ECO-BIOLOGY AND FISHERIES OF THE WHELK, *BABYLONIA SPIRATA* (LINNAEUS, 1758) AND *BABYLONIA ZEYLANICA* (BRUGUIERE, 1789) ALONG KERALA COAST, INDIA

Thesis submitted to Cochin University of Science and Technology in partial fulfillment of the requirement for the degree of

Doctor of Philosophy

Under the faculty of Marine Sciences

By

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Dedicated to My Parents…

Certificate

This is to certify that this thesis entitled **"Eco-biology and fisheries of the whelk, *Babylonia spirata* (Linnaeus, 1758) and *Babylonia zeylanica* (Bruguiere, 1789) along Kerala coast, India"** is an authentic record of research work carried out by Anjana Mohan (Reg.No. 2583) under my guidance and supervision in Central Marine Fisheries Research Institute, in partial fulfillment of the requirement for the Ph.D degree in Marine science of the Cochin University of Science and Technology and no part of this has previously formed the basis for the award of any degree in any University.

Kripa V.

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Date: 27.06.2007

Declaration

I hereby declare that the thesis entitled "Eco-biology and fisheries of the whelk, *Babylonia spirata* (Linnaeus, 1758) and *Babylonia zeylanica* (Bruguiere, 1789) along Kerala coast, India" is an authentic record of research work carried out by me under the guidance and supervision of Dr. V. Kripa, Sr. Scientist, Mariculture Division, Central Marine Fisheries Research Institute, in partial fulfillment for the Ph.D degree in Marine science of the Cochin University of Science and Technology and no part thereof has been previously formed the basis for the award of any degree in any University.

(ANJANA MOHAN)

Date: 27-06-07

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Anjana Mohan

Contents

Chapter 1
Introduction

1. Introduction

Molluscs form one of the earliest recorded groups of living organisms. Their presence on planet earth since the Paleozoic era 540 million years ago has been proved beyond doubt. Abundance, size and diversity and their dual roles as predators and prey make molluscs an indispensable component of tropical marine ecosystems. With more than 80,000 species, the phylum Mollusca is second only to the phylum Arthropoda. Of these, only about 28 species of bivalves and 65 species of gastropods are of commercial importance either in shell trade or for edible purpose and 14 species of cephalopods are exploited commercially. Although only a few reliable comparative data exist, molluscs probably comprise 15-40% numerically of benthic macro invertebrates and are exceeded only by polychaetes and crustaceans in tropical Indo-West Pacific coastal marine environments (Longhurst and Pauly, 1987).

Species of the class Gastropoda of phylum Mollusca with their ornamental shell and succulent meat have been harvested since time immemorial. The production has increased considerably from 30,499 tonnes in 1950 to 1,21,657 t in 2003 (FAO, 2003). The peak during the period 1950 to 2003 has been in 1996, when 1,41,780 t were harvested from the natural beds. During the past 25 years the number of countries involved in gastropod fishing rose from 23 to 47 (Leiva and Castilla, 2002). The four major gastropod groups which contributed to world fisheries in 2003 were whelks (30.9%), stromboid conchs (19.5%), turbo snails (18.7%) and abalone (10.3%). The dominant species were *Buccinum undatum* (31,492 t), *Strombus* spp. (23,666 t), *Turbo cornutus* (22,721 t), *Busycon* spp. (6130 t), *Haliotis rubra* (5094 t) *Concholepas cocholepas* (2857 t) and *Murex* spp. (2337 t). The three main producers of gastropods are Europe (28.65%), North America (25.13%) and Asia (23.23%). The entire quantity of *B.undatum* fished is from Europe. Leiva and Castilla (2002) reviewed the world gastropod fishery. They have stated that the gastropod fishery is mainly from three regions, *viz,* (1) the American continent, where the muricid commonly called "loco", *Concholepas concholepas* is fished from Chile and Peru; strombid conch, *Strombus* spp., from the Caribbean and the abalone, *Haliotis* spp., from California (2) the Asia and Oceania, with the well established abalone fishery, mainly in Australia and New Zealand, and the horned turban snail, *Turbo truncatus,* in Japan and Korea and (3) from Africa and Europe where, *Haliotis midae* is heavily fished from South Africa, and the common periwinkle, *Littorina littorea,* and the whelk *Buccinum undatum* from Europe. Globally six species of genus *Babylonia* are commercially important, viz, *Babylonia areolata, B. japonica, B. formosae formosae, B. formosae habei, B.spirata* and *B. zeylanica.* These are very popular mainly in Southeast Asian countries.

In several parts of the world due to high economic value and excessive capture many marine gastropods show, or have shown serious problems of overexploitation (Tegner, 1989; Castilla, 1996; Ponce-Díaz *et al.*, 1998; Hobday *et al.*, 2001). In many cases this has led to the collapse or permanent closure of the fishery. The social and economic consequences of these collapses have promoted the development of new management perspectives centered on both biological and economical sustainability (Baker *et al.*, 1996; Prince *et al.*, 1998; Castilla, 1997a, 1999, 2000). One of the major gastropod fisheries which has collapsed due to overexploitation is the Chilean muricid fishery. Between 1979 and 1988, Chile was the most important marine gastropod extractor in the world, accounting for over 35% of the world gastropod landings (1980). However, after 1989, the main Chilean gastropod fishery, the muricid gastropod *Concholepas concholepas*, declined most likely due to stock over-exploitation (Castilla, 1995, 1997b; Castilla *et al.*, 1998). Another classic example of over-fishing is the Californian multi-species abalone fishery. In the last 150 years five abalone species: *Haliotis corrugata* (pink abalone), *H. fulgens* (green abalone), *H. rufescens* (red abalone), *H. sorenseni* (white abalone), and *H. cracherodii* (black abalone), have been commercially extracted in California. The overexploitation phase started in 1968 and in May 1997 the entire Californian coast was closed to commercial abalone fishery. Hobday and Tegner (2000) summarized the management history for the California abalone fishery, where several regulatory extraction tools were implemented between 1901 and 1997: minimum size limit, commercial permit fee, minimum commercial landing, recreational limit and recreational and commercial gear regulation. In spite of these management tools, the abalone populations in California continued to decline, until total closure was decreed in 1997.

Leiva and Castilla (2002) have described the utilization of adaptive management tools such as exclusive rights for fishing gastropods which are given to small scale fishers associates (cooperation); Individual Transferable Quotas (ITQs) and Total Allowable Commercial Catches (TACC). Apart from these novel management adaptive tools, such as the implementation of the Benthic Regime for Extraction and Processing (BREP), the introduction of Non-Transferable Individual Quotas (NTIQs) and territorial use rights for benthic fisheries, such as the Management and Exploitation Areas (MEAS) are also presented.

In addition to the targeted resources several other benthic invertebrates also are landed in huge quantities and it has been observed that major share of this is also several species of other gastropods. Leiva and Castilla (2002) have elaborated the need for management plans based on biological, ecological surveys and have considered that eco-biology is an indispensable component of benthic invertebrate fisheries management.

In India, molluscs have occupied a marked place in the affairs of state and economy of mind and aesthetic values, of religion and rites of worship (Mukundan, 1968). Evidence of long standing association between man and mollusc in India is afforded by the shell remains discovered in human habitation of pre-vedic Mohanjedaro, Harappa, Amri, Nal, Nundara and Rupar. These included not only the cowries (*Cyprea*) and chank (*Xancus*) but also their products – bangles and cores of shells from which the bangles have been sawn out (Mukundan, 1968). From India, a total of 3271 species of molluscs belonging to 220 families and 591 genera have been documented and, of these 1900 are gastropods, 1100 bivalves, 2210 cephalopods, 41 polyplacophorans and 20 scaphopods (Appukuttan, 1996).

The southwest and southeast coasts and the coral reef ecosystem in the Lakshadweep and Andaman and Nicobar Islands harbour some of the richest gastropod beds along the Indian coast. One of the earliest records of research on ecology and distribution of molluscs is that of Hornell (1922), who gave an evaluation of the faunistic condition and topographical features of the chank beds of Gulf of Mannar with hypothetical diagrams. Later, Mahadevan and Nayar (1976) made extensive underwater surveys using SCUBA (Self Contained Underwater Breathing Apparatus) during the period 1962-66 and again for a couple of years from 1968. Subsequent to this, the CMFRI has conducted research and development programmes related to gastropods, including the distribution and abundance of molluscs in the Andaman and Nicobar Islands (CMFRI, 1983) and the Lakshadweep Island (CMFRI, 1989). Several species of gastropods are fished and their shell is used for making exquisite pieces of handicrafts. Such shell craft cottage industries and shell trade form a major business in Tamil Nadu and Andaman and Nicobar Islands. Due to over exploitation some species have been listed as endangered. In 2001 the trochus, turbo and large number of other ornamental gastropods have been listed as protected under schedule I of the Wild Life Protection Act, 1972 (Narasimham, 2005). One of the major programmes on gastropods in the country has been the Tropical Marine Molluscan Program (TMMP) which was started in 1991 as a special action in Danish International Development Agency (DANIDA) referred to as ENRECA (Enhancement of Research Capacity). Under this programme, the distribution, fishery, biology and economic importance of several important gastropods like, *Chicoreus ramosus* and *Murex* sp. were studied.

Another major development in the recent years is the increased use of edible gastropods. With the development of Indian marine fishing industry and related seafood trade considerable changes took place in fishing craft and gear resulting in extending of the fishing zone. Consequently, several gastropods which inhabit the deeper waters began to be caught in the trawl and landed as the by-catch. The seafood trader took advantage of this and explored the possibility of developing an external market for the Indian gastropod products. The initial export trials were successful and also lead to greater demand of shells and shell products which resulted in targeted fishing for gastropods.

One of the gastropod resources which became economically important during the last decade is the whelk. Two species of whelks, *Babylonia spirata* (Linnaeus, 1758) and *Babylonia zeylanica* (Bruguiere, 1789) of the family Buccinidae began to be fished and exported from the country to China, Singapore, Thailand and Europe. These resources began to be regularly fished from Kerala since 1993 and number of fishing vessels targeting this resource increased over the years. Whelk meat is exported from the country under the trade name 'Baigai' and there was a steady increase in export (Fig. 1) and unit price of whelk. Initially only frozen products were exported and since 2001 live whelks were also exported. In the year 2003 about 1115 t were exported as fresh/processed to China, Japan, Middle East, Southeast Asia, USA and European Union.

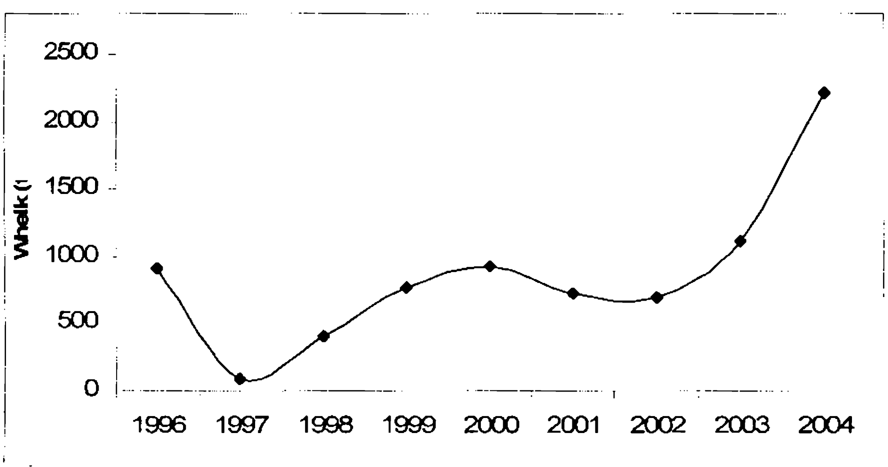


Fig. 1 Whelk exported from India during the period 1996 to 2004

The two species of whelks which support the fishery and trade from India have shells with characteristic features. The spiral Babylon, *Babylonia spirata* (Pl. Ia) is smooth shelled, ovoid, with regular spiral rows of large, rounded or squarish brown patches on a white ground. The spire is of medium height with rounded whorls while, the body whorl is inflated and the suture is channeled with sharp edge.

The columella is smooth, with somewhat strongly thickened callus. The aperture is large, ovate, and constricted posteriorly by a single, thick ridge extending spirally inward on the columellar side. The species is distributed in the Indian Ocean up to 150 m.

The Indian Babylon, *Babylonia zeylanica* (Pl. Ib) has a very smooth shell with high spire, rounded whorls, slightly impressed sutures and a large ovate body whorl. Though the shell bears distinctive brownish patches on white background, the major characteristic is the violet staining at the fasciole. The species is distributed in Indian and Sri Lankan waters.

In India, *B. spirata* is well represented in the Indian Peninsula in Gulf of Mannar, Poompuhar, Nagapattinam, Madras and in the waters around Andaman and Nicobar Islands (Ayyakkannu, 1994). However, *B. zeylanica* is reported only from Kerala. The whelk is landed as by-catch of trawls in Kollam and Tuticorin. As the demand increased, modifications were made to the gear for efficiently fishing this benthic resource at Kollam and Tuticorin. Whelk is fished using traps at Porto Novo (Ayyakkannu, 1994) and Malpe (Sasikumar *et al.*, 2006) and at Pondicherry using ring-nets (Chidambaram, 1997).

A perusal of the literature on gastropod biology implicates that there has been only limited studies on this group of marine molluscs. Moreover, recent developments in gastropod fishery markets and utilization indicate the need to have a strong data line on the eco-biology of targeted gastropods for effective management plans to avoid situation similar to abalone fishery of California. Based on this research need, the study entitled 'Eco-biology and fisheries of *Babylonia spirata* (Linnaeus, 1758) and *B. zeylanica* (Bruguiere, 1789) along Kerala coast, India' was planned. Based on the information obtained from the fishermen, it was understood that these two gastropods inhabit separate regions to the north and south of Kollam. The main objectives of the present study are:

Pl. 1a. *Babylonia spirata*

Pl. 1b. *Babylonia zeylanica*

1. Study the ecology of *B. spirata* and *B. zeylanica* beds, especially hydrographic variations, sediment characteristics, associated fauna and population structure.
2. Study the composition of trawl by-catch to understand the exploitation of co-occupying species and associated fauna in whelk beds.
3. Study the biometric relationships, growth pattern of *B. spirata* and *B. zeylanica* and reproductive biology of *B. spirata*.
4. Estimate the monthly and annual whelk landings in southwest coast of Kerala and the population parameters like mortality rates, exploitation rate and relative yield per recruitment of *B. spirata* and *B. zeylanica*.

Through this study, it is aimed to develop a data base on the habitat requirements of *Babylonia spirata* and *B. zeylanica* and on their biology which will be useful for formulating management measures for sustainable exploitation of this commercially important resource. The information on habitat will be useful to identify sites suitable for sea ranching or for mariculture as resource enhancement programmes. Apart from this, with the information on different groups of molluscs landed at Sakthikulangara-Neendakara, the possibility for effective utilization of these resources in shell craft industry for the welfare of coastal community of the state can also be explored.

Chapter 2

Review of literature

2. Review of literature

Neogastropods are considered to be the most advanced type of prosobranchs exhibiting complex behavioural pattern, internal fertilization and a well developed female genital system which has evolved to meet the requirements of internal fertilization and egg deposition in capsules (Fretter, 1946). They are a diverse group comprising scavengers and predators having a highly developed sense of chemoreception and are distributed from the intertidal to the abyssal zone and in all oceans. These groups of animals by virtue of their several advanced characters have been subjected to extensive research during the last century, some of the significant contributions are that of Peile (1922, 1936), Graham (1939, 1941, 1949), Fretter (1941), Jenner and Chamberlain (1955), Olsson (1956), Marcus and Marcus (1959, 1962), Brown (1959), Fretter and Graham (1962) and Ponder (1970, 1972, 1973).

2.1 Eco-biology of gastropods

Whelks form an important group of neogastropods of families Buccinidae, Melongenidae and Muricidae and their reproductive biology has extensively been studied. *Buccinum undatum*, a boreal species, has been the subject of research mainly due to its emergence as a fishery resource. Various aspects of the growth of this species have been studied (Santarelli and Gros, 1985; Lanteigne and Davidson, 1992; Kideys, 1996 and Kenchington and Glass, 1998). The variation in the shell morphology, the differing maximum shell height and influence of predation on the shell characteristics like thickness and shell aperture has been studied in detail in three different populations on the Atlantic coast of Canada (Thomas and Himmelman, 1988). Studies on buccinids have shown that they have opportunistic feeding behaviours that target live prey as well as dead and moribund animals (Nielson, 1975; Taylor, 1978; Evans, *et al.*, 1996; Tan and Morton, 1998). Kenchington and Lundy (1996) have given a review of the biological character relevant to the development of this resource in Tusket Island area of Southwest Nova Scotia. Observation on tagging has shown adults to be relatively sedentary which could result in local adaptation

(Hancock, 1963; Himmelman and Hamel, 1993; Valentinsson *et al.*, 1999). Local variations have been identified with respect to size at maturity (Gendron, 1992). Valentinsson *et al.* (1999) pointed out that, with reference to fisheries, the reduced gene flow would suggest that a local population will recover slowly once depleted.

The reproductive cycle of commercially important species of the genus *Buccinum* is well documented (Hancock, 1967; Martel *et al.*, 1986a, 1986b; Gendron, 1992; Kideys *et al.*, 1993; Martell *et al.*, 2002). Valentinsson (2002) has studied in detail the reproductive cycle of *B. undatum* and maternal effects on offspring size and number. Similar study on mating, development and effects of female size on offspring number and size in *B. isaotakii* in Japanese water has also been studied (Ilano *et al.*,2004).

The marine gastropod *Buccinanops globulosum* has a wide regional distribution in temperate waters of the southwestern Atlantic Ocean, from Uruguay to Santa Cruz Province, Argentina (de Castellanos, 1967, 1996; Scarabino, 1977). This whelk is a typical inhabitant of coastal waters, existing up to 10 m depth in some areas (Scarabino, 1977; Pastorino, 1993). In very shallow waters, the species occurs mostly over sandy and muddy bottoms or in seagrass. It is necrophagus, feeding mainly on crab and molluscs. Its life span is unknown and the majority of studies deal with the biology of the species, mainly with the reproductive behaviour and early development (Castellanos, 1967; Penchaszadeh, 1971; Lasta *et al.*, 1998). Development is direct and small crawling whelks of approximately 6 mm emerge from the capsules and live within the same area (Penchaszadeh, 1971). This gastropod is an important component of the San Antonio Bay, San Matias Gulf and jointly with the crab *Chasmagnathus granulata,* is the main scavenger of this important marine ecosystem (Scarabino, 1977). Certain aspects related to the breeding biology, growth and shell characters of the whelk *Buccinanops globulosum* has been studied (Narvarte, 2006) to develop a database for management in San Matias Gulf, Argentina.

Six species of the genus *Babylonia* are commercially important, especially in Southeast Asian countries and considerable work has been done to develop seed production and farming techniques. *Babylonia areolata* (Link 1807) has been fished from the Gulf of Thailand and aspects related to spawning and larval development (Poomtong and Nhongmeesub, 1996), growth and survival of juvenile (Chaitanawisuti and Kritsanapuntu, 1998), effect of feeding regime on growth and survival (Chaitanawisuti and Kritsanapuntu, 1999; Chaitanawisuti *et al.*, 2001) have been studied. Apart from this, in the recent years, efforts have been made to develop culture techniques (Chaitanawisuti *et al.*, 2002a, 2002b, 2004; Kritsanapuntu *et al.*, 2005). The larval development of the same species in Vietnam waters has also been studied (Hua *et al.*, 2001).

Babylonia japonica (Reeve 1842) inhabits the Japanese waters and attempts have been made to study its population characters (Yoshihara, 1957) and to produce the seed by induced spawning (Kajikawa, 1978). *Babylonia formosae formosae* (Sowerby 1866) is an important gastropod resource of Taiwan and studies have been conducted on its dietetics (Chang, 1983) and reproductive biology (Chiu and Liu, 1994). Reproductive biology of *Babylonia formosae habei* (Altena and Gittenberger 1981), known as ivory shell, in China has been extensively studied (Ke and Li, 1991, 1992, 1993; Ke *et al.*, 1997). The dietetics of the same species has been studied by Zheng *et al.* (2001) and Chen *et al.* (2005).

Babylonia spirata has been considered as an important resource of Indonesia and India. In Indonesia, investigations have been made on the growth (Yulianda and Dhanakusumah, 2000) and reproductive biology (Yulianda, 2001) of this resource. In India, during the last two decades considerable research has been done on several aspects of *B. spirata* such as, dietetics (Raghunathan *et al.*, 1994, Patterson *et al.*, 1995) reproductive biology (Kannapiran and Patterson, 1996, Sreejaya *et al.*, 2004), salinity tolerance (Patterson *et al.*, 1994), growth in culture systems (Shanmugaraj and Ayyakkannu, 1997) and fishery (Ayyakkannu, 1994; Appukuttan and Philip, 1994; Philip and Appukuttan, 1997; Sasikumar *et al.*, 2006). *Babylonia zeylanica*

(Bruguiere 1789), known as Indian babylon is distributed mainly in Indian and Sri Lankan waters (Wye, 1991). Studies on this whelk are limited except for those related to its fishery along the southwest coast of India (Appukuttan and Philip, 1994 and Philip and Appukuttan, 1997).

Another neogastropod of commercial importance is the veined rapa whelk, *Rapana venosa* (Guo *et al.*, 1999). *R. venosa* is native to the sea of Japan, the Yellow Sea, the East China sea and the Gulf of Bohai (Tsi *et al.*, 1983; Chung *et al.*, 1993 and Zolotarev, 1996). Three species of *Rapana* occur significantly in the Chinese waters: *R. venosa, R. bezoar* and *R. rapiformes.* Harding and Mann (1999) have considered the occurrence of *R. venosa* in Chesapeak Bay as 'bioinvasion' and they have studied the biology of this species in detail. The distribution and shell height-weight relationship of *R. venosa* in the Loizhour Bay (Wu, 1988) and the occurrence of this species in the Aegean Sea (Koutsoubas and Koukoura, 1990) have also been studied.

Among nassarids, the European species *Nassarius obsoletus* has been studied by several workers (Bergman and Graham, 1975; Scheltema, 1956, 1964, 1965). The growth and shell characters of other whelks like, *N. reticulatus* (Rasmussen, 1973 and Tallmark, 1980), *Troschelia berrniciensis* (Olabarria and Thurston, 2004) has been studied. Aspects on natural diet and degree of hunger of *N.festivus* have been studied (Morton and Chan, 2003). The spawning and egg laying of several other neogastropod species including *Urosalpinx cimerea* (Hancock, 1960), *Nucella lapillus* (Feare, 1970) *Thais cinerea* (Houston, 1971) and *Ceratostoma foliatum* (Spight *et al.*, 1974) has been described.

The purple dye murex, *Bolinus brandaris*, is a prosobranch gastropod mollusc, very common in the Mediterranean, which inhabits sandy-muddy bottoms at depths between 5 and 50 m. This gastropod has been studied by several researchers and notable among these are those of Barash and Zenziper (1980) describing the spawning; Dalla Via and Tappeiner (1981) on the biometry of the species; Bartolome

(1985) presenting preliminary study on the biology and fishery; Ramon (1986) on the spawning and larval development and several studies on spermatogenesis (Amor and Durfort, 1990a, b; Amor, 1992).

Large sized ornamental gastropods like, *Trochus niloticus* coming under the family Trochidae and *Turbo marmoratus* of the family Turbinidae are widely distributed in the Indo-Pacific region and have formed an important part of coral reef ecosystem. They have also contributed much to economy of the islanders through shell trade related to tourism, export and local shell craft. Growth, migration and morphology of these gastropods have been studied by several researchers. Nash (1993) has described the growth of this species occurring in the South Pacific. *T. marmoratus* grows to large size and is widely distributed (Poutiers, 1998). It is an important resource of Tonga and the growth of this gastropod based on mark-recapture method has been described by Fa'anunu' *et al.* (2001). The growth of juvenile snails in the hatchery has been described by Dwiono *et al.* (2001). The growth of this gastropod in captivity and culture has been studied in Carolina Island (Heslinga, 1981; Heslinga and Hillman, 1981); in Indonesia (Latama, 1997) and in Australia (Lee, 1997). *Trochus niloticus*, a reef dwelling Indo-West Pacific archaeogastropod (Rao, 1937), is found on coral reefs from high water to 20 m depth (Gail, 1957), but most trochids live in waters shallower than 5 to 6 m (Nash, 1985). Juveniles or small (<5 cm), non-commercial sized *T. niloticus* are most often found on the outer reef-flat rubble zone in water depths <3 m (Heslinga *et al.*, 1984, Nash, 1985). They prefer gently slopping, structurally complex substrate, with abundant coralline and filamentous algae and unobstructed exposure to surf (McGowan, 1958).

There have been few quantitative estimates of the standing stock of *T. niloticus* in a fishery because of the difficulty in estimating abundance and habitat area. Estimates based on quadrate counts over the entire reef are imprecise because of the aggregated distribution of this mollusc (Yen, 1985). The abundance of *T. niloticus* was quantitatively estimated in Guam and Cook Islands; however, its habitat area was not estimated in Guam (Smith, 1987), and estimates of precision were not given for the Cook Islands (Sims, 1985). Nash (1985) reported that he could not accurately estimate the abundance of this species in the Great Barrier Reef region because of the structural complexity of its habitat. The habitat of *T. niloticus* on Tetembia Reef, New Caledonia was mapped using remotely sensed data and aerial photography, although large interpolation and extrapolation errors were found to be associated with this method (Bour *et al.*, 1986). Long *et al.* (1993) tried to develop a coast-effective and accurate method of estimating *T. niloticus* standing stock of Bourke Isles, Australia using Landsat satellite data.

Considerable work has been done on the biology and seed production of this resource. The reproductive cycle of *T. niloticus* in King Soloman waters of Australia has been described by Gimin and Lee (1997). From the seed production reports of Heslinga and Hillman (1981) from Caroture Islands and Bech (1997) from Thailand considerable information on the spawning behaviour of this gastropod is available. Lee and Amos (1997) have reviewed the status of top shell hatcheries in Australia, Indonesia and the Pacific. In India *T. niloticus* is found only in Andaman and Nicobar group of Islands. Information on the gonad development, spawning and sex ratio of this species in Andaman and Nicobar Islands is available from the works of Amrithalingam (1932) and Rao (1936, 1937 and 1939). Nayar and Appukuttan (1983) and Krishnamurthy and Soundararajan (1999) have reported on successful spawning of *T. niloticus* collected from the Indian waters.

Chicoreus ramosus, a neogastropod under family Muricidae popularly known as the Ramure murex is distributed in Indo-Pacific region and along the southeast coast of India and Andaman and Nicobar sea. It is a coral reef gastropod and has a large solid globose-ovate shell with moderately low spire and tumid body whorl. The morphometric and meristic variation of this species in Thai waters, mainly to differentiate two forms of shell with short and long spines has been addressed by Chantrapornsyl and Nateewathana (1992). The growth and mortality rates of the nodulose coral creeper, largest species of the genus has been investigated by repetitive mark and recapture method in Pogo Bay, Guam, Mariana Islands

(Yamaguchi, 1977). The reproductive biology of *Chicoreus ramosus* has been studied and it has been cultured also (Middelfart, 1992a; Nugranad, 1992; Nugranad *et al.,* 1994 and Nugranad and Promchinda, 1995) and the maturity of second genera of hatchery cultured *C. ramosus* has been well documented (Traithong *et al.,* 1997). Morphology and anatomy of *C. torrefactus* and *C. brunneus* (Middelfart, 1992b, 1992c) has also been studied. Middelfart (1996) has described the egg capsules and early larval development of ten muricid gastropods from Thai waters. *Stella et al.,* (1992) have described the size class distribution of this species from the Gulf of Mannar area. The biology of queen conch, *Strombus gigas* has been studied by Randall (1964).

The growth of ear shell molluscs, abalones, mainly based on rearing in different culture systems have been studied (Hahn, 1989 and Chew, 1992) and has been reviewed by Viana (2002). However, in India this resource is sparse and growth of *H. varia* in early stage has been reported by Najmudeen and Victor (2003).

Apart from whelks, several gastropods have been the target of study through out the world due to their significant role in marine ecosystem or due to their economic importance. The sacred chank, *Xancus pyrum* is one of the most studied gastropod in India. Hornell (1914) has written a monograph on chank and Moses (1923) has described its anatomy. Extensive details about the distribution, exploitation, utilization and biological aspects of the sacred chank in Indian and Ceylon waters are available in the works of Hornell (1914, 1915 and 1916), Gokhale (1960), Nayar and Mahadevan (1973 and 1974), Jonklaas (1970) and Appukuttan *et al.* (1980). Pillai and Devadoss (1974) reported on the occurrence of *X. pyrum* in large quantities, off Portonovo and Sreenivasan (1988) has described the fishery of this region.

The growth of *X. pyrum* has been studied through mark-recapture method. This slow growing gastropod has been tagged and released along the southeast coast and such studies have been conducted by Sambandamurthy and Chacko (1969) and

Lipton and Selvakku (2001). Based on this mark-recovery database Devaraj and Ravichandran (1988) have estimated the growth parameter of this resource. The growth of baby chanks under controlled condition has also been studied (Lipton and Selvakku, 2000). The spawning season (Devanesan and Chacko, 1944) and the behaviour of copulating chanks in the natural environment (Mahadevan and Nayar, 1976) have been studied in detail. Lipton and Selvakku (2000) have described the egg masses, embryonic development, and growth of baby chank and have reported on brood-stock requirements, maintenance and larvae rearing of this species.

Biology and ecology of several other Indian gastropods such as *Umbonium vestiarium* (Rajagopal, 1982), *Bullia vittata* (Thilaga, 1985), *Cerithidiopsilla cingulata* (Sreenivasan, 1985), *Hemifusus cochlium* and *Lambis lambis* (Siraimeetan *et al.,* 1988), *Telescopium telescopium* (Sriraman *et al.*, 1988); *Pythia plicata* (Shanmugam, 1995); *Murex tribulus* (Shanmugaraj and Ayyakkannu, (1996) and *Hemifusus pugilinus* (Patterson and Ayyakkannu, 1997) have been studied.

Apart from high value gastropods, several other gastropods have been the target of study mainly because of their role as an integral component of different benthic ecosystems which they inhabit. Some of the significant works and the ecosystem are that on *Batillaria zonalis* in salt marsh (Whitlatch, 1974); *Littorina rudis* in intertidal zone (Roberts and Hughes, 1980); *Hydrobia ulvae* in muddy zones (Armonies and Hartke, 1995); *Bolinus brandaris* in sandy – muddy substratum (Morton *et al,* 1995); *Pomacea canaliculata* in freshwater ponds (Estebenet, 1998); *Batillaria cuminzi* in rocky intertidal zones (Adachi and Wada, 1999); *Drupella cornus* in coral reef (Ismail *et al,* 2000) and *Haminoea orbygniana* in temperate coastal lagoon (Malaquias and Sprung, 2005).

In addition to biological aspects, certain other specific characters such as, variation in shell shape of gastropods has intrigued several malacologists. Morphological variation in relation to age (Esteberet, 1998), as a response to selective pressures such as physical disturbance (Vermeij, 1978; Janson, 1982; Boulding and

Hay, 1993), depth and horizontal separation among population (Etter and Rex, 1990 and Rex *et al.*, 2002), hydrostatic pressure (Hochachka and Somero, 1984) sediment type (Macilvaine and Ross, 1979), food availability (Rowe *et al.*, 1982), biological interactions such as competition and/or predation (Vale and Rex, 1988; Boulding and van Alstyne, 1993) has been the theme of study in different geo-locations.

A perusal of the research contributions on gastropod growth clearly shows that in Indian waters, the studies are limited and there is a need for conducting targeted studies on this group. Coastal zones are variable environments, directly subject to continental, atmospheric and oceanic influences. The instability of the coastal zone affects the benthic community, determining the patterns of distribution and density and the trophic relationships among the species (Santos *et al.*, 2004). Relationships between distribution of benthos and characteristics of the bottom sediment have been of interest to ecologists for many years (Bader, 1954; Craig and Jores, 1966; Peres and Picard, 1964; Purdy, 1964; Rhoads and Young, 1970; Sanders, 1960; Thorson, 1966).

Most of the studies on marine macrobenthic communities have been conducted in north temperate regions and the knowledge on community structure is based largely on these results. By contrast, the tropical macro-benthos is less well known. Among molluscs, gastropods and bivalves form an integral part of the benthic community of marine ecosystem. Changes in the structure of benthic communities have been associated with biotic factors such as competition and predation (Rhoads and Young, 1970; Weinberg, 1984) and abiotic factors such as depth (Hyland *et al.*, 1991), current speed (Wildish and Peer, 1983; Moller *et al.*, 1985), salinity (Jones *et al.*, 1986), temperature (Persson, 1982), sediment type (Gray, 1974; Weston, 1988), organic loading (Dauer and Connar, 1980) and disturbance (Probert, 1984; Hall *et al.*, 1992; Hall, 1994). Much research effort has been concentrated on studies dealing with the effects of multiple environmental factors in structuring the communities (Aschan, 1990; Pires-Vanin, 1993; Bachelet *et al.*, 1996; Santos and Pires-Vanin, 1999). Other studies have sought to establish an index that integrates macro-benthic community structure in terms of response to habitat characteristics (Paiva, 1993; Engle *et al.*, 1994).

The ecological aspects such as hydrographic variations, continental shelf characters and benthos of the Indian coast have been studied extensively. The benthos of the west coast of India has been investigated in detail during the last century and some of the significant observation on the qualitative and quantitative distribution of benthos is given by Kurian (1953, 1967), Seshappa (1953), Parulekar (1973) and Harkantra *et al.* (1980), Ansari *et al.* (1994).

The benthos of the southwest coast of India based on grab and dredge collections from 150 stations distributed in the continental shelf extending from Mangalore to Cape Comorin, covering an area of 30000 km^2 during 1943 to 47 and 1958 to 68 has been described by Kurian (1971). He found a definite relation between nature of the deposits and the intensity of benthos and that fine sand with small percentage of silt form the best ground for macrofauna constituted mostly by polychaetes and crustaceans. Relationship between benthic abundance and percentage organic carbon has been studied by several workers (Bader, 1954; Sanders, 1968; Ganapathy and Raman, 1970). Harkantra *et al.* (1980) found a definite relationship between benthic biomass, organic carbon, nature of substratum and demersal fish catch.

One of the important processes in the coastal region and continental shelf region is the sedimentation process, which is a function of climate, bathymetric and hydrographic changes (Hashimi *et al.,* 1981). They found that western and eastern continental shelves around Cape Comorin show three well-defined regions of depositional environments each having its own characteristic features. The environments extend from Cochin to Quilon, Quilon to Cape Comorin and Cape Comorin to Tuticorin. Sediments of the first region are characterized by a high percentage of fine grained sediments (62.4% silt and clay) where as the 2^{nd} and 3^{rd} regions have only 4.3 and 12.8% respectively. The carbonate content increased from

21.9% off Cochin to 37.4% off Quilon and 71.4% off Tuticorin. Differences in the three sedimentary environments are attributed to the variations in the depositional and erosional processes prevailing in the region (Hashimi *et al.,* 1981).

During the last decade also different aspects of the benthos of west coat has been studied (Saraladevi *et al.,* 1991; Ansari *et al.*, 1994; Harkantra and Parulekar, 1994; Sunilkumar and Antony, 1994; Saraladevi *et al.,* 1999). Reports on benthos from southeast coast are comparatively less (Ganapathi and Raman, 1970; Chandran, 1987; Prabhadevi and Ayyakkannu, 1989; Murugan and Ayyakkannu, 1991; Vijayakumar *et al.,* 1991) and mostly confined to estuarine region. More recently Madhupratap *et al.* (2001) have made an attempt to address the seasonal and spacial variation of the process contributing physics, chemistry and biology of the waters of west coast of India.

2.2. Fishery

Gastropods have been fished from coastal waters, lagoons, reefs and sub-tidal regions almost through out the world but most often these have not been documented in detail primarily because of their sustenance nature and low economic value compared to other nektonic high value molluscan resources like squids and cuttlefishes. Many gastropods are harvested for their meat, at the same time the beautiful shape and colour of shells have attracted and aroused the imagination of man to use them for commercial purposes (Ramdoss, 2003). Traditionally, various kinds of artisanal fishing gear such as trammel nets, basket traps, dragged gears etc. have been used for fishing gastropods. In certain areas, the main fishing gear has been modified for fishing this resource exclusively. Globally the most important gastropods harvested from nature are the whelks. *Buccinum undatum* is the major resource fished and the other species of gastropods which have a documented commercial fishery are *Strombus* spp., *Turbo cornutus, Halotis* spp., *Busycon* spp. *and Cymbium* spp. (FAO, 2003). Muricids are important resource in several parts of the world.

Whelks are fished mainly from Europe. The European whelk (*Buccinum undatum*) fisheries began in the sixties and have increased in the recent years, to fulfill the high demand of the Southeast Asian market. Basically harvested by traditional 8-16 m long potters with 500 to 1000 baited pots lifted per day and per boat, some areas are fully exploited. Traditionally in Canada, the whelk *B. undatum* has been harvested for several years using a variety of traps and boats especially by small, twine, conical pots known as Korean pots. Under a project, special stackable pots were fabricated and tested. The stability of the conical pot allowed fishers to extend the areas fished to deeper and more turbulent water while their stackability enabled vessels to carry more. The relatively light weight of poles as compared to buckets enabled the hauling and setting of the gear to be accomplished more quickly (FDP, 2002). The fishery of *Baccinanops globulosum*, a whelk along the Argentina coast began in the year 2000 and to prevent over exploitation, experimental licenses for fishing were issued via a public draw (Narvarte,2006).

Abalone is harvested from several parts of the world and the production fluctuates between 10000 and 15000 t per year (Berthou *et al.*, 2005). From mid eighties a new type of dragged gear locally called the 'rastell' and specially designed for catching *Murex* spp. began to be used on the Catallan coast. This beam trawl, modified without skates, is used by around 60 vessels, throughout the year, for 5 days a week during the recent years. The abalone fishery in Tasmania is one of the most important (Berthou *et al.*, 2005), reaching a total allowable commercial catch of about 2500 metric tones (nearly half of Australia' total production). Two species are harvested manually by divers: *Haliotis rubra* and *H. laevigata*. This commercial fishery is under a quota management system. Acccess to the quota and the right to take the abalone is formally separated; there are about 350 holders of quota and only 125 divers licensed to harvest abalone. Approximately 4000 recreational abalone diving licenses are issued per year and are restricted to a catch of 10 abalones per day.

Strombus gigas, the queen conch with a beautiful pink shell is a commercially important marine gastropod in the Caribbean Sea. The abundance of this resource has been affected by fishing pressure. This species was much abundant in common shallow intertidal waters and recently it began to be caught from deeper areas. The fishing method also progressed from simple hook and line to SCUBA diving up to 40m depth. Similarly, crafts also changed from wooden canoes to far ranging fiberglass boats with powerful engines (Berg and Olsen, 1989). Another species which has been subjected to targeted fishing is *Bolinus brandaris,* a commercially important gastropod. This has been fished using artisanal fishing gear like trammel nets, basket traps and dragged gear, but later a modified gear 'rastell' began to be used for fishing this resource (Martin *et al.,* 1995).

The Indian marine gastropod production has been mainly contributed by three resources, the sacred chank *Xancus pyrum*, the turban shell *Turbo marmoratus* and top shell *Trochus niloticus*. The sacred chank has been harvested through a regular and organized fishery mainly to meet demand from the bangle industry in West Bengal (Hornell, 1914; Ghazi, 1962; Jones, 1968). The fishery in Tamil Nadu is controlled by the State Govt. which permits fishing by issuing license to fishermen. The annual chank landing varies from 1 to 1.5 million in Gulf of Mannar and Palk Bay and an estimated 17,000 to 20,000 chanks are caught in trawl nets along west coast of India and another 5000 to 6500 chanks are caught by diving along Vizhinjam coast in the southwest coast (Nayar and Mahadevan, 1974; Appukuttan *et al.*, 1980; Alagarswami and Meiyappan, 1989, Narasimham, 2005).

Appukutan *et al.* (1980) described the chank fishery of Kerala coast. The Kerala Government leases the right to collect chanks to co-operative societies. Chanks have been fished since early times along the Trivandrum coast by skin diving in the 10-20 m depth zone. Catamarans are used for transporting and each diver collects about 10 chanks per day. Chanks are also caught incidentally in bottom set gill nets and shrimp trawls. At Sakthikulangara, shrimp trawlers fishing at 40-50 fathom depth land considerable quantity of chanks (length 100-220 mm). Chanks are fished with 250-500 m long line, holding 500-1000 hooks. As hooks are dragged on the sea bed the foot of the chank gets hooked firmly. Long line fishing began at Vizhinjam in 1976.

Pota and Pattel (1988) have reported on the chank fishery of Gulf of Kutch. The Gujarat Fisheries Department controls chank fishing. Chanks are fished along the Gujarat coast in the Gulf of Kutch. The fishing area lies in 200 km coast line between Sachhana and Okha. The chanks are fished in the inter-tidal areas of patchy coral reefs and due to high tidal amplitude vast stretches of inter tidal areas are exposed at low tides. During the spring tides, the fishermen wade through the water, handpick the chanks and empty the catch in a basket known as 'Gumbha'. Thomas *et al.* (1998) reported on the high production of 20,899 chanks in 1984-85. There was decline in chank catches from 1987-88 onwards. In 1996-97 only 798 chanks were caught. The fishermen take out the chank meat for their consumption. The Gujarat Fisheries Development Corporation undertakes marketing of the chanks.

The top shell, *T. niloticus* and turbo shell, *T. marmorates* have been fished from Andaman and Nicobar islands (Amrithalingam, 1932; Setna, 1933; and Rao, 1939; Appukuttan, 1979; Nayar and Appukuttan, 1983; Krishnamurthy and Soundararajan, 1999). Fishing methods for *Trochus* and *Turbo* in the Andaman and Nicobar Islands is by diving and a power boat tows the smaller canoes (sampan) to the fishing area and each sampan with 3-4 divers is left in different fishing grounds. Imported or locally made goggles or glass masks are used by the divers. Such sharing of resources has been observed along the Tamil Nadu coast in the chank beds known as 'sangunilam'. Fishermen reach the fishing ground in plank boat built boat with 10-15 fishermen in each boat. After which they skin dive (without any external respirator apparatus) and collect the chank from 16-24 m depth. In contrast to this, *Umbonium* sp. and *Oliva* sp. are collected from the sandy shore using scoop net from nearshore areas in the Bay of Bengal (Ramdoss, 2003). *Chicoreus ramosus* and *Pleuroploca trapezium* are two important gastropods fished and utilized for shell craft industry along the Indian coast. The fishery information on landing centers in Palk

Bay and Gulf of Mannar has been described by several workers (Ayyakkannu, 1992; Patterson and Ayyakkannu, 1992a, 1992b and Patterson *et al.* 1994).

