Some Aspects of Biology and Nutrition of *Scylla serrata* (Forskal, 1755) From the South Western Region of Bangladesh

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Some Aspects of Biology and Nutrition of *Scylla serrata* (Forskal, 1755) From the South Western Region of Bangladesh

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DECLARATION

The results submitted in this thesis are entirely of the candidate's own investigations and no part of the results has been accepted for any degree, nor it is being concurrently submitted for any degree

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DEDICATED TO

My Elder Brothers and Sisters

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ABSTRACT:

Some aspects of biology *viz.* size-frequency distribution, sex ratio, length-weight relationship and relative condition factor and the proximate biochemical composition of different body parts *viz.* gill, shell, meat, hepatopancreas and egg tissue of the mud crab (*Scylla serrata,* Forskal 1755) were studied from the SW region of Bangladesh for one year at monthly interval in 2001. The maximum number of the mud crab (*Scylla serrata*) harvested from the SW region was between 60 and 100 mm external carapace width in size. About 82.15% (1284 individuals out of 1563) crabs caught form this size. Again 336 female crab from 697 samples were within 70-80 mm size class. The highest 216 individuals males out of 866 samples were within 80-90 mm size class. Crabs caught from high saline zone were larger than the crabs from low saline zone. The maximum and the minimum size of mud crab in the sample were 131 mm and 31 mm respectively.

Overall sex ratio of mud crab in the sample was 1:0.81 (M: F). Sex ratio did not vary with geographic location as in low and high saline zone, the ratio were 1:0.81 and 1:0.79 respectively. The highest and the lowest sex ratio was found in the month of May (1: 1.561) and July (1:0.408) respectively. Male crabs dominate over females round the year except for May and December. In low and high saline zone female crabs dominate over the males in May and November, and in March and May respectively.

ECW-weight relationship for maleand female in SW region was $W= 0.3327 L^{2.7877}$ ($r = 0.89$; $n = 866$) and $W= 1.1138 L^{1.3104}$ ($r = 0.89$; $n = 697$) respectively. The combined ECW-weight relationship for male and female was $W= 1.2491 L^{1.467}$ ($r = 0.94$; $n = 1563$) Condition of crab was better in all the size except 70-100 mm size class. This may be due to mating and spawning of crabs.

The proximate composition of different body parts of male and female mud crabs from 2 different geographical locations showed variation in body parts, sexes and geographical locations. The protein content was found highest in the ovary (27.57%) of female and the lowest (7.86%) in shell. Male body meat contained 16.34% protein followed by

hepatopancreas (9.78%), gill tissue (9.17%) and carapace shell (7.86%). The fat content was found to be the highest in hepatopancreas (13.67%) followed by ovary (3.90%), carapace shell (1.34%), gill tissue (0.64%) and body meat (0.38%). The maximum ash content was found in carapace shell (33.83%) which was followed by gill tissue (3.91%), ovary (2.35%), hepatopancreas (3.34%) and body meat (2.18%). The highest moisture content was noticed in the gill tissue (84.02%) that is followed by body meat (79.83%), hepatopancreas (68.83%), ovary (54.23%) and the carapace shell (47.71%).

Moisture content in all body parts was higher during the post monsoon season than monsoon season. Protein content in the gill, meat, hepatopancreas and egg was during the monsoon than post monsoon. Ash content in gill, shell, meat and egg are higher in monsoon and in hepatopancreas it was higher during the post monsoon. Lipid content in shell, hepatopancreas was higher during the monsoon, while in the gill, meat and egg it was higher during post monsoon. Carbohydrate content in all body parts was higher during monsoon than post monsoon season.

Research on mud crab (*Scylla serrata*) in Bangladesh has not yet done enough. So the people do not know the information on biology and nutrition. As a result the domestic market of mud crab has not yet developed in this region. Commercial culture has not yet developed in SW region. If detailed biological and biochemical research can be done on this species, the commercially important species, will be more demandable in Bangladesh as well as in foreign market.

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List of abbreviation:

ECW = External Carapace Width

SW = South Western

K_n = Condition Factor

HP = Hepatopancreas

M = Moisture

P = Protein

L = Lipid

A = Ash

C = Carbohydrate

ANOVA = Analysis Of Variation

INFS = Institute of Nutrition and Food Science

J = January

F = February

M = March

A = April

M = May

J = June

J = July

A = August

S = September

O = October

N = November

D = December

M: F = Male: Female

Chapter-1: General Introduction

1. *Background information:*

1.1 The species: The mud crab, *Scylla serrata* (Forskal, 1755), one of the biggest crustaceans under the Portunidae family, may attain 2 kg in weight and 22-25 cm in carapace width (Piatek, 1981). Mud crab is widely distributed in the Indo-West-Pacific region as mangrove associated fauna (Macintosh *et al.*, 2002). It is one of the most popular and costly seafoods in the South-East Asian countries (Pripanapong and Tongdee, 1998).

