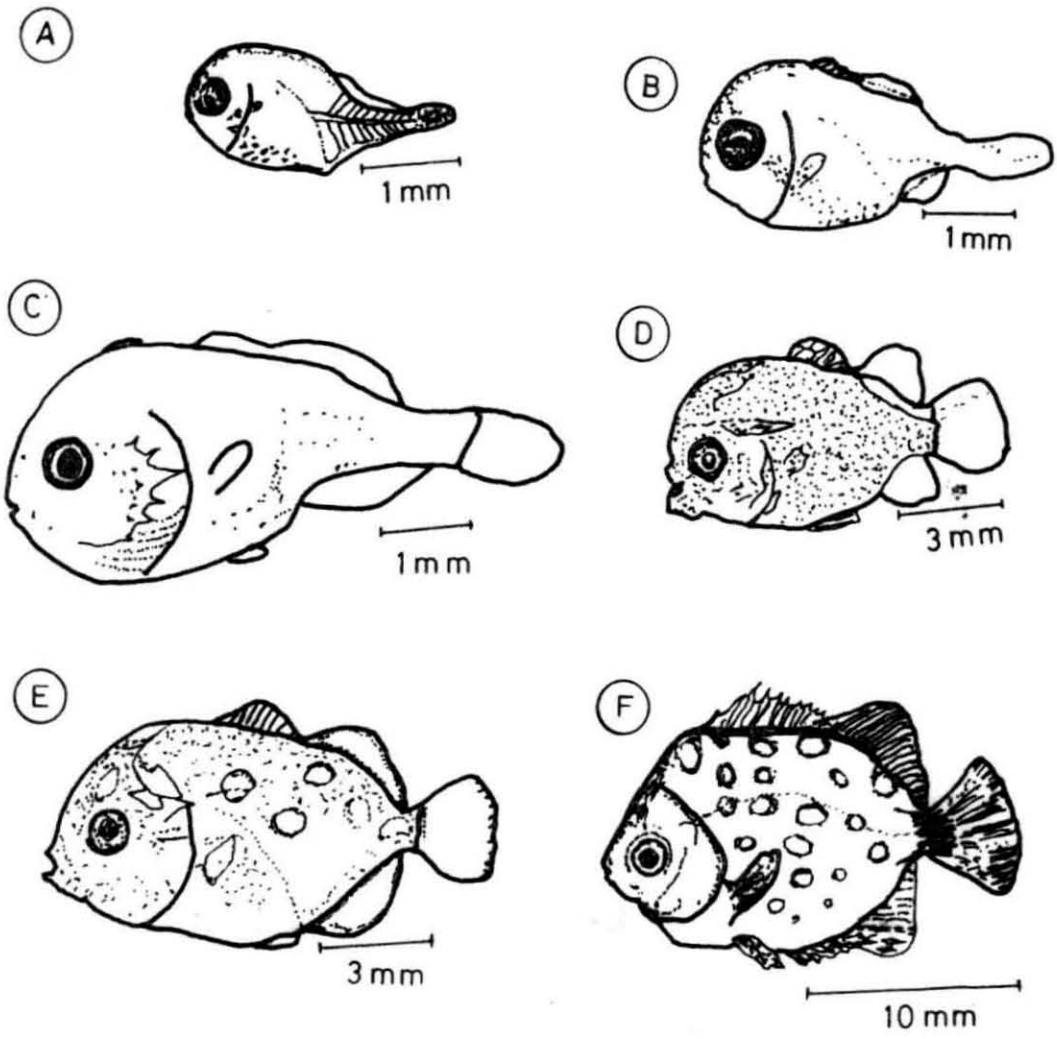
4.11.5. Fry 14 mm (Figure 26E)

The fry took 9 days to reach 14 mm from 11 mm. This was the stage to become juvenile stage after metamorphosis of tholichthys fry. Vermiform teeth were developed well. Among pigment spots, there were also some small patches of chromatophores adjacent to the lateral lines. Spines and rays developed well in the dorsal and anal fins and rays developed well in other fins. Caudal fin was round in shape.

4.11.6. Juvenile 20 mm (Figure 26F)

The fry took 18 days to grow from 14 mm to 20 mm. In this stage, the young fish looked like miniature adult fish. Body was deeply compressed. Colour of the body was light green with numerous small brown spots. Operculum was free from opercular spines. Head became small and the mouth was small with well formed vermiform teeth.

Figure 26 **Developmental stages of scat from fry to juvenile**



Fry 2.5 mm — A —(3 days)→ Fry 3.5 mm — B —(6 days)→ Fry 5.5mm — C —(16 days)→ Fry 11mm — D —(9 days)→ Fry 14mm — E —(20 days)→ Fry 20mm — F

5. DISCUSSION

5.1. TAXONOMY

The spotted scat was named as *Scatophagus argus* by Linnaeus (1766). According to Berg (1940), there are two genera in the family Scatophagidae, with the following taxonomic classification.

Phylum	: Chordata
Sub-Phylum	: Vertebrata
Class	: Osteichthys
Subclass	: Actinopterygii
Infraclass	: Teleostei
Order	: Perciformes
Suborder	: Percoidea
Family	: Scatophagidae
Genera	: *Scatophagus*
	Selenotoca

Pioneer workers like Gunther (1937), Munro (1955), Day (1958), Smith (1961) and Carcassion (1977) have also described *S.argus*.

Different workers had placed *Scatophagus* in different genera and also had named *argus* by different names. It was placed in the genus *Chaetodon* in the year 1788 (Bloch), 1803 (Sha) and 1828 (Bennett). It was also placed in the genus *Ephippus* during 1817 (Cuvier) and 1877 (Bleeker) and in the genus *Cacodoxus* during 1849 (Cantor). The species name *argus* was also named as *atro-maculatus* during 1828 (Bennett), as *argus bougainvillii* during 1831 (Cuvier and Valenciennes), as *arnatus* during 1831 (Cuvier and Valenciennes), 1854 (Bleeker), 1867 (Gunther) and

1876 (Bleeker), as *purpurascens* during 1831 (Cuvier and valenciennes), as *macronotus* during 1845 (Bleeker) and *quadranus* during 1884 (De Vis) (more details on these were given in Appendix-1.

The number of dorsal spines, dorsal rays, anal spine and anal rays recorded by various authors were different (Table 16). This clearly indicated that the number of dorsal spines, dorsal rays, anal spines and anal rays were not consistently the same. However the number of dorsal spines and anal spines recorded by all the authors including that recorded in the present study were the same with the exception of Carcassion (1977) who reported the presence of 12 dorsal spines instead of 11. On the otherhand, the number of dorsal and anal rays observed by all the authors varied from 14 to 18.

Gunther (1937) observed that the width between the eyes was 27% of the length of the head. Day (1958) reported that the eye diameter was 29% of the length of the head. During the present study,it was observed that the diameter of the eye was 24% - 25% of the length of the head. Thus all the findings on eye diameter differed only by 2%.

Gunther (1937) recorded 11 abdominal and 12 caudal vertebrae. The same number of abdominal vertebrae were observed in the present study also. However, the caudal vertebrae observed were 13 in the present study instead of 12 observed by Gunther (1937).

Table 16 Number of dorsal spines, dorsal rays, anal spines, and anal rays of scat.

		Observation			
Author	Year	Dorsal spines	Dorsal rays	Anal spines	Anal rays
Gunther	1937	11	16	4	14
Munro	1955	11	16-18	4	14-15
Day	1958	11	16-17	4	14-16
Smith	1961	-	-	4	-
Carcassion	1977	12	16	4	16
Gandhi	Present study	11	15-17	4	14-15

Munro (1955) noted 95-120 lateral line scales and 80 transverse scales between the dorsal and ventral fins. Day (1958) reported 110 lateral line scales. Carcassion (1977) observed 90 lateral line scales and 76-83 transverse scales. In the present investigation, 100-115 lateral line and 80-85 transverse scales were recorded. Thus observations by all the workers on lateral line scales varied in number. However, all the authors observed the presence of minute ctenoid scales.

Munro (1955) described that the body shape was angular and deeply compressed. Day (1958) stated that the body was somewhat quadrangular and strongly compressed. The dorsal profile was more curved than the abdominal. Smith (1961) described that the body was deep, solid, and often angular. Carcassion (1977) reported that the scats were a small family of deep-bodied and highly compressed fish. The present study also revealed that the body was solid, angular and deeply compressed. There was an obvious curvature above the eye on the rostro-dorsal profile of the head.

Munro (1955) observed that the mouth was small with bands of fine teeth on jaws. There was no teeth on palate. Day (1958) recorded villiform teeth on the jaws. Smith (1961) observed the presence of small mouth with bands of fine teeth on the jaws and no teeth on the palate. Carcassion (1977) stated that the mouth was small, square, terminal and non-protrusible. In the present

investigation also, non-protrusible, small terminal mouth with bands of minute villiform teeth was recorded; and, there were no teeth on the palate.

Gunther (1937) stated that the body and vertical fins had brown spots. Munro (1955) recorded the body colour as blue or greenish gray to dusky brown with numerous large round brown spots which extended on to the soft dorsal fin. Belly was silvery in colour. Fins were pink, or yellowish to brownish gray in colour. Day (1958) observed that the colour of the body was purplish, becoming white on the abdomen. Large round blackish or brownish spots were present with increasing numbers along the back and varying in size and tints.

The second dorsal was yellowish with light brown markings between the rays. Carcassion (1977) stated that the body was olive green, darker above with numerous irregular large black spots which were larger on the back. Fins and tail were dusky. The present investigation revealed that the body colour was light olive green, darker above, becoming silvery on the abdomen with numerous irregular large round dark brown spots extending on to the fins and tail. The size of the spots was larger on the back compared to the other regions of the body. Fins were yellowish with light brown markings between the rays. All the earlier workers have stated that the fish had brown spots on the body. However, Carcassion (1977) indicated that the fish had black spots on the body.

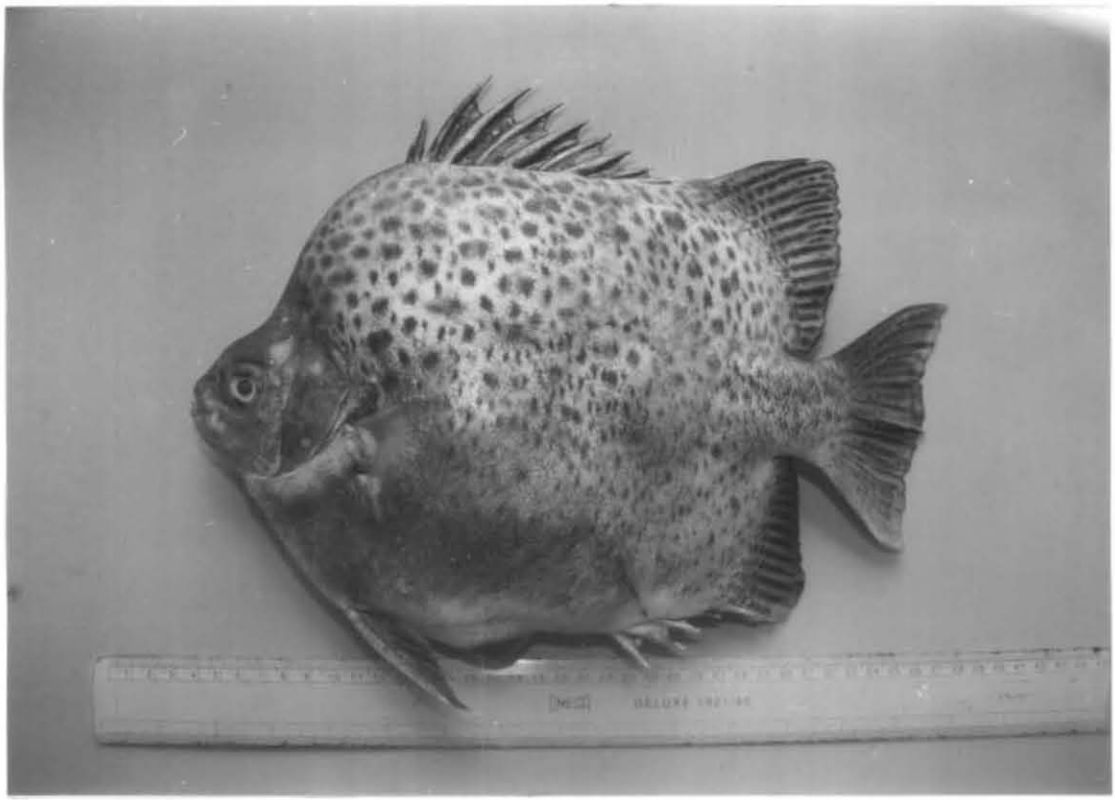
Munro (1955) reported that very young fish had bony plates on the head and a large shoulder spine, whereas Day (1958) reported that the young ones had a bony ridge ending in a spine, passing from the eye to the opercle above. Smith (1961) observed that unlike the adults, the young fish were having bony shields on the head and a larger spine on the shoulder, all vanishing with growth. Carcassion (1977) reported that juveniles were bright orange red in colour on the back with a few irregular black cross bands. During the course of the present investigation, it was observed that juveniles of scat had heavy bony armour on the head and larger spines on the shoulder. The juveniles were olive-brown in colour above the head and bright orange red along the back. The colour of the juvenile scat has been reported earlier only by Carcassion (1977).

Munro (1955) reported that the maximum length of the fish was 12 inches. Day (1958) also reported that the scat could attain a maximum size of a foot in length. Smith (1977) reported that the maximum size of the scat was 30 cm in length. During the course of the present study, a slightly bigger size specimen of scat of 34 cm (13.5 inches) was collected (Plate-5).

5.2. STANDARD LENGTH AND MORPHOMETRIC CHARACTERS

Existing literature revealed that no work has been carried out so far, regarding the biometry of scats. Therefore the present study has brought out the much needed information on the

Plate - 5 Largest size of scat recorded during the study



same. It revealed that pre-dorsal length had the fastest growth rate followed by pelvic fin length and head length. Eye diameter grew faster than snout length and inter-orbital space. The rate of growth for depth of body was more than the depth of caudal peduncle. A comparison of the relative growth of spines showed that the third dorsal spine grew faster than the second anal spine. Among the fin rays, pelvic fin grew faster than the pectoral fin rays. The rate of growth of post-orbital length was greater than the pre-orbital length. Pre-anal length and pre-orbital length had the slowest growth rates.

5.3. LENGTH-WEIGHT RELATIONSHIP

The value of the exponent `n' in the parabolic equation usually lies between 2.54 and 4 (Hile, 1936; Martin, 1949); and in an ideal fish which maintains constant shape, `n' would be 3 (Allen, 1938). Beverton and Holt (1957) reported that important departures from isometric growth (n = 3) were rare. However, as studied by Blackburn (1960) in the case of *Thyrsites atun*, the value of `n' was considerably below 3. In the present study also the value of the exponent `n' was considerably below 3 which might be due to the deep, strongly compressed body of scat. Barry and Fast, (1988) reported that the value of exponents of scat were less than 3 which was expected considering the laterally compressed body form of the scat. The study of the length-weight relationship of the scat indicated that the sudden increase in

weight of the fish on attainment of first maturity could be traced from the parabola. It was also observed that 95% of male scats attained first maturity (Stage I) in the size group of 120 to 129 mm whereas 82% of female scats attained first maturity (Stage I) in the size group 140 to 149 mm. It could be seen that in the females, the increase in weight was gradual till they reached a size of about 140 mm followed by rapid increase in weight above 140 mm indicating attainment of maturity at about this size (Figure 6b). In the case of males the increase in weight was gradual till they reached a size of about 120 mm followed by rapid increase in weight above 120 mm indicating attainment of maturity at about this size (Figure 6a).

Analysis of covariance to test equality of length-weight relationship between males and females revealed that there was significant difference ($p < 0.01$) between sexes.

5.4. FOOD AND FEEDING HABITS

Like many other factors, the distribution and fluctuation in abundance of organisms which form the main food of a species, also affect the shoaling behaviour, migration for food, spawning, growth condition and also the fishery. Therefore considerable attention has been given to this subject of food and feeding habits, by earlier workers.