Along the Indian east coast at Porto Novo, the whelk *Babylonia spirata* has been fished using small traps with dried octopus and eel as bait (Ayyakkannu, 1994). Chidambaram (1997) has explained in detail the modified ring net used for fishing whelk, the CPUE and the seasonal variation in landing along Pondichery coast. Along the west coast with the emergence of shrimp trawls, *B. spirata* and *B. zeylanica* began to be landed as a by-catch in Sakthikulangara - Neendakara (Appukuttan and Philip, 1994). When export market for whelks developed, targeted fishing of whelk by modification of trawls also began (Philip and Appukuttan, 1997). The modified version of the gear has been described recently by Sabu *et al.* (2005).

The population dynamics of only a few marine gastropods has been studied. Philips (1969) has described the population ecology of the dog whelk, *Dicathais aegrota* in Western Australia. The mortality rate of the coral reef gastropod *Cerithium nodulosum* in Mariana Island has been studied (Yamaguchi, 1977). Population dynamics, especially the migration, recruitment and mortality of the netted dog whelk *Nassarius reticulatus* in Sweden has been described by Tallmark (1980).

Abalones form an important group of marine gastropods which are fished in several parts of the world. The recruitment, growth, mortality and population structure of *Haliotis ruba* in a southern Australian population (Prince *et al.*, 1988) and the population dynamics and fishery management of the paua, *Haliotis varia* has been studied (Sainsbury 1982a, 1982b). The growth, mortality, Y/R and MSY of the queen conch, *Strombus gigas* in the Caribbean waters (Appeldoorn, 1984, 1987 and 1988; Olsen 1985 and Berg and Olsen, 1989) and the growth histories of strombid snails from Bermuda (Wefer and Killingly, 1980) have been studied. Population structure and exploitation of the purple dye murex, *Bolinus brandaris* off the Mediterranean coast has also been described (Martin *et al.*, 1995).

Buccinum undatum is considered as a complementary species in the Swedish inshore waters and the population density, CPUE and other details of this resource has been studied (Valentinsson *et al.,* 1999). In Nova Scotia also this resource gained importance a decade back, consequently the population biology has been studied in detail (Kenchington and Glass, 1998).

The population ecology and fishery of the West Indian top shell *Cittarium pica* along the Caribbean coast of Costa Rica has been studied (Debrot, 1990a, 1990b; Schmidt *et al.,* 2002). The volutid snail, *Zidona dufresnei,* a benthic top predator, was subjected to unregulated commercial exploitation for more than 20 years in Southwestern Atlantic Ocean. The estimates of individual growth, production and mortality of this species have been studied by Gimenez *et al.* (2004). Along the Argentina coast, a fishery for the whelk *Buccinanops globulosum* started in the year 2000 and the various population parameters of this emerging fishery resource has been studied by Narvarte (2006).

Population dynamics of only very few gastropods of India has been studied. Devanesan and Chacko (1944) have reported as the bionomics of the sacred chank. The population dynamics of the *X. pyrum* has been estimated and described by Devaraj and Ravichandran (1988).

2.3. Utilization

The gastropods have been utilized for a variety of purposes. Hornell (1918) has described in detail the chank bangle industry and Nayar and Mahadevan (1974) have dealt with the utilization of chank. The sinistral form of chank (shell having opercular aperture at the left side), known as 'valampuri' is a freak and is in great demand for worship in Hindu temples. A good valampuri chank may be priced at Rs. 10,000 or more (Narasimham, 2005). Nayar and Mahadevan (1974) and Mahadevan and Nayar (1980) have reported that along the Tirunelveli coast, four valampuri chank each in 1920, 1957, 1970 and 1980 were collected. Menon (1976) and

Chatterji (1976) have described the possibility of developing shell handicrafts in Andaman and Nicobar Islands. The shell craft industry in Andaman and Nicobar Islands has been described by Dorairaj and Krishnamurthy (1997), Krishnamurthy and Soundararajan (1999) and Appukuttan and Ramdoss (2000). Ramdoss (2003) has also given a consolidated description of the gastropod resources and their utilization in India.

2.4. By-catch

In most countries gastropods are landed as by-catch of trawlers. The trawl is a mobile non-selective fishing gear and this collects every organism in its path. Discarding unwanted species occurs in most fisheries around the world, and is one of the major biological and environmental issues facing modern fisheries. Some or all of this by-catch may be discarded in the sea and includes fish, invertebrates, marine mammals, reptiles and birds. On an average 27 million tonnes of fish are discarded each year in commercial fisheries (Alverson *et al.*, 1994), and 8.3% of the total world fishery landings are molluscs (Malaquias *et al.*, 2006).

The trawl net being an efficient fishing gear with a small cod-end mesh size captures numerous small-sized species as well as juveniles of larger species, compared to any other fishing gear. The problem of discard and by-catch has attracted substantial attention among researchers in the last three decades due to reports on the deleterious impact they have on the marine ecosystem, coupled with documented presence of a colossal amount of biodiversity in the by-catch, particularly young ones of commercially valuable species and endangered species such as sea turtles.

Considering the severity of the problem, many international studies have been conducted on by-catches and discards (Alverson *et al.*, 1994; Clucas, 1997; Annon, 2003 and FAO, 2004). In India several fisheries research organizations have also tried to assess the by-catch and the impact of trawl on the bottom fauna. Some of the major works on the by-catch of shrimp trawlers along both the coast of India are that of George *et al.* (1981), Sukumaran *et al.* (1982), Rao (1988), Sivasubramanian (1990), Gordan (1991), Menon (1996), Menon and Pillai (1996), Rao (1998), Kurup (2001), Kurup *et al.* (2003) and Vivekanandan (2003). Bijukumar and Deepthi (2006) have given a detailed review of trawlers and by-catch and the implications on marine ecosystem. Molluscs are an important component of trawlers and the diversity of the molluscan fauna landed by trawlers has been studied in detail (Malaquias, 2006). The negative impact on bivalves and the stock depletion of certain commercially important species and the effect on certain endangered mollusks has been detailed by Rumohr and Krost (1991), Chemello *et al.*(2000), Craeymeersch *et al.* (2000) and Scotti and Chemello (2000).

Carbonell (1997) has presented a detailed report of the molluscs affected by trawling in the Western Mediterranean. Borges *et al.* (2000 & 2001) and Malaquias *et al.* (2006) have reported on the molluscs caught in the trawl catch of Portugal. The occurrence of mollusks in trawl by-catch in Indian water has been reported by several workers (George *et al.* 1981; Menon, 1996; Kurup *et al.*, 2003 and Bijukumar and Deepthi, 2006). An exclusive report of the molluscan resources and the seasonal variation of the important species have been given by Appukuttan and Philip (1994).

The survival of animals discarded from trawlers has been recently the subject of considerable attention, and it has been realized that it varies between taxonomic groups and even between species within the same genus (Wassenberg and Hill 1989; Bergman and Moore, 2001a and 2001b; Jenkins and Brand 2001; Lancaster and Frid 2002). Wassennberg and Hill (1993) found that the Australian pectinid bivalve *Annachlamys flabellate* (Lamarck) was very robust, with 100% survival 7 days after being caught (Malaquias *et al.*, 2006).

Studies have been conducted to understand the changes in benthic community composition as a result of trawling (Greenstreat and Hall, 1996; Lindedoon and de Groot, 1998). Because of the concern to reduce the damage on the ecosystem, fishing gear technologist started to develop effective method to reduce the by-catch, and provide means to escape the trapped sensitive marine resource. The development of by-catch reduction device (BRD) and turtle excluder device (TED) are results of targeted research programme (Pillai, 1998). The need for quantitative and qualitative database on by-catch and information on biology and ecosystem role of by-catch species has recently been understood and studied (Menon, 1996; Thomas *et al.*, 2004; Bijukumar and Deepthi, 2006).

2.5. Management

Because of their sedentary nature and slow growth rate, gastropod stocks become prone to over exploitation resulting in stock depletion. To overcome this issue, conservation measures or fishery regulations have been formulated. Consequent to over fishing of the queen conch *S. gigas* it has achieved a protected status in several countries like Bermuda (Burnett, 1981), Florida (Hunt, 1980) and the fishery has been closed for a prolonged period in Bonair and Cuba (Berg and Olsen, 1989). Several other regulation measures in vogue for this gastropod have been described in detail by Berg and Olsen (1989). Caddy (1989) has given an elaborate description of the development in Resource Management for wild stock of bivalves and gastropods. Management measures meant for *Cittarium pica* in the Virginian Islands and Puerto Rico has been discussed by Schmidt *et al.* (2002).

In India, the major gastropod resources exploited, like *Xancus pyrum, Trochus* spp. *Turbo* spp. etc. are protected through management measures formulated by governments of different states and union territories. Mahadevan (1987) has elaborately described the management and development of shellfish resource in India. Krishnamurthy and Soundararajan (1999) have reported on the existing rules on gastropod fishery in the Anadaman and Nicobar Islands. In India, chank fishery has been regulated since a very early period and Narasimham (2005) has given a detailed description of the management means currently practiced.

Most of the studies in Indian waters have tried to explain the physical and chemical changes which take place in the marine system and the fishery biologists have tried to relate the variation in demersal fisheries and crustacean fisheries to these changes. The present study is an attempt to relate the population structure of a commercially important gastropod, its biology and fishery to the environment which it inhabits along the Kerala coast.

Chapter 3

Materials and methods

3.1. Sampling:

a. Sample collection from whelk bed for ecology studies

Ecology of the whelk beds was studied by planned experimental trawling using commercial shrimp trawlers in the fishing grounds off Kollam in the Arabian Sea along the southwest coast of India. Detailed enquiry was made with trawl fishers who went for targeted fishing of *Babylonia spirata* and *Babylonia zeylanica* on the occurrence and distribution of these two species. Based on this information trial trawling was conducted from 10 m depth from the shore line to 30 m depth covering the region north and south off Kollam extending from 08° 56' 501 N, 76° 28' 193 E and 08 ° 56' 704 N, 76 ° 26' 262 E. Based on these observations, four sampling sites were fixed (Fig. 2) as given below.

Fig. 2 Map showing the study area

Sl. No.	Site	Depth	Location
1	N_1	10-20m	North of Kollam
2	N_2	20-30m	North of Kollam
3	S_1	10-20m	South of Kollam
4	S_2	20-30m	South of Kollam

The samples were collected during May and October of 2003 and January 2004 covering the pre-monsoon and early and late post-monsoon. At each sampling station the exact geo-location was noted using a Geographical Positioning System (Garmin-12).

Surface and bottom water samples were collected from each station using a Nansen bottle (2 l) attached with reversible thermometer, which recorded the bottom water temperature. Salinity and pH were noted on board using a refractometer and digital pH meter. Dissolved oxygen (DO) content of the water samples collected were estimated by standard Winkler titration method after fixing the samples on board in DO bottles (125ml). Water samples were collected from each site for analyzing ammonia, phosphate, nitrite, nitrate and total suspended solids (TSS) following standard methods. Sediment samples for studying the sediment characteristics and the associate benthic fauna were collected from each station using a van Veen grab ($0.04m^2$). From each sample, sub samples of approximately 50 g were taken for analysis of sediment grain size and organic carbon.

The grab samples were sieved through standard sieve series of 1mm and 0.5mm mesh to separate benthic macrofauna in the field itself. Fauna retained in sieves were collected and preserved in 4% buffered formalin for further analysis in the laboratory. After collecting the water and sediment samples from each station, experimental trawling was conducted for 30 minutes. The entire trawl catch was examined and total weight of the catch and whelk caught were noted immediately after each haul. Sub samples were taken randomly from each haul, iced and later fixed in formalin for further identification and detailed study. At each station and in each sampling period all the samples were collected in triplicate.

b. Sample collection for biology and population studies of whelk

The reproductive biology and population characters of *Babylonia spirata* was studied by analyzing the fishery samples pertaining to the period from January 2001 to December 2002 and *B. zeylanica* for a period of one year from January to December 2002. The samples were collected from trawlers operating from the Sakthikulangara and Neendakara harbours at Kollam district, Kerala except during the trawl ban (15^{th} June-30^{th} July). A total of 1864 *B. spirata* and 583 *B. zeylanica* were analyzed for the biological studies during this period.

c. Data collection for estimating fishery landings

The fishery data was collected from the Neendakara-Sakthikulangara fishing harbours during the period from January 2001 to December 2002 at fortnightly intervals. Enquiries were made with the fishers regarding location of the fishing area and fishing hours. In addition to this, the fishery data collected by Fisheries Resource and Assessment Division (FRAD) of CMFRI using a stratified multistage random sampling design (Srinath *et al.*, 2005) was used for estimating the monthly landing, the catch per unit effort (CPUE) and the percentage contribution of the gastropod and whelk resource to the total marine landing.

3.2. Analysis:

3.2.1. Hydrography

The ammonia in seawater was estimated based on indophenol blue reaction of phenol hypochlorite method (Solarzano, 1969), phosphorous by ascorbic acid method (Murphey and Riley, 1962). Nitrogen present in sea water in the form of nitrite and nitrate were estimated by the method described by Morris and Riley (1963).

3.2.2. Sediment characteristics

Percentage organic carbon in soil was estimated following Wakeel and Relay's titration method (1957). The soil sample was digested with potassium dichromate solution and sulphuric acid. The excess potassium dichromate not reduced by the organic matter of the soil was determined by titration with standard ferrous ammonium sulphate.

Sediment samples were analyzed for grain size distribution following international sieve and pipette method described by Krumbein and Pettijohn (1938) with modifications. Percentage of silt and clay were estimated by standard pipette analysis. The sand fraction was sieved through standard sieves of 2 mm and 200 µm in an automatic sieve shaker and each fraction was weighed. Prior to analysis, dried samples were treated with H_2O_2 to remove organic matter and NaOH was used as dispersant in pipette analysis.

3.2.3. Benthos

In the laboratory, the benthos samples preserved in formalin were placed in fresh neutral formalin of 4% with Rose Bengal vital stain. The preserved specimens were sorted and identified up to the lowest possible taxon using standard nomenclature of Fauvel (1953) and Day (1967a, 1967b) for annelids; Gosner (1971) and Satyamurti (1952) for molluscs. Biomass was expressed as wet weight, excluding hard parts. Sorting and identification were done under a stereomicroscope. The specimens were counted and wet weights were taken with an electronic balance to the nearest 0.01 mg. Wet weight was taken after blotting the specimens completely off formalin.

Standard linear measurements of whelk and other major mollusks, crustaceans and finfishes were also taken. Nekton caught in the trawl net were kept in deep freezer and identified up to the lowest possible taxon. For identification, the taxonomic description by Day (1958) and Fischer and Bianchi (1984) for fin fishes, Chhapgar (1957) for crabs, Wye (1991) and Satyamurti (1952) for molluscs were used. Total wet weight was taken individually for each animal in an electronic balance accurate to 0.01 mg.

3.2.4 By-catch analysis

The sub samples of trawl by-catch were collected at random from the fishing harbour at fortnightly intervals. In the laboratory these were segregated into major groups and weighed separately using a digital balance. These groups were further analyzed to generic or species level and the percentage contributed by each was calculated. Linear measurements of important species were also taken.

3.2.5. Statistical analysis

Changes in hydrographic parameters and sediment characteristics were statistically analysed using analysis of variance to delineate the variation between sites and zones. To analyse the community structure of whelk bed, univariate and multivariate analyses described by Clarke and Warwick (1994) were performed separately for macrobenthos and trawl fauna. Univariate community measures like, Shannon-Weiner diversity index (H'), Simpson's dominance index (1-λ'), Margalef's species richness (d) and Pielou's evenness (J') were calculated using the PRIMER statistical software package developed by the Plymouth Marine Laboratory (Clarke and Warwick, 1994). Comparisons of individuals or gross community parameters such as species richness or diversity may fail to appreciate directional changes in relative species abundance. To detect these changes multivariate discrimination techniques such as ANOSIM and SIMPER were performed. The macrobenthic and trawl catch community structure among the sites and zones were tested using analysis of similarity (ANOSIM). For this the similarity matrix was constructed using the Bray-Curtis similarity index after square root transformation of the data. The interpretation of ANOSIM results is based on the global R statistic value. The R value lies between -1 and 1. R=1 only if all replicates within sites are more similar to each other than any replicate from different site and R is approximately zero when null hypothesis is true. The relative contributions of each species to the average similarity of these groupings were calculated using SIMPER analysis.

To elucidate the relationship of whelk abundance with the biotic and abiotic factors of the whelk bed, the whelk density was correlated with hydrographic, sediment parameters and density of macrobenthos and nekton. The analysis of variance and correlation were tested using SPSS statistical package, version 10.

3.2.6. Reproductive biology

a. Reproductive system

The male sex was determined externally by the presence of a penis on the right side of the head, just behind the right tentacle. Reproductive systems of both the sexes were studied by dissecting the soft tissue.

b. Male and female maturity stages

The gonads were classified in to four different maturity stages based on morphological differences of the testes and prostate gland in male and ovary, albumin gland, capsule gland in female.

c. Seasonal variation in maturity stages

The maturity stages of both male and female snails in the monthly samples were identified based on the criteria of classification described in the section 3.2.6.a and b. The percentage occurrence of each stage in each month was calculated and based on these the spawning period was identified.

d. Length at first maturity

For determining the length at first maturity (L_{m50}), females with ovaries in stages III and IV of maturation were considered as mature and the proportion of this group in each length group was noted and the frequencies were scaled to percentages. The length, at which about 50% of the snails were mature, has been taken as the length at first maturity (King, 1995).

e. Sex ratio

In each month the male and female snails were separated based on the sexual dimorphism. The sex ratio was estimated month-wise. The sex ratio of the population in different size class was studied by observing the male: female ratio in 8 groups at 5mm class intervals ranging from 20-60 mm in *B. spirata* and 9 classes ranging from

25-70 mm in *B. zeylanica*. The ratio was tested by Chi square test at a significance level of 0.05 to understand the variation from normal distribution of 1:1 ratio (Snedecor and Cochran, 1967).

f. Gonadosomatic Index (GSI):

The GSI is useful for determining the progress in maturity and separating spawning and non-spawning animals of the population. The index (Webber, 1977) was calculated for each month from June 2001 to May 2002 using the formula

$$GSI = \left[\frac{Weight\,of\,the\,gonad}{Total\,body\ weight\,(excluding\,shell)} \right] \text{X } 100$$

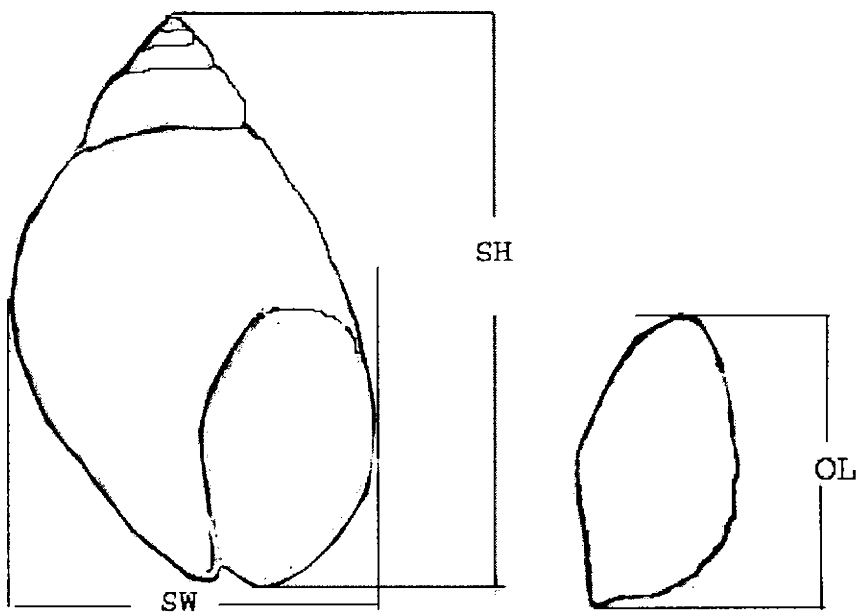
After differentiating the sex, the whole weight of the snail was taken using a digital balance to nearest of 0.01g followed by weighing the gonad in the same manner above. The maturity stage was also noted. From these observations the average GSI for male and female snails for the particular month were separately calculated. The average monthly GSI for the different maturity stages observed during the month was also studied separately for male and female snails.

3.2.7. Food and feeding

The conditions of stomach of *Babylonia* spp. were studied for one year period from June 2002 to December 2002. The degree of fullness of stomach of 850 B. *spirata* and 355 *B. zeylanica* were recorded. The stomach was considered full, ¾, ½, ¼, little and empty depending on the relative fullness and the space occupied by the stomach content. The state 'little' was considered when the stomach content was less than $1/4^{th}$ of full stomach. The percentage occurrence of the different categories was estimated for each month. The snails with stomach full, ¾ and ½ were considered as actively fed, while with ¼, little and empty were taken as poorly fed.

3.2.8. Biometric relationships

To study interrelations between different biometric characters, the linear measurements of *B. spirata* and *B. zeylanica* were taken. The measurements used were total shell height (SH) from apex to tip of columella, shell width (SW) width of body whorl, length of operculam (OL) as the longest distance of operculum (Fig. 3a &b) were measured with a digital vernier calipers to the nearest 0.1mm. Total whole animal wet weight and tissue weight (wet) were also recorded with an electronic balance of 0.01g precision.



SH- shell height, SW- shell width, OL- operculam length

Fig. 3a & b Diagram showing the morphometric measurements

The shell height was regressed on shell width and opercular length assuming a linear relationship Y = a+bX, where Y is total weight; X is shell height, 'a' is the intercept and 'b' is a constant. The shell height with total animal wet weight and tissue weight were fitted to the curvilinear growth equation $W = aL^b$ using linear regression after logarithmic transformation of variables. Analysis was made for each sex separately and Analysis of Covariance (ANCOVA) was performed to compare slopes and intercepts for both the sexes.

To understand the variation in biometric relations in relation to size of the whelk of both the sexes, the two size group 30-40 and 40-50 mm for males and three size group 20-30, 30-40, and 40-50 mm size classes for females were analysed separately. For *B. zeylanica* comparisons were made between 2 size classes 40-50 and 50-60 mm for males and females separately. Subsequent to this, comparisons were made to test the significance of variation between size classes of same sex and between size classes of opposite sexes using ANCOVA.

3.2.9. Length frequency distribution

The length frequency distribution of *Babylonia spirata* was studied by analyzing the fishery samples collected fortnightly, pertaining to the period from January 2001 to December 2002 and *B. zeylanica* for the period of one year from January to December 2002. A total of 1864 numbers *B. spirata* and 583 numbers *B. zeylanica* were analyzed during this period. *B. spirata* of 20-60 mm SH and *B. zeylanica* of 24-68 mm SH were measured using digital calipers (Mikimoto™) to the nearest of 0.1 mm and grouped into 2 mm class intervals.

3.2.10. Age and Growth

Growth rate is defined as the change in body weight or mass over time. Thus the growth in body size is expressed as a function of age. In the present study, length frequency data of 2 years for *B. spirata* and *B. zeylanica* were utilized for estimating growth parameters. This formed the basic input data for analysis of growth, which was assumed to be asymptotic. The parameters of the von Bertalanffy growth formula (VBGF), growth rate (k) and asymptotic length (L_∞) were estimated using pooled data of corresponding months of both the years. For this purpose the ELEFAN routines of the FAO ICLARM Stock Assessment Tools (FiSAT) program (Gayanilo *et al.*, 1988) was used. The non-seasonalized von Bertalanffy growth equation used was:

$$L_t = L_\infty (1 - e^{-k(t - t_0)})$$

where L_t = Length at time t; L_∞ = asymptotic length; k = growth constant; t_0 is age at 0 length (considered as zero here).

The sequence of analysis carried out as follows:

1. For a preliminary arbitrary estimate of L_∞, Powel- Wetherall method was used. The L_∞ thus obtained was used as input for Scan of K values in ELEFAN I.
2. ELEFAN I routine steps in FiSAT program were run to estimate the L_∞ and K, the steps followed were:
   - Scan of K values
   - Response surface analysis
   - Automatic search routine

   From these routines the VBGF growth parameter estimates with the highest Rn value was selected for both the species.
3. Bhattacharya method was used to separate different cohorts for each month from the
L/F distribution.
4. Modal progression analysis to estimate the growth parameters K and L_∞.

The growth increment data obtained by linking of means in modal progression analysis was used to run the Gulland & Holt plot, Munro's and Faben's method to find out the L_∞ and K values assuming that the growth in shell height follows VBGF. From these estimates, the parameters obtained with the best fit are selected.

3.2.11. Mortality coefficients

The total mortality coefficient (Z) was estimated using the Productio/Biomass ratio of benthic invertebrate populations (Brey, 1999) and length converted catch curve method (Pauly, 1983). The Brey's equation used was:

$$Z = 10.154 - (0.271 * \log(M)) - (2824.247 * 1/(T+273)) - (0.063 * \log(D+1)) + (0.130 * \text{Life-ME}) + (0.076 * \text{DDiet-C}) - (0.311 * \text{DTaxon-M})$$

where, M is Mean Individual Body Mass (kJ); T is Bottom Water Temperature (¡C); D is Water Depth (m); ME is Motile Epifauna; Diet C is Carnivorous; Taxon- M is Mollusca.

The natural mortality coefficient (M) was estimated using Brey's (1999) equation of natural mortality rate (M) in benthic invertebrate populations and Pauly's (1980) method. Brey's equation used for estimating M was:

$$M = 1.672 + (0.993 * \log (1/Amax)) - (0.035 * \log (Mmax)) - (300.447 * 1/(T+273))$$

where, Amax is Maximum age (y-1); Mmax is Maximum individual body mass (gDM); T is Bottom water temperature (¡C)

The fishing mortality coefficient (F) was calculated from the formula

$$F = Z - M$$

Here, the Z and M values estimated using Brey's equations were used for the calculations.

3.2.12. Probability of capture

The complete length range of fish or shellfish are not always under full exploitation and the selectivity is determined by the cod end mesh size in trawl nets. The mean length (L_{c50}) at which a fish has 50% chance of being retained by the net (0.5 probability of being caught) is estimated for suggesting the regulatory measures of the gear. The probability of capture by length of the animals was estimated using FiSAT program. The mortality coefficients estimates using Brey's (1999) equations were used here for the analyses.

3.2.13. Relative yield-per-recruit (Y'/R)

Beverton and Holt (1966) proposed relative yield-per-recruit (Y'/R) based on the concept that what matters is the relative difference of Y/R for different values of F. The model is suitable for assessing the effect of mesh size regulations. The Y'/R and B'/R were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano, 1986). The estimates were made using FiSAT.

3.2.14. Length cohort analysis

Length based cohort analysis (Jones 1981) was performed to estimate the dynamics of abundance and fishing mortality and number of survivors for each of the length class. Here it is assumed that all length classes caught during one year reflects that of a single cohort during it entire life span. The input parameters used were, L_∞, K, F/Z.

Chapter 4
Results

4.1. Hydrology

The results of the ecological variations of the surface and bottom water along the two depth zones, 10-20m (N_1) and 20-30m (N_2) in the northern and southern zone (S_1 and S_2) of the study area are given below.

***a. Temperature*:**

In the whelk beds, the sea surface temperature (SST) ranged between 29 and 31°C, while the sea bottom temperature (SBT) was between 28 and 30°C. Along north zone, the average SST was 29.6°C±1.4 and 29.3°C ± 1.2 at N_1 and N_2 respectively, where as the SBT showed a slight decrease, 28.8°C, and 28.9°C at N_1 and N_2 respectively. Along southern zone, the average SST at site N_1 was 29°C and at N_2 29.5°C. The SBT was slightly lower than the SST at both the sites, 28 and 29°C respectively (Fig. 4). ANOVA showed no significant variation in water temperature with depth and zone ($P > 0.05$).

b. Salinity:

In the north zone, salinity of surface water ranged between 29 and 36ppt and bottom water salinity varied between 29 and 37 ppt. The average surface water salinity at N_1 was 33.2 ± 3.97, and at N_2 33 ± 3.63 ppt (Fig. 5). The surface water salinity of the southern zone varied between 30 and 37 ppt and between 30 and 36 ppt for bottom water. The average surface water salinity at S_1 and S_2 were 35.5 ± 0.71 and 33.5 ± 4.95 ppt, while the average bottom water salinity at these sites was 36 and 32 ± 2.83 ppt respectively. Though there were variations in average values of salinity in both the zones, these variations were not statistically significant ($P > 0.05$).

***c. pH*:**

In the northern zone, the surface as well as bottom water pH were almost similar in both the sites. The surface water pH ranged between 8 and 8.4, while the pH of bottom water varied between 8 and 8.3 and the average pH of both surface and bottom water in this region were 8.2. In the southern zone, surface water pH ranged between 8.3 and 8.5, while that of the bottom water ranged from 8.3 to 8.6. The average surface water pH at S_1 and S_2 were 8.5 ± 0.1and 8.4 ± 0.1respectively, and

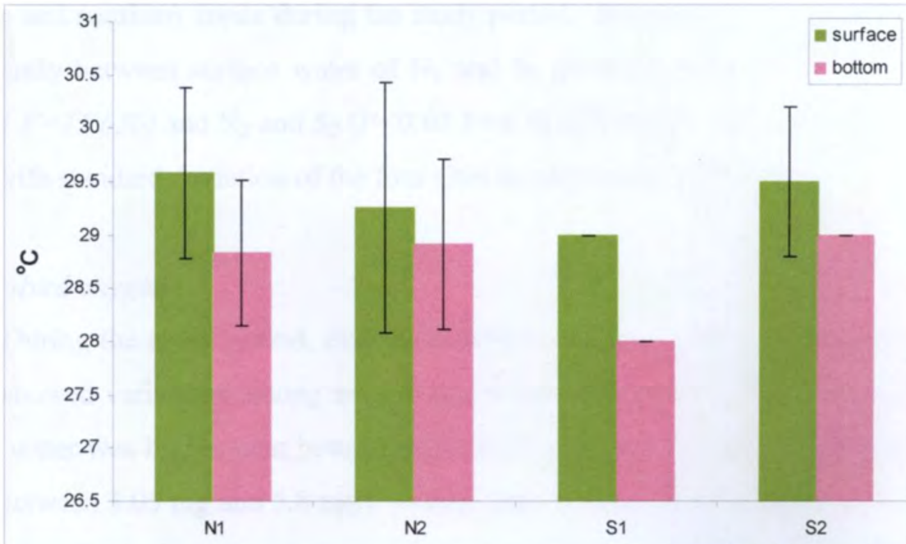


Fig. 4 Average temperature (°C) of surface and bottom water at the four sites

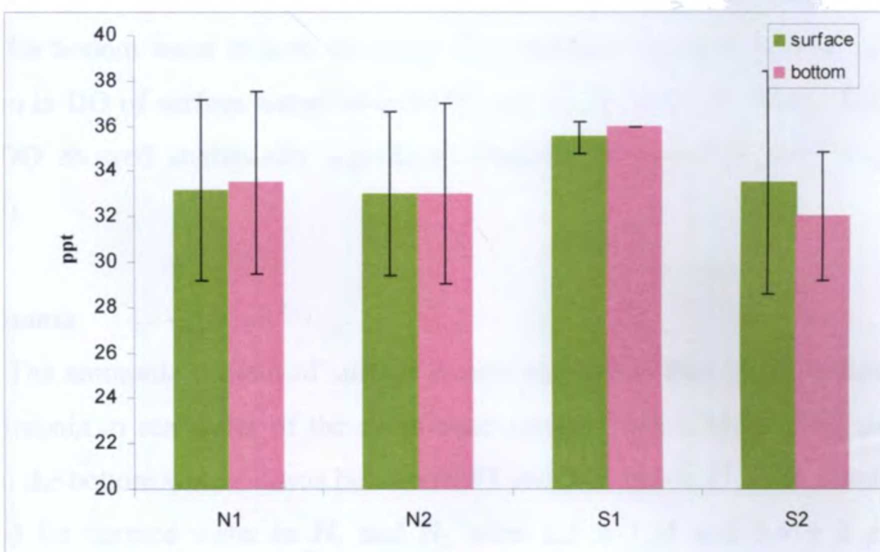


Fig. 5 Average salinity of surface and bottom water at the four sites

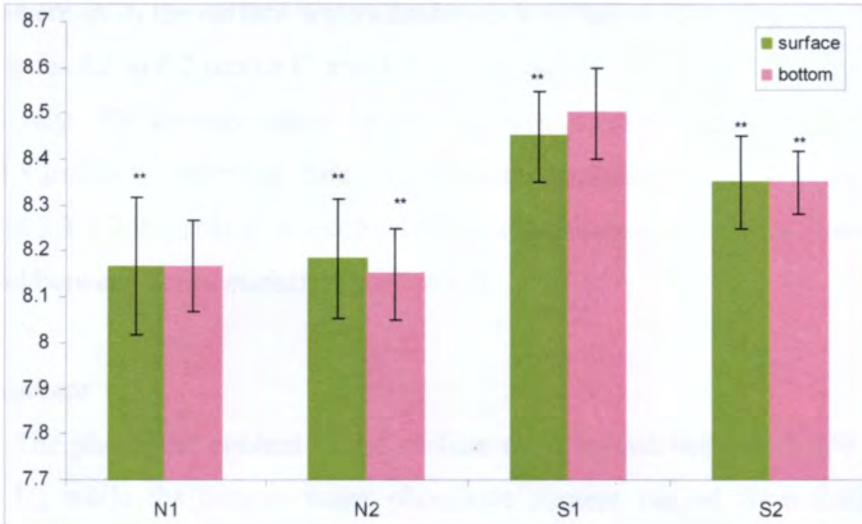
same values were obtained for bottom water in this zone. From the statistical analysis it was found that there was no significant variation in pH between the 2 depths in the northern and southern zones during the study period. However the pH values varied significantly between surface water of N_1 and S_1 (*$P<0.05$ & $F=6.106$*), N_2 and S_2, (*$P<0.01$ $F=13.636$*) and N_2 and S_2 (*$P<0.05$ $F=6.0$*) of bottom water. The average pH values with standard deviation of the four sites are presented in Fig. 6.

d. Dissolved oxygen

During the study period, dissolved oxygen content of the surface and bottom waters showed variations among sites in the north zone and dissolved oxygen in the surface water was higher than bottom water at all stations. The DO of surface water varied between 3.05 mg and 5.8 mg l^{-1}, while that of bottom water ranged from 2.2 to 5.5 mg l^{-1}. The average level of dissolved oxygen at N_1 and N_2 were 5.31 ± 0.44 mg l^{-1} and 4.9 ± 1.05 mg l^{-1}, while it was 4.6 ± 0.76 mg l^{-1} and 3.8 ± 1.34 mg l^{-1} respectively for bottom waters (Fig. 7). In south zone, the bottom water showed higher dissolved oxygen content compared to surface water in shallower region (Fig. 7). In this region, the values ranged between 5.4 and 6.5 mg l^{-1} for surface water and 5.9 to 6.2 mg l^{-1} for bottom waters. The average values obtained for surface water at S_1 and S_2 were 5.6 ± 0.2 mg l^{-1} and 6.4 ± 0.08 mg l^{-1}, while the values were same (6.1 mg l^{-1}) for bottom water in both the sites. The statistical analysis showed significant variation in DO of surface water between N_1 and N_2 (*$P<0.05$, $F=34.8$*). The bottom water DO showed statistically significant variation between N_1 and S_1 (*$P<0.05$, $F=6.48$*).

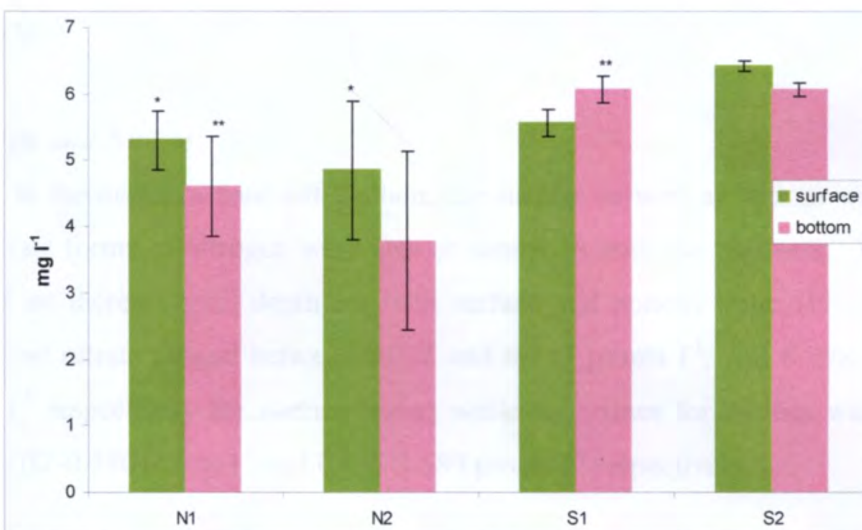
e. Ammonia

The ammonia content of surface waters was lower than in the bottom water. The ammonia in sea water of the north zone ranged from 0.338 to 5.83 μmols l^{-1}, while in the bottom waters it was between 0.93 and 5.83 μmols l^{-1}. The average value recorded for surface water in N_1 and N_2 were 2.3 ± 1.55 and 3.4 ± 2 μmols l^{-1} respectively, while for bottom water the values were 3.3 ± 2.5 and 3.8 ± 1.8 μmols l^{-1}. No significant variations were found in the statistical analysis between the sites (*$P>0.05$*).



** Significant variation between zones

Fig. 6 Average pH of surface and bottom water at the four sites



* Significant variation within sites ** Significant variation between zones

Fig. 7 Average dissolved oxygen of surface and bottom water at the four sites

In south zone, the dissolved ammonia content was similar at S_1 as in north zone, where as in the surface waters ammonia was higher at S_2 (Fig. 8). The values varied from 2.2 to 6.2 μmols l^{-1} and 1.2 to 5.6 μmols l^{-1} for surface and bottom water respectively. The average values for surface water at both the sites were 3.3 ±1.6 and 4.5 ± 2.8 μmols l^{-1}; where as the average ammonia content in bottom water were 4.5 ±1.5 and 3.3 ± 2.9 μmols l^{-1} respectively. No significant variation was found between sites and between zones statistically ($P>0.05$).

f. Phosphate

The phosphate content in the surface water varied between 0.078 and 0.544 μmols l^{-1}, while the bottom water phosphate content ranged from 0.088 to1.865 μmols l^{-1}. The average values of phosphate at N_1 and N_2 were 0.39 ± 0.18 μmols l^{-1} and 0.32 ± 0.2 μmols l^{-1}, while it was 0.63 ± 0.5 μmols l^{-1} and 0.72 ± 0.6 μmols l^{-1} respectively for bottom waters (Fig. 9). The respective values for surface water ranged between 0.381 and 0.707 μmols l^{-1}, where as in the bottom water the values varied from 0.435 to 0.707 μmols l^{-1}. Though phosphate content of north and south zone showed variations, only N_2 and S_2 expressed statistically significant variation ($P<0.05$).

g. Nitrite and Nitrate

In the northern zone off Kollam, the surface as well as bottom water nitrite and nitrate forms of nitrogen were almost similar in both the transects. The values showed an increase with depth for both surface and bottom water (Fig. 10). The nitrite and nitrate ranged between 0.032 and 0.413 μmols l^{-1}, and 0.298 and 2.318 μmols l^{-1} respectively for surface water, while the values for bottom water ranged from 0.032-0.586 μmols l^{-1} and 0.446-3.589 μmols l^{-1} respectively.

Along the south zone also the nitrite and nitrate forms of nitrogen showed similar variations as in north zone (Fig. 10). The surface water nitrite and nitrate ranged from 0.029 to 0.157 μmols l^{-1} and 0.51 to 0.662 μmols l^{-1} respectively, while in bottom water the nitrogen content varied from 0.079-0.608 μmols l^{-1} and 0.401-6.151 μmols l^{-1} respectively. Though there were variations in values among sites and zone, the variations were not statistically significant.

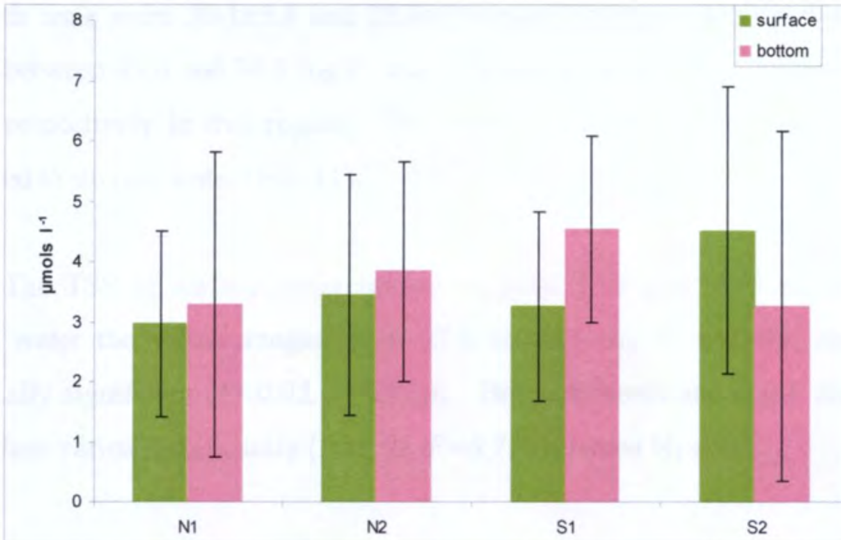
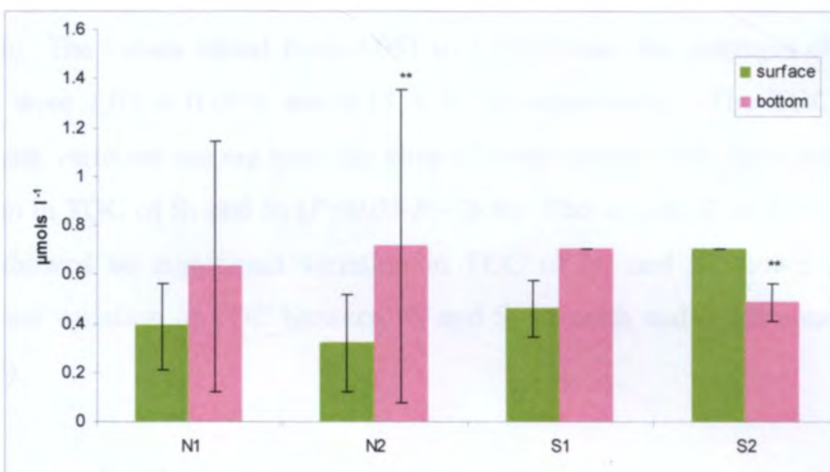


Fig. 8 Average ammonia of surface and bottom water at the four sites



** Significant variation between zones

Fig. 9 Average phosphate of surface and bottom water at the four sites

***h. Total suspended solids* (TSS)**

The average values of total suspended solids of surface water of N_1 and N_2 in the north zone were 20.1±5.8 and 23.8±7.9 mg l^{-1} respectively. The TSS values ranged between 13.6 and 34.8 mg l^{-1} and 15.6 and 35.4 mg l^{-1} in surface and bottom waters respectively in this region. The bottom water had more suspended solids compared to surface water (Fig. 11).