In Bangladesh, mud crab is distributed widely in the tidal rivers of Cox's Bazar, Chittagong, Noakhali, Barisal, Potuakhali, Satkhira, and Khulna up to 40-50 backwaters and around the offshore islands particularly Moheshkhali, Kutubdia, Sandwip and Hatia (Khan and Alam, 1992). The animal is highly abundant in the Khulna and Chokaria Sundarban Mangrove ecosystems. It is also available in the coastal shrimp ponds (Khan and Alam, 1992). The peak abundance of adult crab occurs during mid and late monsoon (June- August) and the winter months from November to February (Ahmed, 1992).

It is commonly known as "green crab" or "mangrove crab" and locally called as "Habba kankra", "Silla Kankra" or "Kankra". It occurs abundantly in the tide fed rivers, estuaries, mangrove swamps and the entire low saline coastal waters of Bangladesh (Shafi and Quddus, 1982; Bhuiyan and Das, 1976; Mahmood, 1977; Islam, 1977). Bangladesh earns considerable amount of foreign exchange though exporting the animal in live condition (Azam *et al.*, 1998). It's fishery support the livelihood of millions of poor fishers, traders and transporters.

Mud crab has nine similar sized spines on each side of their eyes. Males are larger than females. Their hind legs are flattened for swimming and called swimming pads. Mud crabs have very robust claws, used for crushing shells (DPI, 2000). The body of *S. serrata* is dorsoventrally flattened, broader than long being composed of three parts viz. head, thorax and abdomen. Dorsally the entire cephalothorax is covered by a calcareous exoskeletal structure known as carapace. Abdomen consists of a series of seven segments, which remains flexed and folded underneath the cephalothorax. Therefore, its segmentation somites are not apparent dorsally. Mud crab has one pair of chelipeds and four pairs of walking legs. Also referred to as claws, nippers or pincers, the chelipeds are the first pair of legs on a crab and their most distinguishing structure. Chelipeds are used for holding and carrying food, digging, cracking open shells and warning off would be attackers.

Fig.- 1a. Abdomen of male *S. serrata.*

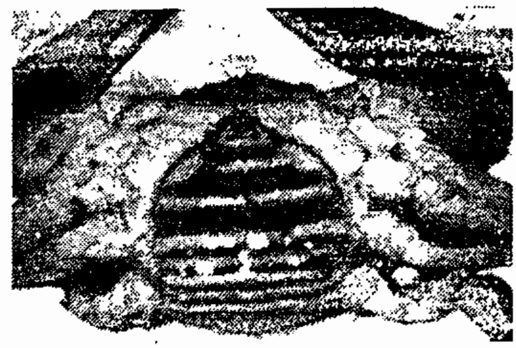


Fig.- 1b. Abdomen of female *S. serrata.*

Estampador (1949a) classified the genus *Scylla* into 3 species and one variety- *S. serrata*, *S. oceanica*, *S. tranquebarica* and *S. serrata* var. *paramamosain* on the basis of external morphological features (colour of carapace and legs, anterolateral teeth of carapace and outer spines of cheliped carpus), mode and form of spermatogenesis and oogenesis, chromosome structure and form, and bionomics from the Philippines. Comparing the genetic and morpho-meristic methods, Keenan *et al.* (1998) stated the presence of 4 different species under the genus *Scylla* as- *S. serrata* (Forskål, 1775), *S. olivacea* (Herbst, 1796), *S. tranquebarica* (Fabricius, 1798), and *S. paramamosain* (Estampador, 1949).

1.2 Life cycle: When the female mud crabs mate, they retain the sperm until they are ready to spawn and produce about two million eggs (Brown, 1993). The eggs are protected under the female's abdomen, attached to the pleopods, for about 17 days prior to hatching. During this time, the female migrates offshore to spawn (Hill 1994). The eggs hatch into planktonic zoea larvae and, over a period of three weeks, undergo five moults, during which time they are transported semipassively by tidal currents back to the coastline (Ong, 1964). In is known that juvenile mud crabs return to the mangrove zone: however, little is known about the settlement and recruitment processes involved for *Scylla serrata* between the megalopa stage and their emergence as juvenile crabs in the mangrove forests (Moser, 2001).