Mookerjee *et al.*, (1949) collected various sizes of *Scatophagus argus* from different places in the estuaries of Bengal and

investigated, through the gut content analysis, the presence of unicellular algae, higher plants, protozoa, sponges, crustaceans, fish scales, sand and mud. During the present study period of August 1995 to July 1997 also, the presence of the above mentioned food components was observed in addition to the presence of coral polyps, bivalves, lepas, prawns, sea-anemones, alphids and foraminifera. The presence of additional food components was probably because of the different types of habitats from which the fish were collected. Mookerjee *et al.*, (1949) collected the fish from the estuaries whereas in the present study fish were collected from the marine environment.

Datta *et al.*, (1984) studied the food of scats inhabiting both fresh and brackish water ponds and reported that the food comprised of aquatic macrophytes, phytoplankton, zooplankton and other macrobenthos. The present findings were also in agreement with their findings. But, the only difference was that they collected specimens of scat for gut content analysis from fresh and brackish water ponds. In the present study, the collection was from the marine environment.

Monkolprasit (1994) studied the composition and food habits of fish collected from the mangrove forests of Phan-NGA and Ban Don Bay of Thailand. He indicated that gut content analysis of *S.argus* showed the presence of diatoms, nematodes, rotifers,

polychaets, insects and foraminifera. During the present investigation also, phytoplankton, crustaceans and foraminifera were recorded.

The present study clearly indicated that the scats fed on whatever was available. Thus phytoplankton, filamentous algae, detritus, *Ulva* spp., sponges, coral polyps, sea-anemones, bivalves, lepas, prawns, other crustaceans, protozoa, copepods, foraminifera, fish scales and alphids were consumed by them. It was also observed that fish measuring 50 mm and below fed on phytoplankton, protozoa, detritus and copepods which was consistent with the findings of Mookerjee *et al.*, (1949). Fish measuring more than 100 mm in length fed mainly on filamentous algae and detritus. Sometimes, *Ulva* spp., also constituted the main food item of the same size fish. Fish below 100 mm in length, fed on phytoplankton in addition to the components explained earlier. Mookerjee *et al.*, (1949) stated that fish measuring 136 mm fed on unicellular algae, multicellular algae, higher plants, protozoa, sponges, crustaceans, fish scales, sand and mud. From the present investigation it could be inferred that big size scats preferred algae and detritus whereas Juvenile fish preferred phytoplankton as well as detritus.

During the present study, it was also observed that eventhough peak appearance food items such as *Enteromorpha compressa*, during May'96, detritus, during July'96, *Ulva* spp., during August'96 and September'96 and sponges, during May'97, occurred

in the gut content of fish above 50 mm in length, they also appeared with other food items throughout the observation period of August 1995 to July 1997. This showed that there was no seasonal or annual variation and selection of food in the feeding habits of this fish.

Observations on selectivity of feeding indicated that the diet of *Scatophagus argus* depended on the availability of food organisms in the environment where they were found commonly. However, scats took filamentous algae and detritus more than the other food items. Mookerjee *et al.*, (1949) have also stated that scats preferred more vegetable food than animal food. Fish measuring 50 mm and below preferred only phytoplankton. Big fish preferred filamentous algae.Thus the present findings also were consistent with the observations of Mookerjee *et al.*, (1949).

During the course of the analysis of gut contents, varying number of `full',`3/4 full', `1/2 full', `1/4 full' and `little full' stomachs were found in all the size groups. However, no variation in feeding habits could be observed irrespective of the status of the fish as to whether they fed actively or poorly.

The presence of filamentous algae in the gut contents during the course of this study indicated that the scats browsed and swallowed them. Presence of attached organisms such as sea-anemones, lepas, bivalves and sponges in the gut contents indicated

that the fish scrapped and swallowed them. This indicated that they could also nibble and swallow coral polyps. The presence of detritus, fish scales and foraminiferan shells indicated that these fish consumed these items also. From these observations, it was clear that the fish had the habit of browsing, scrapping, nibbling and swallowing the prey. Since many of the above mentioned food items were available at the bottom of the sea, these fish could be called as bottom feeders also. Since plankton were recorded in the gut contents of young fish, they could be called in their juvenile stage as surface feeders.

During the period of the present investigation, both animal and plant food items were recorded in the gut contents of the scat. Therefore *Scatophagus argus* is an omnivorous fish. Mookerjee *et al.*, (1949) have also suggested the same. However, they also indicated that they preferred more vegetable food than animal food. Datta *et al.*, (1984) stated that qualitative and quantitative analysis of its diet clearly indicated its omnivorous nature. Monkolprasit (1994) also suggested that *S. argus* was an omnivorous fish. However, Barry and Fast (1988) have reported that adult spotted scats were primarily herbivorous in nature.

5.5. BIOCHEMICAL CHANGES DURING MATURATION AND SPAWNING

Biochemical composition of fish tissues is of significance because, these tissues constitute a rich source of nutrients and caloric value (Joshi *et al.*, 1979). Substantial amount of energy

is required during maturation and spawning activity and hence a considerable change in biochemical composition of body takes place.

Existing literature on biochemical composition of Indian fishes revealed that only a few Indian marine teleosts have been looked into for their biochemical composition. For example, the biochemical composition of *Pseudosciaena aneus* and *Johnius carutta* (Rao, 1967), *Sardinella longiceps* (Sen and Challuvaiah, 1968), *Ambassis gymnocephalus* (Vijayakumaran, 1979), *Mugil cephalus* and *Liza parsia* (Joseph, 1987) and *Sillago sihama* (Jayasankar, 1989) has been studied.

Moisture is a major constituent in animal body which plays an important role in regulating osmotic functions. It also serves as a medium by which nutrients and biochemical constituents are transported to various organs. The amount of moisture in fish is higher than that of all other higher vertebrates. Water is so important that an animal can lose practically all of its fat and half of its protein and still live, but loss of even 10% of its water can cause death (Maynard and Loosli, 1962).

During the present investigation, moisture content of muscle, liver and gonad in male and female scats was more or less same in all the stages with very little difference of 1 to 2%. In both sexes, an inverse relationship of moisture content with carbohydrate and lipid was recorded in muscle, liver, and gonad

irrespetive of their development stages. An inverse relationship between water and lipid content in teleost fishes was not uncommon and has been reported earlier by Hart *et al.*, (1940), Brandes and Diefrich (1958), Groves (1970), Pandey *et al.*, (1976), Reinitz (1983), Sivakami (1986) and Jayasankar (1989).

In the present investigation, protein level in the muscle of female fish decreased from 609 mg/g in stage II to 497 mg/g in stage VI, as the maturation of ovaries advanced, indicating utilization of protein for development of the ovary. In the male also, muscle protein content decreased from 594 mg/g in stage I to 573 mg/g in stage V indicating utilization of protein for the development of testis. However, it was not as great as in the female fish. This was consistent with the finding of Hickling (1930), Love and Robertson (1967) and Iles (1974) who reported that protein synthesised and accumulated in the somatic tissues during prematuration period would be utilized for gamete formation in addition to the growth of fish. Similarly decline of muscle protein content with the advancement of maturation in *Clupea harengus* (Bruce, 1924; Lovern and Wood, 1937), *Gadus morhua* (Dambergs, 1964) and *Cyprinus carpio* (Masurekar and Pai, 1979) has also been reported earlier.

Liver protein content in the female fish showed a decrease from 489 mg/g in stage I to 286 mg/g in stage VI during the advancement of maturation. However, in the male fish, liver

protein content decreased only to a lesser extent i.e., from 532 mg/g in Stage II to 502 mg/g in stage VI during the maturation process. Ovary protein content also decreased from 560 mg/g in stage I to 389 mg/g in stage VII in female and testis protein content in male also decreased from 286 mg/g in stage I to 234 mg/g in stage VII again indicating utilization of protein during maturation process. These observations corroborated well with the observations in other teleosts (Ehlebracht, 1973; Kapur, 1980; Nauriyal and Singh, 1985; Sivakami, 1986).

Muscle carbohydrate content in the female fish showed a general decline from 28 mg/g in stage I to 18 mg/g in stage VI with the advancement of maturation. However, it decreased only slightly from 32 mg/g in stage I to 30 mg/g in stage VII in the male fish indicating utilization of carbohydrate to a lesser extent with the advancement of maturation. In the female, liver carbohydrate content decreased from 187 mg/g in stage I to 145 mg/g in stage VII and in the male it decreased from 310 mg/g in stage I to 299 mg/g in stage VI with advancement of maturation. Carbohydrate content of gonad in the female showed a decline from 290 mg/g in stage I to 244 mg/g in stage VI. Similarly in the male, the decline was from 154 mg/g in stage I to 97 mg/g in stage VI indicating utilization of carbohydrate during maturation and spawning. These observations corroborated well with the observations of carbohydrate allocation during reproductive cycle

studied in *Oncorhynchus tschawytscha* (Greene, 1926), *Salmo salar* (Chang and Idler, 1960) *Mugil cephalus* and *Liza parsia* (Joseph, 1987).

At the time of maturation of gonads and spawning, lipid in fish is utilized mainly for three purposes, viz., (1) as endogenous source of energy for sustaining the fish, since most of them are known to abstain from feeding during spawning and for increased muscular activity of fish that have spawning migratory behaviour; (2) for the synthesis of generative materials (eggs and sperms) and yolk deposition and (3) for the synthesis of steroid hormones.

During the present investigation it was observed that muscle lipid content in the female fish decreased from 54 mg/g in stage I to 50 mg/g in stage VII and in the male fish it decreased from 62 mg/g in stage I to 49 mg/g in stage V indicating its possible mobilization towards gonadal development. Such depletion of muscle lipid in fishes has also been observed by Dambergs, (1934), Masurekar and Pai, (1979), Sivakami, (1981) and Milroy, (1989). Liver lipid content in the female showed a decline from 243 mg/g in stage I to 149 mg/g in stage VII and in the male it showed a little decline from 248 mg/g in stage I to 255 mg/g in stage V indicating utilization of lipid for the development of gonads. During maturation, liver lipid content has been observed to decrease in some fishes (Shchepkin, 1979; Singh and Singh, 1984). In the female gonad, lipid content decreased from

242 mg/g in stage I to 208 mg/g in stage VI and in the male gonad it decreased from 346 mg/g in stage I to 287 mg/g in stage VII indicating diversion of lipid for gonadal maturation. Singh and Singh (1984) and Carvalho (1980) have also reported a similar decline in ovarian lipid during maturation in *Chirrhinus mrigala* and *Hypophthalmus edentatus* respectively. In general, lipid content in fishes has been found to decline during maturation and peak spawning period (Lovern and Wood, 1937; Wilson, 1939; Rao, 1967; Banerjee and Baguchi, 1970; El Maghraby, 1972; Pandey *et al.*, 1976).

In the female fish, the highest caloric values (combined value of protein + carbohydrate + lipid) in muscle (16,928 j/g) and liver (24,396 j/g) were observed in stage I whereas the highest caloric value in gonad (24,794 j/g) was observed in stage IV. Lowest caloric values in muscle (13,228 j/g), liver (14,546 j/g) and gonad (20,164 j/g) were recorded in stage VI. Caloric value was high in gonads of all stages compared to the value found in muscle and liver of all the stages.

In the male, the highest caloric values in muscle (18,209 j/g), liver (31,299 j/g) and gonad (22,939 j/g) were recorded in stage VII. The lowest caloric values in muscle (16,024 j/g), liver (25,899 j/g) and gonad (1,939 j/g) were registered in stage V. Caloric value was high in liver of all the stages,

compared to the caloric values in muscle and gonad of all the stages.

The significance of the present work was that it was the first of its kind carried out on the biochemical composition of *Scatophagus argus*. In conclusion, the present investigation showed variation in the levels of major biochemical constituents in different tissues viz., muscle, liver and gonad of all the stages of female and male scats. Generally there was a decrease in the biochemical content of all stages, with advancing maturation. The present investigation also indicated variations in calculated caloric values of muscle, liver and gonad of all the stages of both sexes.

5.6. REPRODUCTION

The structure of reproductive systems of female and male scat revealed that they were typically teleostean, with a pair of gonads lying ventral to the swim bladder in the body cavity, united posteriorly through a common duct which opened to the exterior through the urinogenetal opening.

5.6.1. Maturity stages

Based on the general appearance of gonads and ova diameter measurement, seven stages for both sexes were identified viz., immature, developing immature and recovering spent, maturing, mature, advanced mature, ripe, and spent. However, Barry *et al.*,

(1988) had identified only five stages in scat viz., primary oocytes, immature oocytes, maturing, final maturation and atresia to induce final oocyte maturation and spawning.

5.6.2. Ova diameter studies

The present ova diameter study revealed that in Stage I (immature), the ovary predominantly contained small transparent immature ova measuring a maximum size of 0.12 mm. In Stage II (developing immature and recovering spent), the mode value of ova diameter was 0.28 mm and the maximum diameter observed was 0.36 mm. In Stage III (maturing), the mode value of ova diameter was 0.39 mm with the maximum diameter 0.47 mm. In Stage IV (mature), the mode value of ova diameter was 0.45 mm and the maximum ova diameter was 0.58 mm. In Stage V (advanced mature), the mode value of ova diameter was 0.61 mm and the maximum diameter observed was 0.69 mm. Stage VI (ripe) showed a mode value of 0.67 mm for ova diameter with the maximum diameter 0.75 mm and this indicated the spawning condition. Barry and Fast, (1988) reported that primary oocytes were of the size 0.04 to 10 mm in diameter. Immature oocytes were of the size 0.10 to 0.35 mm. Maturing ova were of the size 0.35 to 0.60 mm and the final maturing ova had the size of 0.60 to 0.75 mm. The size of the final maturing ova observed in the present study (0.75 mm) was in agreement with the size of the final maturing ova (0.75 mm) observed by Barry and Fast (1988)

5.6.3. Spawning

Various authors have found out that teleostean fishes have been found to exhibit different types of spawning habits (e.g., Hickling and Rutenberg, 1936; Prabhu, 1956; and Karekar and Bal, 1960. Based on their observations, atleast four major groups of fishes have been identified, depending upon their spawning habits. Group I included fishes which had a short spawning period, once a season. The mature ovaries of such fishes showed two distinct groups of eggs, the immature and the mature, distinctly separated from each other. In group II type of fishes, spawning took place only once, but over a long period. Here, the mature eggs were approximately half the total number of eggs. Group III included fishes that were expected to spawn twice a season. Their mature ovaries contained, in addition to the mature group of eggs, another group immediately following it which had undergone about half the maturation process. Group IV included fishes that spawned intermittently over a long period. In the ovaries of such fishes the successive batches of eggs were not sharply differentiated indicating that the maturation process was a continuous one.

A study of the frequencies of ova diameter in mature ovaries of *Scatophagus argus* in the present study showed that they contained, in the early stages of maturation, at least (Fig.20) three groups of ova which were not sharply differentiated. As the fish approached spawning season, the group of mature eggs

appeared to grow at a faster rate and got distinctly separated from the group of maturing eggs. Soon after the discharge of this group of eggs, another group of mature eggs took its place (Fig.23). Thus, with reference to spawning habits, *Scatophagus argus* could be included under Group III of fishes described earlier.

A comparison of data on the maturity of scat over two successive years (August 95 to July 97) indicated that fish of various maturity stages were present in each month of the year. For instance, female fish of maturity Stages I to III were present throughout the year. Stage IV was present throughout the year except during a few months (November 96, February, April and May 97). Advanced stages of development (V and VI) were present in August to November and April to July (Table 17). Spent fishes (VII) were also found during August to November and April to July during the study period. Males of Stages I to III were also present throughout the year. Other advanced Stages, IV to VI, were present during August to November and April to July (Table 18). The present study revealed that spawning occurred in scats twice a year, once during the southwest monsoon season (June, July, August) and the other during the northeast monsoon season (October, November December). Appearance of fry and fingerlings during the above mentioned seasons was in support of these findings. Barry *et al.*, (1988) stated, in their account of natural history of the spotted scat (*Scatophagus argus*), that

Table 17 Percentage occurrence of female *Scatophagus argus* in different stages of maturity during August 1995 to July 1997.