The TSS of surface water ranged between 22.4 and 31.2 mg, where as in bottom water the values ranged from 27.8 to 42.4 mg l^{-1} and the variation was statistically significant ($P<0.05$, $F=29.06$). Between north and south zone also the TSS values varied significantly ($P<0.05$, $F=6.73$) between N_1 and S_1.

4.2. Sediment characteristics

a. Total organic carbon

The total organic carbon of the sediment of north zone showed an increase with depth (Fig. 12). The percentage of organic carbon ranged between 0.87 and 1.75, with an average TOC of 1.18 ± 0.4% at N_1 and 1.28 ± 0.2% at N_2. In contrast to this, along south zone the organic carbon content of sediment decreased with increase in depth. The values varied from 0.051 to 1.051 % and the averages obtained at S_1 and S_2 were 1.05 ± 0.09% and 0.13 ± 0.1% respectively. The TOC showed no significant variation among both the sites of north zone, while there was significant variation in TOC of S_1 and S_2 ($P<0.05$ $F=76.8$). The statistical analysis between the zones showed no significant variation in TOC of N_1 and S_1, however there was significant variation in TOC between N_2 and S_2 of north and south zones ($P<0.001$, $F=46.2$).

b. Grain size distribution

The sediment texture along north zone of Kollam was found to be silt-loam at all stations during the study period. Percentage of clay and sand were observed to increase with increase in depth, where as the contribution of silt was found to decrease with increase in depth. The percentage of clay varied from 12.0 to 26.5% and that of silt ranged from 45.2 to 64.7%. Among sand fraction, fine sand

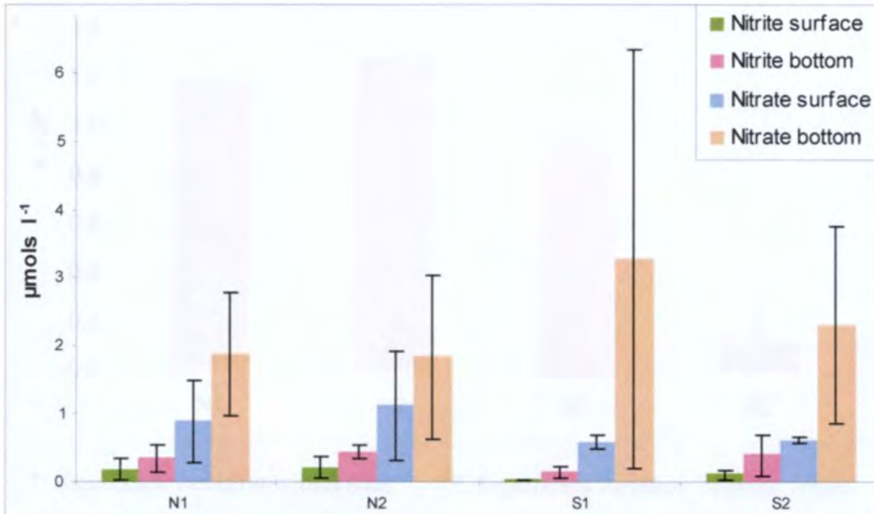
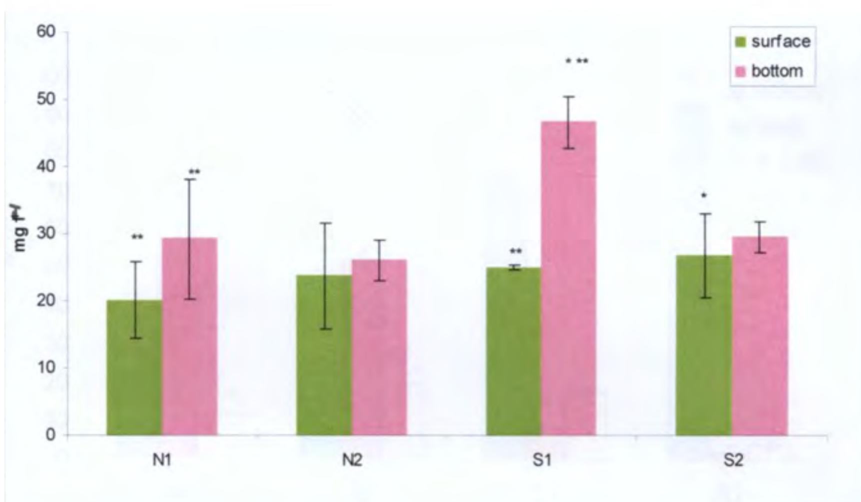
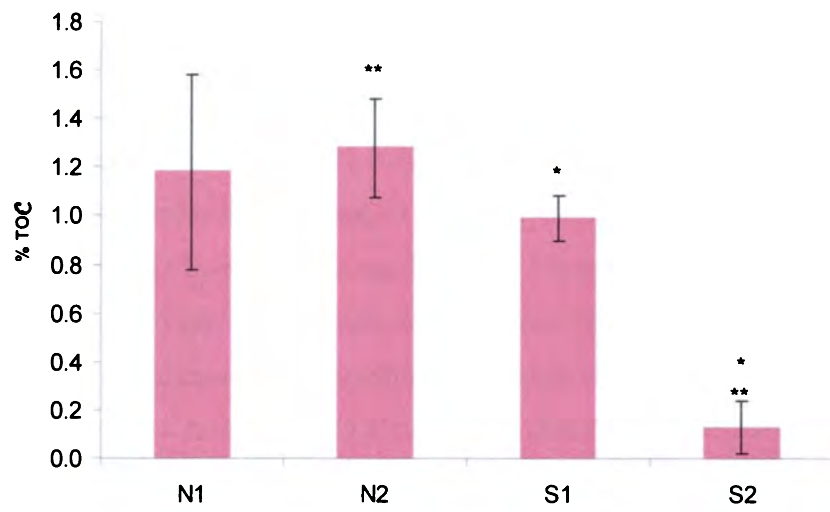


Fig. 10 Average nitrite and nitrate of surface and bottom water at the four sites



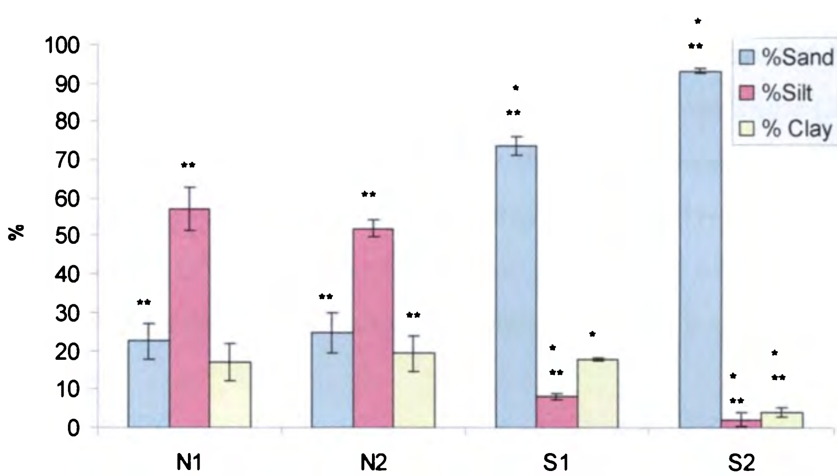
* Significant variation within sites ** Significant variation between zones

Fig. 11 Average total suspended solids of surface and bottom water at the four sites



* Significant variation within sites ** Significant variation between zones

Fig. 12 Average total organic carbon of sediment at the four sites



* Significant variation within sites ** Significant variation between zones

Fig. 13 Grain size distribution of sediment at the sites

dominated over the coarse sand at all stations and the total sand fraction ranged between 16.8 and 31.7% during the period. The details are depicted in Fig. 13.

Along the south zone, sand fraction dominated the sediment texture at all stations and the texture was sand-loam at S_1 and sandy at S_2. The sand fraction varied between 70.2 and 93.6% and coarse sand formed the major component. The silt and clay fractions were very meager and ranged from 0.8 to 9% and 3.3 to 17.85% respectively. The sediment fractions showed significant variation between S_1 and S_2 (sand, $P<0.05$ $F=151.3$; silt $P<0.05$ $F=19.5$ and clay $P<0.05$ $F=290.2$). There was significant variation in sand ($P<0.001$ $F=183.4$) and silt ($P<0.001$ $F=124.3$) fractions at N_1 of north and S_1 of south zones, while the three fractions sand ($P<0.001$ $F=319.4$), silt ($P<0.001$ $F=848.4$) and clay ($P<0.05$ $F=16.0$) showed highly significant variation between N_2 and S_2.

4.3. Whelk distribution and abundance

In the north zone, *Babylonia spirata* was present at both the sites N_1 and N_2 and in the southern zone at S_1 at a low density and was absent in S_2. *B. zeylanica* was observed only at site S_2. Both the species were never found to co-exist. The density of *B. spirata* varied among sites and maximum density was observed at N_2 (6 ind/10 m^2) and minimum at S_1 (0.14 ind/10 m^2). The density of *B. zeylanica* (2 ind/10 m^2) was low compared to the density of *B. spirata* at the same depth in the north zones. Biomass of *B. spirata* was 30.9 g and 88.8 g/10 m^2 at N_1 and N_2 respectively, while it was lower (1.6 g/10 m^2) at S_1. The biomass of *B. zeylanica* observed in the site S_2 was 31 g/10 m^2. The details of density and biomass of whelk is given in Table-1.

Table-1 Average density and biomass of whelk at the four sites

Site	Species	Density ($nos/10m^2$)	Biomass ($g/10m^2$)
N_1	*B. spirata*	2	30.9
N_2	*B. spirata*	6	88.8
S_1	*B. spirata*	0.14	1.6
S_2	*B. zeylanica*	2	31

Length (shell height, SH) composition of *B. spirata* population occurring in the two zones was found to be almost similar. The average shell height of *B. spirata* at N_1 and N_2 was 40.8 ± 3.6 mm and 40.4 ± 3.5 mm respectively, while it was 35.4 ± 4.7 mm at S_1. 93.8% of *B. spirata* at N_1 were in the length range 34 to 46 mm with two modes at, 40-42 and 42-44 mm. Small size whelks of SH<34 mm formed 2.8% of the population and 3.4% were >46 mm at N_1. Similar pattern of length composition of whelk was observed at N_2, where the modal class was 42-44 mm (22.7%) and next dominant class was 38-40 mm (21.5%). 95.9 % of the whelks were of 34-46 mm length and 1.8 % smaller than 34 mm. The smallest specimen of *B. spirata* in the N_1 and N_2 measured 22.2 mm and 22.8 mm respectively, while the maximum SH recorded were 49.7 mm and 47.2 mm respectively. The average shell width (SW) of *B. spirata* was 27.2 and 26.9 mm at N_1 and N_2, the average total weight 15.5 and 14.8 g and average meat weight was 5.5 and 5.8 g respectively. Sex ratio (male: female) was similar, 1:1.3 and 1:1.4 at N_1 and N_2.

The SH of *B. spirata* ranged between 30.4 and 41.5 mm with an average of 35.4 ± 4.7 mm. Other shell and weight characters of *B. spirata* population at S_1 were; average SW 23.5 ± 2.5 mm, average weight 11.6 ± 4.1g and meat weight 3.7 ± 1.2g. The sex ratio was 1:0.5 and males dominated the population. The morphometric characters and length frequency composition of the population are given in Table-2 and Fig. 14 respectively. The shell height and width of *B. zeylanica* at site S_2 of south zone ranged between 36.3-52.9 mm and 21.9-30 mm respectively and the average SH of whelk in the population was 45.4 ± 3.6 mm and girth 26.3 ± 1.8 mm. The population of *B. zeylanica* was dominated by animals of 42 to 50mm (81.8%) SH, where the model class was 44-46 mm (40.9%). The total weight of *B. zeylanica* ranged between 9.1-22.4g and meat weight 3.9-9.8 g, with an average of 15.5 ± 3 g and 6.8 ± 1.5 g respectively. The population was slightly dominated by females; the sex ratio was 1:1.2.

Table-2. Biometric characters and sex ratio of the whelk population at the four sites

		N_1	N_2	S_1	S_2
		B. spirata		*B. zeylanica*	
Shell Height (mm)	Min	22.2	22.8	30.4	36.3
	Max	49.7	47.2	41.5	52.9
	Avg (±stdev)	40.8 ± 3.6	40.4 ± 3.5	35.4 ± 4.7	45.4 ± 3.6
Shell width (mm)	Min	14.6	16	20.6	21.9
	Max	35.3	30.4	26.3	30
	Avg (±stdev)	27.2 ± 2.4	26.9 ± 2.1	23.5 ± 2.5	26.3 ± 1.8
Total Wt (g)	Min	7	3.3	7.1	9.1
	Max	28	22.8	16.8	22.4
	Avg (±stdev)	15.5 ± 3.5	14.8 ± 3.2	11.6 ± 4.1	15.5 ± 3
Meat Wt (g)	Min	0.77	1.01	2.5	3.9
	Max	8.12	8.61	5	9.8
	Avg (±stdev)	5.5 ± 1.3	5.8 ± 1.4	3.7 ± 1.2	6.8 ± 1.5
Sex ratio (M:F)		1:1.3	1:1.4	1:0.5	1:1.2

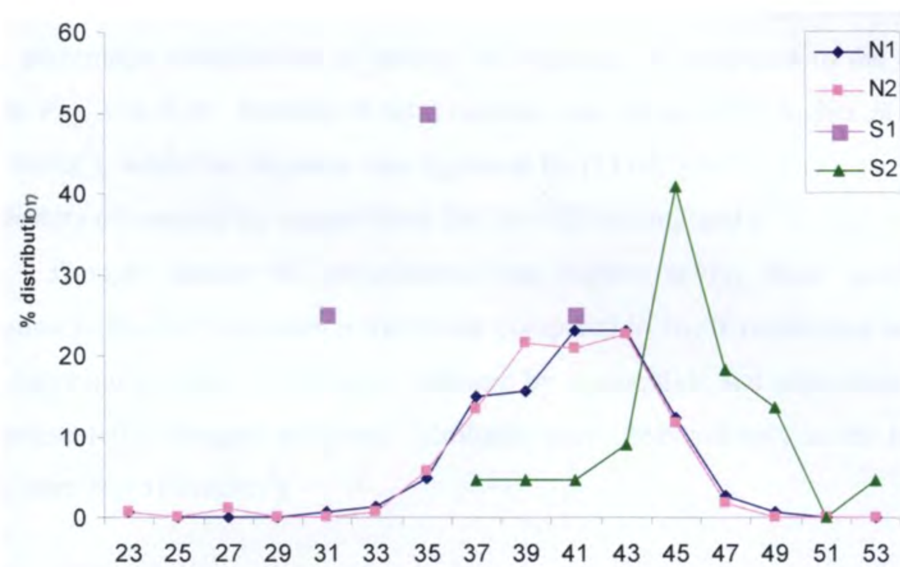


Fig. 14 Length frequency distribution of whelk along the four sites

4.4. Associated Fauna

Fauna associated with *B. spirata* and *B. zeylanica* population in the north and south zones were segregated, identified and quantified to elucidate the community structure of the region.

4.4.1. Community structure of macrobenthos

The benthic community of north zone comprised of six macrofaunal invertebrate taxa and fish larvae. Annelids, mainly polychaetes were the most predominant group forming 81.2% of the population. Species belonging to major Phyla like coelentrata, crustacea, mollusca and echinodermata and in the minor phyla like sipuncula and nemertene were present. Along south zone five invertebrate groups identified were annelids, sipunculids, crustaceans, molluscs and echinoderms.

The univariate diversity measures of the four sites are given in Table- 3. The macrofauna along north zone was more diverse and evenly distributed than the south zone. The species were found to be more diverse and evenly distributed at N_2 and the indices were minimum at S_1, though the number of species was lowest at S_2. The density and biomass of macrofauna along south and north zone are given in Table-4 and the percentage contribution of density and biomass of each taxa to the total is shown in Fig. 15a & b. Density of total benthos was found to be higher at site S_1 (12410 ind/m^2), while the biomass was higher at N_2 (11.087g/m^2). The total macro-faunal density of transect N_1 ranged from 500 to 4525 ind/m2 and at N_2 1125 to 7750 ind/m^2. Though density of polychaetes was higher at N_2, their percentage contribution to the total abundance was lower compared to N_1. Crustaceans were the second dominant group at north zone, followed by sipunculids and other taxa which were represented in meager numbers. Molluscs were observed only in the benthos samples from N_2 (512 ind/m^2).

Table-3 Diversity indices of macrofauna at the four sites

Sites	Species richness	Evenness	Diversity index	Dominance index (1-Lambda')
N_1	5.28	0.70	2.59	0.83
N_2	6.95	0.73	2.96	0.91
S_1	2.33	0.37	1.16	0.46
S_2	2.55	0.70	2.11	0.80

Table-4 Average density (nos/m^2) and biomass (g/m^2) of the different resources of benthos which occurred along with the whelks at the four sites

	Density (nos/m^2)				Biomass (g/m^2)			
	N_1	N_2	S_1	S_2	N_1	N_2	S_1	S_2
Annelida	1696	2742	3133	721	6.776	8.520	4.842	0.635
Sipunculida	71	87.5	8943.75	337.5	0.071	0.080	5.640	0.203
Nemertine	8	41.7	0	0	0.011	0.026	0.000	0.000
Coelentrata	0	4.2	0	0	0.000	0.316	0.000	0.000
Crustacea	146	229	333	683	0.140	1.550	0.212	0.519
Mollusca	0	512.5	0	0	0.000	0.415	0.000	0.000
Fish larvae	38	12.5	0	0	0.002	0.180	0.000	0.000
Total	**1958**	**3629**	**12410**	**1741**	**7.000**	**11.087**	**10.694**	**1.357**

Along south zone, density of polychaetes and sipunculids were higher at S_1 compared to S_2, while crustaceans had a higher density at S_2 than S_1. Sipunculids dominated the macro-benthic fauna at S_1, forming 72.1% of total benthos, while at S_2 polychaetes dominated the fauna and formed 41.4% followed by crustaceans (39.2%).

Average biomass was maximum at transect N_2 (11.1g/m^2) along north zone and at S_1 (10.69g/m2) in south zone. Polychaetes dominated the benthic biomass at north zone and S_2 of south zone, while sipunculids dominated the fauna at S_1. The second dominant resource was crustaceans at both sites of north zone. At S_1, polychaetes were the second dominant and crustaceans at S_2.

The results of SIMPER analysis performed for macrobenthos is given in Table- 5. The similarity within site N_1 was 29.9% and the major species contributing

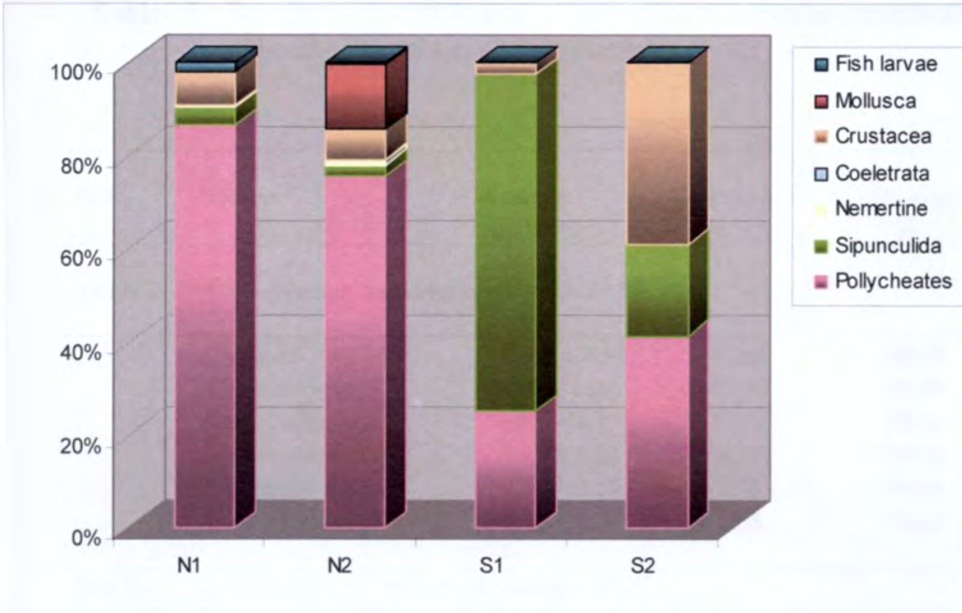


Fig. 15a Percentage contribution of different resources (number) to the total macrobenthos of four sites

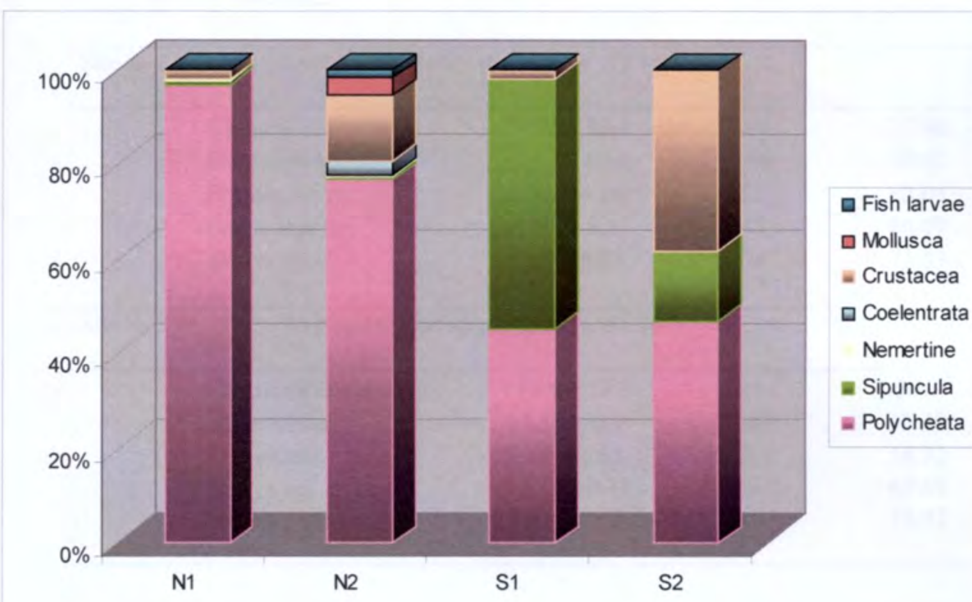


Fig. 15b Percentage contribution of different resources (weight) to the total macrobenthos of four sites

Table- 5 Results of SIMPER analysis showing the species contribution of benthos to within site similarity

Site	Species	Average similarity	Contribution %	Cumulative %
Site N_1	Average similarity percentage 29.99			
	C. coasta	10.48 ± 2.11	34.95	34.95
	Sipunculida	3.4 ± 1.09	11.34	46.29
	Lumbrineris sp.	3.3 ± 1.2	11.02	57.31
	Notomastus spp.	2.43 ± 0.73	8.11	65.42
	Prionospio sp.	2.42 ± 0.69	8.06	73.48
	Ancistrosyllis sp.	1.67 ± 0.77	5.58	79.06
Site N_2	Average similarity percentage 34.83			
	C. coasta	5.92 ± 1.99	17	17
	Lumbrineris sp.	5.09 ± 1.26	14.6	31.6
	Gammarus.	2.93 ± 2.92	8.42	40.02
	Prionospio sp.	2.73 ± 1.19	7.84	47.86
	Scoloplos sp.	2.24 ± 1.1	6.42	54.28
	Notomastus spp.	1.99 ± 0.75	5.71	59.99
	Ancistrosyllis sp.	1.82 ± 1.15	5.24	65.23
	Sipunculida	1.36 ± 0.43	3.91	69.13
Site S_1	Average similarity percentage 77.43			
	Sipunculida	29.39 ± 8.64	37.96	37.96
	Magelona sp.	10.42 ± 8.64	13.46	51.42
	Prionospio sp.	6.67 ± 4.66	8.61	60.04
	Gammarus sp.	4.99 ± 8.7	6.45	66.49
	Tharyx sp.	4.68 ± 6.93	6.04	72.53
Site S_2	Average similarity percentage 65.38			
	Cypridina dentata	19.68 ± 19.5	30.1	30.1
	Sipunculida	11.43 ± 5.9	17.48	47.58
	P. capensis	7.29 ± 6.61	11.15	58.72
	Tharyx sp.	5.82 ± 10.71	8.9	67.63
	Flabelligeridae	5.43 ± 28.2	8.3	75.93

to the similarity were *C. coasta,* sipunculids, *Lumbrineiris* sp. and *Notomastus* sp. The average similarity at N_2 (34.8%) was due to *C. coasta, Lumbrineiris* sp.and *Gammarus* sp. The within site similarity was observed to be higher in south compared to north zone. At site S_1, the similarity was 77.4% and the major contributers were sipunculids, *Magelona* sp., *Prionospio* sp. and *Gammarus* sp. *Cypridina dentate,* sipunculids, *P. capensis* and *Tharyx* sp. were the species responsible for the similarity within site S_2.

Species composition of macrobenthos

A total of 66 species of polychaetes belonging to 28 families were observed in the samples collected during the study. 53 species of 22 families and 33 species of 22 families were recorded in the north and south zones respectively. Free living polychaetes belonging to order Errantia, formed almost one fifth of total polychaete fauna in north zone (16.4%) and south zone (15.8%). Among the two sites of north zone, the percentage contributed by this group was comparatively higher at site N_2 (18.1%) than at site N_1 (14.7%). Six families represented errantia at N_1 and seven families at N_2. Species of the families Pilargidae, Eunicidae, Glyceridae and Nephtyidae were the main resources. Of the 7 families of Errantia at north zone, 6 families except Nereidae were observed along the south zone. Among these 6 families, Pilargidae, Phyllodocidae and Glyceridae had representatives at both the sites of south zone (Table-6).

The annelids, Nereidae, Arenicolidae, Cossuridae and Sternaspidae were absent in south zone and fairly represented in north zone. The annelids exclusively represented at south zone were Flabelligeridae, Owenidae, Scalibregmidae and Opheliidae.

Crustaceans represented mostly by amphipods, copepods, and tanaidaceans occurred along north zone, where as amphipods and ostracods represented the crustacean fauna along south zone. *Apseudes* sp. dominated at site N_1, where as tanaidaceans and gammarid amphipod dominated the crustacean fauna at N_2. The ostracod, *Cypridina dentata*, was observed in high densities, 658 ind/m^2 at S_2 and contributed 96.3% of crustacean fauna and 37.8% of total benthos.

Table- 6 Average density (number/m^2) of the different annelid families observed at the four sites

Errantia	N_1	N_2	S_1	S_2
Pilargidae	100.0	58.3	150.0	50.0
Eunicidae	95.8	308.3	83.3	0.0
Phyllodocidae	4.2	25.0	258.3	16.7
Glyceridae	16.7	62.5	25.0	25.0
Hesionidae	8.3	0.0	0.0	0.0
Nephtyidae	25.0	25.0	0.0	12.5
Nereidae	0.0	12.5	0.0	0.0
Syllidae	0.0	8.3	41.7	0.0
Sedentaria				
Arenicolidae	41.7	20.8	0.0	0.0
Ampharetidae	20.8	66.7	16.7	0.0
Amphictenidae	0.0	0.0	0.0	16.7
Paraonidae	12.5	29.2	0.0	12.5
Maldanidae	20.8	170.8	16.7	0.0
Cirratulidae	20.8	50.0	216.7	91.7
Cossuridae	754.2	695.8	0.0	0.0
Heterospionidae	0.0	41.7	0.0	0.0
Terebellidae	70.8	66.7	25.0	8.3
Magelonidae	20.8	4.2	1483.3	83.3
Capitellidae	162.5	179.2	25.0	8.3
Spionidae	70.8	616.7	716.7	62.5
Sabellariidae	12.5	12.5	25.0	0.0
Orbeniidae	100.0	137.5	8.3	0.0
Sternaspidae	137.5	150.0	0.0	0.0
Chrysopetalidae	0.0	0.0	16.7	0.0
Flabelligeridae	0.0	0.0	0.0	50.0
Owenidae	0.0	0.0	0.0	75.0
Scalibregmidae	0.0	0.0	25.0	183.3
Opheliidae	0.0	0.0	0.0	25.0
Total	**1695.8**	**2741.7**	**3133.3**	**720.8**

Benthic fauna of molluscs was comprised of gastropods, bivalves and scaphopods along north zone, while molluscs were absent in the benthos samples from south zone.

The species composition and percentage contribution of each site varied and the species composition at the four sites is given in Table- 7. The result of ANOSIM performed between sites and the analysis indicates significant difference in species composition of macrofauna in the four sites (Global R-static: 0.613). Among these, highest degree of difference was found between S_1 and S_2 (R-static: 1.0; $P<0.001$), followed by N_2 and S_2 (R-static: 0.988; $P<0.001$). However, there was no significant difference between N_1 and N_2 (R-static: 0.044; $P<0.001$).

SIMPER analysis revealed the contribution of each taxa responsible for the dissimilarity among sites. Sites N_1 and N_2 showed an average dissimilarity of 67.62% with *C. coasta, Lumbrineries* sp., *Prionospio* sp., *Scoloplos* sp. contributing mainly to the dissimilarity (Table- 8).

Sites N_1 and S_1 showed 81.95% dissimilarity with sipunculids (26.11%), *Magelona* sp. (10.11%) and *C. coasta* (6.56%) being the major taxa causing the dissimilarity. The highest dissimilarity was observed between N_2 and S_2 (90.71%). The ostracod, *Cypridina dentata* (8.93%), *C. coasta* (6.75%), *Lumbrineries* sp. (5.31%) and *Prionospio* sp. (4.45%) were the major species responsible for the dissimilarity between these two sites.

Between S_1 and S_2, the dissimilarity percentage was 72.2. More than 50% of the difference was due to sipunculida (25.28%), *Magelona* sp. (9.77%), *Prionospio* sp. (7.83%), *Cypridina dentata* (6.87%) and *Gammarus gammarus* (5.33%). Among these *Prionospio* spp. and *G. gammarus* were absent at S_2 and the density of sipunculids and *Magelona* sp. were remarkably higher at S_1.

4.4.2. Community structure of trawl catch

Trawl catch was composed of finfishes, crustaceans, molluscs, echinoderms and coelentrates (Pl. 2). The average density and biomass of each taxa of trawl resource is given in Table- 9a & b. The percentage of density and biomass of these resources to the total trawl catch is given in Fig. 16a &b.

Pl. 2. By-catch of shrimp trawler

Table- 7 Species composition and average density (no m^{-2}) of macrobenthos

Species	N_1	N_2	S_1	S_2	Species	N_1	N_2	S_1	S_2	Species	N_1	N_2	S_1	S_2
Ancistrosyllis sp.	100	58	150	50	*Caulleriella* sp.	0	4	0	0	*Polyophthalmus* sp.	0	0	0	25
Arabella iricolor	12.5	0	0	0	*C. acicula*	4	8	0	0	Sipunculida	71	88	8944	338
Diopatra sp.	0	4	25	0	*Cirratulus* sp.	4	38	0	0	Nemertine	8	42	0	0
Eunicid sp.	0	0	25	0	*C. chrysoderma*	4	0	0	0	Sea cucumber	0	4	0	0
Lumbrineris sp.	83	304	33	0	*Cirriformia* sp.	4	0	0	0	Amphipod	0	0	0	25
Eteone sp.	4	17	0	0	*Tharyx*	4	0	217	92	*Apseudus* sp.	79	33	33	0
Phyllodoce sp.	0	8	258	17	*C. coasta*	754	696	0	0	Copepod	0	17	0	0
Goniada sp.	17	33	0	0	Heterospionidae	0	42	0	0	*Diastylis* sp.	0	8	0	0
Goniadopsis sp.	0	29	0	0	Terebellidae	0	0	0	8	*Gammarus* sp.	25	58	258	0
Glycera sp.	0	0	25	25	*Lysilla sp.*	71	46	0	0	*Leucon* sp.	0	8	0	0
Hesionidae	8	0	0	0	*Polycirrus* sp.	0	4	25	0	*Tanaidacea* sp.	33	96	0	0
Nephtys sp.	13	13	0	0	*Terebellida stroemi*	0	8	0	0	*Cypridina dentata*	0	0	42	658
N. lycochaeta	13	13	0	13	*T. glacialis*	0	8	0	0	*Penaeus* sp	8	4	0	0
Nereis sp.	0	8	0	0	*Magelona* sp.	21	4	1483	83	Crab	0	4	0	0
Platynereis sp.	0	4	0	0	*Mediomastus* sp.	0	4	0	0	*Dentalium* sp.	0	13	0	0
Syllis sp.	0	8	42	0	*Notomastus* spp.	117	175	25	8	*Anadara* sp.	0	4	0	0
Abarenicola sp.	13	4	0	0	*N. aberans*	21	0	0	0	clam	0	471	0	0
Arenicola sp.	29	17	0	0	*N. fauvelli*	25	0	0	0	Gastropod	0	4	0	0
Ampharetidae	0	0	0	0	*Spionidae*	0	0	0	50	*Conus* sp.	0	21	0	0
Ampharete sp.	17	54	0	0	*Polydora* sp.	0	63	0	0	Fish larvae	38	13	0	0
Amphicthys sp.	4	13	0	0	*Prionospio* sp.	33	538	592	0	**G Total**	**1958**	**3629**	**12410**	**1741**
Melinna sp.	0	0	17	0	*P. cirrifera*	0	17	0	13					
Pectinaria sp.	0	0	0	17	*P. pinnata*	33	0	125	0					
Paraonidae	0	8	0	0	*Spiophanes* sp.	4	0	0	0					
Aricidea sp.	8	21	0	13	*Sabellaria* sp.	13	13	25	0					
Paraonis sp.	4	0	0	0	*Scoloplos* sp.	100	138	8	0					
Asychis sp.	8	0	0	0	*S. scutata*	138	150	0	0					
Clymenura/Axiothella	0	29	0	0	*C. occidentale*	0	0	17	0					
Euclymene sp.	0	21	0	0	Flabelligeridae	0	0	0	50					
Maldane sp.	4	50	0	0	*Owenia* sp.	0	0	0	67					
Maldanella sp.	0	8	17	0	*Owenia fusiformis*	0	0	0	8					
Nicomache sp.	8	63	0	0	*P. capensis*	0	0	25	183					

Table- 8 Results of SIMPER analysis based on different taxa contribution to between site dissimilarity

Species	Average Dissimilarity	Contribution %	Cumulative %
Site N_1 vs N_2	Average dissimilarity = 67.62		
C. coasta	4.58 ± 1.37	6.77	6.77
Lumbrineris sp.	3.29 ± 1.50	4.86	11.63
Prionospio sp.	3.16 ± 0.83	4.67	16.30
Scoloplos sp.	2.72 ± 1.45	4.03	20.33
S. scutata	2.69 ± 1.27	3.98	24.31
Notomastus spp.	2.69 ± 1.42	3.98	28.29
Sipunculida	2.22 ± 1.27	3.28	31.58
clam	2.01 ± 0.44	2.98	34.56
Apseudes sp.	1.97 ± 0.98	2.91	37.46
Ancistrosyllis sp.	1.87 ± 1.26	2.77	40.23
Lysilla sp.	1.77 ± 1.14	2.62	42.85
Tanaidacea sp.	1.73 ± 0.93	2.56	45.40
Gammarus sp.	1.64 ± 1.35	2.43	47.83
Ampharete sp.	1.53 ± 1.26	2.27	50.10
Site S_1 vs S_2	Average dissimilarity = 72.22		
Sipunculida	18.26 ± 9.17	25.28	25.28
Magelona sp.	7.06 ± 3.48	9.77	35.06
Prionospio sp.	5.65 ± 5.77	7.83	42.88
Cypridina dentata	4.96 ± 5.54	6.87	49.75
Gammarus sp.	3.85 ± 16.88	5.33	55.09
Site N_1 vs S_1	Average dissimilarity = 81.95		
Sipunculida	21.39 ± 5.30	26.11	26.11
Magelona sp.	8.29 ± 4.00	10.11	36.22
C. coasta	5.38 ± 1.90	6.56	42.78
Prionospio sp.	4.53 ± 3.36	5.53	48.31
Phyllodoce sp.	3.82 ± 4.96	4.67	52.98
Site N_2 vs S_2	Average dissimilarity = 90.71		
Cypridina dentata	8.10 ± 3.97	8.93	8.93
C. coasta	6.12 ± 1.87	6.75	15.68
Lumbrineris sp.	4.66 ± 1.94	5.13	20.81
Prionospio sp.	4.04 ± 1.03	4.45	25.27
P. capensis	3.91± 2.44	4.32	29.58
Sipunculida	3.34 ± 1.59	3.68	33.26
Tharyx sp.	2.84 ± 3.03	3.13	36.40
Notomastus spp.	2.67 ± 1.37	2.95	39.34
Scoloplos sp.	2.61 ± 1.57	2.88	42.22
S. scutata	2.21 ± 1.06	2.44	44.66
Gammarus sp.	2.19 ± 3.50	2.42	47.08
Flabelligeridae	2.17 ± 4.00	2.39	49.47
Magelona sp.	2.14 ± 1.21	2.35	51.82

Table-9a Average density of different resources of trawl fauna

Resources	N_1	N_2	S_1	S_2
Fin fishes	2.3	3.5	17.5	49.7
Crustacea	45.0	55.6	0.7	3.2
Echinodermata	0.3	0.7	2.5	136.5
Coelentrata	1.4	0.2	0.0	0.0
Mollusca	6.2	21.9	2.5	3.5
Total	**55.3**	**81.9**	**23.2**	**192.9**

Table-9b Average biomass of different resources of trawl fauna

Resources	N_1	N_2	S_1	S_2
Fish	33.6	55.2	130.3	277.3
Crustacea	121.0	290.1	3.5	88.2
Echinodermata	0.2	0.4	1.6	116.7
Coelentrata	0.8	12.4	4.9	0.0
Mollusca	130.7	277.0	49.9	55.7
Total	**286.2**	**635.1**	**190.3**	**537.9**

In the north zone crustaceans (17 species) were the numerically dominant fauna. At N_1 and N_2, the density of crustaceans was 45.03 and 55.6 ind/10m^2, which formed 81.4 and 67.9% of total trawl catch at these two sites respectively. Molluscs were the second dominant group at both the sites and density was higher at N_1 (6.2ind/10m^2) than N_2, (21.9ind/10m^2). Finfishes formed 4.2% (2.3 ind/10m^2) and 4.3% (3.5 ind/10m^2) of total trawl catch at N_1 and N_2 respectively. In terms of biomass also crustaceans and molluscs dominated at north zone.

Along south zone finfishes dominated the fauna at S_1 (17.5 ind/10 m^2) and echinoderms at S_2 (136.5 ind/10m^2) numerically followed by molluscs (2.5ind/10m^2) and finfishes (49.7 ind10m^2) respectively at S_1 and S_2.

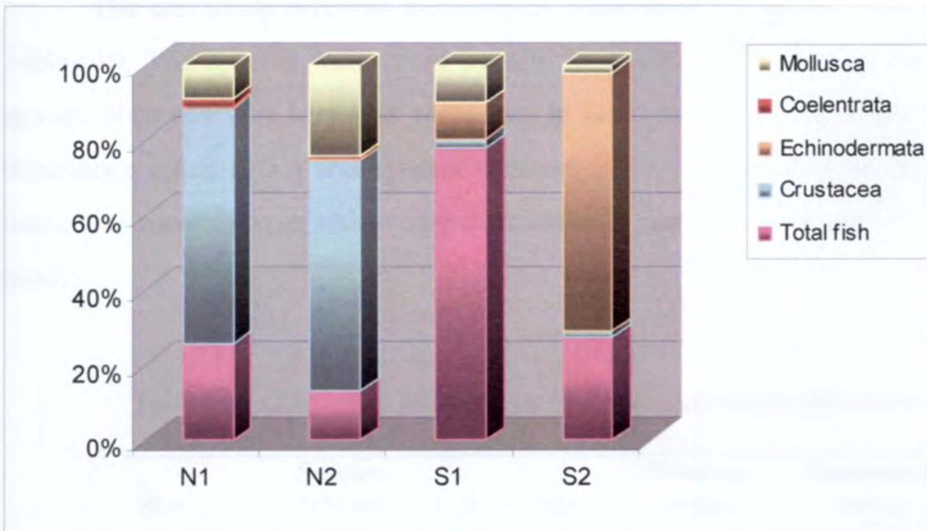


Fig. 16a Percentage contribution of different resources of trawl fauna by number

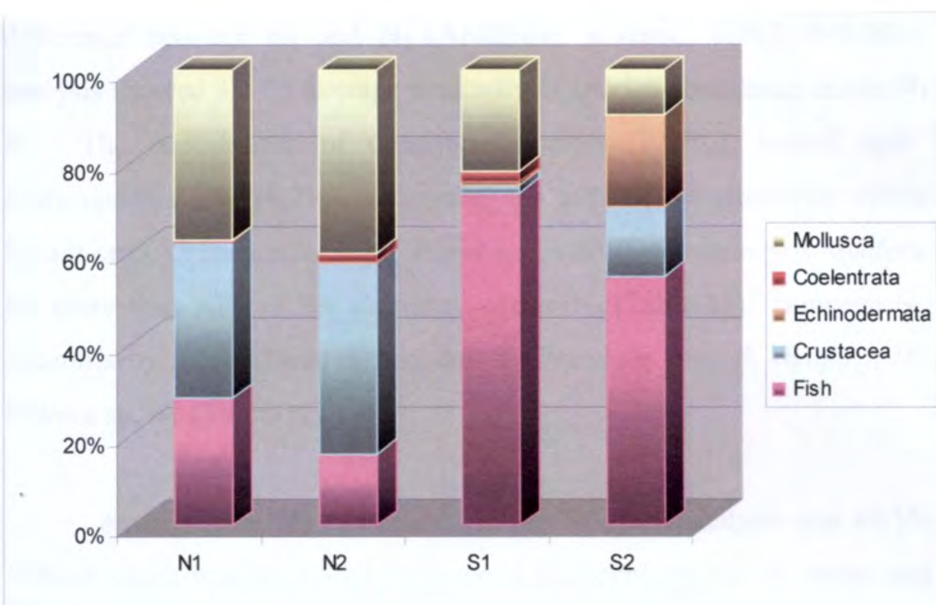


Fig. 16b Percentage contribution of different resources of trawl fauna by weight

The univariate diversity measures of trawl catch of the four sites are given in Table- 10. The species were more evenly distributed at S_1, though the number of species observed was very less compared to other sites. The diversity index (H'), dominance index (1-λ') and species richness (d) were maximum at N_2. The trawl fauna was more diverse and evenly distributed at north zone compared to the south zone.