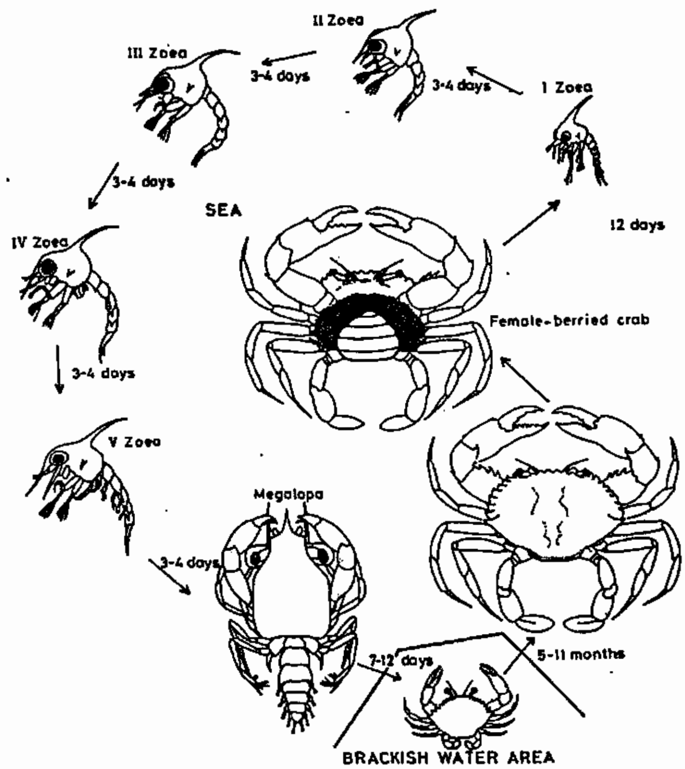


Fig.: 1.1 Life cycle of *S. serrata* (Source: Santhanam *et al.*, 1990).

1.3 *Ecology:* *S serrata* has a major ecological significance in mangrove ecosystem. It burrows characteristic shape and form permeate the mangrove floor which help to aerate the substratum and provide refuge for many other animals including mudskippers, frogs and sea slugs (Azam *et al.*, 1998). The mud crab is an omnivorous opportunistic feeder feed on slow moving and sessile benthic invertebrates and prefer small crabs (mainly grapsid), bivalves and detritus (Macintosh, 1982; Hill, 1976; Prasad *et al.*, 1985; Christopher 1991). It is also a voracious predator of young fish and prawns (Azam *et al.*, 1998). Mud crabs are nocturnal animal, remaining buried during the day and emerging at sunset (Christopher, 1991). However, *S serrata* can not catch fast moving prey (Hill, 1976).

Scylla serrata are common in the mud flats of the littoral, parts of the supralittoral and the intertidal zones of the Bay of Bengal. The species hardly occurs in sandy and rocky areas. It is distributed over a wide range of salinity, from 2 ppt. to oceanic waters, from the coast to the interior brackish waters. They are essentially euryhaline, but die beyond 70 ppt.

Though these crab seem to prefer mangrove swamps, they exist in large numbers in shrimp ponds and in the burrows of the peripheral dykes of the ponds. Crab live in mud burrows, which occur densely in intertidal mangrove swamps, a little above the low tide mark. The burrows are also frequent in embankments of shrimp culture ponds and coastal irrigation project areas. The density of burrows varies with season; increasing with rains and then gradually decreasing during the cool, dry winter. Crab takes shelter in burrows during the day when tides are low. During high tides at night they swim around in search of food (Khan and Alam, 1991).

1.4 Fishery, number of fishers involved livelihood: Crab resources contribute 23-30% to the world crustacean production from 1958 to 1969 (Alverson and Patterson 1974). According to the FAO statistics the total world production of mud crab is 10,000 ton/year however, several countries do not report separate statistics for the mud crab. In the mangrove biotope, mud crab production is about 2 ton/km^2 (Sivasubramaniam and Angell, 1992). A variety of cultural, social, and financial reasons that have hindered the development of crab fisheries in regions in which potential resources exist. In the near past, mud crab was the unexplored marine resource in Bangladesh. A particular group of people, namely the Hindus, Buddhist and Tribal were used to exploit crabs from the wild sources for their own consumption. By the time, it entered into the local market however, the prices were far lower than any other fisheries items. Now a days crab are eaten by a part of the Muslim population who are free from traditional customs. Extensive commercial exploitation of mud crab has been started in 1977 after introduction of its live export by air (Azam *et al.*, 1998).