Month	No. of fish	Stages of maturity						
		I	II	III	IV	V	VI	VII
August'95	50	16	34	22	16	12	-	-
September	52	10	12	11	10	20	31	8
October	46	17	15	13	13	9	24	9
November	50	28	30	16	6	2	4	14
December	27	37	33	19	11	-	-	-
January'96	34	35	29	26	9	-	-	-
February	29	34	28	24	14	-	-	-
March	35	34	29	20	14	3	-	-
April	52	37	27	22	10	6	-	-
May	55	11	13	25	29	22	-	-
June	50	10	12	12	18	14	34	-
July	68	18	15	10	13	12	25	7
August	60	23	22	23	17	-	-	15
September	60	13	12	12	13	15	22	13
October	60	7	7	8	13	18	28	18
November	50	28	20	2	-	-	14	36
December	38	45	37	13	5	-	-	-
January'97	50	50	38	10	2	-	-	-
February	49	55	29	16	-	-	-	-
March	47	23	40	34	2	-	-	-
April	52	19	31	40	-	-	6	4
May	42	12	17	52	-	5	7	7
June	45	7	11	11	16	22	27	7
July	41	7	10	10	17	20	27	10

Table 18 Percentage occurrence of male *Scatophagus argus* in different stages of maturity during August 1995 to July 1997.

Month	No. of fish	Stages of maturity I	II	III	IV	V	VI	VII
August'95	16	19	38	19	13	13	-	-
September	19	11	14	18	18	16	16	8
October	14	21	14	14	14	21	7	7
November	23	35	26	17	9	-	4	9
December	15	33	33	20	13	-	-	-
January'96	11	36	27	18	18	-	-	-
February	15	33	33	20	13	-	-	-
March	25	28	36	20	16	-	-	-
April	23	30	30	17	13	9	-	-
May	30	17	13	23	30	17	-	-
June	23	9	9	13	17	22	30	-
July	27	19	11	11	7	15	26	11
August	27	33	19	22	4	-	-	22
September	22	18	9	9	14	14	27	9
October	20	10	5	5	10	20	35	15
November	21	19	24	5	-	-	14	38
December	22	41	32	18	9	-	-	-
January'97	28	50	32	11	-	7	-	-
February	27	48	37	15	-	-	-	-
March	22	18	36	41	-	5	-	-
April	24	17	25	38	8	-	8	4
May	22	14	18	50	-	14	-	5
June	21	10	5	5	24	19	29	10
July	21	5	10	5	19	19	33	10

spawning probably begins in June and reaches a peak in July. This clearly supported the findings of fry collection data in the present study. They also stated that a high percentage of mature females were caught in September and October suggesting that spotted scat might undergo rematuration and spawn more than once during a single breeding season which also supported the present findings.

5.6.3.1. Frequency of spawning

The multiplicity of modes of ova diameter distribution seen in the mature ovary of the fish clearly indicated that it spawned more than once during a season. Similar observations have also been made by Clark (1934), Hickling and Rutenberg (1936) and de Jong (1940). As the mature group of eggs got discharged, their place was taken up by maturing group of eggs which had already undergone half the maturation process. In the early stage of maturation (Stage III) as seen in the frequency polygon of ova diameter, there was no distinct separation between the first and second batch of eggs. But, in a more advanced stage (Stage V) the mature group of ova appeared distinctly separated from the maturing group. This clear separation of mature group of ova from the maturing group showed that spawning in a single shot might be of short duration. The presence of two groups of eggs in one ovary indicated that an individual fish might spawn more than once during a season.

5.6.4. Gonado-somatic index

According to de Vlaming *et al.*, (1982) the reproductive cycle showed pronounced variations in gonadal size. When assessing gonadal activity, animals of different sizes were frequently sampled and it was generally assumed that gonadal weight depended on animal size and stage of gonad development. Nikolsky (1963) reported that the effects of fish size on gonadal weight were eliminated by expressing gonadal weight as a percentage of body weight. Thus gonado-somatic index (GSI) is broadly utilised as an index of gonadal activity and also as an index of spawning preparedness.

During the present study, the grand mean gonado-somatic index for the entire period was found to be 5.31 for females. However, mean GSI was greater than the grand mean (5.31) during August and September'95 (5.78 and 6.93), May to July'96 (7.55 to 8.60), September and October'96 (6.36 and 7.36) and May to July'97 (5.40 to 7.59) (Table 19). The grand mean gonado-somatic index for the same period was only 1.00 for males. However the gonado-somatic index was greater than the grand mean during August to December'95 (1.31 to 1.06) and January to May'96 (1.06 to 1.09) (Table 20). During South-west (May to September) and North-east (October to December) monsoon months mentioned above, vigorous gonadal activity was evident indicating the spawning season of the scats which has been observed by Barry *et al.*, (1988) also as the same.

Table 19 Gonado-somatic index for female *S.argus*

Year/month	No. of fish	GSI	SD
August '95	50	5.78	3.07
September	52	6.93	4.06
October	46	6.55	4.47
November	50	4.05	3.45
December	27	3.45	2.60
January ,96	34	3.78	2.53
February	29	3.91	3.01
March	35	4.11	3.09
April	52	4.35	3.35
May	55	7.55	3.32
June	50	8.60	3.66
July	68	6.79	4.15
August	60	4.36	2.73
September	60	6.36	3.80
October	60	7.36	4.14
November	50	3.65	3.61
December	38	3.42	1.94
January '97	49	3.60	1.72
February	49	3.84	2.52
March	47	4.14	1.47
April	52	4.54	2.39
May	42	5.40	3.07
June	45	7.34	3.30
July	41	7.59	3.02
Grand mean GSI		5.31	

Table 20 Gonado-somatic index for males *S.argus*

Year/Month	No. of fish	GSI	SD
August ,95	16	1.31	0.33
September	19	0.89	0.40
October	14	1.20	0.33
November	23	1.42	0.45
December	15	1.06	0.29
January '96	11	1.06	0.12
February	15	1.08	0.21
March	25	1.09	0.22
April	23	1.07	0.16
May	30	1.09	0.19
June	23	0.88	0.19
July	27	0.95	0.20
August	27	0.89	0.23
September	22	0.91	0.19
October	20	0.92	0.22
November	21	0.79	0.25
December	22	0.94	0.15
January '97	28	0.97	0.18
February	27	0.87	0.12
March	22	0.96	0.12
April	24	0.95	0.14
May	22	0.98	0.14
June	21	0.93	0.20
July	21	0.88	0.18
Grand mean GSI		1.00	

5.6.5. Size at first maturity

In the present study, the percentage occurrence of gonads in different stages of maturity in relation to size of fish, showed that 95 % of male scats attained first maturity (Stage I) while they were in the size group 120 to 129 mm. On the otherhand 82 % of the female scats attained first maturity (Stage I) when they reached the size group 140 to 149 mm. Thus they were found to be immature when the size was below 120 mm in the male and 140 mm in the female. These findings were in close agreement with that of Barry and Fast (1988) who reported that females reached first sexual maturity at the size of 140 mm and the males reached first sexual maturity at the size of 115 mm.

5.6.6. Fecundity

Fecundity of fishes is generally determined from the number of ova in the ovary of mature fish, a demarcation which varies in different species depending on their spawning habits. Simpson (1951) stated that all his observations on the fecundity of fish had shown that it increased with the size of the fish. Lack (1954) and Bagenal (1957) reported that fecundity was associated more with the size than age. Generally, an exponential relationship between fecundity and length had been noticed, which indicated that fecundity increased more rapidly than the length of the fish (Hickling, 1940; Simpson, 1951; Bagenal, 1957; Qasim and Qayyum, 1963; Morse, 1981). Linear relationship between

fecundity and length has been observed by many workers (Lehman, 1953; Jerald and Brown, 1971; Mathur and Ramsey, 1974). Linear relationship between fecundity and body weight and ovary weight was recorded by some workers (Raitt, 1932; Bagenal, 1957., Pope *et al.*, 1961; Pantulu, 1963). During the present investigation, the fecundity of scat varied from 115,038 to 153,661 in individuals measuring a total length of 235 to 300 mm with body weight ranging from 265 to 350 g. Regression lines fitted to the data relating fecundity and total length, fecundity and body weight, and fecundity and ovary weight appeared linear. Barry and Fast (1988) indicated that the number of oocytes in pre-spawned female scat was proportional to the weight of the fish. The highest number of eggs they found were from a fish that weighed 947 g which produced 807,000 eggs.

5.6.7. Sex ratio

Sex ratio study, considered as one of the most important aspects in fishery biology, was also carried out in the present study to get information on whether one sex dominated the other in the population as a whole or whether males and females moved in separate shoals or whether one sex outnumbered the other at the time of spawning migration.

The findings of the present study indicated that the females always outnumbered the males. Thus the ratio of male to female was 1:2.2. Barry and Fast (1988) have also made similar

observations and found out that the total number of female scats captured each month always exceeded the total number of males and the male to female ratio was 1:3.

5.7. POPULATION GROWTH PARAMETERS

There was no published information on the population growth parameters of the spotted scat in India. Since it formed only a minor fishery, not much information was available. Therefore an attempt was made in the present study to obtain information on the population growth parameters of scat.

During the present investigation, the estimated values of growth parameters were $L\infty$ = 308 and 314 mm, K (/year) = 1.05 and 0.99 for Gulland-Holt plot method and non-linear Algorithm of FISAT respectively and t_o = 0.115 for non-linear Algorithm of FISAT. These values were comparable to the findings of Barry and Fast (1988) who have observed the estimated values (by using Von Bertalanffy growth equation) of $L\infty$ as 250 mm and K as 1.20.

The estimated total instantaneous rate of mortality (Z) for scat calculated by the two methods were 2.32 and 2.35 which were more or less similar. The natural mortality (M) values were 1.83 and 1.75 which were also more or less equal. Fishing mortality coefficients (F) were 0.49 and 0.6. Estimated rate of exploitation (E) ranged from 0.21 to 0.26 (21 to 26%)(Table 14) which

indicated that the stock was underexploited. There was no specific fishing method used to exploit this resource and hence the indication of low rate of exploitation.

It may be noted that the estimates of the above population parameters were all based on data obtained mainly from gill net catches. Hence the results of the present study can be taken only as first approximation to the true population parameters.

5.8. THE ENVIRONMENT AND ECOLOGY OF SCAT

The turbid condition of the Gulf of Mannar waters, during the months of May through September and that of Palk Bay waters during the months of October through April was due to strong winds during South-West and North-East monsoon seasons respectively. Due to this rough weather, the bottom water with nutrients was brought to the surface thereby increasing phytoplankton production. Prasad (1954) found out that during southwest monsoon, the waters in the Gulf of Mannar became turbulent owing to strong winds starting from May and continued upto August. He also found out that the drift of water in this area was from south to north during April through August coinciding with the period of the southwest monsoon when the winds blew from southwest to northeast. From September onwards, i.e., with the onset of the northeast monsoon the direction of the drift got reversed and during this period comparatively calm conditions prevailed in the Gulf of Mannar side because of protection provided by the

landmass. Pillai (1971) has also observed that during northeast monsoon season the Palk Bay side had turbulent seas and turbid waters from September through May. The effects of siltation on corals in the inshore area of Palk Bay side was greater than that in the Gulf of Mannar side, especially during the north east monsoon.

During the present study, it was observed that fishing activities were intensified on the Palk Bay side during the South-West monsoon season and on the Gulf of Mannar side during the North-East monsoon season. According to Jayaraman (1954), the south-west monsoon would last for a period of 6 to 7 months, whereas the north-east monsoon would commence during November and cease in February or early March. With the onset of south-west monsoon, the Gulf of Mannar became rough and choppy, while the Palk Bay was calm. During the north-east monsoon this condition got reversed. Accordingly, fishing operations during the year were done where the sea was calm. Thus, fishing activity on the Palk Bay side was for a larger part of the year and it was of shorter duration on the Gulf of Mannar side. Prabhu (1954) reported that trap fishing was carried out around Mandapam from September to March in the Gulf of Mannar side and from April to August in the Palk Bay side.

During the present study it was observed that the nature of the bottom in the Gulf of Mannar side was of rocky patches intervened by sand and mud, whereas the bottom in the Palk Bay side

was muddy with fine sand. Jayaraman (1954) has already indicated that the inshore region of the Palk Bay was mostly muddy, while the inshore region of the Gulf of Mannar was full of rocky patches with small areas of sand and mud in between. According to a survey conducted by James *et al.*, (1966) bottom conditions in the Palk Bay side were favourable for bottom trawling, whereas the same was not the case in the Gulf of Mannar side because of the presence of patches of rocks and corals with only limited area suitable for trawling operations. According to the present observation, the soil texture in the Gulf of Mannar varied as one went from shore to the deeper region. Near the shore, the bottom consisted of coarse sand and next to this were a region with sand grains, a region with fine sand, and a region with very fine sand. This was supported by the finding of Alakarswamy (1966) that the beach in the Gulf of Mannar near Mandapam as narrow, with very slight sloping and with coarse sand grains near the low water mark, medium sized grains at the middle, and fine grains at the high water mark.

During the present investigation, molluscs, crabs, decapods, holothurians and other associated fauna including fishes were recorded in both the Gulf of Mannar and the Palk Bay. Earlier Nair *et al.*, (1972) had reported that holothurians, *Holothuria atra* and *H.scabra* were common, and decapods were abundant. Closure to the shore, hermit crabs, and snails, especially *Cerrithidea fluviatilis* were abundant. Rao *et al.*, (1972) while studying

the ecology of the intertidal molluscs of the Gulf of Mannar and Palk Bay, observed the presence of prosobranchs, bivalves, sponges, hydroids, polyzoans, polychaetes, isopods, amphipods and crabs.

During the present study, sea grasses, filamentous algae, red algae, brown algae and green algae were recorded. Rao (1972) while studying the ecology of some intertidal algae of Mandapam coast, observed the presence of *Caulerpa* spp., *Turbinaria* spp., *Halimeda opuntia*, *Enteromorpha compressa*, *Sargassum* spp., and *Gracilaria corticata*. He also stated that seagrasses (*Thalassia* and *Cymodocea* spp.,) comprised 16% of the marine plants sampled in the Palk Bay and Gulf of Mannar. Rao (1972) has also reported that the standing crop of all seagrasses in an area of 3.58 km of Palk Bay side alone was about 2000 tons.

Variations in environmental parameters

Some of the important parameters which influence either directly or indirectly the life of fish are temperature, pH, salinity, dissolved oxygen, nutrients such as phosphate, silicate, nitrate and nitrite, primary production and secondary production. According to Ramamirtham (1967), of all the environmental factors, temperature played an important role to influence the behaviour of fish. The sense of temperature in fish seems to be well developed. Salinity variations mainly depend upon rain-

fall, run off from rivers, and evaporation at the sea surface. These variations affect the buoyancy of pelagic eggs and osmotic regulation of fish.

In the present study, the atmospheric temperature did not vary dramatically throughout the study period from August 1995 to July 1997 in both the Gulf of Mannar and Palk Bay sides. Maximum atmospheric temperature values of 32 and 33°C were found during summer months (April, May). Kaliaperumal *et al.*, (1993) have reported similar values i.e, the maximum values of 31 and 32°C in the atmosphere during February 1987 and March 1988 respectively in the Gulf of Mannar side and 32°C during May 1987 in the Palk Bay side. Similarly, the maximum value recorded in the Palk Bay during summer months also coincided with their findings. Similarly Raghuprasad (1954) reported an average atmospheric temperature value of 30°C during 1950 to 1951 in the Gulf of Mannar side. Maximum temperature values of 31 and 32°C in surface water were noticed during summer months in both the Gulf of Mannar and Palk Bay sides in the present study. Kaliaperumal *et al.*, (1993) observed a maximum surface water temperature of 30°C during October 1986 and March 1988 in the Gulf of Mannar side and a maximum value of 31°C in the Palk Bay side during 1988. Thus the maximum values observed during summer months in the present study also coincided with their findings of the Palk Bay side. Raghuprasad (1954) reported a maximum temperature value of 32°C in the surface water during April 1950 and a maximum

value of 31°C in the bottom water during April 1951 in the Gulf of Mannar side. Thus maximum temperature values of 31 and 32°C in surface water noticed during summer months in the present study coincided with the findings of Raghuprasad (1954). Similarly maximum temperature values of 31 and 32°C in the bottom water were noticed during summer months in the present investigation on both the Gulf of Mannar and Palk Bay sides.