Table- 10 Diversity indices of trawl resources at the four sites

Site	Species richness	Evenness	Diversity index	Dominance index
N_1	8.44	0.68	2.44	0.85
N_2	11.77	0.77	3.09	0.95
S_1	4.00	0.75	1.97	0.80
S_2	3.41	0.60	1.76	0.76

Multivariate analysis on the abundance of the trawl catch showed significant difference between N_1 and N_2 (ANOSIM: R-static: 0.087, $P<0.001$). SIMPER analysis showed 33.7% average similarity of species abundance in site N_1 and 32% at N_2. The contribution of *Oratosquilla nepa* (22.2%), hermit crab (18%) and *Platycephalus* spp. (9.7%) contributed for 50% of the similarity within N_1. In N_2, hermit crab, *Oratosquilla nepa*, *Bursa* spp. and *Parapeneaopsis stylifera* contributed for more than 50% of the similarity within N_2 (Table-11). Between N_1 and N_2, the dissimilarity (66.5%) was mainly due to *Charybdis* spp., *P. stylifera*, *M. monoceros*, *Philyra* sp. etc (Table-12).

Average similarity obtained at S_1 in SIMPER analysis was 69.1%, more than 50% of which was due to the presence of *Platicephalus* sp., *P. erumi* and *E. echinus*. The average similarity within site S_2 was 70.5%. The similarity was mainly due to the presence of starfishes, *E. echinus* and *Echinus* sp. (Table-11).

Table- 11 Results of SIMPER analysis showing the species contribution of trawl resources to within site similarity

	Species	Average Similarity	Contribution %	Cumulative %
Site N_1	Average similarity: 33.68			
	Oratosquilla nepa	7.48 ± 3.59	22.20	22.20
	Hermit crab	6.07 ± 0.87	18.03	40.24
	Platycephalus sp.	3.27 ± 4.11	9.72	49.96
	Tibia spp.	3.10 ± 0.88	9.21	59.17
Site N_2	Average similarity: 31.95			
	Hermit crab	6.76 ± 4.22	21.16	21.16
	Oratosquilla nepa	5.65 ± 2.09	17.70	38.86
	Bursa spp.	3.89 ± 1.97	12.19	51.04
	P. stylifera	2.47 ± 0.67	7.73	58.77
Site S_1	Average similarity: 69.05			
	Platycephalus sp.	27.03 ± 7.09	39.14	39.14
	P. erumi	11.03 ± 7.09	15.98	55.12
	E. echinus	9.55 ± 7.09	13.84	68.96
Site S_2	Average similarity: 70.47			
	Star fish	22.91 ± 4.85	32.51	32.51
	E. echinus	13.16 ± 4.51	18.67	51.18
	Echinus sp.	9.21 ± 7.29	13.08	64.26

The species composition at S_1 and S_2 showed significant variation (R-0.914, P<0.001) in ANOSIM. The average dissimilarity between these two sites was 65% and star fishes, *E. echinus* and *Platicephalus* sp. were the major resources contributed to the dissimilarity (Table- 12).

The average dissimilarity between N_1 and S_1 was 81% and between N_2 and S_2 was 87.6%. *Platicephalus*, *Charybdis* sp., Squilla etc were the major resources contributing to the dissimilarity between N_1 and S_1, where as starfishes, *E. echinus*, *Platicephalus* sp., *Echinus* sp., *P. stylifera* and squilla were the major resources forming the dissimilarity between N_2 and S_2 (Table-12).

Table-12 Results of SIMPER showing the species contribution of trawl resources to between site dissimilarity

	Species	Average Dissimilarity	Contribution %	Cumulative %
Site N_1 vs N_2	Average dissimilarity = 66.47			
	Charybdis sp.	6.25 ± 0.96	9.40	9.40
	P.stylifera	4.85 ± 0.82	7.30	16.70
	M. monoceros	3.84 ± 1.04	5.77	22.47
	Philyra sp.	3.79 ± 0.95	5.70	28.17
	Anadara sp.	3.69 ± 0.92	5.55	33.72
	Portunus sp.	3.50 ± 0.67	5.27	38.98
	Hermit crab	3.38 ± 1.32	5.09	44.08
	Modiolus sp.	3.00 ± 0.97	4.51	48.59
	P.indicus	2.85 ± 0.76	4.29	52.88
Site S_1 vs S_2	Average dissimilarity = 65.02			
	Star fish	18.37 ± 3.48	28.25	28.25
	E. echinus	11.65 ± 2.43	17.92	46.17
	Platicephalus sp.	8.06 ± 4.99	12.39	58.56
Site N_1 vs S_1	Average dissimilarity = 81.03			
	Platicephalus sp.	9.18 ± 4.24	11.33	11.33
	Charybdis sp.	6.79 ± 0.70	8.38	19.70
	Oratosquilla nepa	6.59 ± 3.48	8.13	27.84
	Hermit crab	6.15 ± 1.48	7.59	35.42
	P.stylifera	4.61 ± 0.80	5.69	41.11
	E. echinus	4.15 ± 4.89	5.12	46.22
	Modiolus sp.	3.75 ± 0.84	4.63	50.86
Site N_2 vs S_2	Average dissimilarity = 87.63			
	Star fishes	14.89 ± 4.35	16.99	16.99
	E. echinus	10.71 ± 2.94	12.23	29.22
	Platicephalus sp.	7.02 ± 1.49	8.01	37.23
	Echinus sp.	5.52 ± 5.47	6.31	43.53
	P.stylifera	3.56 ± 0.82	4.06	47.59
	Oratosquilla nepa	3.32 ± 2.56	3.79	51.38

Species composition

a. Finfishes

A total of 6 families with 8 species of demersal finfishes were obtained in the experimental trawl catch along the whelk bed. All the species were found to occur along both the zones. Along north, Synodontids, Cynoglossids and Platycephalids were the dominant fauna, while in the sites in south zone *Platycephalus* spp., gobiids and *P. erumi* were the major fauna. Density of fishes was maximum at S_2 (49.7 ind/10 m^2) and minimum at N_1 (2.3 ind/10 m^2) (Table-13).

Table-13 Average density and biomass of fin fish fauna of trawl

	Density (no m^{-2})				Biomass (g m^{-2})			
Family	N1	N2	S1	S2	N1	N2	S1	S2
Cynoglossidae	0.69	1.27	0.361	0.50	8.97	32.57	1.80	2.24
Psettodidae	0.37	0.11	1.855	3.33	3.09	1.45	8.35	17.92
Bothidae	0.00	0.22	0.000	0.25	0.00	0.88	0.00	1.49
Synodontidae	0.73	0.55	0.928	4.56	18.96	14.78	40.81	65.49
Platycephalidae	0.55	0.88	11.131	31.13	2.57	4.48	62.61	124.73
Gobiidae	0.00	0.52	3.246	9.92	0.00	1.02	16.70	65.42
Total	**2.34**	**3.54**	**17.52**	**49.68**	**33.58**	**55.18**	**130.27**	**277.30**

b. Crustaceans

Density of crustaceans at south zone was very low compared to north zone. It was maximum at N_2 (55.59 ind/10 m^2) and lowest was at S_1 (0.67 ind/10 m^2). *Charybdis chaybdis* was the dominant species of crustacean at N_1 (53.78%) and *Portunus* sp. (20.43%) at N_2, where as, *Cryptopodia angulata* (53.84%) and hermit crabs (91.33%) formed major components of crustacean at S_1 and S_2 respectively. The density and biomass of crustaceans is given in Table- 14.

Table- 14 Average density and biomass of crustacean fauna of trawl

	Density (no m^{-2})				Biomass (g m^{-2})			
Species	N1	N2	S1	S2	N1	N2	S1	S2
Penaeus indicus	8.24	5.48	0.000	0.00	3.79	15.03	0.00	0.00
Parapeneopsis stylifera	0.00	8.88	0.000	0.00	0.00	23.08	0.00	0.00
Metapenaeus affinis	0.00	0.30	0.000	0.00	0.00	0.95	0.00	0.00
M. monoceros	0.94	1.31	0.000	0.00	3.82	2.48	0.00	0.00
*Acetes*sp.	0.00	0.00	0.000	0.00	0.00	0.41	0.00	0.00
Caridian shrimp	0.09	0.00	0.000	0.00	0.04	0.00	0.00	0.00
Oratosquilla nepa	4.97	4.33	0.000	0.00	8.87	12.66	0.00	0.00
Phyllosoma larva	0.00	0.55	0.000	0.00	0.00	0.04	0.00	0.00
Charybdis charybdis	24.22	8.41	0.309	0.28	8.70	19.00	0.62	0.00
C. cruciata	0.00	0.05	0.000	0.00	0.00	0.05	0.00	0.00
Portunus sp.	0.00	11.36	0.000	0.00	12.48	82.34	0.00	0.42
P. pelagicus	0.00	0.02	0.000	0.00	0.00	0.99	0.00	0.00
spider crab	0.00	0.06	0.000	0.00	0.00	0.85	0.00	0.00
*Doclea*sp.	0.00	0.14	0.000	0.00	0.00	1.12	0.00	0.00
*Lambrus*sp.	0.00	0.03	0.000	0.00	0.00	0.30	0.00	0.00
Philyra sp.	2.30	4.72	0.000	0.00	3.93	28.70	0.00	0.00
Cryptopodia angulata	0.00	0.00	0.361	0.00	0.00	0.00	2.89	0.00
Hermit crab without shell	2.29	5.97	0.000	0.00	7.85	6.89	0.00	0.00
Hermit crab with shell	2.00	3.98	0.000	2.95	71.51	95.05	0.00	87.80
Total	**45.03**	**55.59**	**0.67**	**3.23**	**120.98**	**289.94**	**3.50**	**88.22**

Crustacean fauna of trawl was composed of 4 species of penaeid shrimps, one caridian shrimp, 8 species of crabs, squilla and hermit crab along north zone. In terms of number and weight, edible shrimps were more at N_2 compared to N_1 (Table-14). *Penaeus indicus* and *Parapenaeopsis stylifera* occurred at all stations of north zone, while *Metapenaeus affinis* and *M. dobsoni* were poorly represented. *P. indicus* was found to be more at N_1 than N_2, where *P. stylifera* dominated the fauna. Shrimps were not observed in catches from south zone, crabs were the dominating crustacean fauna at this site. Four species of edible and 5 species of non-edible crabs were observed in the trawl catch. Squilla, the important component of trawls, formed 15 and 8.3% of trawl catch at N_1 and N_2 respectively and were absent in catches from south zone.

c. Mollusca

Density of mollusca was highest, (21.9 ind/10 m^2) at N_2 followed by 6.24 ind/10 m^2 at N_1. Cephalopods formed 9% of molluscs at N_1 and 5.1% at N_2. At S_2 the density was 1.043 ind/10 m^2 which formed 29.4% of molluscs at S_2. Biomass of molluscs at 4 sites, N_1, N_2, S_1 and S_2 were 131, 277, 49.9 and 56 g/10 m^2 respectively.

Cephalopods, such as *Sepiella inermis* and *Loligo duaucelli* occurred at both sites of north zone, while the octopus *Cistopus indicus* was recorded only at N_2. Cuttlefishes and squids occurred more in number at N_2. Along the south zone, *Octopus membraneous* was found to occur at both the sites and squid at S_2. Gastropods like, *Bursa* sp., *Tibia curta, Murex* sp. and *Natica* sp. were observed to dominate at north zone, while *Bursa* spp., *Nassarius* sp., *Conus* spp. and *Strombus* sp. contributed major share of gastropods at south zone. The density of gastropods was found to be low along south zone. More number of individuals and species were observed at S_2 (Table-15).

4.4.3. Community structure of commercial trawl catch

Crustaceans, fin fishes and molluscs were the major groups in terms of weight landed in Sakthikulangara – Neendakara harbour during 2001 and 2002 (Fig. 17).

Minor quantities of echinoderms, coelenterates and several other marine fauna and flora like, sponges, seaweeds etc. were also landed in very negligible quantity.

Table-15 Average density and biomass of molluscan fauna of trawl

	Density (no m^{-2})				Biomass (g m^{-2})			
	N1	N2	S1	S2	N1	N2	S1	S2
cuttlefish	0.321	0.854	0.000	0.000	4.81	3.36	0.00	0.00
Loligo duaucelli	0.242	0.271	0.000	1.043	0.79	0.47	0.00	22.10
Cistopus sp.	0.000	0.055	0.000	0.000	0.00	4.28	0.00	0.00
Octopos sp.	0.000	0.000	1.546	0.583	0.00	0.00	37.72	12.17
Bursa spp.	1.165	3.968	0.618	0.973	17.97	78.08	8.24	13.34
Murex spp.	0.371	1.524	0.000	0.000	3.83	19.29	0.00	0.00
Fusinus sp.	0.000	1.317	0.000	0.000	0.00	6.10	0.00	0.00
Conus spp.	0.000	0.027	0.000	0.139	0.00	0.08	0.00	2.36
Tibia sp.	1.362	1.953	0.000	0.000	100.76	141.39	0.00	0.00
Natica sp.	0.214	1.958	0.000	0.000	0.83	1.95	0.00	0.00
Nassarius sp.	0.000	0.000	0.361	0.668	0.00	0.00	3.97	4.17
Strombus sp.	0.000	0.000	0.000	0.139	0.00	0.00	0.00	1.53
Patella sp.	0.000	0.421	0.000	0.000	0.00	0.15	0.00	0.00
Dentalium sp.	0.124	0.000	0.000	0.000	0.11	0.00	0.00	0.00
Anadara sp.	0.417	7.189	0.000	0.000	1.18	21.46	0.00	0.00
Arca sp.	0.176	0.042	0.000	0.000	0.18	0.02	0.00	0.00
P. placenta	0.000	0.125	0.000	0.000	0.00	0.01	0.00	0.00
Modiolus sp.	1.848	2.196	0.000	0.000	0.24	0.36	0.00	0.00
Total	**6.240**	**21.900**	**2.525**	**3.544**	**130.70**	**277.00**	**49.93**	**55.68**

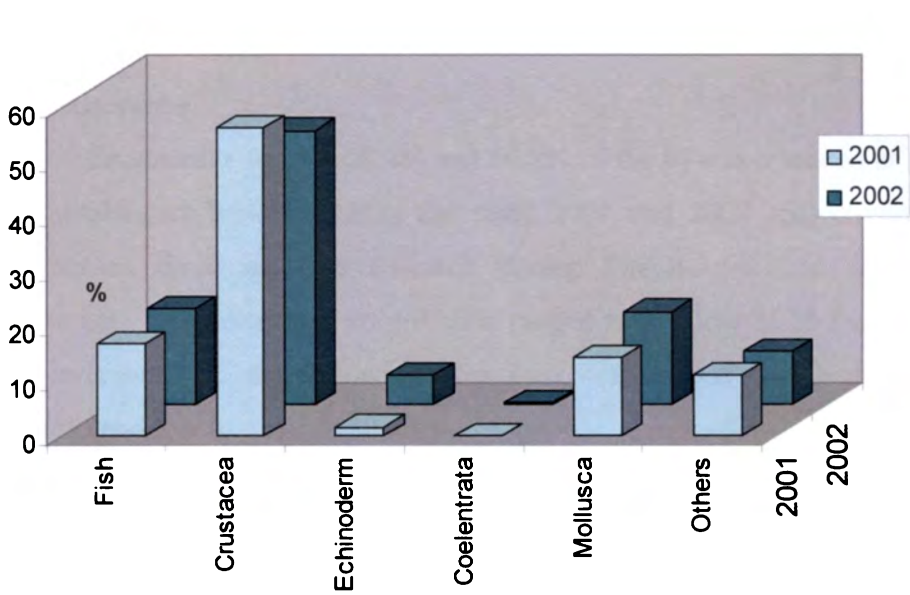


Fig. 17 Major marine resources (% by weight) landed in trawl by-catch at Sakthikulangara-Neendakara harbour during 2001 and 2002

a. Finfishes

Fin fishes formed 16.7 and 17.5 % of total annual by-catch during 2001 and 2002 respectively and formed the second dominant group. This group dominated the by-catch during May and June in 2001 and during June and August in 2002. The percentage contribution of finfishes to total by-catch ranged between 2.8% in October and 51.1% in May during 2001 and 1.8 in November to 54.5% in August in the following year.

Flatfishes of the family Cynoglossidae was represented by a single species *Cynoglossus macrostomus* and formed a major composition of the fish resources landed as trawl by-catch. The total length of these fishes which occurred in the by-catch ranged between 90-140 mm. *Suarida undosquamos* and *S. tumbil* belonging to the family Synodontidae formed a major part of the by-catch during 2001 (38.3%) while, in the second year the contribution was low (16.5%). The average total length of these two species was 140 mm and 130 mm respectively. *Platycephalus* spp., *P. erumi* and *Gobius* sp. were the other demersal finfishes observed in the samples. The percentage contribution of different finfishes during the year 2001 and 2002 are shown in Fig. 18a &b

b. Crustaceans

Crustaceans formed 56.4% and 50.2% of the by-catch landed at Neendakara-Sakthikulangara harbour during the years 2001 and 2002 respectively. In 2001, crustaceans dominated the by-catch during March-April and from August to December. The percentage contribution ranged from a low of 19.1 in May to 86.3% in November. In the following year their contribution was high during March (88.6%) and low in August (30.8%).

Shrimp (37.7%), squilla (34.8 %), crabs (24.5%) and hermit crab (3.0%) were the main crustacean resources landed during the year 2001(Fig. 19a). In the following year also, the same resources constituted the crustacean landing but the percentage varied with shrimps forming 48%, squilla 33%, crabs 17.1% and hermit crab 1.9% (Fig. 19b).

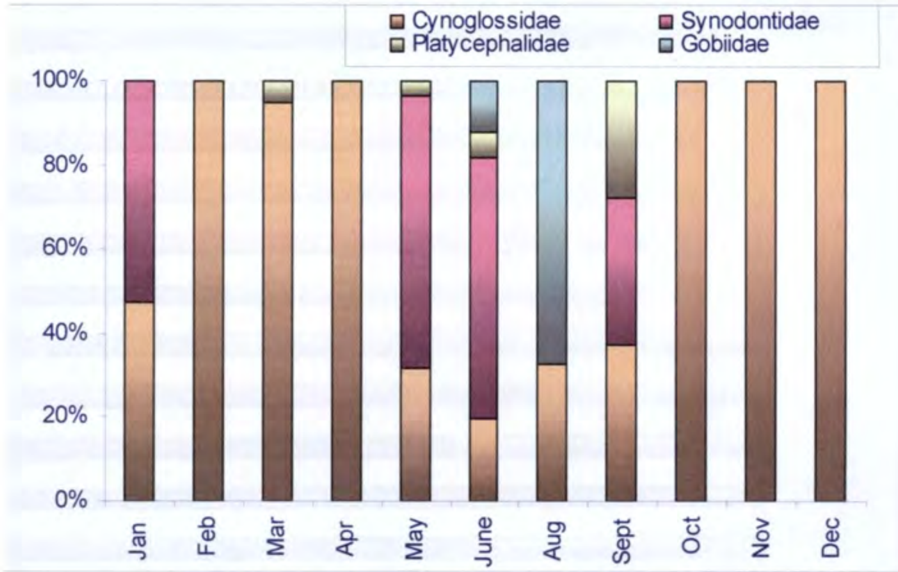


Fig. 18a Percentage contribution (by weight) of finfishes of different families which occurred in the trawl by-catch during the year 2001

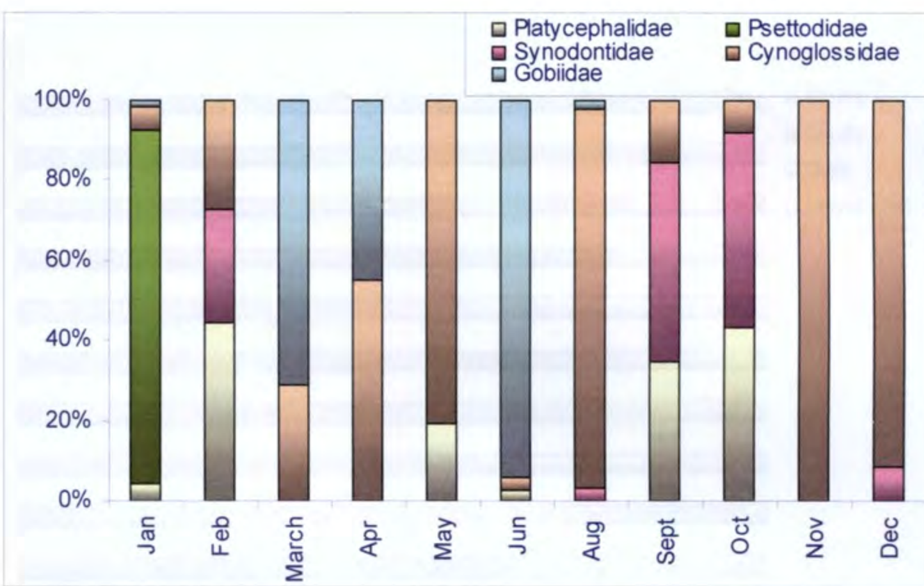


Fig. 18b Percentage contribution (by weight) of finfishes of different families which occurred in the trawl by-catch during the year 2002

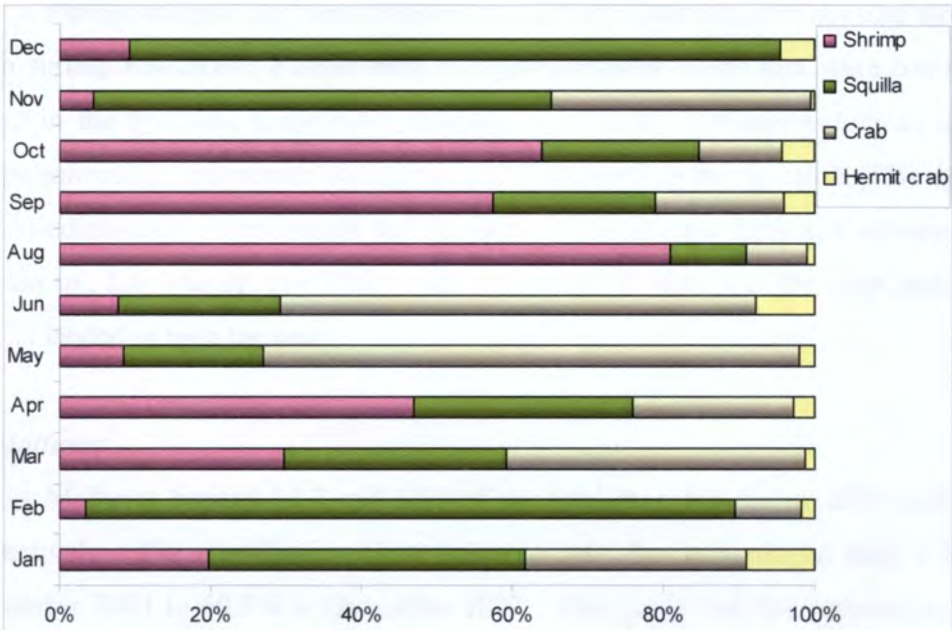


Fig- 19a Percentage composition (by weight) of crustaceans during 2001.

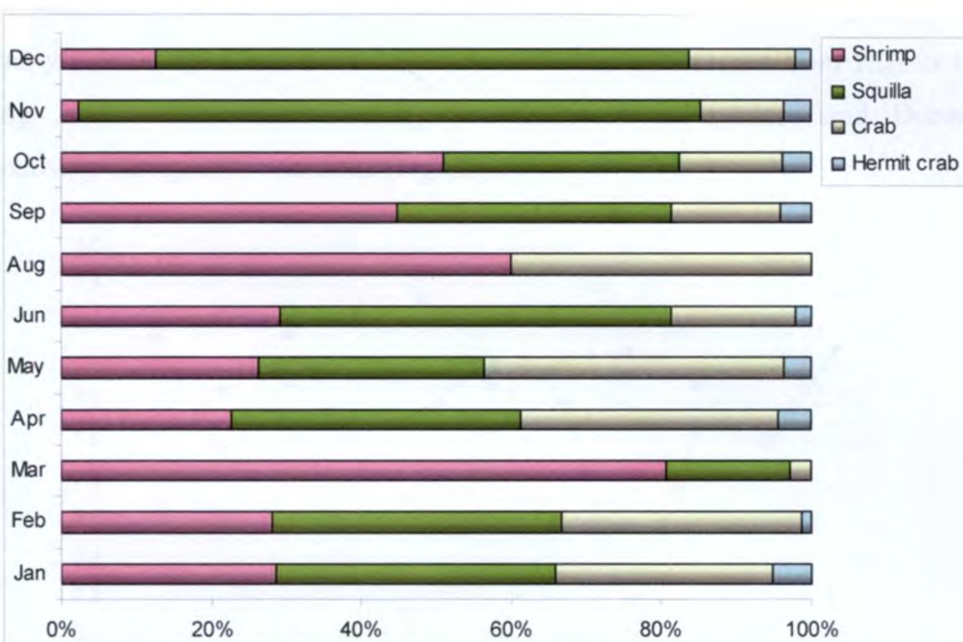


Fig- 19b Percentage composition (by weight) of crustaceans during 2002.

Parapenaeopsis stylifera, Penaeus indicus and *Metapenaeus dobsoni* were the main shrimp resources. Edible crabs of carapace width 22-40 mm were commonly found in the by-catch. *Charybdis cruciata, C. lucifera, Portunus pelagicus and P. sanguinolentus* represented the edible species of crabs in the by-catch. Five species of non-edible crabs identified in the by-catch were, *Calappa lophos*, *Callinassa* sp., *Doclea* sp., *Lambrus* sp. and *Philyra* sp. *Oratosquilla nepa* was the main species of squilla landed in both the years.

c. Mollusca

Molluscs formed 14.2 and 17% of the total by-catch during 2001 and 2002 respectively. The contribution of molluscs to total by-catch ranged from 1.6% in November 2001 to 60.5% in December 2002. This group had fair representation in February (42.6%), March (26.5%), June (21.9%) and December (36%) 2001. During December 2002 molluscs formed 60.5% and were the dominant group.

Molluscs were represented by cephalopods and gastropods and very rarely by scaphopods. The Shannon-Wiener diversity index of molluscan group of trawl by-catch was found to be higher in 2002 (2.145) compared to 2001 (1.540). The diversity index ranged between 0.169 and 1.598 during 2001 and from 1.03 to 1.752 during 2002. Maximum diversity was observed in January and December respectively during 2001 and 2002 (Fig. 20).

Fig.20 The shannon diversity index of molluscan fauna in trawl by-catch

Cephalopods formed 0.8 and 1.3% of total by-catch during 2001 and 2002 respectively and juveniles of cuttlefishes like, *Sepia elliptica* and *Sepiella inermis* and *Octopus membranaceous* measuring 3-5 mm were observed during the study period. They formed part of by-catch during January and March to May in 2001 and February to August and December in 2002.

Gastropods were the dominant molluscan fauna in by-catch of shrimp trawlers (Pl. 3a-d). Gastropods of the families Bursidae, Muricidae, Fasciolariidae, Conidae, Strombidae, Olividae and Cerithidae were recorded during 2001 and 2002, in addition to these resources, gastropods belonging to Turbinidae, Epitoniidae, Naticidae, Patellidae, Tonnidae, Turritellidae and Xenophoridae were also observed. The monthly percentage contribution of each family during the study period is given in Table 16 & 17.

Among gastropods, excluding *Babylonia* spp., *Bursa spinosa* and *Bursa* sp. of family Bursidae together dominated the gastropod fauna during the study period by contributing 41.8 and 34% in 2001 and 2002 respectively. The two species of *Bursa* were present in the by-catch through out the year and dominated the gastropod fauna in March and from August to November during 2001 and in February, April, August, November and December 2002. *B. spinosa* with a total length ranging between 50.2-76.3 mm and *Bursa* sp. of length 20.6-55.2 mm were landed by the trawlers.

Tibia curta of family Strombidae formed 35 & 27.4% of the gastropod fauna of the trawl by-catch in 2001 and 2002 respectively. The average monthly contribution of this species ranged from 25.1 to 70.6% in 2001 and 18.5 to 67% in 2002. *T. curta* dominated the molluscan fauna by weight during 6 months (January to February, April to June and December) of 2001 and 5 months (March, May, June, September and October) of 2002.

Table- 16 Percentage composition (by weight) of gastropods of different family which occurred in the trawl by-catch during the year 2001

	Jan	Feb	Mar	Apr	May	Jun	Aug	Sept	Oct	Nov	Dec	Average
Bursidae	27.5	8.2	53.7	38.0	0.0	33.3	56.9	96.0	58.6	55.0	27.8	41.8
Cerithidae	0.0	0.0	0.0	0.0	0.0	6.9	4.6	0.0	0.0	0.0	0.0	1.4
Conidae	9.7	0.0	4.8	0.0	17.3	6.2	13.4	0.0	0.0	0.0	11.3	6.6
Fasciolariidae	6.9	9.7	4.0	3.5	0.0	3.1	5.7	4.0	6.7	18.3	8.2	5.2
Muricidae	11.3	14.5	0.0	7.5	12.1	8.8	19.4	0.0	9.6	0.0	17.5	9.6
Olividae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	0.0	0.4
Strombidae	44.6	67.6	37.5	51.1	70.6	41.7	0.0	0.0	25.1	0.0	35.1	35.0

Table- 17 Percentage composition (by weight) of gastropods of different family which occurred in the trawl by-catch during the year 2002

	Jan	Feb	March	Apr	May	Jun	Aug	Sept	Oct	Nov	Dec	Average
Turbinidae	0	0	0	0	0	0	0	0	0	0	2.1	1.0
Bursidae	3.1	46.1	26.8	37.4	8.4	11.6	62.3	26.7	36.4	63.0	40.8	34.0
Trochidae	0.0	0.0	0.0	1.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Buccinidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	2.2
Cerithidae	35.6	0.0	13.2	0.0	3.2	0.0	0.0	5.0	4.7	0.0	0.0	4.3
Conidae	26.3	0.0	10.1	10.2	16.9	0.0	9.2	6.2	0.0	6.0	1.8	6.1
Epitoniidae	0.0	33.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.4
Fasciolariidae	30.7	15.4	7.3	15.6	19.5	10.2	3.7	17.3	7.2	30.9	0.0	9.0
Muricidae	0.0	0.0	11.1	8.8	2.8	0.0	0.0	0.0	6.9	0.0	4.3	3.6
Naticidae	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	5.6	2.8
Olividae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Patellidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	4.8
Strombidae	0.0	0.0	31.4	24.7	44.6	67.0	18.5	44.8	44.8	0.0	25.5	27.4
Tonnidae	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Turritellidae	0.0	0.0	0.0	2.2	4.0	10.0	0.0	0.0	0.0	0.0	4.1	2.8
Xenophoridae	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Pl. 3a-3d. Gastropods landed along with whelk

Pl. 3b. *Bursa* spp.

Pl. 3c. *Conus* spp.

Pl. 3d. *Tibia curta*

Gastropods of family Muricidae were commonly observed among the molluscan fauna of trawl by-catch. *Rapana bulbosa, Murex trapa, M. virgineus, M. badius* and *Murex sp.* represented the family during the study period. *Murex* spp. formed 9.6 and 1.7% of total gastropod fauna during 2001 and 2002 respectively, but *R. bulbosa* was rarely observed.

Family Conidae represented by *Conus* spp. formed a major part of the molluscan fauna in most of the months during the study period. The percentage contributed by *Conus* spp. to the total gastropods landed ranged between 4.8 and 17.3% during the year 2001 and 1.8 to 26.3% in 2002. The landing of *Conus* spp. was maximum during May in 2001 and January in 2002.

Fusinus sp. and *Fasciolaria* sp. of the family Fasciolariidae formed part of the gastropod fauna of trawl by-catch. The former species contributed to 5.2 and 3.7% of the gastropod catch in the year 2001 and 2002 respectively, while *Fasciolaria* sp. formed 5.3% during the second year.

Species of genera *Cerithium* were also landed during the study period. *Oliva* sp., *Cantharus* sp., *Epitonium* sp., *Patella* sp., *Tona dolium* and *Xenophora* sp. also formed insignificant part of the trawl by-catch.

d. Other fauna

Echinoderms and Coelenterates were the other groups observed in by-catch analyzed. Echinoderms represented by starfishes, *Echinus echinus* and *Echinus* sp. formed 1.6 and 5.3% of total by-catch during 2001 and 2002 respectively. Jellyfishes, sea cucumbers, sponges and seaweeds were observed in samples in the second year.

4.5 Relationship of whelk abundance with abiotic and biotic factors

Pearson (2-tailed) correlation was performed to elucidate the influence of abiotic factors to the abundance of whelk off Kollam and the result is given in Table-18. Density of *B. spirata* increased with depth, TOC and silt content of sediment in the north zone. The hydrographic parameters had no significant correlation with the density of *B. spirata*, while DO and phosphate of surface water (5%) showed positive correlation with *B. zeylanica*. The density of *B. zeylanica* showed negative correlation with TOC, silt and clay, while the density increased with the sand composition of the sediment.

Pearson correlation was performed between whelk abundance and density of macrobenthos and trawl fauna separately and the results showed no significant correlation with any of the taxa except sipunculida. The density of sipunculids showed significant negative correlation with *B. spirata*.

Table- 18 Results of Pearson correlation analysis between whelk abundance and environmental parameters

Parameters	*B. spirata*	*B. zeylanica*
Depth	0.821**	0.477
Surface water parametrs		
Ammonia	0.047	0.176
Dissolved oxygen	-0.509*	0.516*
Nitrate	0.381	-0.177
Nitrite	0.265	-0.196
pH	-0.458	0.261
Phosphate	-0.341	0.564*
Salinity	-0.066	-0.075
Temp	-0.059	0.102
Tss	-0.244	0.176
Bottom water parameters		
Ammonia	0.084	0.011
Dissolved oxygen	-0.627**	0.425
Nitrate	-0.059	0.112
Nitrite	0.410	0.160
pH	-0.639**	0.277
Phosphate	0.067	-0.122
Salinity	-0.042	-0.200
Temp	0.389	0.122
Tss	-0.452	-0.050
Sediment characters		
Total organic carbon	0.598*	-0.780**
Clay	0.288	-0.753**
Silt	0.660**	-0.675**
Sand	-0.652**	0.765**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

4.6. Reproductive biology

4.6.1 Reproductive system

B. spirata and *B. zeylanica* are gonochoristic with internal fertilization. The anatomy of reproductive system resembles that of any other neogastropod and both the species have the same pattern of organ system.

a. Male reproductive system

Male reproductive system is simple with the testis at the posterior end in apical coil of the shell parallel to digestive gland (Fig. 21). The testis of male develops as a mass of thin, coiled tubes parallel to digestive gland and opens to a sperm duct. The sperm duct leads anteriorly to a prostate, where the sperm is stored. The sperm duct is very thin and clearly visible. The prostate lies on the right side of the mantle cavity within connective tissue along the columellar wall parallel to the hind gut. From the prostate leads a narrow duct, the anterior part of sperm duct, to the muscular penis.

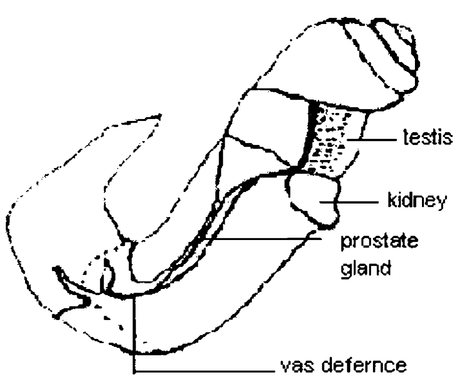


Fig. 21. Diagramatic representation of reproductive system of male *Babylonia* spp.

b. Female reproductive system

Female reproductive system was found to be more complex compared to male, with ovary at the posterior end in apical coil of the shell parallel to digestive gland. From the gonad a narrow and thin oviduct leads to albumin gland, a laterally compressed small gland near kidney, which opens to the capsule gland directly (Fig. 22). The capsule gland is 3 to 4 times larger than albumin gland, is laterally compressed with a lumen, opens exterior through the female opening. Female snails possess a pedal gland on the ventral side of the foot, to shape and harden the egg capsule. Females store the sperm in the ingestion gland, which is laid by the male in the bursa copulatrix during copulation. The ingestion gland opens to albumin gland, where fertilization occurs.

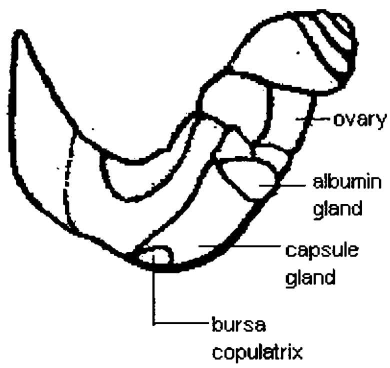


Fig. 22. Diagramatic representation of reproductive system of female *Babylonia* spp.

4.6.2 Classification of maturity stages of gonad

Based on the colour, texture and size of the ovary and accessory glands four stages of maturity were identified in female. In male, the colour, texture and size of the gonad and nature of prostate gland were used. The four stages of maturity of male and female of *B. spirata* are shown in Pl. 4a – d and Pl. 5a - d respectively.

a. Maturity stages of male

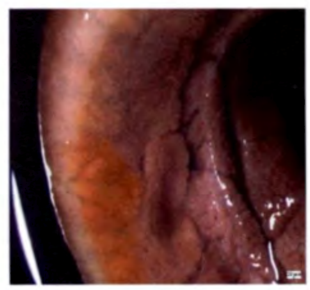
Stage I: Early maturing

Gonad very thin, yellow coloured initially, with developing gonadal tissue on the dorsal side of the digestive gland (Pl- 4a).

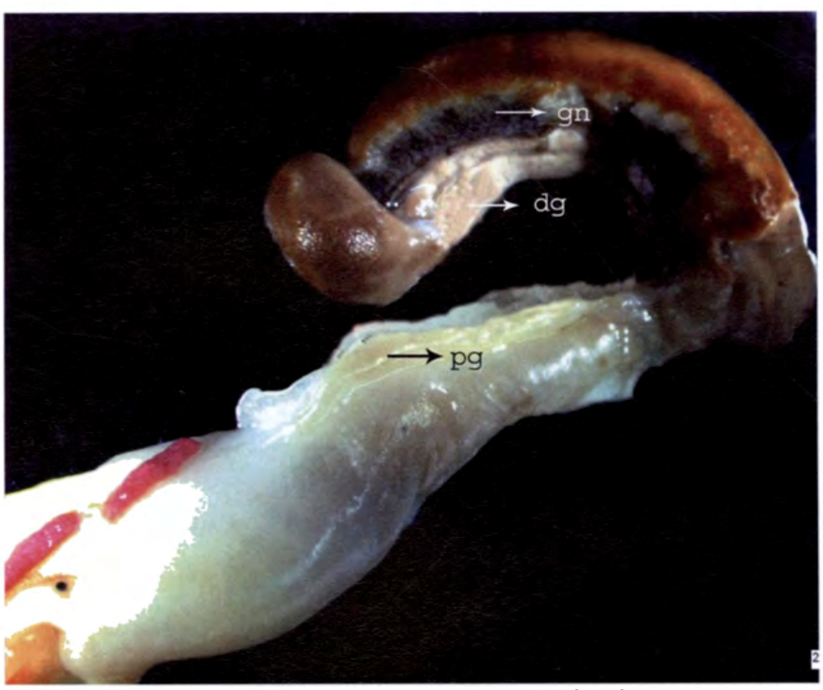
Stage II: Maturing

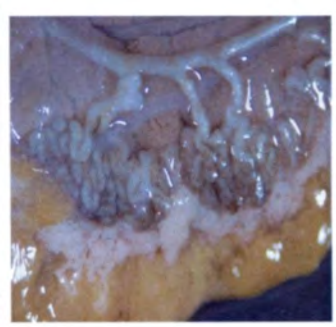
Gonad light brown coloured and tissue starts to develop as a net work of thin tubules from the ventral side near the digestive gland to the periphery. The developing tubules were pale green coloured. The sperm duct up to penis was clearly visible at this stage (Pl-4b).

Pl. 4a. Male gonadal maturity stage I of *Babylonia* spp.



Pl. 4b. Male gonadal maturity stage II of *Babylonia* spp.





(dg- digestive gland, gn- gonad, pg- prostate gland)

Stage III: Mature

The testicular tissue more tubular, except for a very thin dorsal peripheral layer. Tubules greenish in colour filled with seminal fluid. The sperm duct and prostate are also filled with seminal fluid at this stage (Pl- 4c).

Stage IV: Spent

Partially spent and spent gonad were considered as stage IV. The tubules of testis at the ventral region towards digestive gland are dark brown coloured and collapsed. The prostate is filled with seminal fluid at this stage, but in later stage the duct is flabby and yellowish. In the late spent stage the gonad dark brownish with collapsed tubules (Pl-4d).

b. Maturity stages of female

Stage I: Early maturing

Gonad appears as a thin yellowish layer of fat on the dorsal side of the digestive gland in the initial stage. Then the tissue starts to develop as ovary, coloured as coffee brown and spreads on the dorsal side of the digestive gland irregularly. At this stage the albumin gland is very small, translucent and white. Capsule gland white coloured at this stage (Pl- 5a).

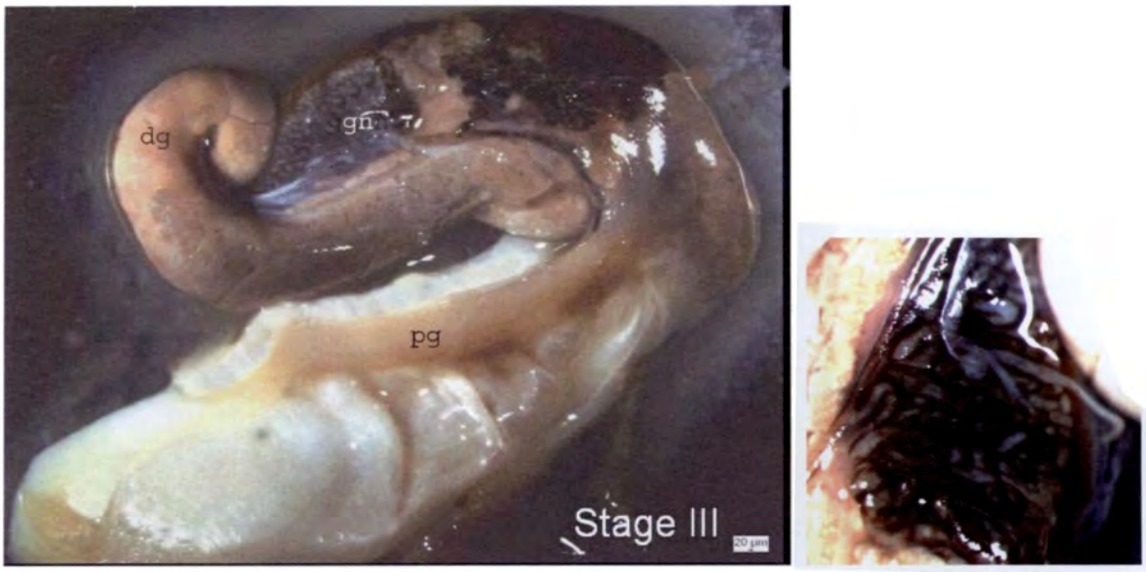
Stage II: Maturing

The ovary is more distinct at this stage and ovary attains the definite shape and covers the entire length of dorsal side of digestive gland. Ovary is dark coffee brown and fleshy. The yellowish fat is absent. Both the accessory glands white in colour but larger (Pl-5b).