Fishermen take advance from the wholesalers or Dadondars in return they are bound to sell their crab without any bargaining. All categories of local people go for crab fishing. Ninety percent of them are landless. Most of the fishermen are Hindu, but a few Muslims also present (Azam *et al.*, 1998). The common fishing crafts and gears used in crab fishing are dingi boat, bamboo trap or "boom/ chai/ tonga", rope line or "don", long metal hook and nets (Azam *et al.*, 1998). However, the income of professional crab fishermen is still below any acceptable standard (Khan and Alam, 1991).

1.5 Economy – export earning: *S. serrata* has emerged as one of the most important foreign exchange earner commodities since 1977 (Azam *et al*., 1998). According to the Export Promotion Bureau (1997) the total export quantity and earnings are increasing steadily since the start of live crab export in 1977. A total of 4445 metric tons of mud crab worth of Tk. 44.51 crore has been exported during July 96 to January 1997, which was about 1.5 times higher than the previous year. Ahmed (1992) estimated the annual landings of mud crab from different coastal area of Bangladesh in 1990 at 2,151 tons. Chantarasasri (1994) reported the yearly production and Maximum Sustainable Yield of mud crab from the Sundarban reserved forest area at 375 MT and 150 MT respectively.

Table:1.1 Export earning from *Scylla serrata* between 1989 to 2000.

Year	Earning (US$)	Year	Earning (US$)
1977-78	2000	1989-90	31,000
1978-79	1000	1990-91	7,68,000
1979-80	24000	1991-92	14,62,000
1980-81	+	1992-93	37,80,000
1981-82	+	1993-94	47,04,000
1982-83	24,210	1994-95	53,97,000
1983-84	35,000	1995-96	57,92,000
1984-85	38,000	1996-97	55,35,000
1985-86	62,000	1997-98	15,68,000
1986-87	213,000	1998-99	11,01,000
1987-88	318,000	1999-2000	2,83,000
1988-89	134,000		

Source: Acharya and Kamal., *1994* Source: Export Promotion Bureau, 2002

+ = Data not available

1.6 Food value: Mud crab is one of the most popular and luxury food item in many parts of the world particularly in the SE Asia (Pripanapong and Tongdee, 1998). In Bangladesh, its excellent and distinctive flavour makes it one of the most delicious and costly food item. The mud crab meat provides an excellent source of nutrition because of its high protein content. It is served as food boiled, roasted, curried, cold with salad and mayonnaise, hot with black pepper, cracked from their shells or eaten whole just after moulting (Warner, 1977; Nandi and Pramanik, 1994). Crab meat is also considered to possess some medicinal value. It is believe to cure asthma and chronic fevers (Chopra, 1935; Chidambaram and Raman, 1994). Information on the nutritive value of *S. serrata* is scanty in Bangladesh. Mannan (1977) and Anon (1980) reported the biochemical composition and mineral content some crabs from Bangladesh along with other fishes. Das *et al.* (1995) reported the proximate composition of the body and claw meat of two portunid crabs, namely *S. serrata* and *Portunus pelagicus,* from the South-Eastern (SE) coast of Bangladesh. Reports are also available on food value of *S. serrata* and *P. pelagicus* from coastal waters of India and Pakistan (Srinivasagam, 1979; Qasim *et al.*, 1990; George and Gopakumar, 1987).

Table: 1.2 Estimated production of mud crab from different areas of Bangladesh.

District / Region	Production (MT)
Cox's Bazar and Chittagong/south east	600* - 992*
Noakhali, Bhola, Barisal, and Patuakhali/Middle south	34.8* - 350*
Khulna- Bagerhat -Satkhira	926 - 1093*
Sundarban reserve forest	375*
South western region (Khulna, Satkhira, Bagerhat)	6,950**
TOTAL (Bangladesh)	**8885.8 - 9760**

Notes: * Azam *et al.*, 1998; ** Kamal, 2002.