Minimum salinity values of 29 ppt during January'97 in the Gulf of Mannar side and 26 ppt during the same month in the Palk Bay side were noticed. Maximum salinity values of 35 and 36 ppt in surface water were seen during southwest monsoon seasons (June to August) in the present study period in both the Gulf of Mannar and Palk Bay. This might have been due to mixing of oceanic water of the Indian Ocean during southwest monsoon season. Kaliaperumal *et al.*, (1993) reported maximum salinity value of 35 ppt during November 1986 and October 1988 in the Gulf of Mannar side and the same maximum value was seen during August 1987 and September and October 1988 in the Palk Bay side. Record of maximum value of salinity in the present investigation also coincided with their findings except that the occurrence was in different months. Jayaraman (1954) reported that maximum salinity value of 36 ppt in surface water was seen during December 1952 in the Gulf of Mannar side and the same value was seen during October 1952 in the Palk Bay side. Maximum salinity values of 35 and 36 ppt in the bottom water were noticed during the southwest

monsoon season in both the Gulf of Mannar and Palk Bay sides. Jayaraman (1954) reported maximum salinity value of 36 ppt in the bottom water during May 1950 in the Gulf of Mannar side. Thus maximum salinity values observed during the southwest monsoon season in the present study also coincided with the findings of Jayaraman (1954).

Maximum dissolved oxygen values of 7 and 8 ppm in surface water were noticed during the southwest monsoon and postmonsoon (January and February) seasons in the present study in the Gulf of Mannar side and during southwest and northeast (November and December) monsoon seasons in the Palk Bay side. Kaliaperumal *et al.*, (1993) have reported slightly higher maximum dissolved oxygen value of 10 ppm during February 1988 in the Gulf of Mannar side and a maximum value of 9 ppm during September 1987 and 1988 in the Palk Bay side. However, Jayaraman (1954) has reported a maximum dissolved oxygen value of 7 ppm in the surface water during January 1950 in the Gulf of Mannar side and a maximum value of 6 ppm during December 1952 in the Palk Bay side. Thus the maximum dissolved oxygen values in surface water during postmonsoon period in the Palk Bay side observed in the present study coincided well with the findings of Jayaraman (1954).

Maximum dissolved phosphate value of 10 ppb in the surface water was seen during the northeast monsoon season in the Gulf

of Mannar and a maximum value of 14 ppb was seen during postmonsoon period in the Palk Bay side. Kaliaperumal *et al.*, (1993) reported maximum dissolved phosphate values of 8.05 ppb and 7.43 ppb during November 1986 and March 1988 respectively in the Gulf of Mannar. Similarly maximum phosphate value of 7.74 ppb was seen by them during July 1988 in the Palk Bay side. The values observed during the present study were higher than those seen earlier. However, Jayaraman (1954) reported maximum dissolved phosphate value of 11 ppb in surface water during March 1952 in the Gulf of Mannar and maximum value of 8 ppb during May 1952 in the Palk Bay side. In the present study, maximum dissolved phosphate values of 8 and 9 ppb in the bottom water were found during the southwest monsoon season in both the Gulf of Mannar and Palk Bay sides. However, Jayaraman (1954) has reported maximum dissolved phosphate value of 11 ppb in the bottom water during February 1952 in the Gulf of Mannar and a maximum value of 7 ppb during November 1951 in the Palk Bay side. Thus there have been fluctuations in the values of dissolved phosphate in the surface and bottom waters.

Maximum dissolved silicate value of 1.19 ppm in surface water was seen during April 1996 in the Gulf of Mannar side and a maximum value of 0.62 ppm was found during June 1996 in the Palk Bay side. Kaliaperumal *et al.*, (1993) have reported maximum dissolved silicate value of 1.24 ppm during April 1987 in the Gulf of Mannar side and a maximum value of 1.26 ppm during July

1988 in the Palk Bay side. The observation of maximum values during summer months in the present study coincided well with the findings of Kaliaperumal *et al.*, (1993) in the Gulf of Mannar side. Similarly the record of maximum values of silicate during the southwest monsoon coincided well with their findings in the Palk Bay side. However, Jayaraman (1954) has reported maximum dissolved silicate value of 0.51 ppm in surface water during December 1954 in the Gulf of Mannar and a maximum value of 0.37 ppm during November 1951 in the Palk Bay. These values were lesser than the values found in the present study. In the present study maximum dissolved silicate value of 0.99 ppm in the bottom water was seen during April 1996 in the Gulf of Mannar side and a maximum value of 1.22 ppm was found during May 1996 in the Palk Bay side. Jayaraman (1954) has reported a maximum dissolved silicate value of 0.40 ppm only in the bottom water during October 1952 in the Gulf of Mannar and a maximum value of 0.48 ppm only during the same period in the Palk Bay side. This clearly indicated that the waters of both the Gulf of Mannar and Palk Bay sides have been loaded with silicate in recent years possibly due to land run off.

Maximum dissolved nitrate value of 89.29 ppb in the surface water was found during May 1996 in the Gulf of Mannar side and a maximum value of 64.43 ppb was seen during June 1996 in the Palk Bay side. Kaliaperumal *et al.*, (1993) have reported a maximum dissolved nitrate value of 51.26 ppb during November 1988 in the

Gulf of Mannar side and a maximum value of 72.41 ppb during September 1988. Jayaraman (1954) has reported a maximum dissolved nitrate value of 57.43 ppb in surface water during July 1951 in the Gulf of Mannar side and a maximum value of 70.03 ppb during December 1951 in the Palk Bay side. Although these values were fluctuating, maximum values found during the southwest monsoon season in the present study were comparable to the findings of Jayaraman (1954) in the Gulf of Mannar side. Maximum dissolved nitrate value of 95.52 ppb in the bottom water was recorded during May 1996 in the Gulf of Mannar side and a maximum value of 55.05 ppb was seen during May 1995 in the Palk Bay side. Jayaraman (1954) has reported a maximum dissolved nitrate value of 61.63 ppb in the bottom water during July 1951 and a maximum value of 71.43 ppb during June 1951 in the Palk Bay side. Maximum values recorded during the southwest monsoon season in the present study in both the Gulf of Mannar and Palk Bay sides were comparable to the findings of Jayaraman (1954).

Maximum dissolved nitrite value of 3.43 ppb in the surface water was seen during February 1997 in the Gulf of Mannar and a maximum value of 5.04 ppb was noticed during July 1996 in the Palk Bay. Maximum dissolved nitrite value of 3.57 ppb in bottom water was recorded during February 1997 in the Gulf of Mannar and a maximum value of 4.41 ppb was seen during January 1997 in the Palk Bay. However, Kaliaperumal *et al.*, (1993) have reported maximum dissolved nitrite value of 11.77 ppb during January 1987

in the Gulf of Mannar and a maximum value of 95.67 ppb during May 1987 in the Palk Bay. These maximum values were too high compared to the maximum values observed in the Palk Bay in the present study.

During the study period of August'95 to July'97, the calculated maximum gross photosynthesis value was 165.37 $mgC/m^3/hr$ in the Gulf of Mannar side and the same in the Palk Bay side was 160.33 $mgC/m^3/hr$ during February'96. The calculated maximum net photosynthesis value of 79.15 $mgC/m^3/hr$ noticed during March 1997 in the Gulf of Mannar side and the maximum value of 146.96 $mgC/m^3/hr$ seen during February 1996 in the Palk Bay side differed from each other. The higher values observed during February'and March'97 both in the Gulf of Mannar and Palk Bay sides indicated that photosynthetic activity was intensive due to clear sunlight in the summer months.

Maximum quantity of zooplankton found was 8.20 ml/l during November 1995 in the Gulf of Mannar side and a maximum quantity of 6.90 ml/l was found during May 1997 in the Palk Bay side. Raghuprasad (1954) has reported maximum zooplankton level of 50 ml/l during October 1950 in the Gulf of Mannar. In the present study the record of maximum level of zooplankton observed during the northeast monsoon was consistent with the findings of Raghuprasad (1954).

5.9. SPOTTED SCAT AS AN ORNAMENTAL FISH IN THE AQUARIUM

During the present study, it was observed that scat fry were able to feed readily on plankton. Thangaraja *et al.*, (1984) have also found out from laboratory experiments that the fry were able to feed on phyto and zooplankton.

5.10. FRY REARING IN THE AQUARIUM

Barry and Fast (1988) described that the tholichthys fry were deep-bodied and laterally compressed. They were usually very dark. They had rough skin without scales and a well developed lateral line. They ranged in size from 0.60 to 1.2 cm approximately. Bony plates were found on their heads. These plates got absorbed as the fry developed into juveniles. However they did not record the number of days taken by the fry to become tholichthys fry. Thangaraja *et al.*, (1984) indicated that the head was protected by bony plates and a strong suprascapular spine. The size of the tholichthys fry was 11 mm. They also have described the various stages of fry development. However they did not observe the number of days taken by the fry to change from one stage to the next stage. During this study also, the presence of bony plates on the head, changes in the development of fry and formation of pigment spots were observed. Unlike the others, the number of days taken by the fry to reach from one stage to the next stage was recorded in the present study. The size of the tholichthys fry was 11.5 mm. Tholichthys fry with bony plates

developed into juvenile stage after metamorphosis in 9 days from the size of 14 mm, loosing the bony plates. Juveniles measuring 20 mm looked like adult scats with light green colour and brown spots.

Thangaraja *et al.*, (1984) have described the various stages of fry ranging from 2 mm to 43.5 mm without recording the number of days taken by the fry from one stage to the next stage. At the time of collection, the length of the fry was 2.5 mm and the exact number of days spent by the fry in the wild after its hatching was not known. From the present observation of rearing fry in the aquarium, it was understood that the fry took more or less 3 days to reach 1 mm in total length. The fry was 2.5 mm at the time of collection. The fry took 3 days to reach a length of 3.5 mm from 2.5 mm, 6 days to reach a length of 5.5 mm from 3.55 mm, 16 days to reach a length of 11 mm from 5.5 mm, 9 days to reach a length of 14 mm from 11 mm and 18 days to reach a length of 20 mm from 14 mm.

5.11. SCAT FISH FISHERY

Mandapam was one of the main and an important marine fish landing centres of the country where there was fishing throughout the year unlike other fish landing centres where there may not be any fishing or may be lesser activity during monsoon seasons. At Mandapam, mechanised boats, boats with in-board engines, big and small size plank-built boats and catamarans were operated

for fishing. Trawl nets, small and big mesh size gill nets, shore seines, hooks, traps and cast nets were the important gears used. During south-west monsoon season, fishing was done on the Palk Bay side, whereas it was done on the Gulf of Mannar side during North-east monsoon season.

Main species which were contributed to major fishery were *Cybium* spp.,*Chirocentrus* spp., *Sardinella* spp., *Dussumieria* spp., *Caranx* spp., *Hemirhamphus* spp., *Tachysurus* spp., *Gerres* spp., *Upeneus* spp., *Leiognathus* spp., *Penaeus* spp., *Portunus* spp., and squids. The species which were contributed to minor fishery were *Lethrinus* spp., *Epinephelus* spp., *Lutjanus* spp., *Plectorhynchus* spp., *Teuthis* spp., *Parupeneus* spp., *chaetodon* spp., *Plotosus* spp., *Callyodon* spp.and mullets.

In recent years scats had become popular and there was a demand in local as well as in inland markets. Scats were considered very good table fish and were expensive fish in the Philippines (Barry *et al.*,1988). Scats were found caught along with other fishes in all types of gears, but in small numbers only. The main source of this fish catch was from small mesh size gill nets (vidu valai). Nowadays, it has formed a minor fishery around Mandapam. Since the scat was caught by small meshed gill nets, locally called vidu valai, the data for this fishery were collected from this type of catch during August'95 to July'97.

Efforts (hours of operation), total catch of fish (other than scats), total catch of scats and its percentage for the months August'95 to July'97 were given in the Tables 21.

During August'95 to July'96, the total catch of fish ranged from 324 to 550 kg, whereas catch of scats varied from 120 (281%) to 242 kg (44%). During August'96 to July'97, the total catch of fish varied from 400 to 728 kg, whereas the catch of scat ranged from 125 (26.32%) to 280 kg (38.46%).

Since the demand for this fish is on the increase in the local as well as in inland markets, the catch of this fish can be increased by increasing the number of hauls and units per day. Since this fish is having the habit of congregating under the bottom of any floating structures on the sea, special structures such as Fish Aggregating Devices can be constructed and utilized for congregating this fish. Then the fish can be caught by scooping them with special type of nets designed for this purpose.

Table 21 Catch data for scat during August '95 to July '97.

Month	Effort (hr)	Total fish catch (kg)	Total catch of scat (kg)	% of scat Fishery
August '95	20	420	120	29
September	25	425	200	47
October	18	324	108	33
November	23	414	138	33
December	25	425	100	24
January '96	20	340	100	29
February	27	459	108	24
March	28	476	168	35
April	26	416	156	38
May	22	528	176	33
June	25	525	225	43
July	22	550	242	44
August	26	520	234	45
September	20	400	200	50
October	28	728	280	38
November	22	462	198	43
December	25	475	125	26
January '97	20	420	140	33
February	27	650	220	34
March	23	621	184	30
April	26	598	208	35
May	25	525	150	29
June	22	594	170	30
July	27	702	243	35

6. SUMMARY

At present the spotted scat *Scatophagus argus* has gained a place among fishes of good market value not only in the coastal markets, but also in the inland markets. Special type of nets locally called Vidu valai were operated to catch this fish. The present study was aimed at getting information mainly about the biology and ecology, because not much information about this fish was available in India except a few works dealing with the food habits of them. A taxonomic study was also carried out to find out variations if any in the description of it by previous workers. Detailed studies on biometry, length-weight relationship, food and feeding habits, reproduction and population growth parameters were carried out. Biochemical composition of muscle, liver and gonad was estimated and its relationship with the gonadal development and spawning was examined. Attention was also given to study the ecology of scat in terms of environmental parameters. Fry rearing was done in marine aquarium tanks. Experiments were also carried out to maintain scat as ornamental fish in aquaria. Data on scat fishery as a minor fishery was also analysed.

During the course of the present study, the scat was found to have 11 dorsal spines, 15-17 dorsal rays, 4 anal spines and 14-15 anal rays. The number of dorsal and anal rays observed by all the previous workers including the present worker varied from

14-18. 11 abdominal and 12 caudal Vertebrae were recorded. 100-115 lateral line and 80-85 transverse scales were found. The observations of all workers on lateral line scales varied in number. The present study indicated that the body of scat was solid, angular and deeply compressed. There was an obvious curvature above the eye on the rostro-dorsal profile of head. Non-protrusible small terminal mouth with bands of minute villiform teeth was found. The body colour was light olive green, darker above, becoming silvery on the abdomen with numerous irregular large round dark brown spots extending on to the fins and tail. Fins were yellowish with light brown markings between the rays.

Juveniles of scat had heavy bony armour on the head and larger spine on the shoulder. The juveniles were olive-brown above the head and bright orange red along the back.

Biometry study indicated that pre-dorsal length had the fastest growth followed by pelvic fin length and head length. Pre-anal length and pre-orbital length had the lowest growth rates. A comparison of the relative growth of spines revealed that the 3rd dorsal spine grew faster than the 2nd anal spine.

Study on length-weight relationship indicated that the value of the exponent "n" was considerably below 3. This might be due to the deep, strongly compressed body of scat. There was sudden increase in weight of the fish on attainment of first maturity.

95% of male scats attained first maturity (Stage I) in the size group 120-129 mm whereas 82% of female scats attained first maturity (Stage I) in the size group 140-149 mm. Analysis of covariance to test equality of length-weight relationship between males and females revealed that there was significant difference between sexes.

Study on food and feeding habits clearly indicated that scats generally preffered phytoplankton, filamentous algae, detritus, Ulva spp., sponges, coral polyps, sea-anemones, bivalves, lepas, prawns, other crustaceans, protozoa, copepods, foraminifera, fish scales and alphids. It was also observed that fish measuring <50 mm fed mainly on phytoplankton, protozoa, detritus and copepods and fish measuring <100mm fed on phytoplankton in addition to the components of other food items. Fish measuring >100mm fed mainly on filamentous algae and detritus.

Study on selectivity of feeding revealed that the diet of scat depended on the availability of food organisms in the environment where they were found commonly. However, scats took filamentous algae and detritus more than other food items. No variation in feeding habits could be observed irrespective of the status of the fish as to whether they fed actively or poorly.