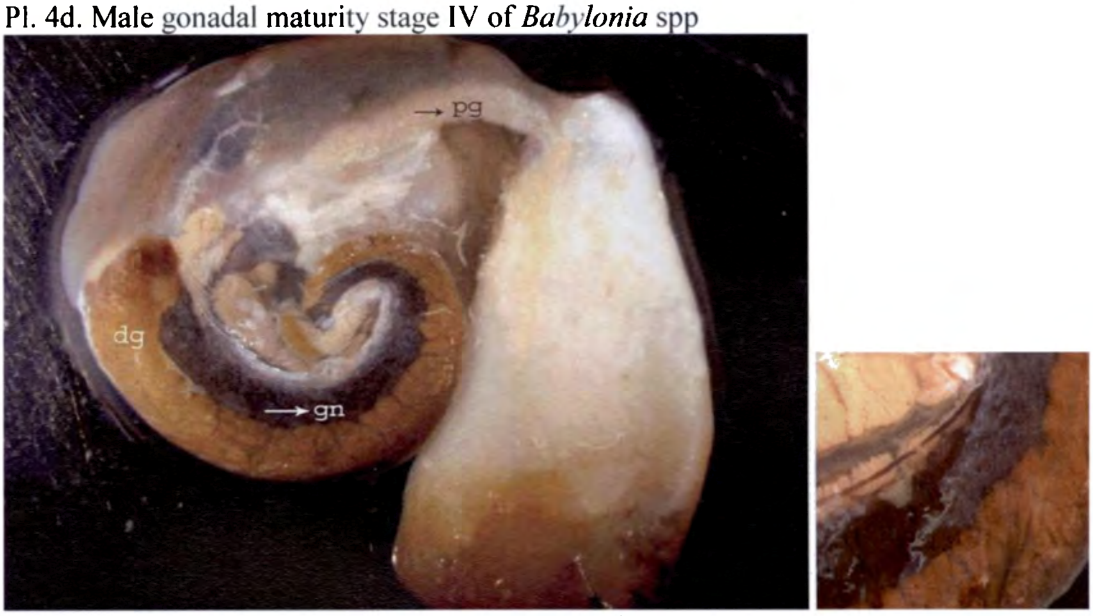
Stage III: Mature

The ovary becomes greenish brown in colour and appears as a thick fleshy layer over the digestive gland. Albumin gland well developed and white coloured. The capsule gland, creamish white in colour, was well developed and firm (Pl- 5c).

Pl. 4c. Male gonadal maturity stage III of *Babylonia* spp.

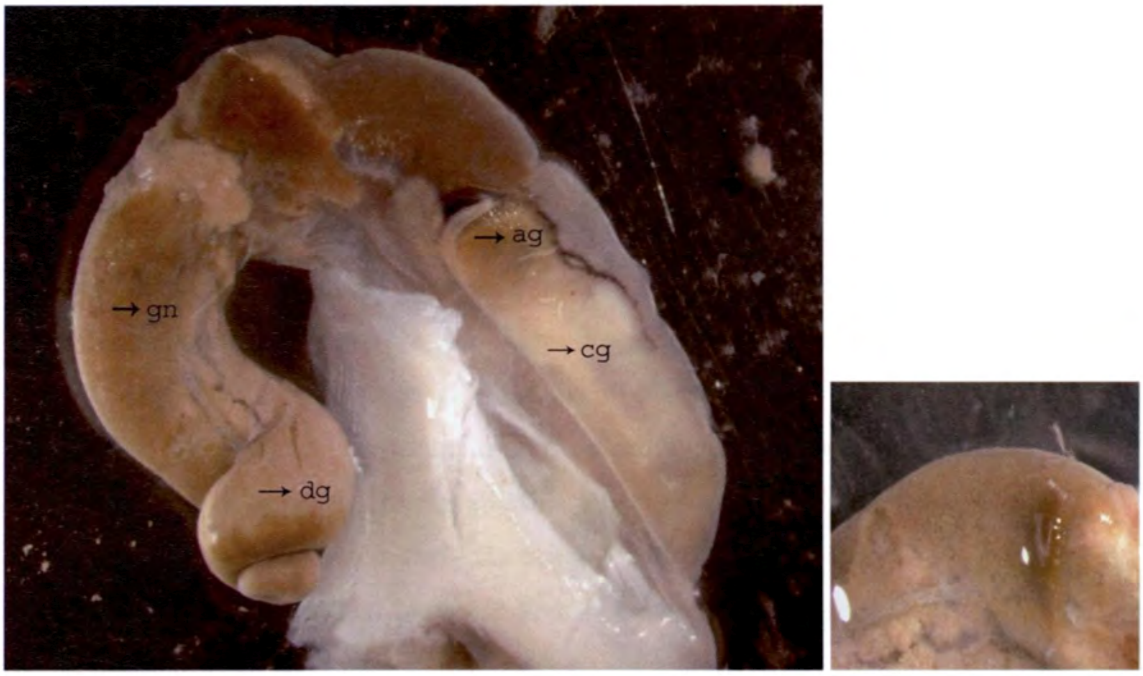


Pl. 4d. Male gonadal maturity stage IV of *Babylonia* spp

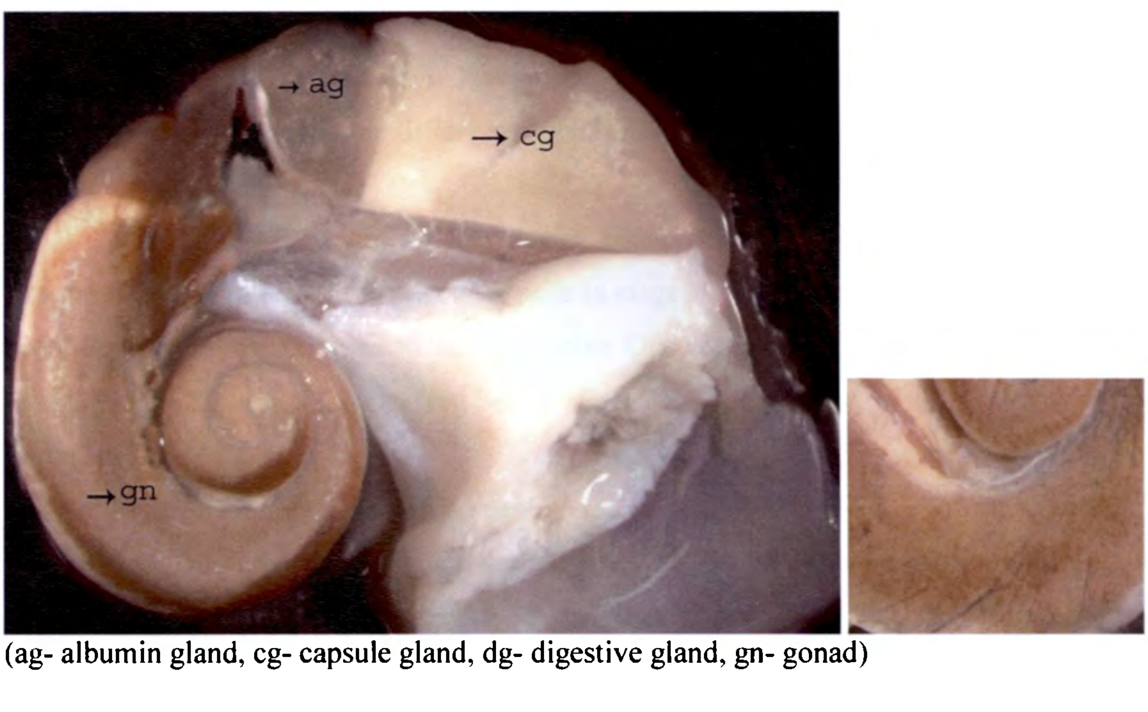


(dg- digestive gland, gn- gonad, pg- prostate gland)

Pl. 5a. Female gonadal maturity stage I of *Babylonia* spp.



Pl. 5b. Female gonadal maturity stage II of *Babylonia* spp.



(ag- albumin gland, cg- capsule gland, dg- digestive gland, gn- gonad)

Stage IV: Spent

Gonad is flabby, thin and dark brown in colour. The albumin gland is cream coloured and capsule gland yellowish and flabby (Pl- 5d).

4.6.3. Seasonal variation of maturity stages

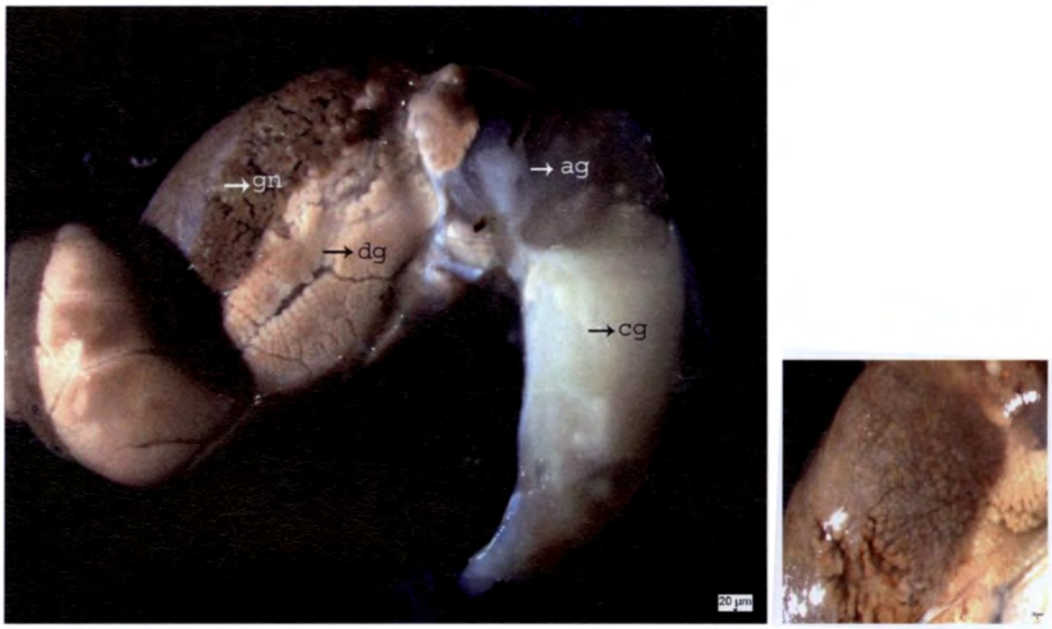
During the study period, male and female snails in different stages of gonad development occurred during different months. The monthly percentage occurrence of female and male of *B. spirata* in different stages of maturity is given in Fig. 23 & 24. Female snails with stage I gonad were observed during June, September, November, January and February and their percentage ranged between 5.3 and 18.3 with maximum in January. During all other months female snails with stage I gonad were absent. Male snails with early maturing gonad were observed only during three months, June, December and May and their percentage ranged from 3.7 to 7.1 with maximum during December.

Female snails with stage II gonad were observed throughout the year except during February while those with fully mature gonad (stage III) occurred all through the year. The percentage of female snails with stage II gonad ranged between 10 in May and a maximum of 35.3 in April. Maximum number of fully matured snails was observed in March (60%). During November to December also high percentage 55.9 and 50% of the females in the fishery were with fully mature gonad.

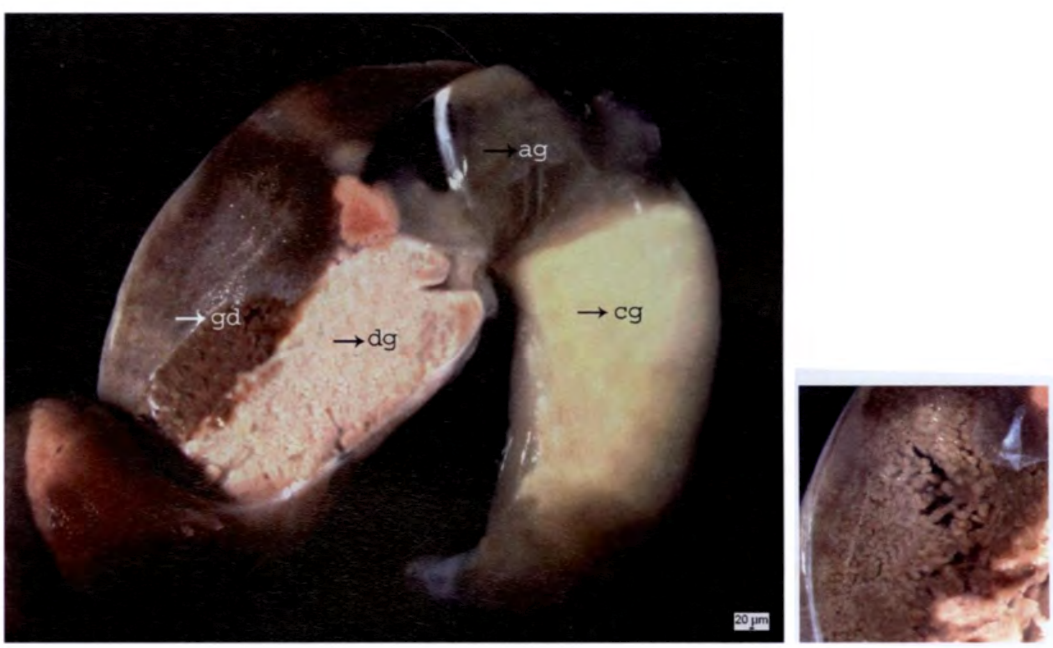
Male snails in stage II and III were observed all through the year except during February to March, when male snails in stage II were absent. More than 50% of the male snails examined in June, October December, February and May were stage III with highest, 72.2% in October.

Male and female snails with spent gonad (stage IV) were noted all through the year. More than 50% of the female snails in the sample were spent condition during September (77.8%), October (74.1%), February (57.9%) and May (62%). More than 50% of male snails were in stage IV during September (70.6%), November (52.2%) and March (57.1%).

Pl. 5c. Female gonadal maturity stage III of *Babylonia* spp.



Pl. 5d. Female gonadal maturity stage IV of *Babylonia* spp.



(ag- albumin gland, cg- capsule gland, dg- digestive gland, gn- gonad)

The presence of female snails with mature and spent gonads indicated that *B. spirata* spawns throughout the year and the occurrence of more than 50% of the female snails in stage IV indicates that peak spawning is during September to October and February and May.

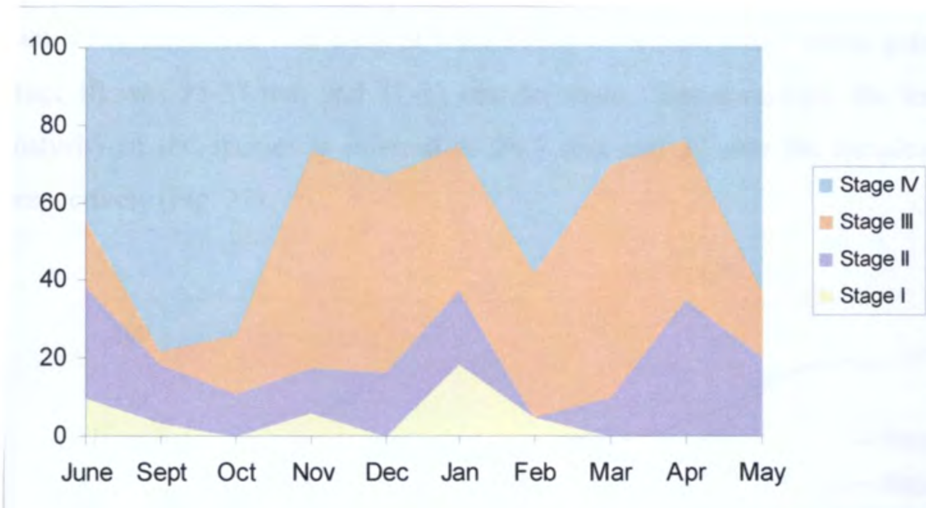


Fig. 23 Percentage distribution of maturity stages of female *B. spirata* during for the period June 2001 to May 2002

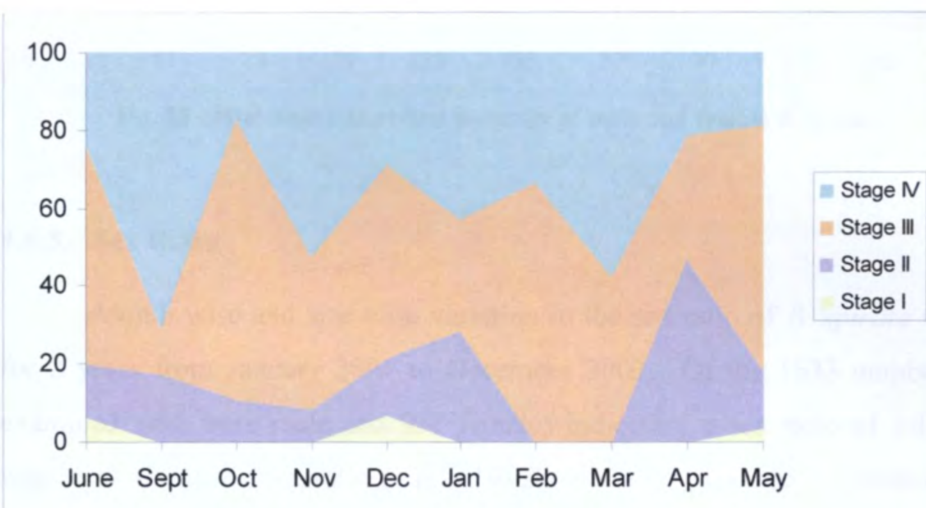


Fig. 24 Percentage distribution of maturity stages of male *B. spirata* during for the period June 2001 to May 2002

4.6.4. Size at maturity

A total number of 363 females ranging in shell height (SH) 28 to 56.5mm and 218 males of SH 26 to 51.3 of *B. spirata* collected during the study period were examined for determining the size at first maturity. The shell height of the smallest female either with late maturing or mature ovary was 31.2 mm and that of male 28.8 mm. The minimum size class at which 50% of female snails attain gonad maturity stage III was 35-37 mm and 31-33 mm for male. Based on this, the length at first maturity of the species is inferred as 36.5 mm and 32 mm for females and males respectively (Fig. 25).

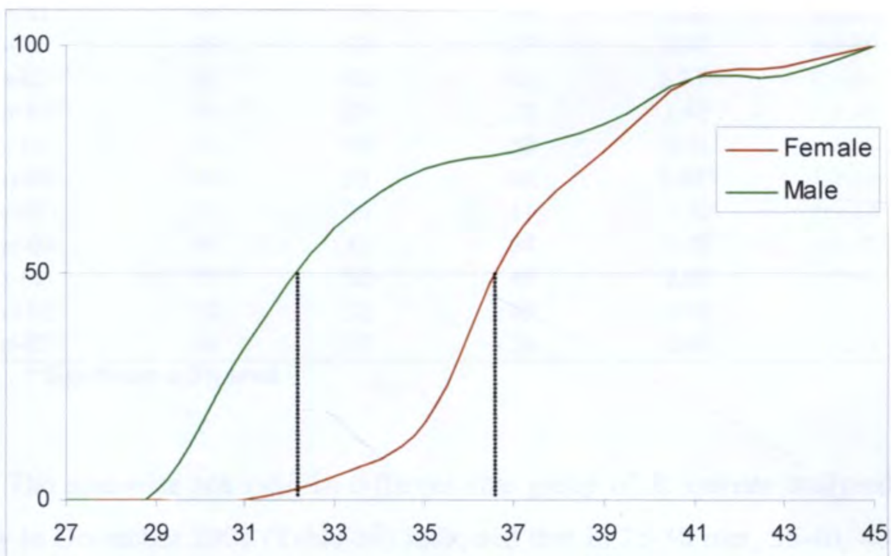


Fig. 25 Minimum size at first maturity of male and female *B. spirata*

4.6.5. Sex Ratio

Month wise and size wise variation in the sex ratio of *B. spirata* was studied for 2 years from January 2001 to December 2002. Of the 1633 number of snails examined, 696 were male and 937 females indicating a sex ratio of 1:1.3. Month wise analysis of the sex ratio (Table-19) showed that expected 1:1 ratio occurred in the population only during March 2001. Females dominated the population in most of the months and significant (*P< 0.05*) preponderance of female was observed during January 2001 and February and May of both the years. Male dominated the population only during April and September 2001 and during January 2002. However, the dominance was not significant.

Table- 19 Sex ratio of *B. spirata* in different months during Jan. 2001 to Dec. 2002

Size class	Number of sample	Number of Male	Number of Female	Chi 2 values	Sex ratio (M:F)
Jan-01	212	86	126	7.55*	1:1.47
Feb-01	30	8	22	6.53*	1:2.75
Mar-01	92	46	46	0.00	1:1
Apr-01	61	31	30	0.02	1:0.97
May-01	64	19	45	10.56*	1:2.37
Aug-01	153	65	88	3.46	1:1.35
Sept-01	42	22	20	0.10	1:0.91
Oct-01	41	15	26	2.95	1:1.73
Nov-01	166	79	87	0.39	1:1.1
Jan-02	59	32	27	0.42	1:0.84
Feb-02	63	22	41	5.73*	1:1.86
Mar-02	55	23	32	1.47	1:1.39
Apr-02	98	40	58	3.31	1:1.45
May-02	133	53	80	5.48*	1:1.51
Jun-02	71	30	41	1.70	1:1.37
Sept-02	95	41	54	1.78	1:1.32
Oct-02	75	30	45	3.00	1:1.5
Nov-02	77	32	45	2.19	1:1.41
Dec-02	46	22	24	0.09	1:1.09

* Significant at 5% level

The size-wise sex ratio in different size group of *B. spirata* analysed during January to December 2001 (Table-20) indicated that in 25-30 mm, 35-40, 40-45 and 45-50 mm, the females were significantly ($P<0.05$) predominant. During the following year, females were significantly ($P<0.05$) dominant in the size groups 40-45, 45-50 and 50-55 mm. Though males were more in number than females in 30-35 mm and 35-40 mm in the second year of study, only the variation in 30-35 mm size group was significant. The number of males decrease with increasing size and males >55 mm were not recorded.

The analysis of the monthly sex ratio of *B. zeylanica* indicated that females dominated the population in all the months except in November 2001. However, the predominance of females was significant only during May 2001 and during rest of the period, the difference was not significant. In November 2001, the chi-square value indicated that the dominance by males was significant (Table- 21).

Table- 20 Sex ratio of *B. spirata* in different size class during Jan. 2001 to Dec. 2002

Size class	Number of sample	Number of Male	Number of Female	Chi 2 values	Sex ratio (M:F)
2001					
20-25	6	2	4	0.67	1:2
25-30	66	22	44	7.33*	1:2
30-35	241	117	124	0.20	1:1.1
35-40	399	168	231	9.95*	1:1.4
40-45	126	41	85	15.37*	1:2.1
45-50	13	1	12	9.31*	1:12
50-55	2	0	2	-	-
2002					
25-30	7	2	5	1.29	1:2.5
30-35	48	31	17	4.083*	1:0.5
35-40	341	174	167	0.14	1:1
40-45	296	98	198	33.78*	1:2
45-50	71	19	52	15.34*	1:2.7
50-55	7	1	6	3.57*	1:6
55-60	3	0	3	-	-

* Significant at 5%

Table- 21 Sex ratio of *B. zeylanica* in different months during Jan. 2002 to Dec. 2002

Size class	Number of sample	Number of Male	Number of Female	Chi ^{2} values	Sex ratio (M:F)
Jan	64	25	39	3.06	1:1.6
Feb	38	16	22	0.95	1:1.4
Apr	65	27	38	1.86	1:1.4
May	25	7	18	4.84*	1:2.6
Jun	80	38	42	0.20	1:1.1
Aug	36	17	19	0.11	1:1.1
Oct	56	31	25	0.64	1:0.8
Nov	43	13	30	6.72*	1:2.3
Dec	35	14	21	1.40	1:1.5

* Significant at 5% level

In all the 9 different size classes starting from 20-25 mm to 65-70 mm, number of females were more than the number of male snails, but the predominance of females were significant only in 2 size classes *viz,* 45-50 mm and 60-65 mm

(Table- 22). The number of males decreased in larger size groups especially above 60 mm.

Table- 22 Sex ratio of *B. zeylanica* in different size class during Jan. 2002 to Dec. 2002

Size class	Number of sample	Number of Male	Number of Female	Chi ^{2} values	Sex ratio (M:F)
25-30	2	1	1	0.00	1:1
30-35	1	0	1	1.00	
35-40	18	8	10	0.22	1:1.3
40-45	122	59	63	0.13	1:1.1
45-50	97	37	60	5.45*	1:1.6
50-55	73	31	42	1.66	1:1.4
55-60	92	41	51	1.09	1:1.2
60-65	32	10	22	4.5*	1:2.2
65-70	5	1	4	1.80	1:4

* Significant at 5% level

4.6.6. Gonadosomatic Index (GSI)

The mean (± SD) GSI estimated for the four different maturity stages of male and female is depicted in Fig. 26. There is a gradual increase in the GSI from stage I to stage III followed by decline in the spent stage. The maximum GSI recorded in stage III for male and female was 18.9 and 19.16 respectively. The mean GSI of male and female at this stage was 11.11 ± 2.77 and 10.41 ± 3.14 respectively. In all the other stages of maturity, the GSI was low (<5.5) for both male and female, the lowest value being 1.01 ± 0.54 in stage I. The average monthly GSI for male and female snails showed variation (Fig. 27). There was a steep increase in the GSI of female *B. spirata* from 4.68 ± 1.74 in Sept. to 8.42 ± 2.77 in Nov. Subsequent to this the GSI reduced to 3.75±1.91 in January. However, during Feb-April the GSI again increased and the monthly average recorded was 7.02±3.91 and 7.70±4.5 respectively. The monthly variation in the GSI of male snails was not as pronounced as it was for females. The values ranged between 5.05±1.68 in Sept. to 9.55±3.99 in Oct. The highest mean GSI (8.42±2.77) was observed in November for females, where as in males (9.55±3.99) the peak was observed in October. In females the mean GSI ranged from 3.75 to 8.42, while the difference in mean values through the months was less in males (5.05-9.55).

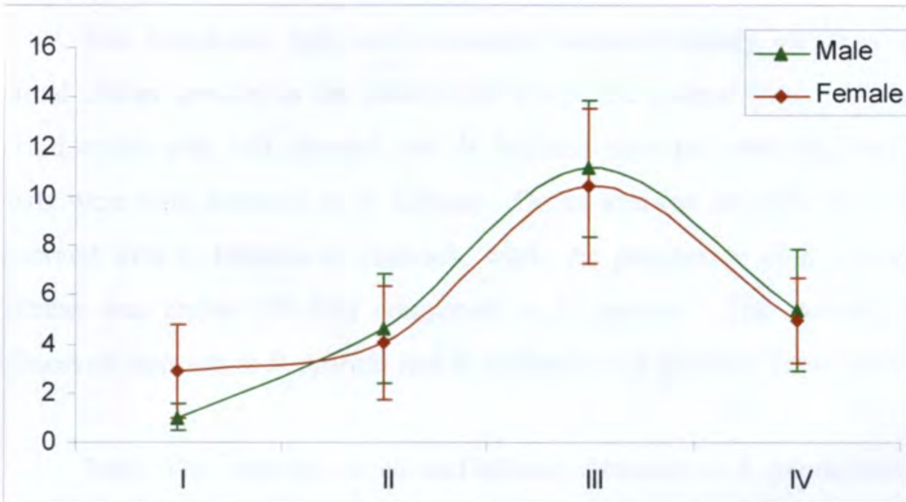


Fig. 26 Variation of gonadosomatic index in the different maturity stages of *B. spirata* (n = 581)

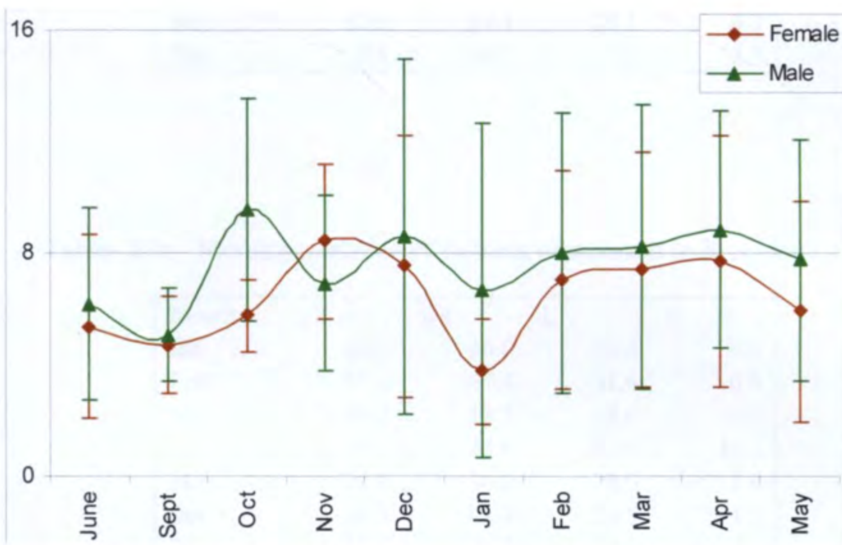


Fig. 27 Monthly variation of avareage GSI of male and female *B. spirata* for the period June 2001 to May 2002 (n = 581)

4.7. Food and feeding

The *Babylonia* spp. are scavengers subsists mainly on dead and decayed animal matter present in the substratum where the animal lives. During the study period snails with full stomach and ¾ fullness were not observed and most of the snails were with stomach of ¼ fullness. On an average only 9% of *B. spirata* were observed with ½ fullness of stomach, while the percentage of *B. zeylanica* with ½ fullness was higher (20.5%) compared to *B. spirata*. The monthly variation of fullness of stomach in *B. spirata* and *B. zeylanica* are given in Table- 23a & b.

Table- 23a Monthly variation of fullness of stomach in *B. spirata* during 2002

Month	1/2	1/4	L	E
Jan	0	62.5	33.3	4.2
Feb	17.1	65.7	17.1	0.0
Mar	3.0	57.6	33.3	6.1
Apr	0.0	50.0	47.1	2.9
May	6.7	66.7	23.3	3.3
Jun	10.2	56.4	28.9	4.5
Aug	13.9	61.1	22.2	2.8
Sep	15.4	61.5	15.4	7.7
Oct	9.8	59.8	26.6	3.8
Nov	12.5	62.4	25.1	0.0
Dec	8.8	60.5	27.8	2.9

Table- 23b Monthly variation of fullness of stomach in *B. zeylanica* during 2002

Month	1/2	1/4	L	E
Jan	26.7	40.0	33.3	0.0
Feb	21.1	47.4	31.6	0.0
Mar	19.2	52.2	28.6	0.0
Apr	10.5	45.6	31.6	12.3
May	28.0	36.0	28.0	8.0
Jun	24.6	48.7	24.8	1.9
Aug	18.5	54.3	27.2	0.0
Sep	15.4	54.7	22.8	7.1
Oct	20.1	47.4	28.9	3.6
Nov	22.3	46.5	31.2	0.0
Dec	19.5	52.6	24.9	3.0

4.8. Biometric relationships

4.8.1. Biometric variation in relation to gender

SH-TWt relation of *B. spirata* (pooled data) showed a positive relationship (r^2- 0.926) and for *B. zeylanica* also there was a positive relationship (r^2- 0.9504) with b-value of 2.24 and 2.2 respectively. When the SH-TWt relationship was studied for the two sexes separately for *B. spirata* it was observed that the relationship was positive with r^2- values 0.95 and 0.96 and the b-values 2.48 and 2.54 respectively (Table- 24) and the variation was not significant (Table- 25). However, for *B. zeylanica* when the SH-TWt relation was analyzed for male and female separately it was observed that though the relationship was positive, the variation in b-value (Table- 25) of the sexes were significantly different at 0.05 level.

The SH-MWt relationship of *B. spirata* pooled data showed a positive relation (r^2- 0.7) and for male and female *B. spirata* the r^2- values were almost similar, 0.71 and 0.7 respectively. The b-values for male and female pooled data and for males and females separately was estimated as 2.6, 2.54 and 2.57 respectively and the variations were not significant ($P>0.05$). The SH-MWt relation of *B. zeylanica* pooled and separately for male and female, the r^2-values were 0.71, 0.72 and 0.76 respectively. However, the b-values were significantly ($P<0.05$) different for male and female (1.8 and 2.1 respectively).

In the SH-SW relation, the b-value for *B. spirata* was 0.61, while that of *B. zeylanica* was 0.41 with intercepts at 2.07 and 7.52 respectively (Table- 24). The r^2-value showed high positive relation (Table- 25). When the SH-SW relation of male and female *B. spirata* was considered separately the b-values were slightly lower (0.58) for males than that of females (0.62) and the values were significantly ($P<0.05$) different. In *B. zeylanica* also the b–values were lower (0.389) for males than that of females (0.42) and the values were significantly different ($P<0.05$). This shows that the rate of growth in body whorl of females is faster than that of males.

In the analysis done for SH-OL, the b-value of regression for *B. spirata* was 0.48, while that of *B. zeylanica* was 0.32 with intercepts at 2.94 and 7.78 respectively. The r^2- value showed positive relation (Table- 25). When the shell height-operculum length relation of male and female *B. spirata* was considered separately, the b-values were slightly higher (0.502) for males than that of females (0.47) and the values were significantly (*P<0.05*) different. In *B. zeylanica* the b–value was lower (0.28) for males than that of females (0.34) and the values were significantly different (*P<0.05*).

Table- 24 Results of the analysis on biometric relations of *B. spirata* and *B.. zeylanica* with the values of slopes and intercepts

	X	Y	n	B	a	R Square
B. spirata male	SH	T Wt	724	2.4899	0.00150	0.9510
B. spirata female	SH	T Wt	975	2.5470	0.00120	0.9670
B. spirata pooled	SH	T Wt	200	2.2408	0.0036	0.9263
B. zeylanica male	SH	T Wt	191	2.0166	0.00690	0.9640
B. zeylanica female	SH	T Wt	283	2.3220	0.00210	0.9780
B. zeylanica pooled	SH	T Wt	200	2.195	0.0035	0.9504
B. spirata male	SH	M Wt	683	2.5980	0.00040	0.7188
B. spirata female	SH	M Wt	930	2.5440	0.00050	0.7073
B. spirata pooled	SH	M Wt	1613	2.5660	0.00040	0.7137
B. zeylanica male	SH	M Wt	227	1.828	0.0057	0.7208
B. zeylanica female	SH	M Wt	328	2.162	0.0017	0.7601
B. zeylanica pooled	SH	M Wt	555	2.026	0.0028	0.7113
B. spirata male	SH	SW	685	0.5827	3.0530	0.9440
B. spirata female	SH	SW	928	0.6232	1.7310	0.9247
B. spirata pooled	SH	SW	1889	0.6120	2.0765	0.9137
B. zeylanica male	SH	SW	173	0.3897	8.5260	0.9550
B. zeylanica female	SH	SW	231	0.4274	6.9180	0.9620
B. zeylanica pooled	SH	SW	404	0.4133	7.5207	0.9219
B. spirata male	SH	OL	289	0.5022	2.0030	0.9290
B. spirata female	SH	OL	464	0.4670	3.2080	0.9327
B. spirata pooled	SH	OL	753	0.4751	2.9379	0.8682
B. zeylanica male	SH	OL	92	0.2775	9.5325	0.9265
B. zeylanica female	SH	OL	139	0.3371	6.8450	0.9542
B. zeylanica pooled	SH	OL	231	0.3162	7.7718	0.8859

SH shell height; T Wt. = total wet weight; M Wt. = meat weight; SW = shell width; OL = operculum length

Table- 25 Results of ANCOVA for testing equality of slopes with F value

Species	Stocks compared	Parameters compared	n	F value of Slope	Sig at 5%
B. spirata	Male *vs* Female	SH *vs* T Wt	1699	2.3	NS
B. spirata	Male *vs* Female	SH *vs* M Wt	1685	0.22	NS
B. spirata	Male *vs* Female	SH *vs* SW	1613	16.67	S
B. spirata	Male *vs* Female	SH *vs* OL	753	5.19	S
B. zeylanica	Male *vs* Female	SH *vs* T Wt	474	39.37	S
B. zeylanica	Male *vs* Female	SH *vs* M Wt	555	23.14	S
B. zeylanica	Male *vs* Female	SH *vs* SW	401	9.02	S
B. zeylanica	Male *vs* Female	SH *vs* OL	231	15.63	S
B. spirata 30-40mm	Male *vs* Female	SH *vs* T Wt	1096	2.11	NS
B. spirata 30-40mm	Male *vs* Female	SH *vs* SW	1044	5.45	S
B. spirata 30-40mm	Male *vs* Female	SH *vs* OL	478	5.26	S
B. spirata 40-50mm	Male *vs* Female	SH *vs* T Wt	496	2.67	NS
B. spirata 40-50mm	Male *vs* Female	SH *vs* SW	457	0.04	NS
B. spirata 40-50mm	Male *vs* Female	SH *vs* OL	196	3.33	NS
B. zeylanica 40-50mm	Male *vs* Female	SH *vs* T Wt	201	0.65	NS
B. zeylanica 40-50mm	Male *vs* Female	SH *vs* SW	167	8.16	S
B. zeylanica 40-50mm	Male *vs* Female	SH *vs* OL	94	2.15	NS
B. zeylanica 50-60mm	Male *vs* Female	SH *vs* T Wt	167	0.31	NS
B. zeylanica 50-60mm	Male *vs* Female	SH *vs* SW	134	0.2	NS
B. zeylanica 50-60mm	Male *vs* Female	SH *vs* OL	79	0.1	NS

4.8.2. Biometric variation in relations to size

The SH-TWt relationship of two length groups of male and 3 length groups of female *B. spirata* showed that the smaller group (30-40mm) of male has a higher b-value (2.56) than 40-50mm group (2.26) (Table- 26), the variation was not significant (Table- 27). The females also had a lower b-value with increase in length however, the variations were not statistically significant. The b-value of SH-TWt showed a slight increase with increase in size for both male and female *B. zeylanica*, but the differences were not significant.

The SH-SW relationship of different size classes of male and female *B. spirata* showed that, the b-value of 30-40 mm males was slightly greater (0.62) than that of 40-50 mm group (0.58), however the difference was not significant. The b-value of this linear relationship for female *B. spirata* was found to be high (0.77) in smaller size class (20-30 mm) than for larger size groups. The b-values were 0.77, 0.66 and 0.59 for the three size groups. However the difference in slopes between the 20-30 and 30-40 mm size groups were not significantly different, while the difference was significant ($P<0.05$) for the 30-40 mm and 40-50 mm size group.

The b-value relationship of SH-SW of *B. zeylanica* showed positive correlation in both the size groups in male and female and the b-values of 40-50 mm size group male *B. zeylanica* was higher (0.51) than for the same size female whelk and higher size group males, but the variations were not significant ($P>0.05$).

The linear equation of SH-OL relationship indicated that the b-value of 30-40 mm size group of male was higher than that of 40-50 mm and the values showed same pattern of growth for females too. The b-values were found to decrease with the increase in shell length for females in the 3 size groups analyzed and the values showed significant variation statistically for both male and female ($P<0.05$). In *B. zeylanica* the b-value was higher (0.43) in males of size 40-50 mm than that of 50-60 mm (0.39) and similarly, it was higher in female 40-50 mm than that of 50-60 mm. However, the variation was not significant for males, but there was significant variation in female (Table- 27).