1.7 Problem statement: The export of mud crab from Bangladesh has increased many folds in the last few decades. The ever increasing demand and good price for the species in international market has resulted in overfishing of the species from various wild sources of Bangladesh. More than 50,000 fishers are involved in mud crab harvesting throughout the year from the Sundarban mangrove swamps alone (Acharya and Kamal, 1994). In addition, about 30,000 people are engaged in crab fishing for 6 months (personal communication). In absence of alternative income option numerous unemployed people are entering into highly profitable mud crab harvesting from the swamps of the SRF both in legal and illegal ways. Therefore, the stock of the mud crab, production and the CPUE have been declined significantly in the last few years.

1.8 Rationale: Culture and fattening of mud crab in small pond and pen has been started with great attention in many South-east Asian countries (Escritor, 1972; Minijoy, 1991; Baliao *et al.*, 1981). As mud crab is a fast growing species, grow best in brackish water of 10-15 ppt salinity and spawn throughout the year, entire coastal region of Bangladesh is suitable for its cultivation and fattening. Particularly, by introducing fattening practice, the rejected and under size individuals can be grown into marketable size within 2-3 weeks (Kamal, 2002).

The species has a high demand in export market. With proper attention the culture of mud crab could play an important role in enhancing protein production, foreign exchange earnings and internal trade development (Ahmed, 1992). The livelihood of many people in the coastal region of Bangladesh are absolutely or partially on crab catching and marketing. So it can be a source of better livelihood through proper management and culture regime.

Mud crab meat contains high protein value (20%) (Warner, 1977; Wang *et al.*, 1995). The other part of the body is also important for nutritive as well as other purpose like medicine, refinery, surgery etc. (Wang *et al.*, 1995). Although mud crab possesses high food value but is not consumed extensively by the mass people in our country, therefore there is no substantial local market for the species in Bangladesh. For sustainability, any product needs a local market. Again, the community consume crab are not regular in diet because the species is not available throughout the year. So the domestic market is very limited. Once local market is established, we would not face any problem related to foreign market fall, low demand, low price etc. Because foreign markets are highly instable. Another problem is related to religious culture for the small local market of mud crab. About 85% people of our country are Muslim. According to Hadis (Stated by the Prophet Hazrat Mohammad SM), to eat crab is Makruh (Not preferable) (Anon, 1861; Rahim, 1918). Same condition is true for the shrimps. People are eating shrimp extensively. So there is no special religious prohibition against crab like shrimp. In this context we can create local market through highlighting its table quality and nutritive value.

1.9 Objectives: The objectives of the study is as follows:

a. To assess the population structure, sex ratio, condition factor and length-weight relationship of *Scylla serrata* from the South-western region.
b. To estimate proximate composition of different body parts (gill, shell, meat, hepatopancreas. and egg) of male and female mud crab by season and geographic location.

Chapter- 2: Some aspects of Biology

2.01 Introduction

For commercial fisheries, the determination of optimum catch volume is the mandatory in order to determine the optimum level or rate of any aquatic animals of commercial value, the information on its exploitation, abundance, size, sex, and growth, recruitment and mortality are essential. In any fisheries management regime, the growth, sex ratio, length-weight relationship, size-frequency distribution and other biological factors are foremost important in taking a balanced management decision.

Knowledge of length-weight relationship is essential to establish growth equation in production computation (Rao, 1987). It can also provide data of seasonal variation, multiple spawning and variation in food composition. (Rounsefell and Everhart, 1953; and Lager, 1956). The length-weight relationship is used in fishery geology to investigate environmental adaptability, racial discrimination as well as to estimate growth of species. The departures from the relationship between length and weight are used in fishery biology to investigate environmental suitability, racial discriminations, general well being or relative robustness of fish by means of a condition factor (Hile, 1936). The condition factor also serves as a useful index of the nutritional and biological cycle *viz.* gonadal development, spawning etc. of the species.

Sex ratio gives an account of the number of male and female in a particular habitat to support successful reproductive outputs, i.e. spawning and recruitment. Information of sex ratio in the nature is very much useful and used to determine appropriate number of male and female during artificial spawning programme in commercial seed production in hatcheries. Sex ratio can also be a devise to ensure a proportional fishing of the two sexes. Information of sex ratio is of importance in the interpretation of the population structure and reproductive performance in crustaceans (Cheewasedtham, 1990). Spawning migration in female mud crabs can be interpreted from sex ratio data.

Relative condition factor (K_n) is a useful index for estimating the physical well being as well as nutritional and biological cycle. A cyclic change in condition occurs annually as the fish, particularly the female develops its gonad. While upon grow the fish become relatively heavier, so that 'n' increases and may be greater than 3. Directly after spawning the fish is thin and poor in condition so value of 'n' drops down to less than 3 (Le Cren, 1951).