The presence of filamentous algae in the gut contents indicated that the scats browsed and swallowed them. Presence of attached organisms such as sea-anemones, lepas, bivalves and

sponges in the gut contents indicated that fish also scrapped and swallowed them. The fish could also nibble and swallow coral polyps. The presence of detritus, fish scales and foraminiferan shells indicated that these fish consumed these food items also. From these observations, it was clear that the fish had the habit of browsing, scrapping, nibbling and swallowing the prey. Since many of the above mentioned food items were available at the bottom of the sea, the fish could be called a bottom feeder. Since plankton were recorded in the gut contents of young fish, they could be called in their younger stage, as surface feeders. Both animal and plant food items were recorded in the gut contents of scat. Therefore *Scatophagus argus* is an omnivorous fish.

Percentage of moisture content in the muscle, liver and gonad in male and female fish was more or less same in all the stages. However, the moisture content was inversely related to the lipid and carbohydrate content of muscle, liver and gonad. This was observed in both males and females irrespective of the different stages of growth.

Protein content and carbohydrate content in muscle, liver and gonad of both the male and female fish decreased with advancement of maturation, indicating utilization of protein during gonadal development and spawning. Similarly lipid content

in muscle, liver and gonad in male and female fish decreased during gonadal maturation and spawning.

In the male, the highest caloric values (Combined value of protein + carbohydrate + lipid) in muscle, liver and gonad were recorded in stage VII. In female, the highest caloric values in muscle and liver were observed in stage I, whereas the highest caloric value in gonad was observed in stage IV.

Generally there was a decrease in the biochemical composition of all stages, with advancing maturation. The significance of the biochemical analysis lies in the fact that it was the first time it was carried out on this fish *S. argus*.

The present ova diameter study revealed that in stage I (immature), the ovary predominantly contained small transparent immature ova measuring a maximum size of 0.12 mm. In stage II (developing immature and recovering spent), the mode value of ova diameter was 0.28 mm and the maximum diameter was 0.36 mm. In stage III (maturing), the mode value of ova diameter was 0.39 mm with the maximum diameter 0.47 mm. In stage IV (mature), the mode value of ova diameter was 0.45 mm and the maximum ova diameter was 0.58 mm. In Stage V (advanced mature), the mode value of ova diameter was 0.61 mm and the maximum diameter was 0.69 mm. Stage VI (ripe), showed a mode value of 0.67 mm for ova diameter with the maximum diameter 0.75 mm and this indicated the spawning

condition. Stage VII was the spent stage having some residual eggs measuring 75 mm.

In the present study, mature ovary of scat showed that they contained in the early stages of maturation, atleast three groups of ova which were not sharply differentiated. As the fish approached spawning season, the group of mature eggs appeared to grow at a faster rate and got distinctly separated from the group of maturing eggs. Soon after the discharge of this group of eggs, another group of mature eggs took its place. The multiplicity of modes of frequency of ova diameter seen in the mature ovary of the fish indicated that it spawned more than once during a season. The present study also revealed that spawning occurred in scats twice a year, once during the southwest monsoon season (June to August) and the other during the northeast monsoon season (October to November). The mean gonado-somatic indices of male and female fish were greater than the grand mean (1.00 in male, 5.31 in female) during the southwest and northeast monsoon months indicated above. This coincided with the spawning season of the scat.

In the present study, the percentage occurrence of gonads in fish in different stages of maturity in relation to size of fish showed that 95% of male scats attained first maturity (Stage I) while they were in the size group 120 - 129 mm. On the other hand, 82% of the female scats attained first maturity (Stage I) only when they reached the size group 140 - 149 mm. The fecundi-

ty of scat varied from 115,038 to 153,661 in individuals measuring a total length from 235 to 300 mm with the body weight ranging from 265 to 350 g. Regression lines fitted to the data relating fecundity and total length, fecundity and body weight, and fecundity and ovary weight appeared linear. Sex ratio study indicated that the females always outnumbered the males. Thus the ratio of male to female was 1:2.2.

The estimated values of growth parameters were $L\infty$ = 308 and 314 mm, K (1 year) = 1.05 and 0.99, calculated by Gulland-plot method and non-linear Algorithm of FISAT statistical package method respectively and to = 0.115 for non-linear Algorithm of FISAT. The estimated total instantaneous rates of mortality (Z) were 2.32 and 2.33 which were more or less equal (observed by the two methods). The natural mortality values (M) were 1.83 and 1.75 which were also more or less similar. Fishing mortality coefficient (F) ranged from 0.21 to 0.26 (21% to 26%) which indicated that the stock was under-exploited.

With the onset of the south-west monsoon Gulf of Mannar became rough and choppy, while Palk Bay was calm. During the north-east monsoon, this condition got reversed. Accordingly fishing operations during the year were done where the sea was calm. During the south-west monsoon the flow of water was from the Gulf of Mannar side to Palk Bay side and during north-east

monsoon the flow was from the Palk Bay side to the Gulf of Mannar side.

It was observed that the nature of the bottom in the Gulf of Mannar was rocky patches intervened by sand and mud whereas the bottom in the Palk Bay side was muddy with fine sand. Molluscs, crabs, decapods, holothurians and other associated fauna including fishes were recorded in both the Gulf of Mannar and Palk Bay sides. Sea grasses, filamentous algae, red algae and green algae ware also recorded.

Monthly variations in atmospheric temperature, water temperature, salinity, dissolved oxygen and nutrients in the inshore waters of the Gulf Mannar and Palk Bay near Mandapam (South India) were recorded during August 1995 to July 1997. Atmospheric temperature, surface water and bottom water temperature ranged from 26.0 to 32.2°C; 25.6 to 32.0°C and 25.7 to 32.0°C respectively during August'95 to July'97 in the Gulf of Mannar side whereas the same parameters varied from 25.7 to 33.0°C, 26.2 to 32.0°C and 26.4 to 32.0°C respectively during August'95 to July'97 in the Palk Bay side.

pH of surface water ranged from 8.1 to 8.3 and that of bottom water ranged from 8.0 to 8.6 during the study period in the Gulf of Mannar side. At the same time the pH of surface water varied from 8.0 to 8.8 and that of bottom water ranged from 8.1 to 8.6 in the Palk Bay side. Salinity of surface water ranged

from 29.6 to 36.0 ppt and in the bottom water it ranged from 28.7 to 36.0 ppt during the study period in the Gulf of Mannar side. At the same time salinity of surface water varied from 26.3 to 35.4 ppt and in the bottom water it ranged from 26.9 to 35.6 ppt in the palk Bay side.

Dissolved oxygen of surface water ranged from 4.9 to 7.8 ppm and in the bottom water it ranged from 4.7 to 9.7 ppm during August'95 to July'97 in the Gulf of Mannar side. During the same period the dissolved oxygen of surface water varied from 4.3 to 8.4 ppm and in the bottom water it ranged from 4.9 to 8.6 ppm in the Palk Bay side. Dissolved phosphate of surface water ranged from 0.9 to 10.7 ppb and in the bottom water it varied from 0.9 to 10.7 ppb during August'95 to July'97 in the Gulf of Mannar side. Dissolved phosphate of surface water varied from 1.6 to 14.1 ppb and in the bottom water it ranged from 0.9 to 12.2 ppb during the same time in the Palk Bay side. Dissolved silicate of surface water ranged from 0.04 to 1.19 ppm and in the bottom water it ranged from 0.04 to 0.99 ppm during August'95 to July'97 in the Gulf of Mannar side. At the same time the dissolved silicate of surface water varied from 0.08 to 0.62 ppm and in the bottom water it ranged from 0.08 to 1.22 ppm in the Palk Bay side.

Dissolved nitrate of surface water ranged from 10.51 to 89.29 ppb and in the bottom water it ranged from 10.55 to 95.52 ppb during the study period in the Gulf of Mannar side. Dis-

solved nitrate of surface water varied from 10.51 to 64.43 ppb and in the bottom water it varied from 10.51 to 55.05 ppb during the study period in the Palk Bay side. Dissolved nitrite of surface water ranged from 0.14 to 3.43 ppb and in the bottom water it ranged from 0.14 to 3.57 ppb during August'95 to July'97 in the Gulf of Mannar side. At the same time the dissolved nitrite of surface water ranged from 0.14 to 5.04 ppb and in the bottom water it ranged from 0.14 to 4.41 ppb in the Palk Bay side.

Gross photosynthesis ranged from 22.04 to 165.37 $mgC/m^3/hr$ and net photosynthesis ranged from 8.82 to 79.15 $mgC/m^3/hr$ during the study period in the Gulf of Mannar side. At the same time gross photosynthesis ranged from 33.58 to 160.33 $mgC/m^3/hr$ and net photosynthesis ranged from 10.18 to 146.96 $mgC/m^3/hr$ in the Palk Bay side. The quantity of zooplankton ranged between 2.50 and 8.20 ml/l during August'95 to July'97 in the Gulf of Mannar side which it ranged from 3.30 to 6.90 ml/l during the same period in the Palk Bay side.

Frank (1979) has commented that the scat was always an active fish, and behaved in a friendly and peaceful manner towards other species. He also pointed out that its `wobbly' style of swimming was reminiscent of that of Angelfishes. Morgan (1983) stated that they were attractive species, and the body shape resembled butterfly fishes, a group to which they were

closely related. Scats were a popular aquarium species because of their appearance, hardiness, slow growth and personable behaviour. These characters of the scats were also observed during the present study.

Barry and Fast (1988) reported that food recommended for aquarium fish included boiled lettuce or spinach, steeped oatmeal and common aquarium plants such as *Nitella* spp., or *Riccia* spp., water fleas, worms, insects and dried feeds. Through the present investigation, it was understood that cheap food items like trash fish and freely available marine filamentous algae were the best fresh food for maintaining scats in marine aquaria for ornamental purpose.

From the present study of rearing fry in marine aquarium tanks, it was understood that the fry took more or less 3 days to gain 1 mm in length. The fry was 2.5 mm at the time of collection. It was calculated that the fry took 3 days to reach a length of 3.5 mm from 2.5 mm, 6 days to reach a length of 5.5 mm from 3.5 mm, 16 days to reach a length of 11 mm from 5.5 mm, 9 days to reach a length of 14 mm from 11 mm and 18 days to reach a length of 20 mm from 14 mm.

The scats were caught by small meshed gill nets and formed a minor fishery. During the one year period from August `95 to July `96, catch of scats varied from 120 to 242 kg. During the

following year August `96 to July `97, the catch of scats ranged from 125 to 280 kg.

The present study was the first one in India where food and feeding habits of scats were investigated well and it revealed that the scats fed on filamentous algae as well as small animal organisms proving that they were omnivorous. Culture of these species can be carried out in freshwater, brackishwater and coastal ponds where filamentous algae and other organisms grow naturally or they can be grown in culture ponds at low costs. The availability of large number of scat seed from the wild during monsoon season will be a boon to enhance the culture of this fish. The present study also has recorded for the time the occurrence of scat fry and fingerlings during monsoon season. This was also the first time in India that spawning biology of scats was investigated. The study indicated that scats spawned during monsoon periods. During spawning seasons, fishing activity should be avoided to prevent the catch of breeders which are responsible to increase the scat fishery. During such off-seasons, culture of this fish can be practiced to compensate the absence of catch from the wild. Through the study of population parameters, it was observed that fishing mortality was less because of poor catch of scats commercially by indigenous gill nets. The scat catch can be increased by using modern types of gill nets. Since scats are having the habit of congregating,

artificial fish shelters or Fish Aggregating Devices can be used for catching these fish.

This was also the first time in India that biochemical composition of scat was studied. Study of biochemical composition of scats showed that they were rich in protein and lipids similar to that in commercially and economically important food fishes. Thus scats can enrich our diet now to fulfill the nutrient requirements. Being an ornamental fish, the young ones can be exploited for aquarium trade. Eventhough scat fry is available in the wild freely at present, there will be a great demand in future. Hence in future, fry can be produced by induced breeding techniques also.

The importance of the present findings can be communicated to the fisherfolk. Since the scats are spawning during monsoon seasons, the fishermen can be advised not to catch adult scats and during that off season they can involve in culture of scats because they can collect scat seed from the wild during the same season. Since there is a great demand for scat seed in other countries especially in the United States of America for aquarium purpose, the fishermen can be encouraged to collect scat seed for the purpose of aquarium trade. Since the scats are rich in protein and lipids and are table fish, awareness can be created among the public to use this fish.

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8. APPENDIX-1

Details of authors, years, genus and species of *Scatophagus* spp described earlier.

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Appendix-2: Index of preponderance of food items (based on occurrence and volume) in *Scatophagus argus* during the month of August 1995.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	33.33	50.00	1666.50	57.14	1
Detritus	33.33	25.00	833.25	28.57	2
Fish scale	11.12	12.50	139.00	4.77	4
Protozoa	22.22	12.50	277.75	9.52	3
	100.00	100.00	2916.50	100.00	
50 to 100 mm					
Unicellular algae	14.43	19.23	277.49	26.87	1
Enteromorpha compressa	14.43	11.53	166.38	16.11	3
Ulva spp.	10.31	7.69	79.28	7.68	5
Sponges	11.34	15.38	174.41	16.89	2
Sea-anemones	7.22	7.69	55.52	5.38	8
Coral polyps	8.25	7.69	63.44	6.14	6
Prawn	3.09	3.85	11.90	1.15	10
Bivalves	2.06	1.92	3.96	0.38	12
Foraminifera	3.09	1.92	5.93	0.57	11
Other crustaceans	5.16	11.53	59.49	5.76	7
Fish scale	6.19	3.85	23.83	2.32	9
Detritus	14.43	7.69	110.97	10.75	4
	100.00	100.00	1032.60	100.00	
100 to 200 mm					
E.compressa	19.42	49.24	956.24	61.67	1
Ulva spp.	12.59	21.28	267.92	17.28	2
Sea-anemones	10.79	4.26	45.97	2.96	4
Sponges	11.52	3.04	35.02	2.26	5
Coral polyps	7.19	2.43	17.47	1.13	6
Prawn	8.99	1.82	16.36	1.05	7
Other crustaceans	6.47	1.21	7.83	0.50	8
Detritus	14.39	13.68	196.86	12.69	3
Fish scale	3.60	0.91	3.28	0.21	9
Foraminifera	1.80	0.61	1.10	0.07	11
Lepas	2.16	0.91	1.97	0.12	10
Bivalves	1.08	0.61	0.66	0.04	12
	100.00	100.00	1550.68	100.00	

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
>200 mm					
Ulva spp.	14.81	26.56	393.35	23.52	2
E. compressa	21.00	50.18	1053.78	63.01	1
Sponges	11.11	3.69	41.00	2.45	4
Sea-anemones	12.35	1.48	18.28	1.09	5
Coral polyps	8.64	0.74	6.39	0.38	7
Other crustaceans	6.17	1.48	9.13	0.55	6
Prawn	2.47	1.48	3.66	0.22	9
Lepas	2.47	1.10	2.72	0.16	10
Bivalves	3.70	1.48	5.48	0.33	8
Detritus	12.35	11.07	136.71	8.17	3
Fish scale	3.70	0.37	1.37	0.08	11
Foraminifera	1.23	0.37	0.46	0.04	12
	100.00	100.00	1672.33	100.00	