4.9. Length frequency distribution

B. spirata of length ranging from 20-54 mm contributed to the fishery in the year 2001, while in the following year whelks of 26-60 mm size were observed the fishery. *B. spirata* of length less than 30 mm occurred in the fishery in all the months except during June in 2001, while in the second year of study small size whelk (<30 mm) were observed only during January, April, September, November and December. About 88 % of the fishery was contributed by 30-46 mm length during 2001 and in the subsequent year this size group formed 92.5% of fishery. The annual percentages of smaller animals of shell height less than 30 mm were 10.2 % and 0.9%

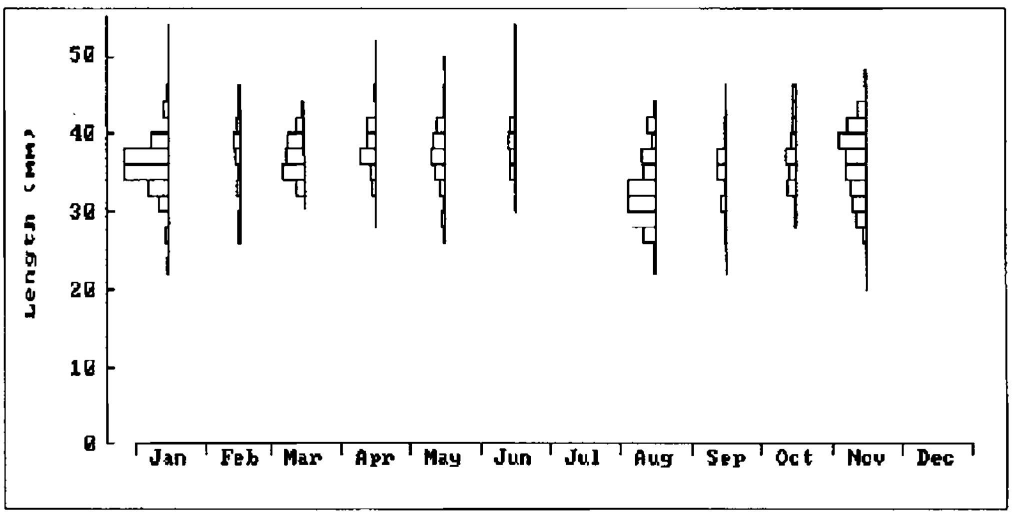
Table- 26 Results of the regression conducted on different size groups of male and female *B. spirata* and *B. zeylanica*

	Size class	X	Y	n	b	a	R Square
B. spirata male	30-40	SH	T Wt	547	2.5605	0.0011	0.802
B. spirata male	40-50	SH	T Wt	149	2.2699	0.0033	0.7107
B. spirata female	20-30	SH	T Wt	64	2.6948	0.0007	0.813
B. spirata female	30-40	SH	T Wt	552	2.6767	0.0008	0.7915
B. spirata female	40-50	SH	T Wt	350	2.5135	0.0014	0.7141
B. zeylanica male	40-50	SH	T Wt	94	2.3199	0.0021	0.8327
B. zeylanica male	50-60	SH	T Wt	64	2.36	0.0018	0.8648
B. zeylanica female	40-50	SH	T Wt	110	2.1967	0.0034	0.8032
B. zeylanica female	50-60	SH	T Wt	106	2.2648	0.0027	0.8165
B. spirata male	30-40	SH	SW	507	0.6238	1.5761	0.7918
B. spirata male	40-50	SH	SW	144	0.5851	2.8322	0.6231
B. spirata female	20-30	SH	SW	62	0.7703	-2.5725	0.7826
B. spirata female	30-40	SH	SW	540	0.6687	0.1159	0.7729
B. spirata female	40-50	SH	SW	316	0.5929	3.0392	0.7208
B. zeylanica male	40-50	SH	SW	83	0.5181	2.9144	0.804
B. zeylanica male	50-60	SH	SW	59	0.4857	3.2114	0.7323
B. zeylanica female	40-50	SH	SW	87	0.4093	7.7357	0.7675
B. zeylanica female	50-60	SH	SW	78	0.4629	5.2916	0.7715
B. spirata male	30-40	SH	OL	214	0.539	0.8279	0.8111
B. spirata male	40-50	SH	OL	54	0.1815	-15.027	0.0721
B. spirata female	20-30	SH	OL	47	0.672	-3.3364	0.7685
B. spirata female	30-40	SH	OL	267	0.4761	3.168	0.6857
B. spirata female	40-50	SH	OL	145	0.3478	8.0655	0.3845
B. zeylanica male	40-50	SH	OL	44	0.4374	2.6716	0.8238
B. zeylanica male	50-60	SH	OL	33	0.3944	2.9377	0.421
B. zeylanica female	40-50	SH	OL	53	0.5077	-0.6525	0.8092
B. zeylanica female	50-60	SH	OL	49	0.4168	2.7529	0.815

Table- 27 Results of ANCOVA for testing equality of slopes of different size groups of male and female *B. spirata* and *B. zeylanica*

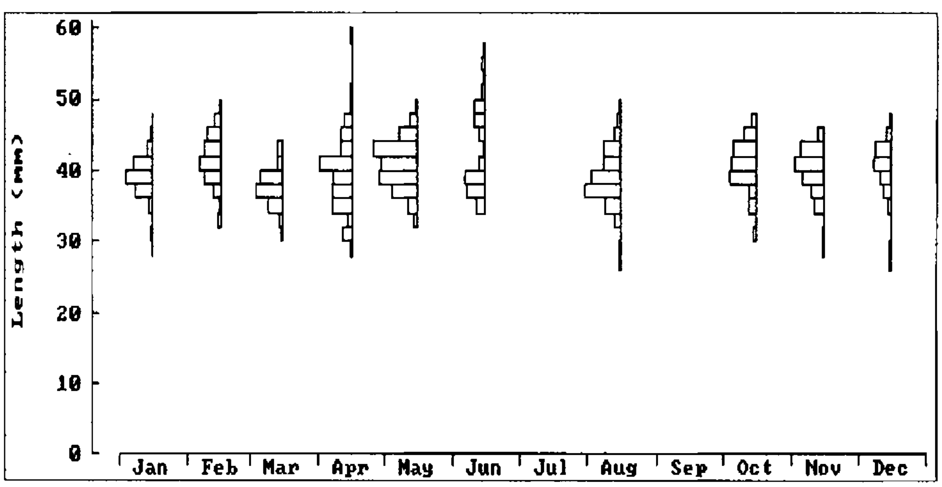
Species	**Stocks compared**	**Parameters compared**	**F value of Slope**	**Sig at 5%**
B. spirata male	30-40 *vs* 40-50	SH *vs* T Wt	3.67	NS
B. spirata male	30-40 *vs* 40-50	SH *vs* SW	0.89	NS
B. spirata male	30-40 *vs* 40-50	SH *vs* OL	27.03	S
B. spirata female	20-30 *vs* 30-40	SH *vs* T Wt	0.01	NS
B. spirata female	20-30 *vs* 30-40	SH *vs* SW	2.92	NS
B. spirata female	20-30 *vs* 30-40	SH *vs* OL	10.19	S
B. spirata female	30-40 *vs* 40-50	SH *vs* T Wt	2.01	NS
B. spirata female	30-40 *vs* 40-50	SH *vs* SW	7.45	S
B. spirata female	30-40 *vs* 40-50	SH *vs* OL	9.83	S
B. zeylanica male	40-50 *vs* 50-60	SH *vs* T Wt	0.06	NS
B. zeylanica male	40-50 *vs* 50-60	SH *vs* SW	0.47	NS
B. zeylanica male	40-50 *vs* 50-60	SH *vs* OL	0.29	NS
B. zeylanica female	40-50 *vs* 50-60	SH *vs* T Wt	0.22	NS
B. zeylanica female	40-50 *vs* 50-60	SH *vs* SW	2.03	NS
B. zeylanica female	40-50 *vs* 50-60	SH *vs* OL	3.96	S

in 2001 and 2002 respectively. The percentage of smaller *B. spirata* was maximum in August (28 %) followed by September (12%) and November (11.4%) during 2001. During 2002, the presence of smaller animals was negligible (0.9%) compared to 2001, when they occurred during January, April, September, November and December. The presence of bigger snails (>46mm) were also negligible (0.57% and 6.6 % in 2001 and 2002 respectively). The annual mode of the fishery during 2001 was 36-38 mm and 38-40 mm during 2002. The monthly length frequency distribution of *B. spirata* in 2001 and 2002 is shown in Fig. 28a & b.



Smallest ML : 21.0 mm, Largest ML : 53.0 mm, Class interval : 2.0 mm

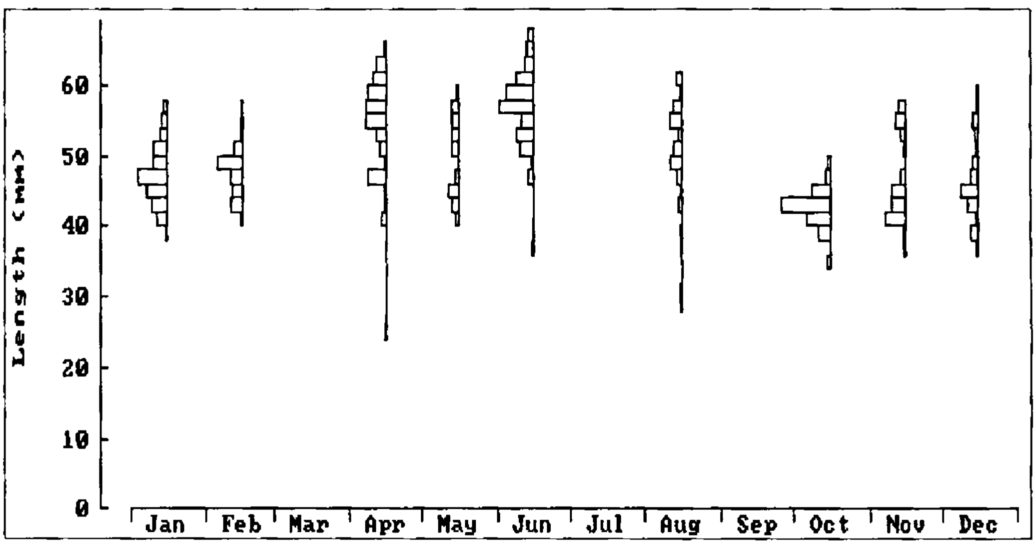
Fig. 28a Length frequency distribution of *B. spirata* during 2001



Smallest ML : 21.0 mm, Largest ML : 59.0 mm, Class interval : 2.0 mm

Fig. 28b Length frequency distribution of *B. spirata* during 2002

B zeylanica of 40-60 mm (87.5%) supported the fishery through out the year 2002. The smallest animal observed in the fishery was 24.2 mm and the largest 68 mm during the study. Snails below 40 mm formed 4.7 % of annual landing and above 60mm formed 7.7%. During the peak fishing season (April – June) 46-64 mm length dominated the fishery (87.2%) and *B. zeylanica* above and below this range formed 8.2 and 4.6% respectively. The smaller snails less than 40mm were maximum during December (14.3%) followed by August (11.2%) and October (10.3%), and in other months the presence was negligible or nil. Larger snails (>60mm) formed 25.5% during June. The monthly length frequency distribution of *B. zeylanica* is shown in Fig. 29.



Smallest ML : 25.0 mm, Largest ML : 67.0 mm, Class interval : 2.0 mm

Fig. 29 Length frequency distribution of *B. zeylanica* during 2002

4.10. Mean length

The annual mean length of *B. spirata* showed an increase from 37.4 mm in 2001 to 40.1 mm in 2002. The monthly mean shell height of *B. spirata* was greater in 2002 than in 2001 (Fig. 30). The mean shell height of the fishery attained a maximum in June and smallest was observed in August for both years. This indicates that the main recruitment to the fishery is in August. The multiple cohorts observed in the population supports that *B. spirata* is a continuous breeder with peak breeding seasons.

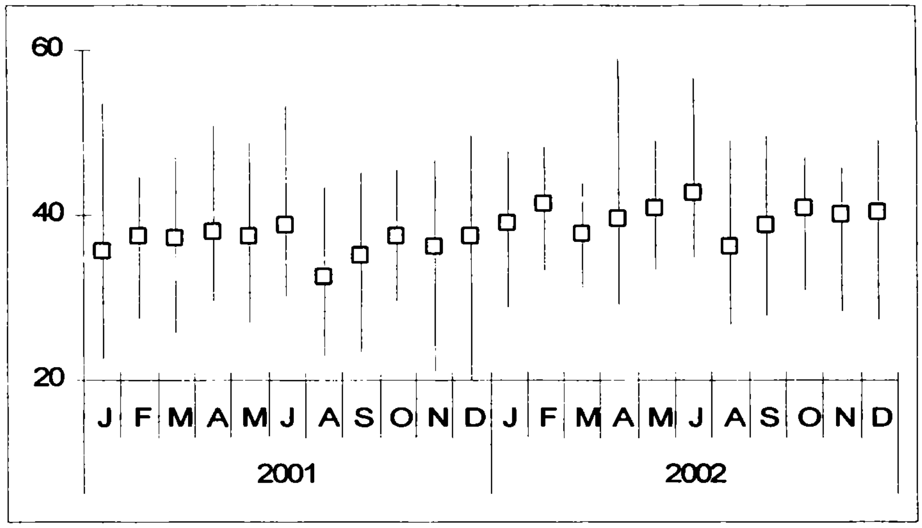


Fig. 30 Variation in monthly mean length of *B. spirata* for 2001 and 2002

The annual mean shell height of *B. zeylanica* in 2002 was 49.9mm. The highest mean length was observed in June and the least was in October (Fig. 31).

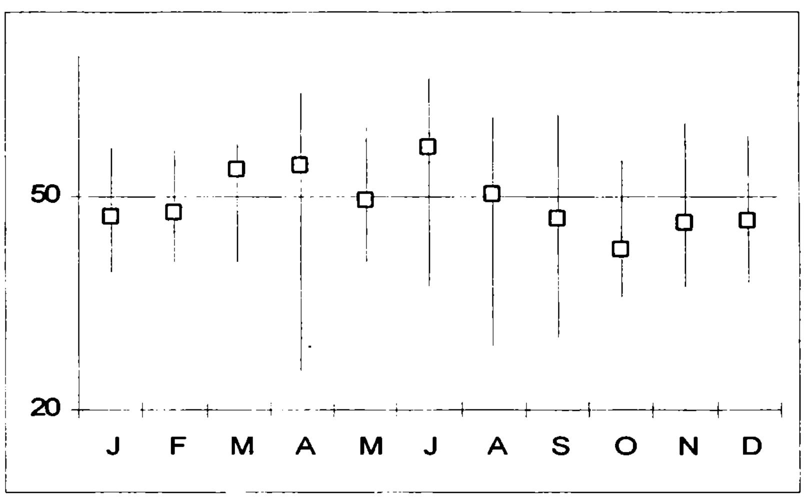


Fig. 31 Variation in monthly mean length of *B. zeylanica* in 2002

4.11. Growth

The shell length of *B. spirata* and *B. zeylanica* ranged between 21 to 58.9 mm and 25.5-66.9 mm respectively in the samples. Size frequency of *B. spirata* and *B. zeylanica* exploited along off Kollam during the study is detailed in section 3.8 and Fig. 28a & b and 29. Using this data, a preliminary estimate of asymptotic length (L_∞) was obtained by Powell and Wetherall method (1986) as 58.5 mm for *B. spirata* and 65.9 mm for *B. zeylanica*.

The L_∞ thus obtained for the 2 species used for further analysis of length frequency data in ELEFAN I for estimation of growth parameters. The preliminary estimates of K values obtained in scan of K values for *B. spirata* and *B. zeylanica* were 1.2 and 1.0 respectively.

The analysis also gave the estimation of Φ (growth performance index) 3.61 and 3.64 for *B. spirata* and *B. zeylanica* respectively. From further analyses in Response surface analysis and Automatic search routine, the best fitting (with high goodness of fit) growth curves were selected. The L_∞ was estimated at 68.7 and K at 1.08 for *B. spirata*. The corresponding growth curve with L/F data is shown in Fig. 32a & b.

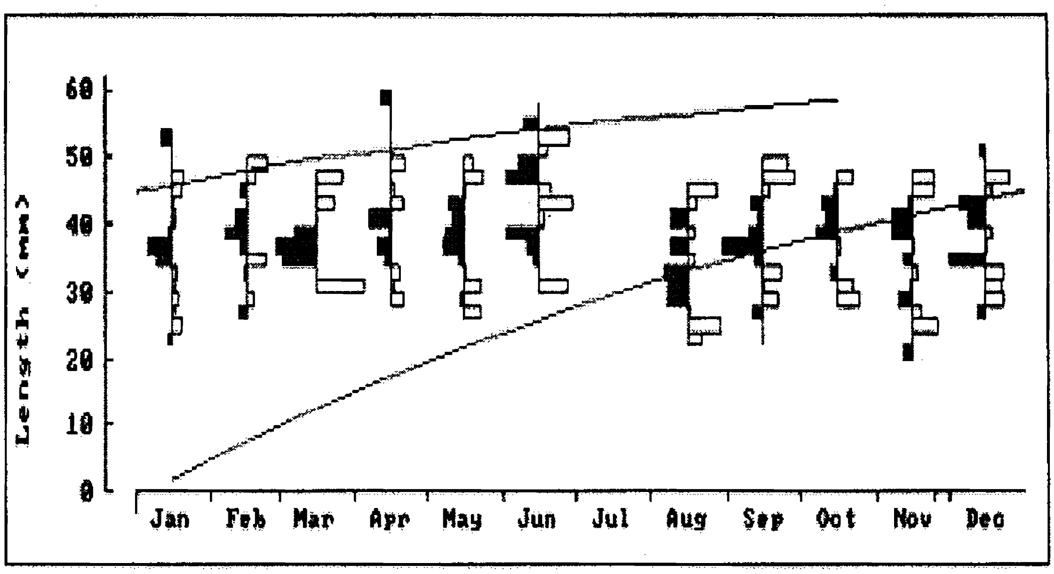


Fig. 32a. Growth curve of *B. spirata* fitted to length- frequency data using L_∞ - 68.7mm, K - 1.08, Starting length 36mm (Rn = 179)

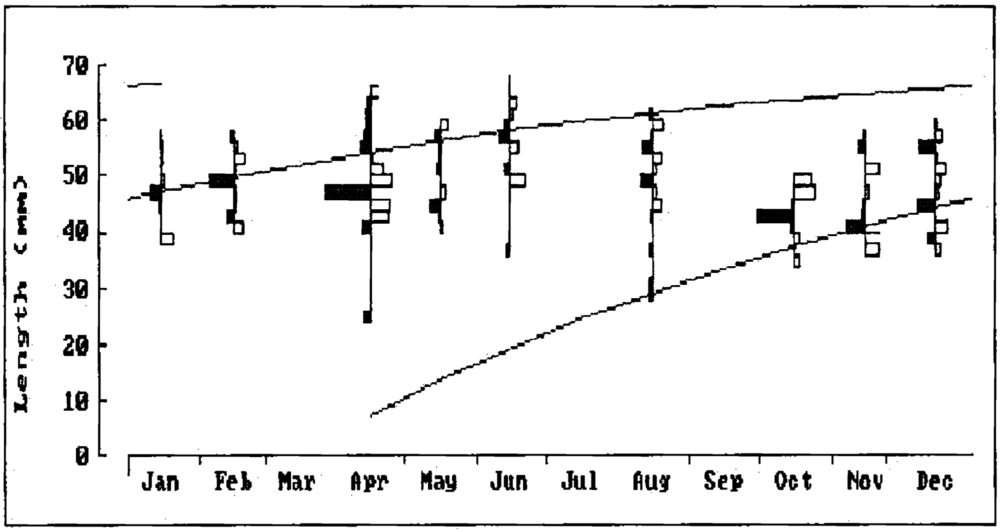


Fig. 32b. Growth curve of *B. zeylanica* fitted to length- frequency data using L_{∞}- 76, K - 1.15, Starting length 44mm (Rn = 221)

Further, the growth parameters were estimated using Gulland & Holt (Fig. 33a&b), Munro's (Fig. 34a&b) and Faben's (Fig. 35a&b) methods in FiSAT program. The von Bertalanffy growth parameters obtained in the different analysis carried out are given in the Table- 28. The observed L_{max} of *B. spirata* and *B. zeylanica* were 58.9 mm and 68 mm respectively.

Table- 28 The L_{∞} and growth constant estimated for whelk using different methods

	B. spirata		*B. zeylanica*	
	L∞	k	L∞	k
ELEFAN I	68.7	1.08	76	1.15
Gulland & Halt	70.91	1.33	72.68	1.13
Munro's	70	1.33	58.64	3.64
Faben's	56.2 ± 6.6	1.97 ± 0.77	66.2 ± 8.92	1.72 ± 1.025

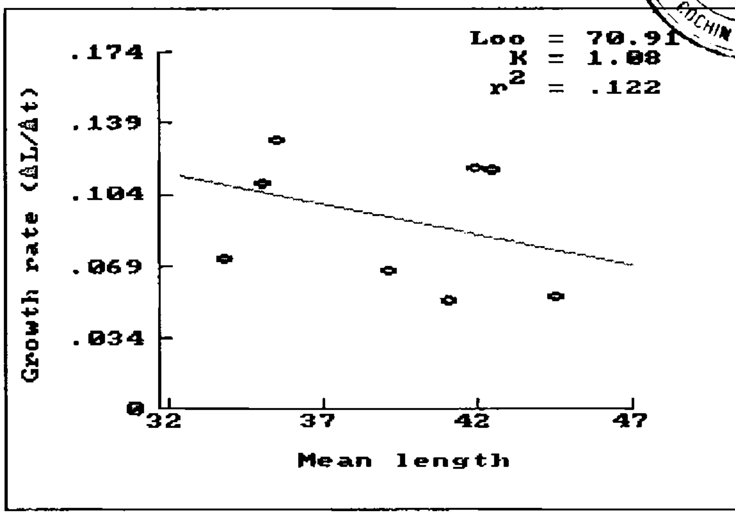


Fig. 33a. Gulland & Holt plot fitted to *B. spirata*

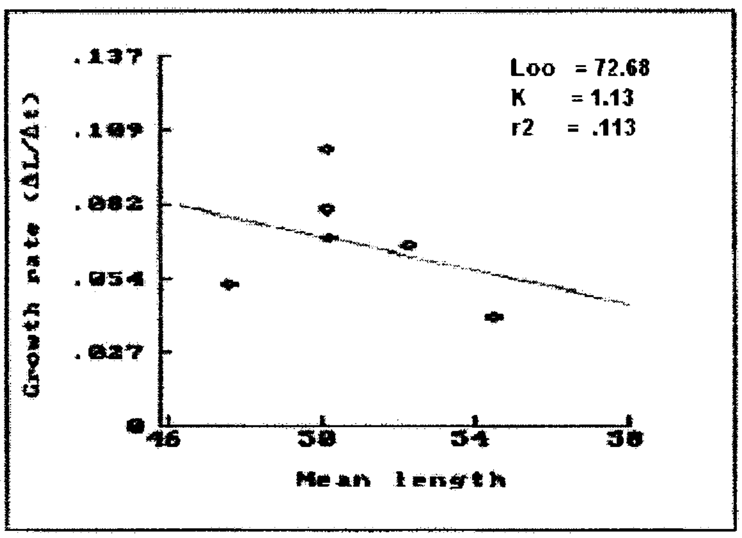


Fig. 33b. Gulland & Holt plot fitted to *B. zeylanica*

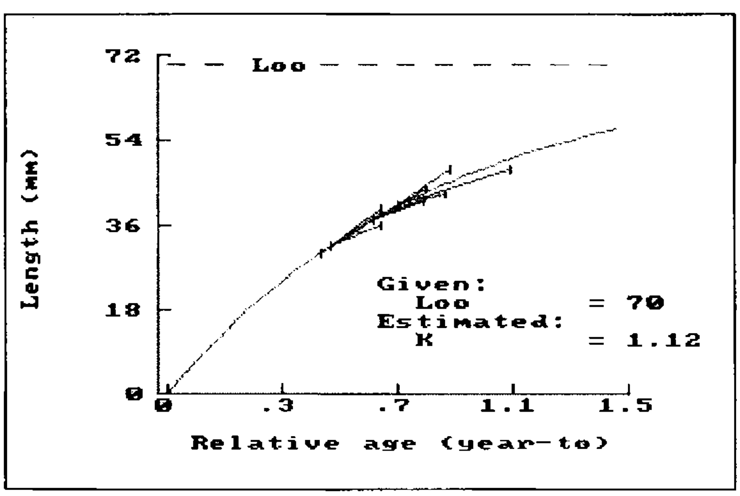


Fig. 34a. Munro's plot fitted for *B. spirata*

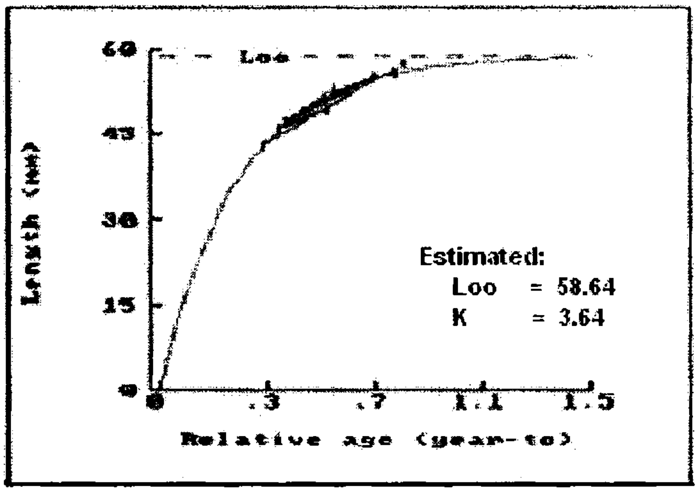


Fig. 34b. Munro's plot fitted for *B. zeylanica*

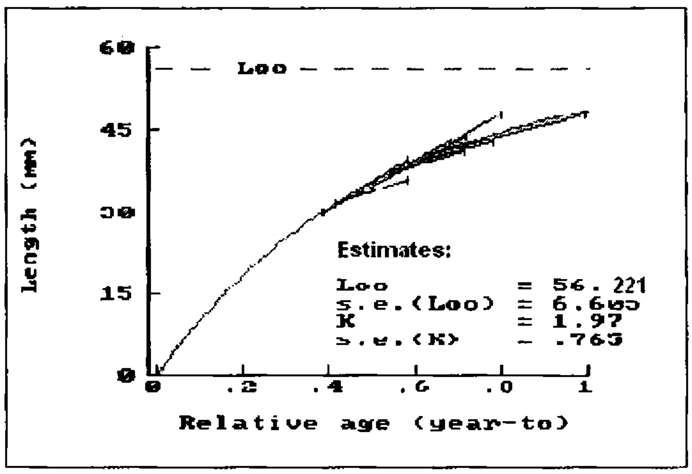


Fig. 35a. Faben's plot fitted to *B. spirata*

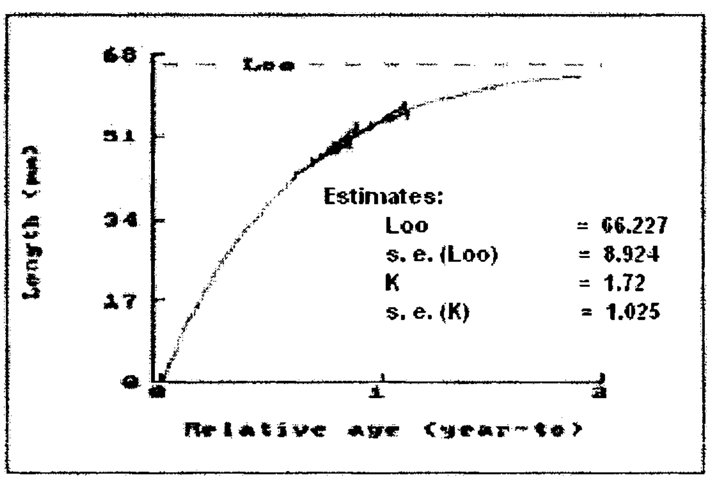


Fig. 35b Faben's plot fitted to *B. zeylanica*

The parameters obtained in ELEFAN I is considered as most suitable because the L_∞ obtained in Gulland & Holt and Munro's were much higher than the observed L_{max} of *B. spirata*, where as in Faben's estimate the L_∞ was less than L_{max}. In the case *B. zeylanica*, the L_∞ estimated by Munro's and Faben's method are lower than the L_{max}. The values obtained in ELEFAN I were substituted in the von Bertalanffy's growth equation for both the species as given below.

B. spirata $L_t = 68.7\ (1 - e^{-1.08\,(t - t_0)})$
B. zeylanica $L_t = 76\ (1 - e^{-1.15\,(t - t_0)})$

where, L_t = length at time t; k = growth coefficient; t = age; t_0 = age when length is zero.

Both the species appears to grow at faster rate and attains maximum size within 3 years. The life span of *B. spirata* was calculated as 2.8 years using the K value as 1.08/year and of *B. zeylanica* as 2.6 years when the K value is 1.15/year.

4.12. Fishery

4.12.1. Gastropod Landing

Gastropods were landed through out the year, except during the month of July, when trawl-ban was enforced by the Government of Kerala. The annual landing of gastropods at Neendakara - Sakthikulangara was estimated as 780.6 t, 879 t and 659.8 t during the period 2001, 2002 and 2003 respectively. The estimated average annual landing was 773.1 t. Gastropods formed 1.2% of marine landing at the center in 2001 and 2002 and 2.4% in 2003.

The estimated average monthly landing of gastropods for the three years showed an increasing trend from January to reach a peak in May (Fig. 36). The highest landing in May was estimated as 322 t, 301 t and 204 t respectively during the period 2001 to 2003. The lowest landing (2 t) was observed in December 2003. The monthly landing for the study period is given in Table-29.

The percentage contribution of gastropods to the total landing also showed wide monthly variations. In June 2001, gastropods formed 17.29% of the total marine landing while during the same year their contribution was as low as 0.15% in August and January. In following two years, percentage contribution of gastropods ranged between 0.2 and 6.69 and 0.62 to 10.7 respectively (Fig. 37).

Table- 29 The estimated total marine landing, landing of gastropods, *B. spirata* and *B. zeylanica* at Neendakara - Sakthikulangara harbour, Kollam, Kerala during the period 2001 to 2003

Months	Total trawl landing (t)	Gastropods (t)	*B. spirata* (t)	*B.zeylanica* (t)
2001				
January	1950	3.0	1.4	0.1
February	3163	22.0	9.0	0.3
March	1734	20.0	12.0	0.9
April	1286	160.0	16.6	85.4
May	6572	322.0	1.2	157.5
June	568	98.2	9.2	49.9
August	18177	27.0	8.0	1.3
September	12298	39.0	11.2	1.0
October	7396	34.0	9.8	2.3
November	4826	32.4	13.5	3.9
December	7132	23.0	11.2	2.7
Total	**65102**	**780.6**	**103.1**	**305.1**
2002				
January	4258	22.0	9.8	1.1
February	4815	43.0	12.9	0.8
March	5745	64.0	27.1	2.3
April	5036	157.0	33.7	86.5
May	4721	301.0	95.2	156.5
June	1883	126.0	52.8	51.0
August	19754	59.0	10.9	0.5
September	11077	30.0	8.5	0.4
October	8697	17.0	5.8	0.4
November	3093	29.0	13.0	0.4
December	2376	31.0	16.5	0.4
Total	**71455**	**879.0**	**286.1**	**300.3**
2003				
January	844	25.9	15.1	0.3
February	2330	25.9	11.4	0.6
March	777	31.7	11.2	0.4
April	2430	78.0	18.6	38.2
May	2015	204.9	24.4	146.2
June	1523	163.0	42.0	98.0
August	10273	80.1	17.6	0.2
September	1569	12.3	2.5	0.2
October	3361	20.7	9.3	0.3
November	325	15.3	8.3	0.4
December	2623	2.0	9.5	0.4
Total	**28070**	**659.8**	**169.9**	**285.3**

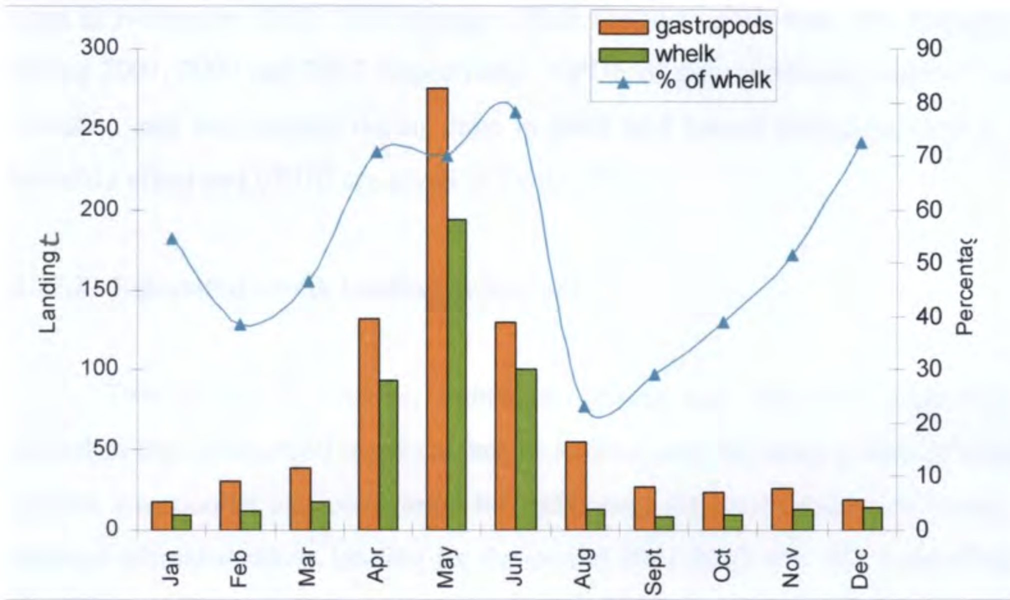


Fig. 36 **Estimated average monthly landing of gastropods and whelk and the percentage contribution of whelk to total gastropods landed at Neendakara-Sakthikulangara fishing harbour for the period of January 2001 to December 2003**

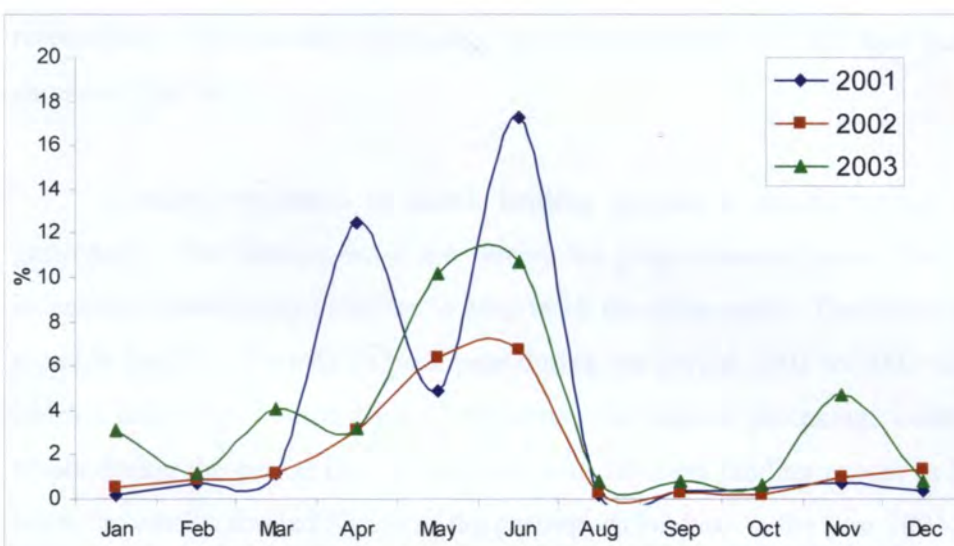


Fig. 37 **Monthly percentage contribution by gastropods to the total marine trawl landing during the period 2001 to 2003 at Neendakara - Sakthikulangara harbour, Kollam**

The effort was high during the post-monsoon period in all the years. Maximum effort (22993 units) was recorded in August 2001 and the minimum 1455 units in November 2003. The average CPUE for gastropods was 14.1, 9.8 and 13 kg during 2001, 2002 and 2003 respectively. CPUE of gastropods also showed monthly variation and was highest during June in 2001 and lowest during January in 2001. Monthly effort and CPUE are given in Table-30.

4.12.2. Estimated whelk landing at Kollam

Two species of whelks, *Babylonia spirata* and *Babylonia zeylanica* were landed in the commercial trawl catches at Kollam and the landing data of these two species was pooled and considered for estimating the total landing of whelk. The average estimated whelk landing for the period 2001-2003 was 487 t contributing to 62.5% of the total gastropod landing. During the study period the annual catch was lowest at 419.4 t during 2001 and highest at 586.5 t during 2002 indicating an increase of 28.5% within a year. This was followed by a decline of 22.4%, when the catch dropped to 455 t in 2003. The total whelk landed contributed to 53.7%, 66.7% and 67.1% of the gastropods landed at Kollam during the years 2001, 2002 and 2003 respectively. The monthly percentage contribution of whelk to the total gastropods is shown in Fig. 38.

Monthly variations in whelk landing showed a similar pattern as that of gastropods. The landing were low during the post-monsoon period but showed an increasing trend during February to May in all the three years. The highest estimated monthly landing of whelk in each year during the period 2001 to 2003 was 169.9 t, 251.6 t and 170.6 t respectively. However, the highest percentage contribution of whelk during the period did not coincide with the peak landing except in May 2002, when the whelks formed 83.6% of the gastropods landed. In the year 2001, the whelk contribution to gastropod landing was highest (64.7%) in June and in 2003, the highest contribution of whelk was recorded as 85.9% in June. Though whelk formed more than 50% of the gastropod landed in 15 months of the 33 months observation period, their contribution was low, less than 25% of the gastropod landing in August 2002 and 2003.

Table- 30 Total whelk landed, effort expended and catch per unit effort of Gastropods and whelk at Neendakara - Sakthikulangara harbour, Kollam, Kerala during the year 2001- 2003

	Whelk (kg)	**Effort (no. of units)**	**CPUE of whelk (kg)**	**CPUE Gastropods (kg)**
2001				
January	1468	4586	0.3	0.7
February	9300	6846	1.4	3.2
March	12944	5276	2.5	3.8
April	101924	5556	18.3	28.8
May	169912	7324	23.2	44.0
June	59050	1620	36.5	60.6
August	9250	22993	0.40	1.2
September	12180	12468	0.98	3.1
October	12085	11954	1.0	2.8
November	17356	7665	2.3	4.2
December	13880	10383	1.3	2.2
Average	**38123**	**8788.3**	**8.0**	**14.1**
2002				
January	10900	7358	1.5	3.0
February	13674	7926	1.7	5.4
March	29423	9359	3.1	6.8
April	120261	9236	13.0	17.0
May	251696	10112	24.9	29.8
June	103729	4392	23.6	28.7
August	11390	17126	0.7	3.4
September	8800	11101	0.8	2.7
October	6220	10659	0.6	1.6
November	13424	8101	1.7	3.6
December	16902	5375	3.1	5.8
Average	**53310.8**	**9158.6**	**6.8**	**9.8**
2003				
January	15404.0	2603	5.9	9.9
February	11955.0	5136	2.3	5.0
March	11669.0	3571	3.3	8.9
April	56776.0	6936	8.2	11.3
May	170624.0	6547	26.1	31.3
June	140005.0	3339	41.9	48.8
August	17831.0	14666	1.2	5.5
September	2681.0	5293	0.5	2.3
October	9570.0	4537	2.1	4.6
November	8730.0	1455	6.0	10.5
December	9883.0	3910	2.5	5.2
Average	**41375.3**	**5272.1**	**9.1**	**13.0**

4.12.3. Estimated landing of *B. spirata* and *B. zeylanica*

Both, *B. spirata* and *B. zeylanica* were landed in all the months except during July when there was a ban on trawl operations (Pl. 6a & b). The estimated monthly and annual landing of both the species during 2001 to 2003 is given in Table-29. The annual landing of *B. zeylanica* was estimated as 305 t, 300 t and 285 t during the period 2001, 2002 and 2003 respectively, while the annual landing of *B. spirata* was 114 t, 286 t and 169.8 t during the corresponding period. *B. zeylanica* formed more than 50% of the whelk landing with contributions of 72.8%, 51.2% and 62.7% during the three year period.

The estimated monthly landings of *B. zeylanica* followed the same pattern for the 3 years. The monthly average of *B. spirata* and *B. zeylanica* are shown in Fig. 39. *B. zeylanica* dominated whelk landing contributing to 61% of the annual average landings and the rest by *B. spirata* (39%). However the monthly landings showed variations throughout the year in all the 3 years. The landing of *B. zeylanica* ranged from a low of 63 kg in Jan. 2001 to a high of 157.5 t in May 2001. The percentage contribution varied from a low of 1.3% in August 2003 to a maximum 92.7% in May 2001. *B. zeylanica* dominated the fishery during April to June. The catch was negligible during the post-monsoon months.

Monthly landing of *B. spirata* ranged from 1.4 t to 16.5 t in 2001 and in the following year, the landings were higher ranging from 5.8 t to 95.1 t. In 2003, the landing of the species decreased and ranged between 2.4 t and 42 t (Table-29).

The average estimated CPUE for whelk was 8, 6.8 and 9.1 kg during the period 2001, 2002 and 2003 respectively (Table-30). The CPUE showed wide monthly variations, ranging from 0.3 in January to 36.5 in June 2001; from a low of 0.6 kg in October to a maximum of 23.6 kg in August 2002 and 0.5 kg in August to 41.9 kg in June during 2003. In all the years maximum recorded CPUE was during June.

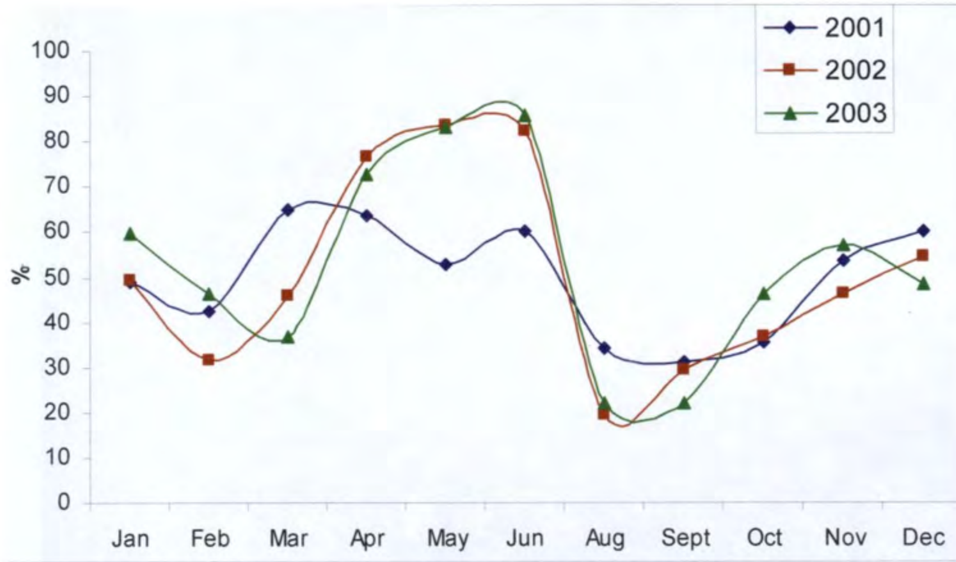


Fig. 38 Monthly percentage contribution by whelk to the total gastropod trawl landing during the period 2001 to 2003 at Neendakara - Sakthikulangara harbour, Kollam

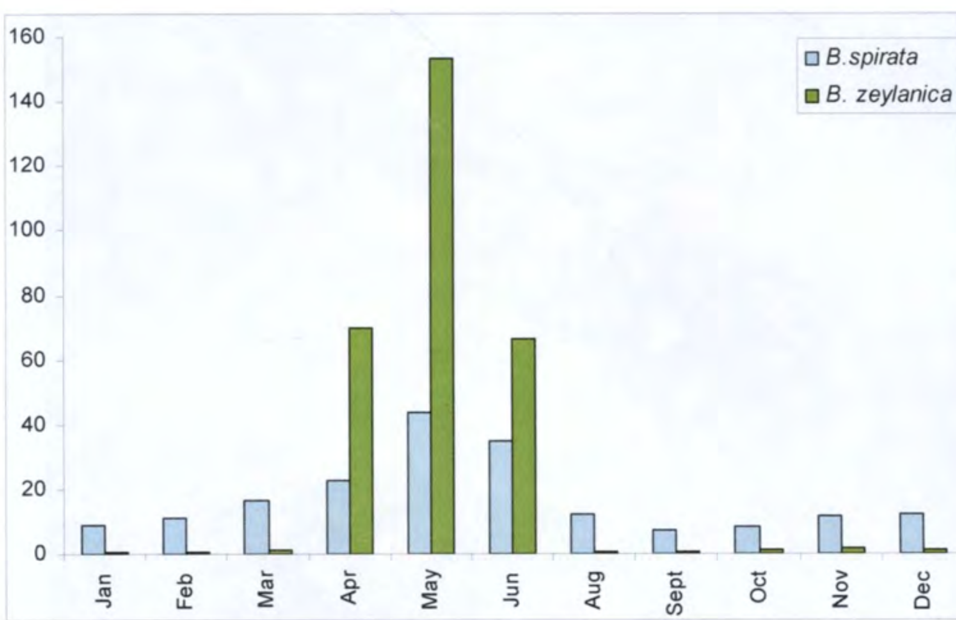


Fig 39 Estimated average monthly landing of the *B. spirata* and *B. zeylanica* landed at Neendakara-Sakthikulangara fishing harbour during the period January 2001 to December 2003

Pl. 6a. Commercial landing of *Babylonia spirata* at Neendakara-Sakthikulangara harbour

Pl. 6b. Commercial landing of *Babylonia zeylanica* at Neendakara- Sakthikulangara harbour

During the peak season (April-June), 20 to 40 boats were engaged in exclusive fishing of whelk. The CPUE in the modified trawlers targeted for whelk fishing was observed to range from 250 to 500 kg with an average of 400 kg.