Appendix-3: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of September 1995.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	40.00	25.00	1000.00	18.18	2
Fish scale	20.00	25.00	500.00	09.09	3
Detritus	40.00	50.00	4000.00	72.73	1
	100.00	100.00	5500.00	100.00	
50 to 100 mm					
Unicellular algae	16.00	5.06	80.96	5.78	3
E.compressa	16.00	63.29	1012.64	72.39	1
Sea-anemones	10.00	3.80	38.00	2.72	5
Sponges	14.00	7.59	21.59	1.54	6
Prawn	8.00	6.33	50.64	3.62	4
Bivalves	6.00	2.53	15.18	1.09	8
Fish scale	14.00	1.27	17.78	1.27	7
Detritus	16.00	10.13	162.08	11.59	2
	100.00	100.00	1398.87	100.00	
100 to 200 mm					
Ulva spp.	12.74	11.33	144.34	7.29	3
E.compressa	22.93	61.19	1403.09	70.88	1
Coral polyps	9.56	1.70	16.25	0.82	6
Sea-anemones	11.46	4.53	51.91	2.62	4
Crustaceans	6.37	3.97	25.29	1.28	5
Foraminifera	4.16	0.57	2.54	0.13	9
Lepas	1.91	1.42	2.71	0.14	8
Detritus	22.93	14.16	324.69	16.40	2
Fish scale	7.64	1.13	8.63	0.44	7
	100.00	100.00	1979.45	100.00	
>200 mm					
Ulva spp.	10.31	10.35	106.71	7.62	3
E.compressa	15.46	46.55	719.66	51.42	1
Sea-animones	8.59	2.07	17.78	1.27	5
Bivalves	6.87	1.38	9.48	0.68	9
Prawn	6.19	2.76	17.08	1.22	6
Fish scale	12.03	1.38	16.60	1.19	7
Alphids	1.72	2.07	3.56	0.25	10
Sponges	13.75	1.38	18.98	1.36	4
Lepas	9.62	1.03	9.91	0.71	8
Detritus	15.46	31.03	479.72	34.28	2
	100.00	100.00	1399.48	100.00	

Appendix-4: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of October 1995.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	37.50	50.00	1875.00	52.94	1
Protozoa	25.00	16.67	416.75	11.77	3
Detritus	37.50	33.30	1249.88	35.29	2
	100.00	100.00	3541.63	100.00	
50 to 100 mm					
Unicellular algae	15.00	2.67	40.05	2.83	4
E.compressa	15.00	48.00	720.00	50.94	1
Prawns	7.50	1.33	9.98	0.71	8
Sea-anemones	10.00	5.33	53.30	3.77	3
Lepas	5.00	2.67	13.35	0.94	7
Foraminifera	7.50	1.33	9.98	0.71	8
Coral polyps	10.00	2.67	26.70	1.89	5
Fish scale	15.00	1.33	19.95	1.41	6
Detritus	15.00	34.67	520.05	36.80	2
	100.00	100.00	1413.36	100.00	
100 to 200 mm					
E. compressa	19.55	43.62	852.77	48.94	1
Detritus	19.55	30.14	589.24	33.82	2
Ulva spp	11.36	10.64	120.87	6.94	4
Sea-anemones	7.27	1.42	10.32	0.59	5
Coral polyps	5.45	1.06	5.78	0.33	7
Sponges	12.73	11.70	148.94	8.55	3
Crustaceans	8.18	1.06	8.67	0.50	6
Fish scale	15.91	0.36	5.73	0.33	7
	100.00	100.00	1742.32	100.00	
>200 mm					
Detritus	18.35	26.93	494.17	30.66	2
Ulva spp	13.76	23.08	317.58	19.70	3
E.compressa	18.35	38.46	705.74	43.79	1
Crustaceans	11.01	1.54	16.96	1.05	5
Sponges	7.34	6.92	50.79	3.15	4
Bivalves	5.50	0.77	4.24	0.26	7
Lepas	2.75	0.38	1.05	0.07	8
Sea-anemones	9.18	1.15	10.56	0.66	6
Fish scale	13.76	0.77	10.60	0.66	6
	100.00	100.00	1611.69	100.00	

Appendix-5: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of November 1995.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Fish scale	28.58	16.67	476.43	13.80	3
Unicellular algae	35.71	33.33	1190.21	34.48	2
Detritus	35.71	50.00	1785.50	51.72	1
	100.00	100.00	3452.14	100.00	
50 to 100 mm					
Unicellular algae	17.19	2.27	39.02	2.36	3
E.compressa	17.19	51.52	885.63	53.58	1
Copepods	9.38	1.51	14.16	0.86	6
Sea-anemones	7.81	3.03	23.66	1.43	4
Foraminifera	10.93	0.76	8.31	0.50	8
Coral polyps	7.81	1.51	11.79	0.72	7
Fish scale	12.50	1.51	18.88	1.14	5
Detritus	17.19	37.89	651.33	39.41	2
	100.00	100.00	1652.78	100.00	
100 to 200 mm					
Ulva spp	12.63	14.86	187.68	13.04	3
E.compressa	15.40	38.85	598.29	41.58	1
Prawns	5.05	0.64	3.23	0.22	8
Sponges	13.89	10.62	147.51	10.25	4
Bivalves	6.32	1.27	8.03	0.56	7
Lepas	3.79	0.64	2.43	0.17	9
Sea-anemones	12.12	5.52	66.90	4.65	5
Fish scale	15.40	1.06	16.32	1.13	6
Detritus	15.40	26.54	408.72	28.40	2
	100.00	100.00	1439.11	100.00	
>200 mm					
E.compressa	15.22	45.71	695.71	50.39	1
Ulva spp	10.86	20.41	221.65	16.06	3
Sponges	13.04	12.24	159.61	11.56	4
Detritus	15.22	16.33	248.54	18.00	2
Sea-anemones	11.96	1.64	19.61	1.42	5
Crustaceans	8.70	1.22	10.61	0.77	7
Bivalves	4.35	0.41	1.78	0.13	9
Lepas	5.45	0.82	4.45	0.32	8
Fish scale	15.22	1.22	18.57	1.35	6
	100.00	100.00	1380.53	100.00	

Appendix-6: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of December 1995.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
<50 mm					
Unicellular algae	27.27	25.00	681.75	26.09	2
Protozoa	18.19	12.50	227.38	8.70	4
Fish scale	27.27	12.50	340.88	13.04	3
Detritus	27.27	50.00	1363.35	52.17	1
	100.00	100.00	2613.36	100.00	
50 to 100 mm					
E.compressa	15.19	42.73	649.07	46.69	1
Unicellular algae	15.19	5.13	77.92	5.60	4
Prawn	10.13	3.42	34.64	2.49	6
Sponges	11.39	13.68	155.82	11.21	3
Sea-anemones	8.86	5.13	45.45	3.27	5
Foraminifera	5.06	1.17	8.65	0.63	8
Coral polyps	3.80	0.85	3.23	0.23	9
Fish scale	15.19	1.71	25.97	1.86	7
Detritus	15.19	25.64	389.47	28.02	2
	100.00	100.00	1390.22	100.00	
100 to 200 mm					
Ulva spp	11.77	11.49	135.24	9.61	3
E.compressa	15.29	42.01	642.33	45.64	1
Sea-anemones	9.80	1.80	17.64	1.25	4
Sponges	11.77	11.49	135.24	9.61	3
Coral polyps	7.84	1.44	11.29	0.80	6
Prawn	7.06	1.08	7.62	0.54	7
Fish scale	15.29	1.26	16.55	1.18	5
Lepas	3.14	0.35	1.10	0.08	8
Bivalves	2.75	0.35	0.96	0.07	9
Detritus	15.29	28.73	439.28	31.22	2
	100.00	100.00	1407.25	100.00	
>200 mm					
E.compressa	12.00	29.64	355.68	29.99	1
Ulva spp	12.00	24.69	292.28	24.64	2
Prawn	12.00	2.47	29.64	2.50	6
Sponges	12.00	12.35	148.20	12.49	4
Sea-anemones	12.00	3.70	44.40	3.74	5
Lepas	8.00	1.23	9.84	0.83	7
Bivalves	8.00	1.23	9.84	0.83	7
Detritus	12.00	22.22	266.64	22.48	3
Fish scale	12.00	2.47	29.64	2.50	6
	100.00	100.00	1186.16	100.00	

Appendix-7: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of January 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	30.77	20.00	615.40	21.62	2
Fish scale	23.08	10.00	230.80	8.11	3
Copepods	15.38	10.00	153.80	5.40	4
Detritus	30.77	60.00	1846.20	64.87	1
	100.00	100.00	2846.20	100.00	
50 to 100 mm					
Unicellular algae	15.89	2.70	42.90	2.81	4
E.compressa	15.89	46.85	744.45	48.79	1
Sea-anemones	11.21	2.70	30.27	1.98	5
Sponges	13.08	13.52	176.84	11.59	3
Crustaceans	7.48	0.90	6.73	0.44	7
Foraminifera	4.67	0.45	2.10	0.14	8
Fish scale	15.89	1.35	21.45	1.41	6
Detritus	15.89	31.53	501.01	32.84	2
	100.00	100.00	1525.75	100.00	
100 to 200 mm					
E.compressa	16.05	45.20	725.46	47.93	1
Ulva spp.	12.35	15.07	186.11	12.30	3
Prawns	10.28	1.13	11.62	0.77	6
Bivalves	7.40	0.75	5.55	0.37	8
Sea-anemones	8.64	0.75	6.48	0.43	7
Sponges	13.18	6.03	79.48	5.25	4
Fish scale	16.05	0.94	15.09	1.00	5
Detritus	16.05	30.13	483.59	31.95	2
	100.00	100.00	1513.38	100.00	
>200 mm					
E.compressa	15.79	45.72	721.92	48.40	1
Ulva spp.	13.16	19.06	250.83	16.82	3
Sea-anemones	10.53	0.95	10.00	0.67	5
Bivalves	5.26	0.95	5.00	0.34	7
Foraminifera	10.53	0.95	10.00	0.67	5
Lepas	7.89	0.95	7.50	0.50	6
Fish scale	15.79	1.90	30.00	2.01	4
Coral polyps	5.26	0.95	5.00	0.34	7
Detritus	15.79	28.57	451.12	30.25	2
	100.00	100.00	1491.37	100.00	

Appendix-8: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of February 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	30.77	9.09	279.90	9.41	2
Protozoa	23.08	4.55	105.01	3.54	3
Fish scale	15.38	4.55	69.98	2.35	4
Detritus	30.77	81.81	2517.29	84.70	1
	100.00	100.00	2971.98	100.00	
50 to 100 mm					
Unicellular algae	13.80	1.85	25.53	1.92	5
E.compressa	13.80	44.45	613.41	46.05	1
Copepods	8.61	1.85	15.93	1.20	6
Prawns	10.33	3.70	38.22	2.87	4
Sea-anemones	13.80	1.85	25.53	1.92	5
Sponges	12.06	14.82	178.73	13.42	3
Fish scale	13.80	1.85	25.53	1.92	5
Detritus	13.80	29.63	408.89	30.70	2
	100.00	100.00	1331.77	100.00	
100 to 200 mm					
Ulva spp	12.05	14.98	180.51	14.83	3
E.compressa	12.35	39.93	493.14	40.50	1
Coral polyps	9.04	1.16	10.49	0.86	7
Lepas	8.43	0.67	5.65	0.46	9
Bivalves	9.63	1.00	9.63	0.79	8
Sponges	12.05	9.98	120.26	9.87	4
Sea-anemones	11.75	1.33	15.63	1.28	5
Fish scale	12.35	1.00	12.35	1.01	6
Detritus	12.35	29.95	369.88	30.38	2
	100.00	100.00	1217.54	100.00	
>200 mm					
E.compressa	12.50	32.00	400.00	32.43	1
Ulva spp	12.50	26.67	333.38	27.02	3
Crustaceans	8.33	1.33	11.08	0.90	6
Sea-anemones	12.50	1.33	16.63	1.35	5
Bivalves	8.33	1.33	11.08	0.90	6
Fish scale	12.51	1.33	16.64	1.35	5
Lepas	8.33	1.33	11.08	0.90	6
Sponges	12.50	5.34	66.75	5.41	4
Detritus	12.50	29.34	366.75	29.74	2
	100.00	100.00	1233.39	100.00	

Appendix-9: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of March 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Protozoa	16.66	7.14	118.95	4.41	4
Fish scale	27.78	7.14	198.35	7.35	3
Unicellular algae	27.78	14.29	396.98	74.71	2
Detritus	27.78	71.43	1984.33	73.53	1
	100.00	100.00	2698.61	100.00	
50 to 100 mm					
Unicellular algae	13.33	1.81	24.13	1.95	4
Fish scale	13.33	0.60	8.00	0.62	8
Detritus	13.33	30.12	401.50	32.42	2
Copepods	9.99	1.21	12.09	0.98	7
E.compressa	13.34	48.19	642.85	51.90	1
Sponges	8.89	12.05	107.12	8.65	3
Sea-anemones	7.78	2.41	18.75	1.50	5
Coral polyps	5.56	0.60	3.34	0.27	10
Crustaceans	6.67	2.41	16.07	1.30	6
Foraminifera	7.78	0.60	4.67	0.38	9
	100.00	100.00	1238.52	100.00	
100 to 200 mm					
Detritus	12.11	28.30	342.71	29.97	2
E.compressa	12.11	40.43	489.61	42.81	1
Ulva spp.	9.69	12.13	117.54	10.28	3
Prawns	9.20	1.08	9.94	0.87	8
Sponges	10.89	10.78	117.39	10.27	4
Coral polyps	9.20	0.81	7.45	0.65	9
Bivalves	6.05	0.81	4.90	0.43	10
Lepas	7.26	2.70	19.60	1.71	6
Sea-anemones	11.38	1.88	21.39	1.87	5
Fish scale	12.11	1.08	13.08	1.14	4
	100.00	100.00	1143.61	100.00	
>200 mm					
E.Compressa	12.66	42.42	537.04	43.32	1
Detritus	12.66	29.09	368.28	29.71	2
Crustaceans	10.33	2.42	25.00	2.02	5
Sponges	12.66	7.28	92.16	7.44	4
Sea-anemones	10.13	2.42	24.51	1.98	6
Lepas	7.59	2.42	18.37	1.48	7
Bivalves	8.85	0.61	5.40	0.44	9
Fish scale	12.66	1.22	15.45	1.25	8
	100.00	100.00	1239.65	100.00	

Appendix-10: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of April 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	35.72	25.00	893.00	25.64	2
Fish scale	28.56	12.50	357.00	10.25	3
Detritus	35.72	62.50	2232.50	64.11	1
	100.00	100.00	3482.50	100.00	
50 to 100 mm					
Unicellular algae	12.58	1.41	17.74	1.45	6
E.Compressa	12.58	45.94	577.93	47.18	1
Prawns	9.94	2.12	21.07	1.72	5
Bivalves	6.62	0.71	4.70	0.38	8
Sea-anemones	10.60	3.53	37.42	3.05	4
Coral polyps	5.30	0.71	3.76	0.31	9
Sponges	11.92	12.72	151.62	12.38	3
Foraminifera	5.30	0.35	1.86	0.15	10
Fish scale	12.58	0.71	8.93	0.73	7
Detritus	12.58	31.80	400.04	32.65	2
	100.00	100.00	1225.07	100.00	
100 t0 200 mm					
Ulva spp.	10.72	14.37	154.05	13.08	3
E.Compressa	12.50	43.12	539.00	45.77	1
Copepods	8.04	1.03	8.28	0.70	6
Prawns	7.14	0.82	5.85	0.50	8
Sponges	9.82	5.55	54.50	4.63	4
Bivalves	5.36	0.82	4.40	0.37	11
Lepas	4.46	1.23	5.49	0.47	9
Sea-anemones	9.46	1.03	9.74	0.83	5
Coral polyps	7.50	0.82	6.15	0.52	7
Fish scale	12.50	0.41	5.13	0.44	10
Detritus	12.50	30.80	385.00	32.69	2
	100.00	100.00	1177.59	100.00	
>200 mm					
E.Compressa	11.27	40.53	456.89	41.30	1
Ulva spp.	11.27	20.27	228.44	20.65	3
Prawns	8.45	1.35	11.48	1.04	8
Sponges	9.86	4.05	39.93	3.61	4
Bivalves	9.86	1.35	13.31	1.19	7
Lepas	8.45	1.35	11.41	1.03	9
Sea-anemones	11.27	3.38	38.09	3.44	5
Coral polyps	7.03	1.35	9.49	0.86	10
Fish scale	11.07	2.03	22.88	2.09	6
Detritus	11.27	24.33	274.20	24.79	2
	100.00	100.00	1106.12	100.00	

Appendix-11: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of May 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
<50 mm					
Unicellular algae	30.77	16.67	512.94	17.78	2
Fish scale	23.08	8.33	192.26	6.67	3
Protozoa	15.38	8.33	128.12	4.44	4
Detritus	30.77	66.67	2051.44	71.11	1
	100.00	100.00	2884.76	100.00	
50 to 100 mm					
E.compressa	14.95	44.78	669.49	43.36	1
Unicellular algae	12.15	0.99	12.03	0.78	6
Fish scale	14.02	0.99	13.88	0.90	5
Sponges	15.89	14.02	237.24	15.37	3
Sea-anemones	7.48	0.50	3.74	0.24	7
Crustaceans	8.41	1.99	16.74	1.08	4
Foraminifera	5.61	0.50	2.81	0.18	8
Bivalves	4.62	0.50	2.34	0.15	9
Detritus	16.82	34.82	585.67	37.94	2
	100.00	100.00	1543.91	100.00	
100 to 200 mm					
Fish scale	12.50	0.80	10.00	0.82	6
Ulva spp	11.05	8.85	97.79	8.04	4
E.compressa	12.50	48.79	609.88	50.14	1
Bivalves	8.14	0.54	8.68	0.71	7
Lepas	9.01	0.54	4.87	0.40	9
Prawns	10.75	1.88	20.21	1.66	5
Sponges	11.63	13.40	155.84	12.81	3
Sea-anemones	7.56	0.80	6.05	0.50	8
Coral polyps	4.36	0.27	1.18	0.10	10
Detritus	12.50	24.13	301.63	24.82	2
	100.00	100.00	1216.13	100.00	
>200 mm					
E.compressa	12.39	39.07	484.08	36.50	1
Ulva spp	11.21	12.40	139.00	10.48	5
Sea-anemones	10.32	1.09	11.25	0.85	6
Foraminifera	5.31	0.31	1.65	0.13	10
Lepas	2.66	0.61	1.62	0.12	11
Sponges	11.80	13.95	164.61	12.41	3
Fish scale	12.39	0.93	142.77	10.77	4
Coral polyps	8.85	0.62	5.49	0.41	8
Bivalves	8.26	0.47	3.88	0.29	9
Prawns	4.42	1.55	6.85	0.52	7
Detritus	12.39	29.45	364.89	27.52	2
	100.00	100.00	1326.09	100.00	

Appendix-12: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of June 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
<50 mm					
Unicellular algae	37.50	15.39	577.13	15.80	2
Fish scale	25.00	7.69	192.25	5.26	3
Detritus	37.50	76.92	2884.50	78.94	1
	100.00	100.00	3653.88	100.00	
50 to 100 mm					
E.compressa	15.08	52.09	785.52	53.35	1
Unicellular algae	15.08	2.08	31.39	2.13	3
Foraminiferans	6.35	1.04	6.60	0.45	8
Crustaceans	7.94	1.57	12.47	0.85	6
Coral polyps	8.73	1.04	9.08	0.62	7
Bivalves	5.55	0.52	2.89	0.20	9
Fish scale	12.70	1.04	13.21	0.90	5
Sea-anemones	13.49	1.04	14.03	0.95	4
Detritus	15.08	39.58	596.87	40.55	2
	100.00	100.00	1472.04	100.00	
100 to 200 mm					
Ulva spp	13.71	13.60	186.46	13.79	3
E.compressa	13.71	42.49	582.54	43.07	1
Sponges	13.15	12.47	163.98	12.12	4
Prawns	10.29	1.13	11.63	0.86	5
Fish scale	12.57	0.85	10.68	0.79	6
Sea-anemones	8.57	0.57	4.88	0.36	7
Lepas	6.86	0.28	1.92	0.14	9
Bivalves	7.43	0.28	2.08	0.15	8
Detritus	13.71	28.33	388.40	28.72	2
	100.00	100.00	1352.57	100.00	
>200 mm					
E.compressa	12.20	38.35	467.87	42.13	1
Ulva spp	10.77	22.55	242.86	21.87	3
Prawns	9.09	0.75	6.82	0.61	6
Fish scale	11.24	1.00	11.24	1.01	5
Foraminifera	7.17	0.50	3.59	0.32	7
Sponges	9.56	11.29	107.93	9.72	4
Bivalves	6.46	0.50	3.23	0.29	8
Coral polyps	7.66	0.38	2.91	0.26	9
Lepas	4.31	0.25	1.08	0.10	10
Sea-anemones	10.77	0.63	6.79	0.61	6
Detritus	10.77	23.80	256.33	23.08	2
	100.00	100.00	1110.65	100.00	

Appendix-13: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of July 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	37.93	18.18	689.57	18.80	2
Detritus	37.93	72.73	2758.65	75.22	1
Fish scale	24.14	9.09	219.43	5.98	3
	100.00	100.00	3667.65	100.00	
50 to 100 mm					
Unicellular algae	17.17	02.69	46.19	3.44	4
E. Compressa	10.10	37.59	379.66	28.29	2
Sponges	8.08	6.71	54.22	4.04	3
Sea-anemones	12.12	1.34	16.24	1.21	7
Foraminifera	7.07	0.67	4.74	0.35	9
Fish scale	15.16	2.01	30.47	2.27	5
Copepods	9.09	2.68	24.36	1.82	6
Bivalves	4.04	0.67	2.71	0.20	8
Detritus	17.17	45.64	783.64	58.38	1
	100.00	100.00	1342.23	100.00	
100 t0 200 mm					
E.Compressa	14.23	42.71	607.76	47.07	1
Ulva spp.	9.12	10.68	97.40	7.54	4
Ponges	9.85	11.39	112.19	8.69	3
Prawns	6.57	1.42	9.33	0.72	7
Sea-anemones	9.49	1.07	10.15	0.77	6
Coral Polyps	8.40	0.71	5.96	0.46	8
Fish scale	11.68	0.89	10.40	0.82	5
Bivalves	10.95	0.52	5.69	0.44	9
Lepas	5.48	0.36	1.97	0.15	10
Detritus	14.23	30.25	430.46	33.34	2
	100.00	100.00	1291.31	100.00	
>200 mm and above					
Ulva spp.	10.98	13.72	150.65	12.18	3
E.Compressa	13.17	41.15	541.95	43.79	1
Prawns	9.76	1.37	13.37	1.08	7
Sea-anemones	10.24	1.37	14.03	1.13	6
Foraminifera	8.54	0.82	7.00	0.57	8
Sponges	9.27	8.23	76.29	6.16	4
Fish scale	13.17	1.10	14.49	1.17	5
Bivalves	6.82	0.42	2.86	0.23	9
Lepas	4.88	0.27	1.32	0.11	10
Detritus	13.17	31.55	415.51	33.58	2
	100.00	100.00	1237.47	100.00	

Appendix-14: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of August 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	28.00	11.54	323.12	11.73	2
Fish scale	28.00	7.69	215.32	7.82	3
Protozoa	16.00	3.85	61.60	2.24	4
Detritus	28.00	76.92	2153.76	78.21	1
	100.00	100.00	2753.80	100.00	
50 to 100 mm					
Unicellular algae	14.29	3.15	45.01	3.22	4
E.compressa	14.29	47.24	675.06	48.23	1
Crustaceans	10.00	1.57	15.70	1.12	7
Sponges	12.85	9.46	121.56	8.69	3
Sea-anemones	11.42	1.57	17.93	1.28	6
Fish scale	14.29	1.57	22.44	1.60	5
Bivalves	8.57	0.79	6.77	0.48	8
Detritus	14.29	34.65	495.15	35.38	2
	100.00	100.00	1399.62	100.00	
100 to 200 mm					
E.compressa	12.65	40.90	517.39	43.82	1
Ulva spp	9.55	15.58	148.79	12.60	3
Sponges	10.02	8.77	87.88	7.44	4
Prawns	9.07	1.17	10.61	0.90	6
Sea-anemones	10.74	0.98	10.53	0.89	7
Fish scale	12.65	1.08	13.66	1.16	5
Bivalves	6.68	0.49	3.27	0.28	9
Lepas	7.64	0.39	2.98	0.25	10
Coral polyps	8.35	0.49	4.09	0.35	8
Detritus	12.65	30.15	381.40	32.31	2
	100.00	100.00	1180.60	100.00	
>200 mm					
Ulva spp	10.85	15.03	163.08	15.40	3
E.compressa	10.85	37.59	407.85	38.51	1
Prawns	9.49	1.13	10.72	1.01	7
Coral polyps	8.47	1.32	11.18	1.06	6
Sea-anemones	10.51	0.94	9.88	0.93	8
Sponges	10.17	12.03	122.35	11.55	4
Fish scale	10.85	1.13	12.26	1.15	5
Foraminifera	6.78	0.75	5.09	0.48	10
Lepas	6.10	1.13	6.90	0.65	9
Bivalves	5.08	0.75	3.81	0.36	11
Detritus	10.85	28.20	305.97	28.89	2
	100.00	100.00	1059.09	100.00	

Appendix-15: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of September 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	35.00	27.27	954.45	28.00	2
Fish scale	30.00	18.18	545.40	16.00	3
Detritus	35.00	54.55	1909.25	56.00	1
	100.00	100.00	3409.10	100.00	
50 to 100 mm					
Unicellular algae	15.85	2.61	41.37	2.75	4
E.compressa	15.85	48.70	771.90	51.23	1
Detritus	15.85	34.78	551.26	36.58	2
Sea-anemones	9.76	1.74	16.98	1.13	7
Sponges	7.32	3.48	25.47	1.67	6
Foraminifera	8.54	1.74	14.86	0.99	8
Crustaceans	10.98	5.21	57.20	3.80	3
Fish scale	15.85	1.70	27.58	1.83	5
	100.00	100.00	1506.62	100.00	
100 to 200 mm					
E.compressa	14.01	44.01	616.58	48.55	1
Ulva spp.	8.70	19.56	170.17	13.40	3
Sponges	12.08	7.33	88.55	6.97	4
Coral polyps	10.63	0.98	10.42	0.82	7
Prawns	7.25	0.73	5.29	0.42	8
Sea-anemones	13.04	0.98	12.78	1.01	6
Fish scale	14.00	1.47	20.58	1.62	5
Bivalves	6.28	0.49	3.08	0.24	9
Detritus	14.01	24.45	342.54	26.97	2
	100.00	100.00	1269.99	100.00	
>200 mm					
Ulva spp.	10.97	22.60	247.92	22.02	3
E.compressa	11.62	36.16	420.18	37.32	1
Sea-anemones	9.87	0.90	8.88	0.79	7
Lepas	8.33	0.68	5.66	0.50	8
Bivalves	8.55	0.56	4.79	0.43	10
Sponges	10.53	9.04	95.19	8.45	4
Coral polyps	7.68	0.68	5.22	0.46	9
Prawns	9.21	1.36	12.53	1.11	5
Fish scale	11.62	0.90	10.46	0.93	6
Detritus	11.62	27.12	315.13	27.99	2
	100.00	100.00	1125.96	100.00	

Appendix-16: Index of preponderance of food items (based on occurrence and volume) in *S.argus* during the month of October 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	23.81	11.11	264.53	9.62	2
Fish scale	28.57	5.56	158.85	5.77	3
Protozoa	19.05	5.56	105.92	3.85	4
Detritus	28.57	77.77	2221.89	80.76	1
	100.00	100.00	2751.19	100.00	
50 to 100 mm					
Unicellular algae	10.26	1.90	19.49	1.58	8
E.compressa	13.68	36.01	492.62	39.79	1
Ulva spp.	8.54	11.37	97.10	7.84	4
Sponges	11.11	9.48	105.32	8.51	3
Sea-anemones	9.40	1.90	17.86	1.44	9
Coral polyps	11.96	2.37	28.35	2.29	6
Prawns	7.69	4.74	36.45	2.94	5
Fish scale	13.68	1.90	25.99	2.10	7
Detritus	13.68	30.33	414.91	33.51	2
	100.00	100.00	1238.00	100.00	
100 to 200 mm					
ULva spp.	11.51	12.50	143.88	12.92	3
E.compressa	11.51	45.14	519.56	46.67	1
Sponges	10.07	10.42	104.93	9.42	4
Prawns	8.64	2.08	17.97	1.61	5
Bivalves	7.19	0.69	4.96	0.45	9
Foraminifera	6.48	0.69	4.47	0.40	10
Sea-anemones	7.91	1.39	10.99	0.99	7
Coral polyps	8.64	1.04	8.99	0.81	8
Fish scale	11.51	1.39	16.00	1.44	6
Lepas	5.03	0.35	1.76	0.16	11
Detritus	11.51	24.31	279.81	25.13	2
	100.00	100.00	1113.32	100.00	
200 mm					
Ulva spp.	10.28	13.12	134.87	11.83	3
E.compressa	11.96	41.58	497.30	43.60	1
Sponges	10.28	9.85	101.26	8.88	4
Sea-anemones	8.97	1.09	9.78	0.86	8
Bivalves	8.42	0.66	5.56	0.49	9
Lepas	7.10	0.66	4.69	0.41	10
Fish scale	11.96	1.31	15.66	1.37	6
Crustaceans	9.35	1.97	18.42	1.62	5
Coral polyps	9.72	1.31	12.73	1.11	7
Detritus	11.96	28.45	340.26	29.83	2
	100.00	100.00	1140.53	100.00	

Appendix-17: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of November 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
50 mm					
Unicellular algae	41.67	33.33	1388.86	37.04	2
Detritus	41.67	50.00	2083.50	55.56	1
Copepods	16.66	16.67	277.72	7.40	3
	100.00	100.00	3750.08	100.00	
50 to 100 mm					
Unicellular algae	15.53	2.26	35.10	2.40	4
Ulva spp.	7.78	4.52	35.17	2.40	4
E.compressa	15.53	54.23	842.19	57.58	1
Crustaceans	6.80	1.13	7.68	0.52	7
Sea-anemones	8.74	1.13	9.88	0.68	6
Sponges	11.65	5.65	65.82	4.50	3
Foraminifera	5.82	1.13	6.58	0.45	8
Fish scale	12.62	1.70	21.45	1.47	5
Detritus	15.53	28.25	438.72	30.00	2
	100.00	100.00	1462.59	100.00	
100 to 200 mm					
Ulva spp.	6.67	3.57	23.81	1.56	3
E.compressa	16.00	53.57	857.12	56.33	1
Sponges	8.89	2.23	19.82	1.30	4
Coral polyps	9.33	0.89	8.30	0.55	7
Sea-anemones	11.11	1.12	12.44	0.82	6
Copepods	5.34	0.45	2.40	0.16	9
Crustaceans	8.00	0.67	5.36	0.35	8
Bivalves	4.44	0.45	2.00	0.13	10
Fish scale	14.22	1.34	19.05	1.25	5
Detritus	16.00	35.71	571.36	37.55	2
	100.00	100.00	1521.66	100.00	
200 mm					
E.compressa	12.46	49.91	621.88	51.93	1
Ulva spp.	7.61	3.84	29.22	2.44	4
Prawn	10.38	1.15	11.94	1.00	7
Lepas	6.23	0.77	4.80	0.40	9
Coral polyps	9.68	0.96	9.29	0.78	8
Sponges	10.73	3.07	32.94	2.75	3
Sea-anemones	9.00	1.34	12.06	1.01	6
Foraminifera	5.54	0.77	4.27	0.36	10
Bivalves	4.84	0.38	1.84	0.15	11
Detritus	12.46	36.47	454.42	37.94	2
Fish	11.07	1.34	14.83	1.24	5
	100.00	100.00	1197.49	100.00	

Appendix-18: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during for the month of December 1996.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
<50 mm					
Detritus	40.00	76.93	3077.20	80.01	1
Unicellular algae	40.00	15.38	615.20	15.99	2
Fish scale	20.00	7.69	153.80	4.00	3
	100.00	100.00	3846.20	100.00	
50 to 100 mm					
E.compressa	14.49	58.82	852.30	59.78	1
Unicellular algae	11.59	1.47	17.04	1.19	6
Sea-anemones	10.15	1.47	14.92	1.04	7
Sponges	13.04	4.41	57.51	4.03	3
Bivalves	8.71	0.74	6.45	0.45	8
Crustaceans	13.04	1.47	19.17	1.34	5
Fish scale	14.49	2.21	32.02	2.25	4
Detritus	14.49	29.41	426.15	29.92	2
	100.00	100.00	1425.56	100.00	
100 to 200 mm					
Ulva spp.	10.36	6.06	62.78	4.55	3
E.compressa	14.25	48.48	690.84	50.04	1
Crustaceans	10.88	1.52	16.54	1.20	6
Sponges	11.14	4.55	50.69	3.67	4
Copepods	9.07	1.21	10.97	0.79	7
Foraminifera	9.33	1.06	9.89	0.72	8
Bivalves	7.25	0.91	6.60	0.47	9
Fish scale	12.95	1.36	17.61	1.28	5
Detritus	14.77	34.85	514.73	37.28	2
	100.00	100.00	1380.65	100.00	
>200 mm					
Ulva spp.	13.64	16.00	218.24	16.90	3
E.compressa	13.64	40.00	545.60	42.26	1
Lepas	9.09	2.00	18.18	1.41	6
Bivalves	4.54	2.00	9.08	0.70	7
Sponges	13.64	4.00	54.56	4.23	4
Sea-anemones	4.54	2.00	9.08	0.70	7
Coral polyps	4.54	2.00	9.08	0.70	7
Prawns	9.09	2.00	18.18	1.41	6
Fish scale	18.64	2.00	27.28	2.11	5
Detritus	13.64	28.00	381.92	29.58	2
	100.00	100.00	1291.20	100.00	