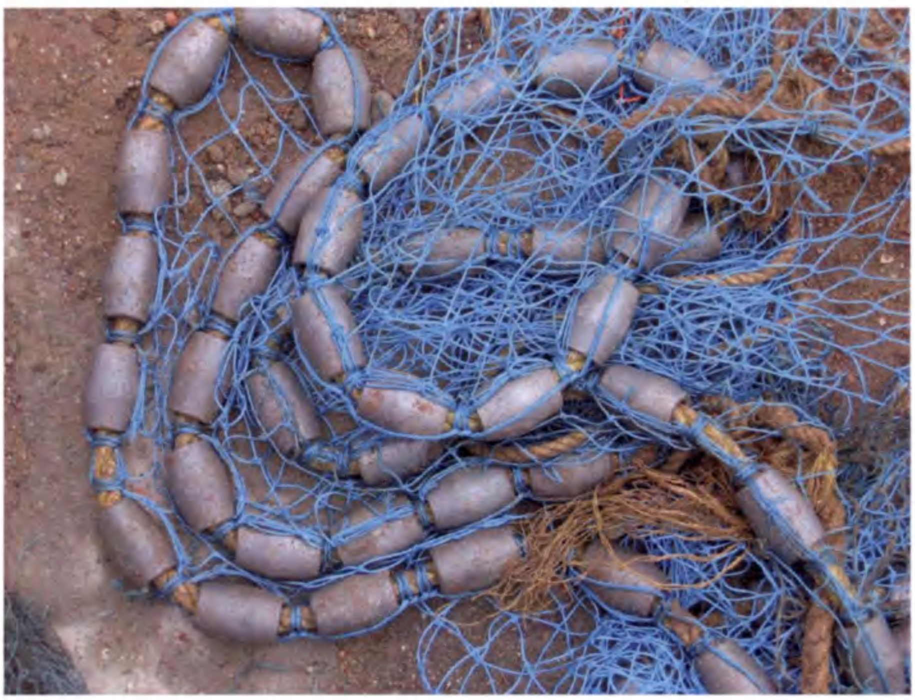
The modified gear used for targeted fishing is a two seam high opening trawl. The net has an upper and lower jib, wing, broad belly, throat and a cod end with mesh size 40 mm. The head rope is having a length of around 22 m with floats. The foot rope is having a length of 26 m and is attached with 200 lead weights of 200 g (Pl- 7). Polyethylene rope of 14 mm diameter is used as trawling rope. The belly region of the net has a mesh size of 60 mm with 185 meshes in depth. The throat with 150 meshes depth is made of 50 mm mesh size. The material used for making the net is polyethylene twine having a diameter of 1.25 mm except for cod end. Polyethylene twine of 1.5 mm is used for the cod end. The cod end is of 150 meshes in depth. The net weighs about 20.5 kg without the lead weights. V-type otter boards are used in whelk trawls. The gear is operated in 15-30 m depth along north of Kollam coast for *B. spirata* and at 25-40 m depth of south coast off Kollam for *B. zeylanica*.

The fishing starts in the early morning for *B. spirata*, the trawlers depart around 6 o'clock in the morning and return by noon. There are 3-4 crew members in each unit. The hauling is done for 5 to 6 times a day depending on the catch. Each haul takes about 15 to 30 minutes. *B. zeylanica* is fished in the night hours. The trawlers depart by 6 o'clock in the evening and come back by 6 to 8 in the morning.

The net is operated in medium sized trawlers of 13.6 to 16.6 m L_{OA} to larger trawlers of 18.5 m L_{OA}. The trawlers are equipped with 124 hp and 177 hp engines respectively. Because the net weighs more than the normal trawl, the hauling of the net requires more power and is operated at the maximum efficiency of the engine.

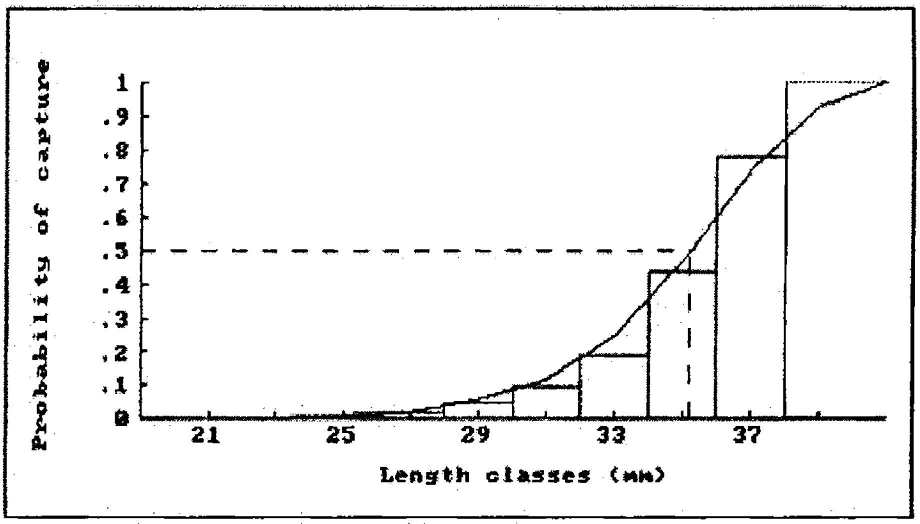
4.12.4. Probability of capture

Probability of capture of *B. spirata* and *B. zeylanica* by the trawl net was estimated. The values L-25; L-50 and L-75 estimated are the average shell length at



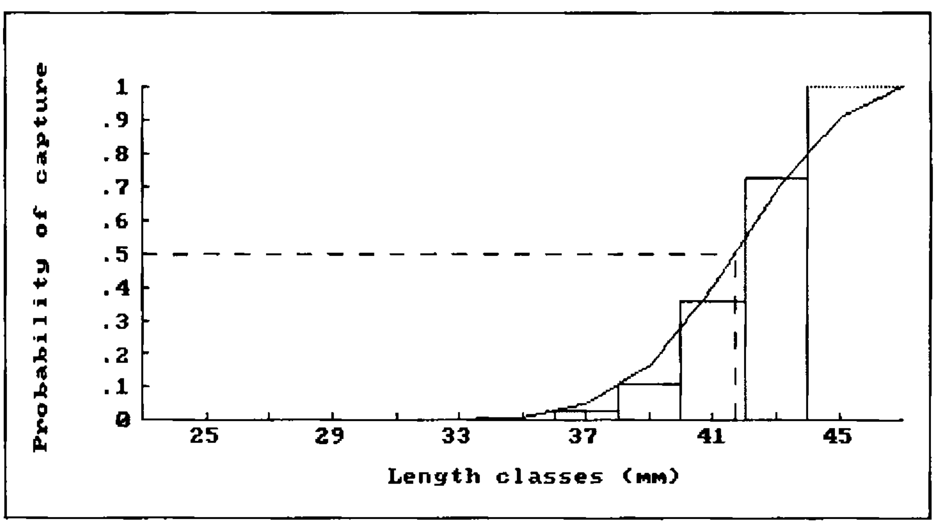
Pl. 7. The modified foot rope of shrimp trawl net for whelk fishing

which 25%, 50% and 75% of animals are retained in the trawl nets. The values were 33.06, 35.2 and 37.09 mm respectively for *B. spirata* (Fig. 40). The estimated values of L-25; L-50 and L-75 for *B. zeylanica* were 39.74, 41.7 and 43.52 mm respectively (Fig. 41).



L-25: 33 mm, L-50: 35.2 mm, L-75: 37.1 mm

Fig. 40 Probalility of capture of *B. spirata*



L-25: 39.7 mm, L-50: 41.7 mm, L-75: 43.5 mm

Fig. 41 Probability of capture of *B. zeylanica*

4.12.5. Mortality coefficients

The total instantaneous mortality coefficient (Z)

The estimated values of 'Z' by Brey's equation were 6.05 and 5.02 respectively for *B. spirata* and *B. zeylanica*. The 'Z' estimated by length converted catch curve method was 8.4 and 4.26 for *B. spirata* and *B. zeylanica* respectively.

The instantaneous natural mortality coefficient (M)

The instantaneous natural mortality coefficient (M) estimated by Brey's (1999) equation as 1.61 and 1.65 for *B. spirata* and *B. zeylanica* respectively, where as the values were 2.88 and 3.37 respectively using Pauly's (1980) equation.

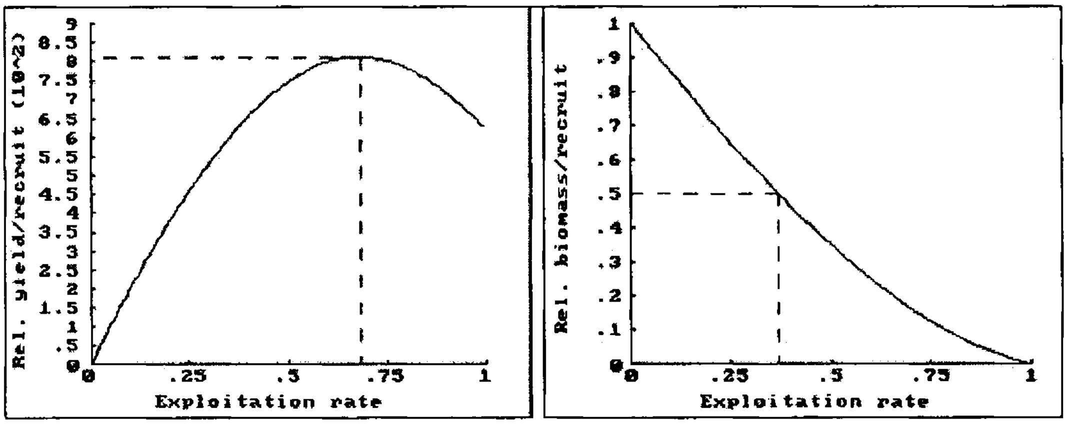
The instantaneous fishing mortality coefficient (F)

The mortality coefficients Z and M estimated using Brey's equation were taken for further analysis of fishing mortality coefficient and the values obtained were 4.44 and 3.37 respectively for *B. spirata* and *B. zeylanica*.

4.12.6. Relative Yield-per-recruit (Y'/R)

The relative yield-per-recruit (Y/R) and biomass-per-recruit (B/R) were determined as a function of Lc/L_∞ and M/K respectively. The Lc/L_∞ and M/K at E_{max} for *B. spirata* were 0.512 and 1.074 respectively. The Fig. 42 shows the maximum allowable limit of Y'/R for the study period. The present exploitation rate (0.73) has exceeded the optimum exploitation rate E_{max} (0.68). The $E_{0.1}$ and $E_{0.5}$ obtained were 0.6535 and 0.3681 respectively.

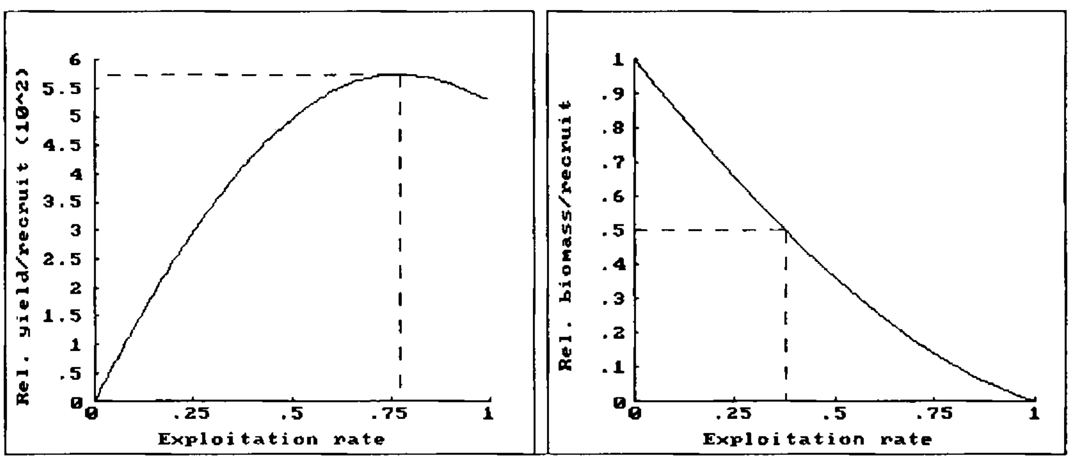
The Lc/L_∞ and M/K at Emax were 0.548 and 1.435 respectively for *B. zeylanica*. The Fig. 43 shows the estimated values of Y'/R and B'/R for the study period. The present exploitation rate E (0.71) has almost attained the optimum, E max (0.77), where as the $E_{0.1}$ was 0.717 and $E_{0.5}$ 0.3769.



Optima:

Emax :	0.6828	Lc/Loo	= 0.51
E-.1 :	0.6535	M/K	= 1.07
E-.5 :	0.3681		

Fig. 42 Relative yield-per-recruit of *B. spirata*



Optima:

Emax :	0.7730	Lc/Loo	= 0.55
E-.1 :	0.7170	M/K	= 1.43
E-.5 :	0.3769		

Fig. 43. Relative yield-per-recruit of *B. zeylanica*

4.12.7. Length Cohort analysis

The result of length cohort analysis of *B. spirata* for the 2 years, 2001 and 2002 pooled, showed that the 'delta t' increased from 0.04 in 20-22 mm size class to 1.25 in 58-60 mm size class (Table-31). Fishing mortality (F) increased to a maximum of 5.98 in the length class 40-42 mm and the maximum exploitation (79.8 t) was in the size class 38-40 mm. The catch constituted mainly of 38-40 mm size class. The biomass increased from 11.9 t in the size class 20-22 mm to the maximum (22.3 t) in the size class 32-34 mm and gradually reduced to 0.3 t in 56-58 mm. The total yield of *B. spirata* estimated was 423.26 t and standing stock was 216.15 t for the 2 years. The spawning stock biomass was estimated as 92.87 t and the number recruited were 84565.

Table- 31 Results of length cohort analysis (LCA) for *B. spirata*

Lower limit Length	Time Interval	Population Numbers	Fishing mortality	Average Number in population	Average biomass (kg)	Yield (kg)
2.1	0.04	84565	0.00	3221	11913.4	29.8
2.3	0.04	77939	0.02	3095	13912.1	218.7
2.5	0.04	71531	0.04	2966	15954.0	571.8
2.7	0.05	65330	0.14	2829	17966.3	2572.5
2.9	0.05	59111	0.34	2673	19815.1	6670.2
3.1	0.05	52717	0.51	2496	21381.5	10803.5
3.3	0.05	46326	1.11	2276	22333.5	24888.0
3.5	0.06	39112	2.00	1982	22106.8	44273.7
3.7	0.06	31069	3.74	1589	20004.3	74898.4
3.9	0.06	21854	4.94	1145	16162.8	79838.2
4.1	0.07	13848	5.98	746	11753.3	70306.0
4.3	0.08	7852	5.31	458	8008.4	42530.3
4.5	0.08	4478	4.92	282	5450.0	26828.4
4.7	0.09	2509	4.74	171	3625.9	17170.1
4.9	0.10	1351	4.93	98	2288.1	11290.9
5.1	0.11	664	3.37	56	1423.1	4801.5
5.3	**0.13**	360	1.05	38	1041.4	1098.0
5.5	0.15	243	4.71	23	697.0	3283.9
5.7	0.17	86	3.80	10	311.9	1184.2
5.9	0.21	29	5.56			
Spawning stock biomass(t)			92.87			
Standing stock biomass(t)			216.15			
Total yield(t)			423.26			
Recruitment (Nos)			84565			

The result of length cohort analysis of *B. zeylanica* for the year 2002 showed that the 'delta t' increases as size increases (Table-32). Fishing mortality was negligible for smaller length groups (up to 45 mm). Highest fishing mortality has observed for the largest length group 66-68mm. Exploitation was highest in the size group 56-58 mm. The catch constituted mainly of 56-58 mm size class. The biomass increased from 13.8 t in the size class 24-26 mm to the maximum (28.5 t) in the size class 42-44 mm and gradually reduced to 1.3 t in 64-66 mm. The total yield was estimated as 356.4 t against the estimated landing of 300.3 t for the year 2002. The standing stock biomass was estimated as 404. 1 t and the spawning stock biomass as 267.7 t.

Table- 32 Results of length cohort analysis (LCA) for *B. zeylanica*

Lower limit Length	Time Interval	Population Numbers	Fishing mortality	Average Number in population	Average biomass (kg)	Yield (kg)
2.5	0.03	92782	0.02	3108	13848.5	250.1
2.7	0.04	86017	0.00	2998	15716.9	0.0
2.9	0.04	79547	0.00	2888	17617.0	7.7
3.1	0.04	73312	0.00	2778	19522.0	8.8
3.3	0.04	67316	0.00	2667	21409.2	0.0
3.5	0.04	61560	0.00	2555	23254.6	10.2
3.7	0.05	56044	0.01	2442	25026.8	291.6
3.9	0.05	50745	0.00	2328	26702.6	116.0
4.1	0.05	45710	0.46	2189	27946.1	12831.0
4.3	0.05	39981	0.70	2014	28469.7	19864.8
4.5	0.06	34229	1.25	1802	28091.8	35216.5
4.7	0.06	28080	0.94	1588	27174.0	25602.8
4.9	0.07	23157	0.09	1439	26929.4	2451.9
5.1	0.07	19921	1.31	1279	26086.7	34081.0
5.3	0.08	15491	1.73	1057	23429.8	40486.7
5.5	0.09	11382	2.49	818	19642.7	48982.2
5.7	**0.10**	7575	4.24	554	14350.2	60814.9
5.9	0.11	4035	4.08	324	9036.7	36881.1
6.1	0.12	2016	3.53	182	5476.0	19348.8
6.3	0.15	977	4.50	94	3011.8	13541.9
6.5	0.17	355	4.18	39	1332.3	5570.0
6.7	0.22	109	5.28			
Spawning stock biomass(t)			267.68			
Standing stock biomass(t)			404.07			
Total yield(t)			356.36			
Recruitment (Nos)			92782			

Chapter 5
Discussion

5. Discussion

Neogastropoda is a diverse group comprising of carnivorous whelks that are scavengers and predators distributed from the intertidal to the abyssal zone in all the oceans (Martell *et al.*, 2002). In the present study, *B. spirata* was found to be distributed in the region from 5-30 m depth in the region north of Kollam, while *B. zeylanica* was found only in deeper sites more than 25 m depth in the southern region. Similarly, *B. spirata* occurs in the 5-25 m depth region off Pondicherry and Porto Novo coast (Ayyakkannu, 1994; Chidambaram, 1997). However, along the Tuticorin coast, Selvarani (2001) has reported on the occurrence of whelks in deeper region. In the present study *B. zeylanica* abundance was more in deeper regions. The 5 to 30 m zone along the southeast Indian coast has supported the fishery of several commercially important gastropods apart from the whelks. Chank distributions in Gulf of Mannar were found to be similar to the whelk distribution, in 10 to 20 m zone with sandy bottom (Hornell, 1922) and in the Palk Bay chanks were found to occur in depths up to 12 m and along Coromandel coast at depths varying from 6 to 20 m. The chank fished off the coast of Trivandrum and Kanyakumari districts are also from the same depth zones (Nayar and Mahadevan, 1973). However, in the Gulf of Kutch they are found to inhabit comparatively shallower regions (Narasimham, 2005).

In the present study *B. spirata* and *B. zeylanica* were never found to coexist. Though the faunal composition of benthos was basically the same, *viz,* dominated by polychaetes, the two habitats were different in sediment texture. Consequently the benthic faunal composition, with respect to the species of polychaetes and other minor invertebrates was different in the two sites. One significant variation was the higher contribution by sipunculids at the *B. zeylanica* beds. Laboratory studies related to feed preference of adult *B. spirata* and *B. zeylanica* have shown that they are not active predators. Hence, it can be presumed that it is the preference for a specific substratum, *viz,* sandy substratum by *B. zeylanica* and more silty by *B. spirata* rather than the feed is the causative factor for the heterogeneous population distribution. An almost similar observation was made on the population of two marine mud snails *Hydrobia ulvae* and *H.*

ventrosa which are common in littoral muddy sediments and which partly coexist in a homogenous habitat (Grudemo and Bohlin, 2000). However, along the Swedish coast, *H. ulvae* dominated coarse grained sediments and *H. ventrosa* in fine grained and their distribution was correlated to sediment type (Grudemo and Johannesson, 1999).

In the present study *B. spirata* were found to prefer silt and showed negative correlation with sand and *B. zeylanica* were observed only in sandy beds. However, *B. spirata* and *B. zeylanica* were not observed in the same depth zone along south Kerala presumably because of the different sediment texture. Occurrence of *B. spirata* and *B. zeylanica* in the coastal zone off Kollam can be mainly due to the sediment structure. Based on a study on distribution and relationship to mean grain diameter, silt-clay content, abundance of dead shell materials and feeding type of 39 molluscan species Driscoll and Brandon (1973) have found that the factors most clearly correlated with the distribution of these species were the clay content of the sediment, abundance of dead shell material and substratum stability. In the laboratory *B. spirata* and *B. zeylanica* have been found to burrow in the substratum with only the probosis extended to the surface of substrata. The soft bottom nature of the study area could be supporting the burrowing behavior of *B. spirata* and *B. zeylanica*. The type of substratum in this geo-location has been studied in detail by several oceanographers (Veerayya and Murty, 1974; Varshney, *et al.*, 1988; Prakash, 2000).

Prakash (2000) has found that the shoreline changes its orientation from 290° to 350° N at Thangasseri headland. This demarcates the coast south of Thangasseri as southern shelf and north of it as northern shelf. Most of the area is covered by sand and silty clays while fine-grained ones (clay) occur in the northern most shelf. The southern shelf is entirely covered by sand. Also, there are a few sandy patches off Chavara and in the outer-innershelf of the northern shelf. In the present study also the sediment texture has been found to be similar to that reported by Prakash (2000). The distribution of the principal modes of coarse fraction demonstrated that the area is covered by fine to medium sand category. In the same study he has found that the southern shelf was carpeted by medium sand of moderately sorted nature whereas the outer-innershelf was dominated by moderately to poorly sorted medium sand. The rest of the shelf is covered by poorly sorted silt and clay. In general, the sediments were found to be getting progressively finer towards the northern side. High percentage of sand in the southern shelf is attributed to the absence of estuaries or backwaters which trap coarser sediments (Hashimi, *et al.,* 1981). In addition, the winnowing action of waves aided by the steep bathymetry might be another reason for high concentration of sand in the southern shelf region. The high percentage of fine sand in the Cochin-Quilon region is the result of trapping of coarse sediment by the Vembanad Lake near Cochin (Veerayya and Murty, 1974) and Ashtamudy backwater near Quilon (Rao, 1968). South of Quilon, rivers comparable to, for example Periyar are absent, hence the percentage of fineness decreases sharply and sand becomes the most prominent sediment type on the shelf (Harkantra *et al.*, 1980).

The TOC of the soil was found to be positively correlated to *B. spirata* abundance. This can be related to their feeding habits. In a laboratory experiment during the present study *B. spirata* of length >20 mm were not active predators, rather they accepted dead meat of shrimp, fish, mussel and polychaetes. The whelk beds along Kollam coast are trawling grounds and it is possible that whelks are exposed to ample quantity of small fishes and crustaceans destroyed due to trawling, which can form their food. The dead and injured fauna left on the sea floor or exposed in trawl tracks aid the addition to the benthos of offal and dead moribund by-catch increases opportunities for mobile scavengers/predators (Kaiser and Spencer, 1994; Kaiser and Ramsay, 1997).

Among the hydrographic parameters there was no significant correlation between temperature, salinity and nutrients with the abundance of whelk. The variation in salinity and other parameters were not pronounced when compared to the near-shore areas of the same coast. *B. spirata* has been reported to be stenohaline, with salinity <19 ppt causing high mortality (Patterson, 1994). Such low salinity conditions do not occur in the present bed, since the sites are away from the points of freshwater discharge areas from the land.

The population changes of *Nassarius reticulatus* in Sweden has been found to be highly influenced by the variation in temperature (Tallmark, 1980). In the field he had observed that the different activities of the snails like, locomotory activity, inshore migration, spawning, growth, offshore migration and quiescence in different years were commenced at the same water temperature but in different dates. The threshold temperature could be narrowly defined. For instance, the snails taken to the laboratory before spawning were held at 10° C and they did not spawn for 30 days in this temperature but at 12° C they started copulation within 2 days and produced egg capsules after another 3 days (Tallmark, 1980). In *B. spirata* also, temperature was found to influence the early development stages which was observed in the CMFRI hatchery as part of the ICAR AP Cess funded project on *Babylonia* spp. However, direct observation in the field was not possible.

Apart from the specific substratum dependent zonation of *B. spirata* and *B. zeylanica* there was variation in density or abundance of the whelk within the specific beds. Similar variation in distribution between two gastropods of commercial importance, *Trochus niloticus* and *Turbo marmoratus* has been observed in Andaman and Nicobar Islands (Nayar and Appukuttan, 1983). *T. niloticus* occurs in the intertidal and mangrove area where they congregate underneath rocks and coral boulders while, in the same area *T. marmoratus* occur at depths of 12 to 25 m and rarely in shallow waters. Distribution and abundance of coral reef associated herbivorous gastropods has been related to density of micro-algae present, variation in physical and biological factors such as desiccation and predation (Ompi, 1994). Soemodihardo and Kastoro (1982) found more than 10 species of the genus *Turbo* distributed on various substrata at varying densities from the intertidal to deeper waters.

The density of *Stramonita* (*Thais*) *haemastoma*, was low along the Israeli Mediterranean coast (Rilov *et al.*, 2001) compared to that of a subspecies *S. haemastoma floridana* in the Gulf of Mexico, where in the intertidal habitats tens to hundreds of individuals per m^2 have been reported (Butler, 1985; Richardson and Brown, 1990). Comparatively higher density of *B. globulosum* was found along the coast of Argentina.

The distribution of benthic organisms has been found to be related to local environmental factors, food availability, predation and competition (Ompi, 1994).

The distribution and abundance of whelk in the fishing grounds off Kollam has been studied by seasonal experimental trawling and sampling in the fishing grounds as the information is vital in fisheries management. The size distribution of whelk, observed in the experimental trawling well represented the commercial fishery landings. The population of both *B. spirata* and *B. zeylanica* skewed to large sized snails. The length composition of *B. spirata* and *B. zeylanica* was different within their respective populations in the study area, with *B. spirata* having different size groups of whelks in the population. However, the occurrence of small sized *B. spirata* was low and young ones of *B. zeylanica* were absent in the population in all the samples. The absence of small size *B. zeylanica* and continued occurrence of large sized whelks in population was conspicuous. In the fishery also, the percentage of small sized whelks were very less through out the period of study. The presence of large whelks in the population indicates a stable condition. Rilov *et al.* (2001) also found the population structure of whelks skewed to large individuals in the Israeli Mediterranean coast. Small individuals were absent through out the five year of their study, but mean whelk size increased. The authors have suggested that the results imply impaired recruitment of whelks. Similarly the size distribution of *Nassarius reticulatus* in the population in Gullmar Fjord, Sweden showed absence or low number of small snails in deeper sites (Tallmark, 1980). However, larger proportion of small snails occurred in some years in area outside the Bay, which is shallow and richer in detritus.

Tallmark (1980) has made an extensive study to understand the variation in population of the dog whelk, *N. reticulatus*, in Sweden. He found that settling of young ones (recruits) took place only in areas with high organic matter and that metamorphosis of larvae depends on the substrate and that detritus is the main food during the first three years. Tallmark (1980) has indicated that the dog whelks change their diet with growth, with larger whelks preferring carrion, while the younger ones feed on detritus. The larger snails gathered around dead and dying fishes, crabs and bivalves stranded in shallow water. Kohn (1961) has commented on the chemoreception of gastropods. Even extremely low concentration of a certain glycoprotein from oyster fluid (10^{-10} molar) induced a 50% response in *N. obsoletus* (Gurrin and Carr, 1971).

Differential distribution of different size groups of a species in a geo-location has been reported (Martin *et al.*, 1995; Valentinsson *et al.*, 1999). The muricid gastropod, *Bolinus brandaris* showed a size distribution that correlated slightly with depth. The small and medium sized specimens were found distributed in 3 to 25 m depth, while larger one (>65 mm SL) were found from a depth of 20 m and were even absent in hauls made in a protected zone at <15 m (Martin *et al.*, 1995). Based on these results the authors inferred that this species carries out an ontogenic migration towards deeper waters. The formation of groups prior to spawning has also been reported (D' Asaro, 1970). Similarly, size frequency distribution of common whelk, *Buccinum undatum,* was markedly different between areas in the Swedish waters with larger individuals more in deeper waters (Valentinsson *et al.*, 1999). Similarly, in the present study also the young ones must be settling in the inshore waters rich in detritus and which are more productive. During the year 2005, some small whelks were observed in the pots kept for lobster fishing in the near shore area. But continued occurrence was not observed. Enquiries with fishermen also indicated that small whelks are not fished in the trawl grounds.

The variety and abundance of benthic fauna is determined greatly by the physical and chemical structure of the substratum (Kinne, 1972). Small scale variations of benthic distribution are attributed to sediment grain size, organic matter content etc. (Parsons, *et al.*, 1979). Along the Indian southwest coast, Harkantra *et al.* (1980) also found higher organic carbon in fine substrate of clay and silt than sandy substrata. The community structure and the dominant groups of the benthos observed in the present study are found to be similar to their observations. Wijnsma *et al.* (1999) observed that in the tidal flats and shallow inshore waters of the Banc d' Arguin, in Mauritania, West Africa, polychaetes were the most diverse group with 42 species belonging to 20 families. However, they found that the total density was independent of any sediment characteristic, probably because of large range of species. However, densities of dominant species did show a correlation with sediment size.

In the bathyal (154-3400 m depth) macrofaunal community in the North Atlantic, Eastern Pacific and Indian Oceans, latitude, sediment-organic carbon content and bottom water oxygen concentration were the significant factors that together explained 52-87 % of the variation in species richness ($E(S_{100})$), Shannon-Wiener Index (H'), Dominance index (D) and evenness (J') (Levin and Gage, 1998). In the shallow coastal waters also annelids were the most abundant and depth, sediment grain size and sediment organic matter content influenced the abundance, distribution and composition of benthos. Temperature had no effect (Melake, 1993).

Apart from *Babylonia* spp, the whelk bed had rich resource of other gastropod fauna. The co-occurrence of gastropods like, *Bursa, Tibia, Natica* and *Conus* in high numbers in this region indicates the richness of the molluscan diversity.

The number of species of molluscs obtained in the experimental trawling from the whelk bed was much lower than that obtained in the commercial trawls presumably because of the low hauling duration and restricted fishing area. However, both results indicate the rich molluscan diversity of the region. Similar rich molluscan fauna with almost similar feeding habits (scavenger/preying) has been observed in other regions along the Indian coast (Kasim, 1988; Ramesh *et al.*, 1996; Jayabaskaran *et al.*, 1996; Murugan and Edward, 2000). In the present study the diversity index H' was 2.145 with an average number of 22 species. Kohn and Nybakken (1975) studied the diversity of species of eastern Indian Ocean fringing reefs and found, number of species (S) as 15 and species diversity (H') as 2.3 in the most heterogenous habitat type, namely the topographically complex subtidal reef platform. On subtidal reef platforms with large areas of sand substrate and less coral limestone, mean values were S=10 and H' = 1.6.

Whelk formed an important component of the shrimp trawler by-catch even a decade back (Appukuttan and Philip, 1994). Apart from these resources, several finfishes, crustaceans, molluscs, echinoderms and holothurians were recorded in the by-catch landed at Sakthikulangara-Neendakara harbour in the present study. These resources showed wide fluctuations and percentage contribution as well as the occurrence of different species in by-catch varied during both the years. The Environmental Justice Foundation, London (Annon, 2003) reported that shrimp trawling contribute to the highest level of discard/catch ratio of any fisheries ranging from 3:1 to 15:1 and the amount of by-catch varies in relation to target species, season and area.

In the present study juveniles/undersized crabs and cephalopods were observed. Similarly, shrimp trawl by-catch in Visakhapatnam was found to have 25-30% of juvenile shrimps (Rao, 1998) and he estimated the discard from Visakhaptnam coast as 2,00,000 tonnes. Kurup *et al.* (2003) have estimated the discard along Kerala coast as 2.62 and 2.25 lakh tones during 2000-01 and 2001-02 respectively and they have attributed the reason to the use of very small cod end mesh size against the statutory mesh size of 35 mm prescribed by the Govt. of Kerala. Menon (1996) has also recorded high diversity in the by-catch landed by trawlers in Karnataka, Kerala and Tamil Nadu. He has also observed the occurrence of young ones of several fin fishes and cephalopods.

The trawl net being an efficient but unselective fishing gear with a small cod end mesh size captures numerous small-sized species as well as juveniles of larger species, compared to any other fishing gear. The increase in prawn landings in Kakinada, Andhra Pradesh, during 1970s had been due to the gradual reduction in cod end mesh size of trawl nets which, ultimately resulted in the reduction of average size of the prawns. The quantity of juveniles and sub-adults in the by-catch depends upon the type of trawl net used. In the south Indian states, an annual average of 6200 t of juveniles/young fishes was recorded to be landed by trawl nets. The annual economic loss generated due to catching of juvenile fishes by a single trawler in Kerala coast was estimated as 28.3 lakhs (Bijukumar and Deepthi, 2006).

Crustaceans were the major group observed in the by-catch at Neendakara-Sakthikulangara. Kurup *et al.* (2003) have reported that in the discards of bottom trawlers in Kerala crustaceans were represented by 8 species of shrimps, 2 species of stomatopods and 12 crabs. Bijukumar and Deepthi (2006) have reported higher diversity of crustaceans (4 species of prawns,42 species of crabs, 5 species of stomatopods, several species of hermit crabs and 3 species of lobster) in the trawl by-catch of Kerala including both discards and by-catch of trawlers. During the monsoon period high catch rates of *Charybdis smithii* up to 1200 kg/haul, has been observed off Cochin. In general, they have reported the catch per hour for crabs as 48 kg and the catch-per-unit as 450 kg and the CPUE for *C. smithii* was computed as 395 kg/unit. Crabs were found to be the major crustacean resource during June and in the present study also crabs were observed in the by-catch.

The stomatopod, *Oratosquilla nepa* has been found to be a major component of the by-catch during the period of study. This species is distributed up to 75 m throughout the Kerala coast with higher abundance in north Kerala (Kurup *et al.*, 2003). However, considerable variation has been found in the quantity and percentage contribution of stomatopods in by-catch. Squilla accounted for 81% of the annual landing of trawlers in the southern region of India during 1985-90 (Menon, 1996) while in the recent years (2000-02) the percentage contributed by this resource was found to be low 15 to 18% (Kurup *et al.*, 2003).

In the present study it was observed that shrimps formed nearly 43% of the by-catch at Sakthikulangara-Neendakara harbour. Sukumaran *et al.* (1982) made an appraisal of the trawl fishery of Karnataka based on data obtained from Mangalore and Malpe during the fishing seasons 1980-81 and 1981-82, and recorded that shrimps represent only 13% of the annual average trawl catch. The trawl by-catch was as high as 85% during this period.

The quantity and the species contributing to the finfish resources landed as by-catch showed seasonal variation in the present study. Kurup *et al.* (2003) have reported considerable higher number of finfish species (103) from the entire coast of the state and Bijukumar and Deepthi (2006) have recorded more than double the number of finfish species from the trawl by-catch and discards of Kerala. Silver bellies, flatfishes, goatfish, sciaenid and other small sized fishes are landed through out the Indian coast. The dominance of elasmobranches has been cited as a characteristic feature of the by-catch of tropical penaeid shrimp fisheries (Hall, 1999). Teleosts have been found to dominate in the prawn trawlers in the Gulf of Mexico (Nance and Scott-Denton, 1996). Ilona *et al.* (2001) have observed that 82% of the trawl by-catch of Australian penaeid prawn fishery was highly diverse with more than 350 species and dominated by species which occur rarely (75% of species occurred in <10% of trawls) and in low abundance (<10no h^{-1}) and biomass (<1kg h^{-1}).

The utilization of the fin fishes landed as by-catch is a significant aspect of Indian fisheries. In large trawlers performing multi-day fishing, the last day's by-catch is brought to the land and the larger economically important fish and shell fish in by-catch are marketed fresh. Smaller variety or large species present in abundance (soles, lizard fishes, anchovies, carangids, sardines, mackerel etc.) are either semi dried or salt dried. George *et al.* (1981) have reported that the major quantity of sun dried fishes is used for local consumption while some quantity is exported. During the present study it was observed that all the fishes landed were utilized either after drying or in the iced condition.

Molluscs formed the third major taxa represented in the by-catch of Sakthikulangara-Neendakara harbour and were composed of species belonging to 21 genera. Several important species like, *Sepia elliptica* and *Sepiella inermis* and *Octopus membranaceous* were found to occur with *Babylonia* spp. They were landed in the commercial catches also. The faunal diversity of gastropods was remarkable and the population in the region off Kollam was heterogeneous comprising molluscs of important families like, Bursidae, Muricidae, Fasciolariidae, Conidae, Strombidae, Olividae and Cerithidae. Appukuttan and Philip (1994) have recorded 29 species from the same area. Kurup *et al.* (2003) have reported 82 species of molluscs comprising 65 gastropods, 12 bivalves and 5 cephalopods from the entire Kerala coast while Bijukumar and Deepthi (2006) have observed 140 species of molluscs from same maritime state. Menon (1996) has found 23 genera of gastropods and 15 genera of bivalves in the trawl by-catch of three states, Karnataka, Kerala and Tamil Nadu during the period 1985-90.

Malaquias *et al.* (2006) have found a different range of molluscan species in the crustacean trawl (34 species) and fish trawl (24 species) operating in the same area in Portugal. Twenty species were only caught by crustacean trawl, 10 species by fish trawl and 14 species were common to both. In total there were 15 bivalves, 28 gastropods and 1 polyplacophoran. They also observed that the crustacean trawl had impact on a different range of molluscs species in winter/spring compared with the summer/autumn period; where as the fish trawl seemed to impact a similar range of species all through out the year. In the western Mediterranean 92 species of mollusc (39 bivalve, 52 gastropod and 1 scaphopod) have been found to be affected by trawling (Carbonell, 1997). However, only few species are retained for commercial purposes.

The American continent (including South, Central and North America) contains the principal gastropod fisheries of the world. They are concentrated in the Pacific Southeast (Chile and Peru) and on the Pacific and Atlantic coasts of Central and North America. The main fishery countries: Chile, Mexico, Peru and the USA, show overall catches averaging over 5,000 mt annually throughout the past 20 years (with the exception of larger catches in Chile from 1979–1988) (Leiva and Castilla, 2002). Multi-species abalone fishery of Baja California Peninsula and the highly diverse Peruvian catches indicate that the gastropod beds are rich in species and the diversity is high. Peruvian gastropod catches are characterized by high diversity of species, many of which are reported by FAO (1998) as "non-identified species" (Leiva and castilla, 2002). Another region where gastropod diversity has been visible is in Chile.

Gastropod catches in Chile include at least 20 different species, several of which belong to the families Muricidae and Fisurellidae. Gastropod fisheries comprise 53% of the total gastropod extraction in Chile and compose the group with the largest economic value. The muricid gastropod *Concholepas concholepas* ("loco" or false abalone) has historically been the gastropod with the highest levels of extraction and economic importance in Chile (Hancock, 1969; Castilla and Becerra, 1975; Bustamante and Castilla, 1987; Castilla, 1988, 1997b; Castilla *et al.*, 1998). During the last two decades, exportation of "loco" has generated revenues for Chile of over US$390 million (SERNAPESCA, 1999). Other muricid species extracted commercially in Chile are (in decreasing order of importance): *Thais chocolata* (caracol locate), *Chorus giganteus* (caracol trumulco), *Trophon geversianus* (caracol *Tropho*n), and *Xanthochorus cassidiformis* (caracol rubio). These species are endemic to the southeast Pacific and the Patagonian region of Chile and Argentina (Osorio *et al.*, 1979; Stuardo, 1979; Gallardo and González, 1994; Santana, 1997). The multispecies fishery of key-hole limpets, which includes at least 10 different *Fissurella* species (Bretos, 1988; Oliva and Castilla, 1990, 1992), is also of importance. In 1998, approximately 3,000 mt of keyhole limpets were extracted, representing 41% of the total gastropods fished in Chile that year (SERNAPESCA, 1999). The rest of the gastropod extraction is composed of four species of lesser importance: *Tegula atr*a, *Adelomelon ancill*a, *Odontocymbiola* spp. and *Argobuccinum undatu*m. In the whelk beds off Kollam also highly diverse gastropod fauna were obtained in the experimental trawling and these resources are fished by the commercial trawlers also with the other nekton and landed as by-catch.

The utilization of the molluscs caught as a by-catch has been found to differ considerably in different geographic region. In India most of the shelled molluscs are brought to the shore where they are used commercially for shell trade (Appukuttan and Philip, 1994) in contrast to certain other region where only selected species are retained after the major share of the mollusc caught are discarded (Malaquias *et al.,* 2006). In the present study *Bursa spinosa* was the major mollusc (next to *Bạbylonia* spp) followed by *Tibia curta,* which were landed as by-catch and it was observed that these were very effectively used for shell trade. Appukuttan and Philip (1994) have also found that these two species were dominant in by-catch contributing to 23.3 and 15.3% respectively and have estimated the landing of *Bursa spinosa* as 78.9 t and that of *T. curta* as 51.8 t. All other gastropods and bivalves are also used. These are accumulated and utilized later for shell craft industry.

Carbonell (1997) has stated that of the 92 species of mollusc caught in western Mediterranean, only one was systematically retained for commercial purposes, namely the gastropod *Charonia lampas,* while 6 (the bivalves *Callista chione, Pecten jacobeus* and *P. maximus* and the gastropods *Bolinus brandaris, Hexaplex trunculus* and *Galeodea echinophora* were sometimes sold. The other 85 species were always discarded. Negative impacts on molluscan fauna have been brought to light recently (Lindeboon and de Groot, 1998). Larger bivalves in the path of a beam trawl typically suffer mortality of 20% or more. As a result species like the bivalve *Arctica islandica* have almost disappeared in heavily trawled areas (Rumohr and Krost, 1991; Craeymeersch *et al.*, 2000). Chemello *et al.* (2000) and Scotti and Chemello (2000) listed both Mediterranean and world molluscs that are endangered as a result of fisheries exploited. In the current study, the species which are listed as threatened or endangered were not observed in the by-catch.