Appendix-19: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of January 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	37.50	11.77	441.38	12.01	2
Fish scale	25.00	5.88	147.00	4.00	3
Detritus	37.50	82.35	3088.13	83.99	1
	100.00	100.00	3676.51	100.00	
50 to 100 mm					
Unicellular algae	13.93	2.11	29.39	2.17	4
E.compressa	13.93	47.37	659.86	48.77	1
Sea-anemones	9.84	2.63	25.88	1.91	5
Copepods	6.56	1.05	6.89	0.51	9
Crustaceans	9.02	1.59	14.34	1.06	6
Sponges	13.11	6.31	82.72	6.12	3
Foraminifera	7.38	1.05	7.75	0.57	8
Fish scale	12.30	1.05	12.92	0.96	7
Detritus	13.93	36.84	513.18	37.93	2
	100.00	100.00	1352.93	100.00	
100 to 200 mm					
Ulva spp.	9.11	9.15	83.36	6.70	4
E.compressa	13.30	41.19	547.83	44.01	1
Prawns	8.20	1.14	9.35	0.75	7
Bivalves	8.74	1.37	11.97	0.96	6
Coral polyps	9.47	1.26	11.93	0.96	6
Lepas	7.29	0.92	6.71	0.54	9
Sea-anemones	6.92	1.03	7.13	0.57	8
Sponges	11.29	8.01	90.43	7.27	3
Fish scale	12.39	1.60	19.82	1.59	5
Detritus	13.29	34.33	456.25	36.65	2
	100.00	100.00	1244.78	100.00	
>200 mm					
Ulva spp.	13.79	8.11	111.84	0.97	6
E.compressa	13.79	43.24	596.28	48.75	1
Sponges	13.79	10.82	149.21	12.20	3
Sea-anemones	6.90	1.35	9.31	0.76	7
Bivalves	3.45	1.35	4.66	0.38	8
Foraminifera	6.90	1.35	9.32	0.76	7
Lepas	3.45	1.35	4.66	0.38	8
Crustaceans	10.35	2.76	27.95	2.29	5
Fish scale	13.79	2.70	37.23	3.04	4
Detritus	13.79	27.03	372.74	30.47	2
	100.00	100.00	1223.20	100.00	

Appendix-20: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of February 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Detritus	28.57	82.76	2364.45	87.28	1
Fish scale	19.05	3.45	65.72	2.43	3
Copepods	9.52	3.45	32.84	1.21	5
Protozoa	14.29	3.45	49.30	1.81	4
Unicellular	28.57	6.89	196.85	7.27	2
	100.00	100.00	2709.16	100.00	
50 to 100 mm					
Ulva spp.	8.82	6.31	54.07	4.54	3
E.compressa	12.50	49.82	622.75	52.25	1
Unicellular algae	12.50	1.53	19.13	1.61	5
Sponges	11.03	4.60	50.74	4.26	4
Sea-anemones	9.56	1.91	18.26	1.53	6
Foraminifera	5.88	1.53	9.00	0.75	9
Crustaceans	8.09	1.91	15.45	1.30	7
Coral polyps	7.35	0.77	5.66	0.47	10
Fish scale	11.77	1.15	13.54	1.14	8
Detritus	12.50	30.65	383.13	32.15	2
	100.00	100.00	1191.73	100.00	
100 to 200 mm					
E.compressa	11.16	42.16	470.51	43.52	1
Ulva spp.	10.28	11.92	122.54	11.34	3
Sponges	10.57	6.42	67.85	6.28	4
Prawns	9.99	1.10	10.99	1.02	7
Bivalves	7.78	0.92	6.49	0.66	9
Lepas	7.05	0.92	6.49	0.60	10
Sea-anemones	9.54	1.28	12.21	1.13	6
Copepods	5.14	0.82	4.21	0.39	11
Fish scale	10.72	1.28	13.72	1.27	5
Detritus	11.16	32.08	358.01	33.12	2
Foraminifera	6.61	1.10	7.27	0.62	8
	100.00	100.00	1080.96	100.00	

>200 mm samples were not available

Appendix-21: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of March 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Unicellular algae	38.46	10.53	404.98	10.76	2
Protozoa	23.08	5.26	121.40	3.22	3
Detritus	38.46	84.21	3238.72	86.02	1
	100.00	100.00	3765.10	100.00	
50 to 100 mm					
Unicellular algae	10.39	1.49	15.48	1.28	6
E.compressa	12.99	44.78	581.69	48.28	1
Sponges	9.09	11.94	108.53	9.01	3
Sea-anemones	7.79	2.24	17.45	1.45	5
Copepods	6.49	1.49	9.67	0.80	8
Bivalves	3.90	0.75	2.93	0.24	9
Foraminifera	2.60	0.75	1.95	0.16	10
Coral polyps	9.09	1.49	13.54	1.12	7
Fish scale	12.99	2.24	29.10	2.42	4
Detritus	12.99	31.34	407.11	33.79	2
Crustaceans	11.68	1.49	17.40	1.45	5
	100.00	100.00	1204.85	100.00	
100 to 200 mm					
Ulva spp	10.60	6.61	70.07	6.08	4
E.compressa	11.84	46.26	547.72	47.54	1
Prawns	10.25	1.54	15.79	1.37	5
Sponges	10.95	7.05	77.20	6.70	3
Sea-anemones	8.83	1.10	9.71	0.84	8
Coral polyps	6.71	0.88	5.90	0.51	10
Copepods	7.95	0.99	7.87	0.68	9
Foraminifera	9.19	1.21	11.12	0.97	7
Fish scale	11.84	1.32	15.63	1.36	6
Detritus	11.84	33.04	391.19	33.95	2
	100.00	100.00	1152.20	100.00	
>200 mm					
Ulva spp	12.50	24.49	306.13	25.53	3
E.compressa	12.50	32.65	408.13	34.04	1
Prawns	6.25	2.04	12.75	1.06	5
Sponges	12.50	2.04	25.50	2.13	4
Sea-anemones	12.50	2.04	25.50	2.13	4
Coral polyps	6.25	2.04	12.75	1.06	5
Bivalves	6.25	2.04	12.75	1.06	5
Lepas	6.25	2.04	12.75	1.06	5
Fish scale	12.50	2.04	25.50	2.13	4
Detritus	12.50	28.58	357.25	29.80	2
	100.00	100.00	1199.01	100.00	

Appendix-22: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of April 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50					
Unicellular algae	35.71	22.22	793.48	20.40	2
Detritus	42.86	66.67	2857.48	73.48	1
Fish scale	21.43	11.11	238.09	6.12	3
	100.00	100.00	3889.05	100.00	
50 to 100 mm					
Unicellular algae	16.30	4.35	70.91	4.93	4
E.compressa	14.13	32.61	460.78	32.05	2
Sea-anemones	8.70	2.17	18.88	1.31	6
Crustaceans	6.52	2.17	14.15	0.99	7
Sponges	13.04	17.39	226.77	15.77	3
Copepods	5.44	1.09	5.93	0.41	8
Fish scale	15.22	2.17	33.03	2.30	5
Bivalves	4.35	1.09	4.74	0.33	9
Detritus	16.30	36.96	602.45	41.91	1
	100.00	100.00	1437.64	100.00	
100 to 200 mm					
E.compressa	14.07	49.11	690.98	51.14	1
Ulva spp.	12.14	12.29	149.20	11.04	3
Sponges	12.86	6.82	87.71	6.49	4
Crustaceans	10.92	1.36	14.85	1.09	5
Bivalves	9.22	0.82	7.56	0.56	7
Lepas	6.07	0.55	3.34	0.25	9
Coral polyps	8.50	0.95	8.08	0.59	6
Foraminifera	4.37	0.27	1.18	0.09	10
Sea-anemones	7.77	0.55	4.27	0.32	8
Detritus	14.08	27.28	384.10	28.43	2
	100.00	100.00	1351.27	100.00	
>200 mm					
Ulva spp.	16.07	13.43	251.82	15.93	3
E.compressa	16.07	44.78	719.61	45.53	1
Prawns	10.72	0.75	8.04	0.51	5
Coral polyps	7.14	0.75	5.36	0.34	6
Sea-anemones	5.36	0.37	1.98	0.13	9
Sponges	8.93	5.23	46.70	2.95	4
Lepas	4.46	0.37	1.65	0.10	10
Bivalves	7.14	0.37	2.64	0.17	8
Foraminifera	8.04	0.37	2.97	0.19	7
Detritus	16.07	33.58	539.63	34.15	2
	100.00	100.00	1580.40	100.00	

Appendix-23: Index of preponderance of food items (based on occurrence and volume) in *S.argus* during the month of May 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Detritus	35.71	80.00	2856.80	81.08	1
Unicellular algae	37.71	13.31	476.01	13.51	2
Protozoa	28.58	6.67	190.63	5.41	3
	100.00	100.00	3523.44	100.00	
50 to 100 mm					
Unicellular algae	14.29	2.27	32.44	2.04	3
E.Compressa	16.33	56.81	927.71	58.38	1
Sponges	10.20	2.27	23.15	1.46	4
Copepods	8.17	1.14	9.31	0.59	7
Prawns	12.24	1.14	13.95	0.88	5
Foraminifera	10.20	1.14	11.63	0.73	6
Sea-anemones	12.24	1.14	13.95	0.88	5
Detritus	16.33	34.09	556.69	35.04	2
	100.00	100.00	1588.83	100.00	
100 to 200 mm					
E.Compressa	13.49	41.34	557.68	42.54	1
Ulva spp.	12.70	19.38	246.13	18.78	3
Crustaceans	12.44	1.29	16.05	1.22	5
Bivalves	9.26	0.90	8.33	0.64	7
Lepas	7.41	0.52	3.85	0.29	9
Foraminifera	8.73	0.65	5.67	0.43	8
Sponges	11.90	5.17	61.52	4.69	4
Sea-anemones	10.58	1.03	10.90	0.83	6
Detritus	13.49	29.72	400.92	30.58	2
	100.00	100.00	1311.05	100.00	
>200 mm					
Ulva spp.	12.38	13.93	172.45	14.30	3
E.Compressa	12.38	44.77	554.25	45.94	1
Sponges	11.43	9.95	113.73	9.43	4
Bivalves	8.57	1.00	8.57	0.71	7
Sea-anemones	9.52	1.49	14.18	1.18	5
Foraminifera	7.62	1.00	7.62	0.63	8
Lepas	5.72	0.50	2.86	0.24	9
Crustaceans	10.48	1.00	10.48	0.87	6
Coral polyps	9.52	1.49	14.18	1.18	5
Detritus	12.38	24.87	307.89	25.52	2
	100.00	100.00	1206.21	100.00	

Appendix-24: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of June 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	Vi Oi / Σ(Vi Oi) x100	Rank
<50 mm					
Fish scale	28.58	15.38	439.56	12.70	3
Unicellular algae	35.71	23.08	824.19	23.81	2
Detritus	37.71	61.54	2197.59	63.49	1
	100.00	100.00	3461.34	100.00	
50 to 100 mm					
Ulva spp.	6.45	7.10	45.80	3.65	4
Unicellular algae	11.29	1.78	20.10	1.60	7
E.Compressa	13.71	47.34	649.03	51.67	1
Sponges	9.68	5.92	57.31	4.56	3
Sea-anemones	10.48	2.37	24.84	1.98	5
Crustaceans	8.87	1.76	15.61	1.24	8
Copepods	6.45	1.18	7.61	0.61	10
Bivalves	7.26	1.18	8.57	0.68	9
Foraminifera	12.10	1.78	21.54	1.71	6
Detritus	13.71	29.59	405.68	32.30	2
	100.00	100.00	1256.09	100.00	
100 to 200 mm					
E.Compressa	13.08	47.24	617.90	48.31	1
Ulva spp.	13.08	15.75	206.01	16.11	3
Coral polyps	10.00	1.18	11.80	0.92	7
Sea-anemones	11.53	1.18	13.61	1.06	6
Lepas	7.69	0.79	6.08	0.48	9
Sponges	9.23	3.94	36.37	2.84	4
Crustaceans	10.77	0.79	8.51	0.67	8
Fish scale	11.54	1.57	18.12	1.42	5
Detritus	13.08	27.56	360.48	28.19	2
	100.00	100.00	1278.88	100.00	
>200 mm					
Ulva spp.	11.17	12.08	134.93	11.21	3
E.Compressa	12.41	45.25	561.55	46.65	1
Sponges	11.66	7.54	87.92	7.30	4
Bivalves	9.43	0.90	8.49	0.71	7
Lepas	7.44	0.75	5.58	0.46	8
Copepods	6.94	0.60	4.16	0.35	10
Coral polyps	7.94	0.60	4.76	0.40	9
Crustaceans	9.93	0.90	8.94	0.74	6
Fish scale	10.67	1.21	12.91	1.07	5
Detritus	12.41	30.17	374.41	31.11	2
	100.00	100.00	1203.65	100.00	

Appendix-25: Index of preponderance of food items (based on occurrence and volume) in *S. argus* during the month of July 1997.

Food items	% of occurrence (Oi)	% of volume (Vi)	Vi Oi	$\frac{Vi\ Oi}{\Sigma(Vi\ Oi)} \times 100$	Rank
<50 mm					
Protozoa	19.44	9.52	185.07	6.92	4
Fish scale	25.00	9.52	238.00	8.91	3
Unicellular algae	27.78	14.29	396.98	14.86	2
Detritus	27.78	66.67	1852.09	69.31	1
	100.00	100.00	2672.14	100.00	
50 to 100 mm					
Unicellular algae	14.29	2.63	37.58	2.69	4
E.compressa	14.29	43.87	626.90	44.83	1
Crustaceans	10.39	1.75	18.29	1.31	7
Sponges	12.98	5.26	68.27	4.88	3
Sea-anemones	11.69	1.75	20.46	1.46	6
Copepods	9.09	1.75	15.91	1.14	8
Fish scale	12.98	2.63	34.14	2.44	5
Detritus	14.29	40.36	576.74	41.25	2
	100.00	100.00	1398.29	100.00	
100 to 200 mm					
Ulva spp.	11.46	7.23	82.86	6.66	3
E.compressa	12.74	48.19	613.94	49.35	1
Crustaceans	10.83	1.61	17.44	1.40	6
Bivalves	9.56	1.61	15.39	1.24	8
Lepas	8.28	1.20	9.94	0.80	9
Sponges	12.10	3.21	38.84	3.12	4
Sea-anemones	10.19	1.61	16.41	1.32	7
Fish scale	12.10	1.61	19.48	1.57	5
Detritus	12.74	33.73	429.72	34.54	2
	100.00	100.00	1244.02	100.00	
>200 mm					
E.compressa	10.66	48.65	518.61	49.38	1
Ulva spp.	10.15	7.72	78.36	7.46	3
Sea-anemones	10.41	1.54	16.03	1.53	5
Coral polyps	9.65	1.16	11.19	1.07	7
Bivalves	8.38	1.16	9.72	0.93	8
Sponges	10.66	3.09	32.94	3.13	4
Lepas	7.61	0.77	5.86	0.56	9
Crustaceans	10.15	1.54	15.63	1.49	6
Alphids	2.03	0.39	0.79	0.08	10
Fish scale	9.64	1.16	11.18	1.06	8
Detritus	10.66	32.82	349.86	33.31	2
	100.00	100.00	1050.17	100.00	