In addition to the species belonging to three major taxa discussed above several species of reptiles, echinoderms, sea turtles, holothurians, seaweeds and sea grass are also caught as by-catch (Lindeboon and de Groot, 1998; CMFRI, 2002; Shankar *et al.,* 2004 and Bijukumar and Deepthi, 2006). In the current study also several species of echinoderm, holothurians, sponges, jellyfish and seaweeds were obtained.

The co-occurring species in the whelk bed other than gastropods and polychaetes were finfishes, shrimps, crabs and other resources. The coexistence of such a diverse fauna belonging to different trophic levels is typical of benthic ecosystem. A rich and diverse fauna comprised of different species of invertebrate phyla and finfishes were also observed in the chank beds along southeast coast of India (Mahadevan and Nayar, 1974). The ecology of chank beds assessed by Mahadevan and Nayar (1974) showed predominantly *Xancus*–terebellid-echinoderm communities. Similar to the whelk grounds of Kollam, the nature of bottom in Palk Bay zone was found to be essentially of sand of fine texture superficially muddy inhabited by rich polychaete fauna and several small shrimps. Almost similar community structure has been reported in the *B. brandaris* population off Catalan coast, northwestern Mediterranean. The co-occurring species were sole (*Solea* spp.), prawn (*Penaeus kerathurus*), mantis shrimp (*Squilla mantis*) and cuttlefish (*Sepia officinalis*) (Martin *et al.,* 1995). The natural population of *B. undatum* in the Swedish waters co-existed with 26 other species of molluscs, crustaceans, echinoderms and fishes (Valentinsson *et al.,* 1999).

In an entirely different ecosystem like the coral reefs and sea grass beds, gastropods with different feeding habits have been observed. In such areas, both herbivorous gastropods like, *Trochus, Turbo* and carnivorous gastropods like *Strombus, Conus* etc. have been observed (Mahadevan and Nayar, 1974; Appukuttan *et al.,* 1989; Narasimham, 2005).

The role of whelks in the ecosystem is predominantly that of scavengers. In the laboratory of CMFRI, the brood stock maintained in the tanks were found to consume meat of shrimps, squids, bivalves but never preyed on these when live feed were provided (Personal observation). *Buccinanops globulosum*, a typical inhabitant of coastal waters of San Matias Gulf, Argentina, has been found to be necrophagus, feeding mainly on crabs and molluscs. This whelk together with the crab *Chasmagnathus granulata* formed the main scavengers of this ecosystem (Narvarte, 2006). In another instance, the egg capsules of *Nassarius reticulatus* was found in the stomach of the fish *Ctenolabrus rupestris* (Tallmark, 1980). Predation of large whelk has been found to be low. Whelks like *N. reticulatus* are nocturnal and remain buried during day time; this reduces predation (Eriksson and Tallmark, 1974; Eriksson *et al.,* 1975). During the present study the animals maintained in the lab were also found to bury in the substratum and move out only for taking food. Moreover, they were not continuous feeders and were not very active (personal observations).

Babylonia spirata and B. zeylanica were found to be gonochoristic and reproductive system was similar to neogastropods like, *Buccinum undatum* and *Nassarius reticulatus*. These two species showed clear sexual dimorphism characterized by the occurrence of a penis in males and a pipe like genital opening in the cephalic region of the females for the entrance of penis and also for the release of eggs. A ventral pedal gland is also located near the anterior end of the foot in the female which is known to functions to shape and harden the egg capsule released from the capsule gland. These dimorphic characters have been observed in *B. spirata* population in West Java (Yulianda, 2001) and in *B. areolata* in Phanthiet, Vietnam (Hua *et al.*, 2001). Apart from these, Hua *et al.* (2001) also observed difference between shell of male and female *B. areolata*, the shell of female being smoother than male. However, in the present study, in both the species of *Babylonia* such morphological shell differentiations between genders were not observed. One interesting feature in the muricid gastropod *Chicoreus brunnius* is the occurrence of penis in female (Middelfart, 1992a). The size of the female penis was smaller almost half that of male. Such modifications were not found in *B. spirata* and *B. zeylanica*. The first indication of sexual dimorphism in *B. spirata* was observed in whelks of 18-19 mm shell height, when a small knob like protuberance was observed behind the right tentacle marking the development of a penis which gradually increased in size with the growth of the snail. Yulianda (2001) has also observed the gradual increase in size of penis with the growth of the whelk.

The gonad of male and female of *B. spirata* and *B. zeylanica* had almost the same colour, ranging in shades of yellow to brown, these variation were related to different stages of maturity. The spent gonad of *B. spirata* in the present study was found to be dark brown, while the same species inhabiting the Parangipettai coastal waters along Indian southeast coast was found to have a greenish brown colour (Kannapiran and Patterson, 1996). In *B. spirata* in Indonesian waters, the testis was found to be yellow or orange and ovary dark brown (Yulianda, 2001). Similarly in carnivorous gastropods like, *Hemifusus pugilinus*, the spent gonad was white in both male and female, while in females the initial maturing gonad was cream in colour, which changed to light brown during the maturing stage and became dark when fully matured. In the male of the same species, the initial maturing gonad was yellow, which changed to orange during the maturing stage, and finally became brown in fully mature stage (Patterson and Ayyakkannu, 1997). In the top shell *Trochus niloticus* occurring in Andaman and Nicobar islands, the gonad colour of male and female was found to be different (Amrithalingam, 1932). The male gonad was found to be white or cream, while female gonad was green. Similar colouration such as, cream coloured male and green coloured female gonad has been observed in the abalone *Haliotis varia* occurring in Thailand (Jayaraband and Paphavasit, 1996). In bivalve molluscs, especially in several species of marine mussels (Mytilidae) and scallops (Pectinidae) variation in colour of male and female gonad and intensification in pigment of female gonad with maturity has been observed. However, in several other bivalves like oysters and clams the male and female gonads have almost the same colour.

From the occurrence of higher percentage of spent females and the low GSI in Sept-Oct, it can be inferred that the spawning had taken place during this period and during the preceding month. Since samples could not be obtained during July-Aug due to rough weather conditions this inference cannot be substantiated. The high GSI during Nov-Dec indicated gonad development which resulted in spawning during Jan-Feb and this cycle was repeated during the succeeding period with a minor spawning peak in April-May, indicating that *B. spirata* is a continuous breeder with multi-annual peaks. The observations made by Sreejaya *et al.* (2004), which was done concurrently with the present study support the inference that the *B. spirata* is a continuous breeder along west coast of India. It was observed that, in the laboratory though spawnings were obtained almost through out the year except during June-July, the intensity of spawning, as evaluated by the number of egg capsules laid and the frequency of spawning varied in different months. It is probable that in natural bed also such variations occur and the different percentage of mature and spent whelks in the fishery samples throughout the year is supportive to this. The studies on *B. spirata* population along the east coast have indicated that it breeds during Feb-May as inferred from the GSI values (Kannapiran and Patterson, 1996), laboratory based studies on the breeding biology of *B. spirata* along the east coast of India (Shanmugaraj and Ayyakkannu, 1997). Shanmugaraj and Ayyakkannu (1997) have stated that the spawning season of *B. spirata* is from Jan-Aug in the post monsoon months. Poomtong and Nhongmeesub (1996) have observed spawning of *B. areolata* in the hatchery almost through out the year except during Nov and Dec. In these animals, highest spawning frequency was observed in March and July with maximum number of egg capsules in April.

Whelks have been found to have strong breeding behaviour, where the male and female copulate and the sperm are deposited in the bursa copulatrix of female, to be transferred to the seminal receptacle later, which will be retained for a long period until oocytes pass through the albumin gland, where fertilization occurs (Martel and Larrive, 1986).

Most studies on breeding biology of whelks (Martel *et al.*, 1986b; Kannapiran and Patterson, 1996 and Yulianda and Danakusumah, 2000) have been based on histology of gonad and gonad index. However, Martel *et al.* (1986a) have found that it is possible to relate the timing of copulation and egg laying based on the presence or absence of sperms in bursa and seminal receptacle in females. Their study was based on field observations in the northern Gulf of St. Lawrence, Canada and concurrent laboratory observations. It was observed that in the field, mating begin with the aggregation of whelks caused by movement of male towards gravid females. Such attraction of males to female during the copulation period has been reported for other neogastropods also (Magalhaes, 1948; Pearce and Thorson, 1967; Edwards, 1968 and D' Asaro, 1970) and the reason for such behaviour has been attributed to pheromones released by gravid females.

In the present study, sperm were observed in bursa copulatrix and in the ingestion gland almost through out the year. This also indicates that, after maturity there is no prolonged rest period for the gonad, rather, soon after egg laying a new cycle of development of ovary and testis begins followed by copulation and egg laying. Martel *et al,* (1986) have found that the sperms transferred to the seminal receptacle of female by the male may be kept up to 8 weeks. The sperm stored by the female serve to fertilize the oocytes as they pass through the pallial oviduct during egg laying. Thus the presence of spermatozoa in the bursa indicates that the copulation has just happened, where as the presence of spermatozoa in the seminal receptacle indicates that the female is capable of laying egg.

In the Indian waters spawning period of *Xancus pyrum* has been found to be between November and April in the southeast coast (Devaraj and Ravichandran, 1988). In the Andaman and Nicobar Islands Amruthalingam (1932) has stated that *Trocus niloticus* spawns immediately after warm season (March-June), while Rao (1937) has reported that this species may be a continuous breeder with perhaps an intense spell during or immediately after the warm season. In the same ecosystem, *Turbo marmoratus* breeds through out the year (Setna, 1933).

In King Solomon Island of Western Australia, *T. niloticus* spawns mainly during July-Aug and Feb-April with minor spawning through out the year (Gimin and Lee, 1997). The spawning season of another important gastropod, the abalone *H. varia* in the Gulf of Mannar and Palk Bay region has been found to be from Dec-Feb coinciding with the end of northeast monsoon, when the temperature and salinity were very low. The spawning season of *Hemifusus pugilus* is during post-monsoon and summer months (Patterson and Ayyakkannu, 1997) and that of *Pythia plicata* along the south east coast is during post-summer to early northeast pre-monsoon (Shanmugam, 1995).

The size at first maturity has been found to differ for male and female of the same species of gastropods (Narasimham, 2005). In the present study males were found to mature faster than females. In the *B. spirata* population along the east coast, Kannapiran and Patterson (1996) found males attain sexual maturity at 36 mm size while the female attain maturity at 39 mm. The size at first maturity for *B. spirata* has been found to be different in other Southeast Asian countries (Yulianda, 2001). In West Java, Yulianda (2001) found *B. spirata* to mature at 20 mm size. Such variations in size at maturity in same species at different geographic locations have also been observed. *T. niloticus* which is basically a coral reef inhabiting gastropod has been found to attain maturity at 9 mm SD in female and 6-7 mm SD in males (Rao, 1937), while the same species in Australian waters attain maturity at 5-9 mm for females and 5-7 mm for males (Hahn, 1989).

Similarly, in the Indian population of *H. varia*, Najmudeen and Victor (2003) found males to attain sexual maturity at 20-22 mm and female at 22-24 mm. While the same species along south central Vietnam coast attain maturity at 21.9 mm for male and 25.6 mm for females (Minh, 2000). Variation in length at first maturity between male and female gastropod in Indian waters has been observed for *X. pyrum* (Devanesan and Chacko, 1944), *T. niloticus* (Rao, 1937) and *H. varia* (Najmudeen and Victor, 2003). The male chank attains sexual maturity when they are 57-60 mm MSD and females at larger size. In all these species males became mature earlier than females. Kannapiran and Patterson (1996) have related this to the comparatively higher growth rate and larger size of females than males and also to high quality of feed consumed and resultant maximum reproductive success.

The proportion of females in the commercial landing of both *B. spirata* and *B. zeylanica* was high almost through out the year during present study. Similar dominance in whelk population along the east coast of India has also been reported (Kannapiran and Patterson, 1996; Patterson and Ayyakkannu, 1997 and Hua *et al.*, 2001). Apart from the general sex ratio variation it was also observed that the ratio was significantly different in most months and dominated by females in larger size groups in both the species. Kannapiran and Patterson (1996) also found that the expected 1:1 ratio occurred in this population only during 5 month period and have presumed that the predominance of female may be due to the faster growth rate of females or the early death of rachiglossan males. Similar gender based dominance has been reported in several species (Gibbs *et al.*, 1988; Martel *et al.*, 1986b and Shim *et al.*, 2000) and this has been attributed to the bigger size females and retention of larger animals in the gear (Narvarte, 2006).

The super family Buccinacea is probably the least specialized of rachiglossan gastropods in terms of feeding mechanism (Kohn, 1983). During the study the percentage of actively fed snails were very less compared to poorely fed according to the fullness of the stomach for both the species. However, it could be because of their feeding habits. A number species of the family Buccinidae feed mainly on carrion (Taylor, 1980) and according to Morton (1990) *Babylonia lutosa* is opportunistic feeder and can survive long periods of starvation (>100 days). The study on diet of *Nassarius festivus* by Morton and Chan (2003) indicated that the snail feeds largely upon organic material in the form of carrion, unidentified tissue, polychaetes and crustaceans. The gut content analysis of Buccinid, *Engina armillata* revealed that the diet consistes of serpulid and spirobid polycheates (Tan and Morton, 1998). When gut content of whelks analysed in the present study, digested animal matter could be identified, polychaete setae or hard parts of crustaceans were not observed. The completely digested condition could also be due to the fact that the whelks remain alive for more than 8 hours after they are caught and before frozen for analysis. During this long duration, the food consumed will be completely digested. In the experimental trawl samples also the gut content was completely unidentifiable digested matter, thereby supporting the views of Taylor (1980) and Morton and Chan (2003) on the food of whelks.

Growth rate indicating the change in body mass and weight has been studied in gastropods through sampling the population (Morton and Chan, 2004) and by direct measurement in captivity (Yulianada and Dhanakusumah, 2000) or by mark (tag) – recapture method (Yamaguchi, 1977). Several factors are known to affect the growth and size of gastropods ranging from position of occurrence in the intertidal zone (Vermeij, 1978), degree of wave exposure (Boulding and van Alstyne, 1993), presence within a conspecific aggregation (Lafferty, 1993), diet (Bowling, 1994), sex of the individual (Fotheringham, 1971; Sousa, 1983), trematode parasitism (Curtis, 1995) and depth (Olabarria and Thurston, 2003). The shape of the gastropod shell and its adaptive value has been widely recognized and studied and it has become clear that gastropod shell has to be consistent with a diversity of inter-related functions (Ekarante and Crisp, 1983).

Maximum shell length and growth of *B. spirata* observed in the present study is similar to that observed along the Porto Novo waters along the southeast coast (Shanmugaraj *et al.*, 1994 and Shanmugaraj and Ayyakkannu, 1997) and differed from the Pelabuhan Ratu bay, Indonesia (Yulianda and Dhanakusumah, 2000). *B. areolata* recorded in Thailand were about the same size as that of *B. spirata* but smaller than *B. zeylanica* recorded in present study.

It has been observed that within the same species in populations in different localities, variation in life span and growth can be observed as noted by Crichton (1942) for *Bullia vittata* along Madras coast and along Porto Novo by Thilaga *et al.* (1987). Crichton (1942) suggested that *B. vittata* was able to attain full size within a period of less than 6 months, while Thilaga *et al.* (1987) have reported that this species attained shell height of 17, 34.5, 42.5 and 50.2 mm during the first, second, third and fourth year respectively in Porto Nova waters. *Chicoreus ramosus* attains 107.7 mm in the first year in Indian waters (Stella *et al.*, 1992), while in Thai waters it attains only 78.15 mm (Nugranad *et al.*, 1994).

In the present study, *B. spirata* and *B. zeylanica* showed positive allometric relationship between shell height and shell width and between shell height and total weight. Yulianda and Dhanakusumah (2000) found good correlation between total weight and shell length and also found that gonad weight and meat weight improved in the laboratory in the initial phase, when provided with ample feed. But the weight remained constant three weeks after acclimatization. The difference can be due to variation in food availability, temperature and shore topography (Mc Killup *et. al.*, 1993). Morton and Chan (2004) found that food availability is a critical factor in growth of gastropods. They found that *Nassarius festivus* attained larger shell height in Starfish Bay compared to Tai Mong Tsai and Tai Mong Bay because of the high level of food available in the form of carrion comprising fishery by-catch and damaged fauna due to clam digging.

In the biometric studies on *B. spirata* and *B. zeylanica*, slightly different slopes were obtained for different size classes, younger size class having higher values than the larger classes. In *N. festivus* significant difference in increase in SH and growth of two size classes was obtained. These studies indicate that smaller and larger size groups invest different amounts of energy in growth, more in small individuals and less in large ones. Small individuals allot energy to shell growth in order to achieve larger size, while larger individuals allocate more energy to reproduction (Siddal *et al.,* 1993 and Morton and Chan, 2004).

Considerable variation in the length composition of male and female *B. spirata* and *B. zeylanica* was observed in the population. It was noted that L_{max} of male *B. spirata* (51.3 mm) and was much lower than that of female (63 mm). In *B. zeylanica*, the L_{max} of male and female were not much different, but the proportion of males in the larger size class was low. In ampullariid snail, *Pomacea urceus* (Burky, 1974) and *P. canaliculata* (Estebenet and Gazzaniga, 1997) such differences in population of male and female of larger size classes have been observed and this has been attributed to a sexually dimorphic growth pattern. In *Pomacea urceus* (Lum Kong and Kenny, 1989), *Marisa cornuaietis* (Demian and Ibrahim, 1972) also larger size females have been observed.

Adult females of any given shell height were found to weigh more than males of equivalent size. Such gender based deference in weight has been observed for several marine gastropods and also in freshwater gastropods of the family Ampullariidae like, *P. canaliculata* (Estebenet, 1998). The presence of mature animals in the samples almost through out year and the increased gonad weight mainly by the albumin gland must have lead to higher weight of female. However, in *B. spirata* and *B. zeylanica*, the maximum percentage of gonad weight to total weight has been <10%, but in some gastropods like *P. canaliculata* the albumin gland can represent 68% of body weight.

Variation in allometric relation (SH vs SW) between male and female *B. spirata* and *B. zeylanica* were observed in the present study. Strong sexual dimorphism in shell height, opercular length, shell weight, total weight, tissue weight and percentage meat yield was observed for *B. undatum* in Atlantic Nova Scotia (Kenchington and Glass, 1998) and from Tusket Shoal, Southwest Nova Scotia (Kenchington and Lundy, 1996). Though such sexual dimorphism is marked in same characters, the differences in mean values between sexes are small and it is unlikely that these characters can be used to separate sexes in this species (Kenchington and Glass, 1998).

The growth coefficient, K value, was almost same for *B. spirata* (1.08) and *B. zeylanica* (1.15) in the present study and the life span of these two whelks were estimated a 2.8 and 2.6 years respectively. The K value estimated for other commercially important gastropods like the chank is lower, 0.946 (Devaraj and Ravichandran, 1988) and 0.264 (Narasimham, 2005). The L_{∞} based on the growth data from chank tagging studies (Sambandamurthy and Chacko, 1969) was estimated as 119 mm in MSD and from this the theoretical life span was estimated a 51 years and the observed life span was 31.5 years, for 113 mm MSD, the largest chank recorded (Devaraj and Ravichandran, 1988). From the data collected by the mark-recapture of chank in Gulf of Mannar, Lipton and Selvakku (2001) estimated size at age 1 to 5, 10 and 15 as 23.9, 42.3, 56.5, 67.5, 75.6, 96.6 and 102.3 mm MSD. However, the laboratory reared baby chanks grew faster, attaining 31.47mm MSD in 360 days (Lipton and Selvakku, 2000).

The growth of larger ornamental gastropods like, *T. niloticus* and *T. marmoratus* is slow compared to *B. spirata* and *B. zeylanica* but with higher longevity. Rao (1937) has stated that *T. niloticus* grows to 5 cm, 5-8 cm and 8-10 cm SD in 1 to 3 years and the life span is 10+ years. Nash (1993) has reported that gastropod have even slower growth, 30 mm during first year, 60 mm after 2 years and about 80 mm SD by third year in various parts of the world. Hatchery reared *T. niloticus* seed of 2.2 months age had a mean size of 2.1 mm (Heslinga and Hillman, 1981) and a juvenile top shell grew to 6.2 mm SD after 12 months, indicating faster growth rate in the hatchery for smaller snails than reported by field observations. Heslinga (1981) attributes this variation to temperature, habitat and food.

The green turban shell, *Turbo marmoratus*, the biggest species under the genus Turbo grows to a maximum size of 25 cm SD weighing more that 2 kg (Yamaguchi, 1993). Based on mark recapture studies it has been observed that snail of 57 mm shell height grows to average length of 112.2 mm in 1 year and to 146.6 mm in 2 years (Fa'anunu' *et al.*, 2001).

The K value of most gastropods is low, *Cittarium pica*, 0.19 to 0.28 (Schmidt *et al.*, 2002); *Strombus gigas*, 0.21 to 0.4 (Navarrete, 2002); *Buccinum isaotakii,* 0.117 to 0.132 (Ilano *et al*, 2004) and *B. undatum*, 0.0274 (Kenchington and Glass, 1998). However, in small size gastropods like *N. festivus* the K value has been found to be high (2 to 2.7). The maximum age of many gastropods have been assessed and found to be high, *Monodonta lineate* (9+) (Williamson and Kendall, 1981); *Shaskyus festivus* and *Ocenebra poulsoni* (10 and 9, respectively) (Fotheringham, 1971); *Busycon carica* (20) (Kraeuter *et al.,* 1989); *Buccinum undatum* (20) (Siddall *et al.*, 1993) and *Tegula funebralis* (30) (Frank, 1965).

Though the fishery of *Babylonia spirata* and *B. zeylanica* started as a by-catch of trawl in Sakthikulangara-Neendakara in 1993 (Appukuttan and Philip, 1994), it gradually developed as a resource worth fishing exclusively. This development in fishing from an incidental catch to targeted fishing with modification in fishing gear indicates the significance of whelk in the global market.

The average annual landing of *Babylonia* spp. in Sakthikulangara-Neendakara harbour increased from 188.9 t in 1993 (Appukuttan and Philip, 1994) to 586.5 t in 2002 indicating an increase of 4.7 times during the last decade. This hike in landing can be attributed to increased targeted trawling using modified gear by nearly 40 vessels during the April to June period. The substantial difference in the CPUE for *Babylonia* spp. between the regular shrimp trawler and modified gear is similar to that reported earlier (Appukuttan and Philip, 1994; Sabu *et al.,* 2005). Such variation in CPUE between non-mechanized and modified gears has been observed for other gastropods like chank (Nayar and Mahadevan, 1974; Appukuttan and Philip, 1994; Selvarani, 2001).

Along east coast at Pondichery, *Babylonia* spp. is caught with a slightly modified ring net normally used for crab fishing. Along the Tuticorin coast, whelks are fished by trawlers (Selvarani, 2001) and a modified ring net is used along certain regions of east coast (Chidambaram, 1997). Similar diversified methods of fishing have been reported for chank along the east coast. Apart from the traditional method of skin diving, chanks are caught by light trawls locally known as 'Vellaivalai' and 'thurivalai' operated from catamaran and bottom set gillnets (Nayar and Mahadevan, 1974). Similar to the modification in trawl made for whelk fishing in Sakthikulangara-Neendakara, few trawlers are modified for chank fishing. These modified trawls known as Chankuvalai are operated along Rameswaram Coast. Similar modification of trawls has been reported for fishing the purple dye murex, *Bolinus brandaris* in the Mediterranean Sea at depths between 5 and 50 m.

A clear seasonality was observed in the fishery of whelk during the present study as reported by Appukuttan and Philip (1994). Even after a decade of fishing and with changes in fishing pattern, the seasonal variations in whelk fishery remain the same. Seasonal variation of gastropod landing in India has been mainly based on meteorological changes in the Bay of Bengal and Arabian Sea. The turbulent sea, strong winds and turbid water have been found to restrict the fishery. However in some villages, fishery exists even during monsoon. The fishery of *Bolinuas brandarus* in the Mediterranean also maintained the same temporal variation in maximum and minimum catches even after modification of the fishing gear (Martin *et al.,* 1995). These results suggest that the growth and reproductive changes taking place in the population are not affected. This can be due to the fact that whelks are targeted only for 3 months and during the rest of the year the population is only partly harvested. Biologically the whelk reproduces almost through out the year, there by supporting the population growth.

A typical example of whelk fishery and the fluctuations in fishery due to market demand is that recorded at Jersey, Channel Island. At the beginning of 1996, a fishery previously unexploited, developed in waters east of Jersey, Channel Islands, for the common whelk, *B. undatum* (Morel and Bossy, 2004). Although a market existed in France, supporting a commercial fishery exploited by the French in this area, the large scale commercial activity in the Island was primarily fuelled by the development of markets in the Far East, largely Korea. Catches of whelks by Jersey boats rose from approximately 1 t in the early 1990s to over 400 t in 1997. However, a serious economic downturn in the Far East and the subsequent collapse of the whelk market caused a major reduction in the whelk fishery in 1998 to a third of the 1997 landings. This decreased further in 1999 when less than 8 t were landed. A recovery of the market led to substantial increases in landings in 2000 with a further increase in 2001 to 518 t (Morel and Bossy, 2004).

The length frequency of *B. spirata* and *B. zeylanica* contributing to the fishery indicates that there is a localized population of *B. spirata* and migratory spawning population of *B. zeylanica* along the Kollam coast. A wider length distribution of the population contributed to the fishery of *B. spirata* and the L_{25} and L_{50} where 33.06 and 35.2, while for *B. zeylanica* only large sized whelks were found in the fishery. The L_{25} and L_{50} of *B. zeylanica* were 39.7 and 41.7 respectively. Since the same trawls were used for *B. spirata* and *B. zeylanica*, the influence of gear on selecting the large sized whelk can be eliminated and the non-occurrence of small-sized whelk in the fishery is due to their absence in the natural bed. Moreover, the condition of the gonads of both male and female of *B. zeylanica* were either in the ripe or spent stage. Here the absence of immature or indeterminate stages indicates that this is a spawning stock. Narvarte (2006) has supported the view that local movements and migration may occur due to predating or reproductive behaviour and may contribute to large variation in density in the same location. Philip and Appukuttan (1997) reported that, along the Kollam coast during the fishing season of whelks, in one particular fishing boat an unusual catch of 1t of whelk was obtained in a day. This supports the view that *B. zeylanica* have spawning congregation along the Kollam coast. Congregation of *B. spirata* spawning females in large breeding tanks has been observed in the hatchery of CMFRI at Kochi. Large clusters of egg capsules very close to each other, with slight overlapping has been observed, when *B. spirata* collected from the fishery were maintained for seed production in the project on *Babylonia* at CMFRI. These observations substantiate the inference that *B. spirata* has community spawnings and aggregate in certain areas for egg laying. The population of *B. spirata* was slightly similar to *B. zeylanica* stock in that the mean size of the population was almost similar to the length at which whelk attain maturity. However, the difference was that immature *B. spirata* young ones also occurred occasionally in the population. In the life history of *B. spirata,* planktonic and creeping stages have been observed (Sreejaya *et.al.,* 2004). These stages help in dispersal of the population. The absence of <18 mm size *B. spirata* in the fishery and experimental trawling indicate lack of juvenile whelks. This must be due to comparatively low number or due to the settlement and growth of early juveniles in other areas.

In a study on *B. globulosum* only two main modes or sizes, 10-28 mm and 40-62 mm groups were observed with a notorious hiatus between them which was explained to be due to the fact that these whelks have a different feeding behaviour when they are carrying egg and that they are not attracted to bait during this period (Narvarte 2006). There are no studies on food habits of *B. globulosum*, but different behaviour (Stoner *et al.*, 1998) could affect the proportions of medium size individuals in the sample and may cause bias in the sampling in favour of smaller and larger sizes.

In *Nassarius reticulates* a clear change in diet during the life history has been observed. Juvenile snails (≤15mm) were greatly attracted to detritus rich substrates, whereas larger ones congregated on carrion and this has been considered as a factor influencing intra-specific competition. When nearly 4 year old they become sexually mature and from then on most of them participated in yearly migration. They showed migration from deeper water (1-5 m depth) during winter to the bay (0-1m) where they spend the summer and then back again. These activities were also found to be affected by temperature (Tallmark, 1980). Several factors are considered to affect the migratory habits of whelks (Takada, 1996), such as avoidance of competition (Branch, 1975), food abundance (Stoner *et al.,* 1998), escape from predators (Iversen *et al.*, 1989; Mc Quaid, 1982; Stoner and Waite, 1990), escape from strong wave action and maximization of reproductive output (Paine, 1969; Spight, 1977).

The fishing method for whelks along the Kerala coast is effective, resulting in profitable catch. However, the sedentary lifestyle of the gastropods makes them vulnerable to over fishing and may require a conservative management approach in future.

Because of the limited domestic demand for meat of whelk, fluctuation in landings often reflect the changes in export market rather than changes in abundance of the resource. Such fluctuations have been observed in fishery of *Paphia malabarica* in Ashtamudi Lake Kerala (Kripa, personal communication). When there is an export order for this resource, commercial fishing is intense and the fishers harvest nearly 3000 t within a month. But if fishery has to cater to the domestic market alone, then the fishery will be maintaining a low profile. Such instances have been observed for edible molluscs, but for ornamental molluscs, fishery is independent of export market since the internal demand is high and the market is progressively widening. The meat of *Babylonia* is mainly for export and there is a very strong link between the whelk export and fishery. The intense fishing during April-June is a reflection of the demand in seafood trade.

It has been found that there are clearly two types of status for gastropod fishery, few that are under exploited which can become more beneficial to the fishers and those that are overexploited and urging for conservation and management measures. Valentinsson *et al.* (1999) have found that the stock of *B. undatum* in the Swedish waters is of commercial importance but would be vulnerable to overfishing. Similarly the Fishery Diversification Program of Canada (FDA, 2002) has also stated that fishery of *B. undatum* can be an extra source of income in rural areas of Newfoundland and Labrador.

Overfishing has been reported in other gastropod fisheries. Such situation have been observed especially in many trochus fisheries, Andamans (Setna, 1932); Papua New Guinea (Glucksman and Lindholn, 1982); Great Barrier reef (Nash, 1985); New Caledonia (Bouchet and Bour, 1980); Micronesia (McGowan, 1956); Okinawa (Honma, 1988); French Polynesia (Yen, 1985). *Trocus niloticus* is probably susceptible to over-fishing because it is long-lived (10-14 years); slow maturing (2-3yr) has limited dispersal capabilities (Heslinga, 1981; Nash, 1985) and can be easily located and collected with simple equipment (Long *et al.*, 1993).

The total mortality coefficient (Z) and fishing mortality coefficient (F) were higher for *B. spirata* that for *B. zeylanica*. The present rate of exploitation of *B. spirata* was found to be higher than the optimum exploitation rate where as that for *B. zeylanica* the present exploitation rate has nearly attained the optimum. Population dynamics of Indian chanks as worked out by Devaraj and Ravichandran (1988) shows that the initial stock size varies from year to year. They also found depth and size related variation and suggested that it was possible to increase the catch of 60-80 mm MSD chanks as more than 81mm size chanks were well exploited. This can be achieved by fishing in 20-30m in Gulf of Mannar.

In a study on the whelk *Cittarium pica* fishery, the length frequency histogram showed a strong shift towards smaller species at exploited sites than the unexploited site and the Z values were also higher (Z = 4.47) compared to the unexploited site (Schmidt, *et al.*, 2002). Exploitation rate more than 0.6 for both the sites indicated overexploitation and recruitment over-fishing. They recommended regulations of the fishery such as a minimum landing size and a closure of fishery during its reproductive period.

Abalone fisheries in Australia during the second half of last century has faced several problems. Modern Australian abalone extraction techniques (commercial diving with compressed air supplied from the surface) started in the mid-1960's, and during the last part of the 1960's most Australian states moved to limit entry: controlling the number of commercial abalone divers, first by using a system of nontransferable abalone extracting licenses, then using a system of reallocation, and later on establishing a system of license transferability. During the mid-1980's individual transferable quotas for abalone and total allow-able commercial catches (TACCs) were introduced to control rising catches (Harrison, 1986; Prince *et al.*, 1998). In spite of these management steps, the Australian abalone fisheries have shown serial depletions, particularly for individual abalone beds, since most divers tend to extract their quotas from the same abalone beds or reefs. This, according to Prince *et al.* (1998), gives rise to a local "tragedy of the commons" (Hardin, 1968). Therefore, size limits and quotas set over broad zones of the fishing ground for species showing aggregate distributions or "nuggets of stock", as in the case of abalone, give little protection to the most favorable dive beds, where most of the extraction pressure is focused.

The exploitation rate of *B. spirata* and *B. zeylanica* has exceeded the optimum exploitation rate (0.6) and the population is under fishing pressure. This shows that Still the fishery is sustaining because both the gastropods are having a higher growth rate compared to other species *X. pyrum, T. niloticus, T. marmoratus, C. pica, S. gigas, B. isaotakii, B. undatum* etc. The L_{opt} of *B. spirata* is 40 mm in the present study and it attains the t_g (the average age at which an individual capable of producing young ones) at 0.55 y. That means the species produces its off springs at the age of 6 or 7 months. Again the GSI results show that both the species are continuous spawners and the multiple cohorts observed in monthly mean length analysis support this. The VPA result of *B. spirata* shows that average biomass of survivors is 51% of the biomass caught and 42% of the standing stock is spawning stock. One of the chief goals of fisheries management is that recruitment over fishing must be prevented and adequate spawning stock be maintained to ensure future productivity of the stock (Mohamed and Rao, 1997). The annual mean length of *B. spirata* showed an increase from the previous year, which also agrees that there is no recruitment over fishing of the population in the area.

The annual mean length of *B. zeylanica* (49.9 mm) is above L_{opt} 44 mm in the present study and attains t_g at 0.48 y. The higher K value and t_g explains faster maturity capability to sustain the population at a heavy exploitation rate. The length cohort analysis shows that average biomass of survivors is 113% of the yield during 2002 and 66% of the standing stock biomass is spawning stock biomass. The faster growth rate, early maturity and short life span of the species explain the sustainable fishery under a higher exploitation rate. More over, the undersized whelks are not exploited, since the presence of younger ones were negligible in the commercial fishery. Hence, the present state of fishing is not leading to a stock depletion of whelk population off Kollam.

Bruce (2006) has compared the fishery of the knobbed whelk in the Bay of Delaware and in the Ocean. He has related the larger mean length of whelk in Ocean compared to that in Bay to the lower level of fishing effort and exploitation rate in the Ocean. The Delaware landing data also implicated that the fishery is at a peak as landing and effort have been consistently high. Similarly, the Chilean muricid fishery has declined due to stock over exploitation (Castilla, 1995, 1997b, Castilla *et al.*, 1998). Hobday and Tegner (2000) summarized the management history for the California abalone fishery, where several regulatory extraction tools were implemented between 1901 and 1997 *viz*, minimum size limit, commercial permit fee, minimum commercial landing, recreational limit and recreational and commercial gear regulation to improve the fishery. In spite of these management tools the abalone populations in California continued to decline, until total closure was decreed in 1997.

Based on the observations made on the by-catch of shrimp trawlers in the Sakthikulangara-Neendakara harbour, an income generating programme is suggested. The huge quantity of gastropod shells landed are at present utilized as raw materials for shell trade industries which are based along the southeast coast. There is ample scope to develop these shells as value-added products like key chain, curios, shell curtains, ornaments etc. through cottage industries in the state itself. These can be initiated by the Dept. of Fisheries and the local fishers, especially the low income group can be trained on cleaning, polishing, cutting shells and even in product development. Nearly 10 units can be set up in the district itself and can be marketed through linkages with Dept. of Tourism; Dept. of small scale industries and these items can also be exported also. This shell craft industry can be more active during the monsoon period when the fishery is lean and employment opportunities are low.

Chapter 6
Summary

6. Summary

The two species of whelks, *B. spirata* and *B. zeylanica* were never found to co-exist. The hydrographic parameters like temperature, salinity, ammonia, nitrite and nitrate of surface and bottom water were similar between the sites of the two whelk beds. pH, dissolved oxygen, phosphate and total suspended solids of surface and bottom water showed significant variations among zones. Total organic carbon of sediment was analysed for all the stations and significant variations were observed between S_1 and S_2 and N_2 and S_2. Significant variation in sediment texture between *B. spirata* and *B. zeylanica* beds was observed. The sediment texture in the *B. spirata* bed was silt-loam at all stations, while in the *B. zeylanica* bed, it was sand-loam at S_1 (10-20 m) and sandy at S_2 (20-30 m). In the north zone, *Babylonia spirata* was present at both the sites N_1 and N_2 and in the southern zone at S_1 at a low density and was absent in S_2. *B. zeylanica* was observed only at site S_2 (2 no/10m^2). The density of *B. spirata* varied among sites and maximum density was observed at N_2 (6 no/10m^2) and minimum at S_1 (0.04 no/10m^2). The density of *B. zeylanica* was low compared to the density of *B. spirata* at the same depth in the north zones. Length composition of *B. spirata* population in the two zones was similar, dominated by adult whelks. Females dominated the population in north zone, while males dominated the population at S_1. *B. zeylanica* inhabited only the deeper regions of south zone and the population was dominated by adult whelks and females out numbered males. *B. spirata* abundance was high in areas with more silt and TOC, and showed negative relationship with sand composition. *B. zeylanica* density increased with sand and significant negative relationship observed with clay, silt and TOC.

The whelk beds benthic community of north zone comprised of six macrofaunal invertebrate taxa constituting 53 species of annelids, 8 species of crustaceans, 5 species of molluscs, sipunculids, nemertine and coelenterates and fish larvae, while along south zone three invertebrate taxa with 33 species of annelids, 4 species of crustaceans and sipunculids were identified. Annelids dominated (81.2%) the macro benthos in north zone and S_2 (41.4%) of south zone, while sipunculids were the dominant fauna at S_1 (72.1%). The results of ANOSIM indicated significant difference in species composition of macro-fauna in the four sites. Among these, highest degree of difference was found between S_1 and S_2 followed by N_2 and S_2.

Other associated fauna in the beds of *B. spirata* and *B. zeylanica* were composed of benthic fin fishes, crustaceans, molluscs, echinoderms and coelenterates. Multivariate analysis on the abundance of benthic associated fauna showed significant difference between N_1 and N_2 and S_1 and S_2. The univariate analysis on macro-benthos showed the highest species diversity (6.95) and evenness (0.73) at N_2 and minimum at S_1 (2.3 and 0.4 respectively). The dominance index was also found to be higher at N_2. The nekton and other associated fauna were more diverse and evenly distributed at N_2 compared all other sites.

B. spirata and *B. zeylanica* are gonochoristic with internal fertilization. Four maturity stages have been identified depending on the GSI and texture and colour of the gonad. *B. spirata* spawns through out the year with two peak-spawning periods *viz*, September to December and February to March. Shell height at first maturity was estimated as 32 mm and 36.5 mm for male and female *B. spirata* respectively. The sex ratio studies showed that females dominated the population of whelk and a significant predominance of females observed in January, February and May of 2001 and 2002. The sex ratio in different size groups varied and the number of males decreased with increase in size. The GSI of male and female *B. spirata* increased from stage I to III and decreased in spent stage. The GSI of female *B. spirata* showed gradual increase in September to November and decreased in January. Again an increase was observed in February upto April coinciding with spawning activities. The monthly variation of GSI in male was not as pronounced as it was in females and the peak was observed in October.

The shell height – total weight (SH-TWt) relation of *B. spirata* and *B. zeylanica* showed a high positive correlation (R^2 = 0.96). In *B. spirata* the sex wise SH-TWt relation showed no significant variation of b-values. But in the case of *B. zeylanica,* the b-values significantly varied for male and female. The SH-SW relationship, the b-value of *B. spirata* and *B. zeylanica* showed the high positive correlation. When considered separately for male and female, the b-values were slightly lower for males than that of females and the values were significantly different for both species. The rate of growth in body width of females was faster than that of males. Shell height – opercular length (SH-OL) relationship showed positive correlation for both species. When the relation of male and female *B. spirata* was considered separately the b-values were significantly higher for males and in *B. zeylanica,* the b–value was significantly lower for males than for females. The SH-TWt relationship showed a decrease with increase in size for both male and female *B. spirata* and a reverse a phenomenon was observed in *B. zeylanica.*

The growth of whelk was studied by using ELEFAN I programme. The growth parameters L_∞ and K were estimated as 68.7 mm and 1.08 for *B. spirata*, and 76 mm and 1.15 for *B. zeylanica* respectively. The longevity of *B. spirata* was calculated as 2.8 years using the K value as 1.08 yr^{-1} and of *B. zeylanica* as 2.6 years when the K value is 1.15 yr^{-1}.

The annual landing of gastropods at Neendakara - Sakthikulangara was estimated as 780.6 t, 879 t and 659.8 t during the period 2001 to 2003 with an average annual landing of 773 t forming 1.2 to 2.4% of the total marine landing. The average annual CPUE for gastropods was 14.1, 9.8 and 13 kg during 2001, 2002 and 2003 respectively. The average estimated whelk landing composed of *B. spirata* and *B. zeylanica* for the period 2001-2003 was 487 t contributing 62.5% of the total gastropod landed during this period. There is a targeted fishing of whelk along the coast using modified trawl from April to June every year. *B. zeylanica* formed more than 50% of the whelk landing and dominated the fishery during April to June, while the catch was negligible during the post-monsoon months. The average estimated CPUE for whelk was 8, 6.8 and 9.1 kg during the period 2001, 2002 and 2003 respectively. During April-June 20-40 boats were engaged in exclusive fishing of whelk with modified trawlers in which the CPUE ranged from 250 to 500 kg with an average of 400 kg.

B. spirata of length range 20-60 mm was observed in the fishery during 2001-2002 and 30-46 mm size class supported (90%) the fishery. The annual mean length of *B. spirata* showed an increase from 37.4 mm in 2001 to 40.1 mm in 2002. The annual mean shell height of *B. zeylanica* in 2002 was 49.9 mm. L-50 of *B. spirata* was estimated as 35.2 mm and of *B zeylanica* 41.7 mm.

Total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) of *B. spirata* were estimated as 6.05, 1.61 and 4.44 respectively. The Z, M and F of *B. zeylanica* were 5.02, 1.65 and 3.37respectively.

The present exploitation rate of *B. spirata* (0.73) has exceeded the optimum exploitation rate E_{max} (0.68). For *B zeylanica*, the present exploitation rate has almost attained the optimum (0.71), where the E_{max} was 0.77. The estimated standing stock of *B. spirata* along off Kollam during the period 2001 and 2002 was 216.2 t and the spawning stock biomass was estimated as 92.87 t. The standing stock biomass of *B. zeylanica* was estimated as 404 t and the spawning stock biomass as 267.7 t for the year 2002. From the results it can be summarized that there is no overexploitation or threat on the population of whelk in the study area at the present level of fishing. But increase in fishing effort can lead to stock depletion.

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