2.02 Literature review:

2.02.1 Sex ratio: The sex ratio of *S. serrata* has been reported by several workers from different geographical localities (Ahmed, 1992; Khan and Alam, 1992; Devi, 1985; Jameson *et al.*, 1982; Jayamanna and Jinadasa, 1993; Cheewasedtham, 1990).

The sex ratio in natural population is expected to be 1:1. In general, the sex ratio is highly variable in lobsters, crabs and shrimps (Cobb and Caddy, 1989). The overall sex ratio of male to female was found to vary between 1:0.82 and 1:3 (Lari, 1995; Cheewasedtham, 1990; Kathirvel and Srinivasagam, 1992).

Sex ratio of *S. serrata* can be varied by size and season (Quinn and Kojis, 1987). Khan and Alam (1992) have reported a high seasonal variation in sex ratio of mud crab from the coastal regions of Bangladesh as female crabs in commercial catches were 50-55% during wet season and 40-45% during winter.

Wenner, (1972) reported that sex ratio might vary due to differential mortality, migration or habitat selection, and restricted nutrition. While, the variation in sex ratio by size may be caused by a variety of factors such as hermaphroditism, differential growth, or mortality.

2.02.2 Size frequency distribution: In *Scylla* sp. male and female growth rates differ; after puberty, females generally grow slowly than males (Brown, 1993) because females allocate more resources for gonadal development and parental care, and because eggs are attached to the abdomen until hatching which prolong the inter moult period (Cobb and Caddy, 1989).

Jennings *et al.* (2001) reported that the size increments with moulting tend to decrease as size increase- ranging from 20 to 40% in small crustaceans to 5% or less in large adults. Juvenile female mud crabs, at age of 1 year and carapace width of 3-10 cm, gradually develop a wider abdominal flap (female character) and their claw weights are 22% of the total body weight (Thongkum, 1988). Similar trend is noticed in male crabs at this stage. Afterwards, the claws of the males grow rapidly and reaching from 30-35% of body weight at 10-15 cm CW (carapace width) to 45% body weight at 14-20 cm CW (Thongkum, 1988). But the weight of claws in female's remains constant (22% of body weight) as it attains 3-10 cm CW where as the claw in adult males may reach up to 45% of total body weight (Lee, 1992). In general, the growth rate is higher in males than the females, for instance, from 6 to 15 cm males have an average growth rate of 2. 7 cm/month and females of 2.3 cm/month (Le Reste *et al.*, 1976). In contrast, Devi (1985) reported a faster growth rate in female *S. serrata* (10 mm/month) than the male (7 mm/month) from Indian waters.

Robertson (1996) reported that the absence of size classes of crabs in the catches from some estuaries probably indicates that little or no recruitment occurred in these estuaries in some years. Hill (1975) also deduced that recruitment of *S serrata* into the Kowie estuary was good in some years and poor in others.

2.02.3 Length - weight relationship: The length-weight relationship of fish has often been studied to yield biological information (Rao, 1987) and the determination of a precise mathematical relationship between length and weight of fish/invertebrate has numerous applications in fishery biology. With the help of the derived equation, one measure can be converted into the other (Jhingran, 1968).

The length-weight data is also used in estimating many other population estimates such as population fecundity and biomass. The length-weight relationship can provide information on the condition of fish or invertebrate (Jennings *et al.*, 2001). The weight of an animal increases in relation to the increase in volume and so the relationship between length (L) and weight (W) can be expressed using a power function of the form: $W= aL^b$. The value of a is widely used as an index of the animal condition, such as an animal with a higher value of *a* is heavier for its length which is calculated as: a=W/L^{b} (Jennings *et al.*, 2001). A number of indices, called condition factors are based on this relationship.

Information on the carapace width (CW) and body weight (W) relationship in *S. serrata* is scanty. In Asia, Prasad and Neelakantan, (1988), George *et al.*, (1986), Devi, (1985), Cheewasedtham, 1990 reported the length-carapace width relationship in *S. serrata* from different geographic regions.

Cheewasedtham (1990) reported that the relationship between CW (mm) and W (g) as 0.097131L$^{3.369}$ and 0.559879 L$^{2.559}$ for males and female respectively from Thailand. In Bangladesh, Khan and Alam (1992) reported the relationship as 0.00158L$^{2.62}$ for male and 0.00071L2.73 for female mud crab from Bangladesh coast.

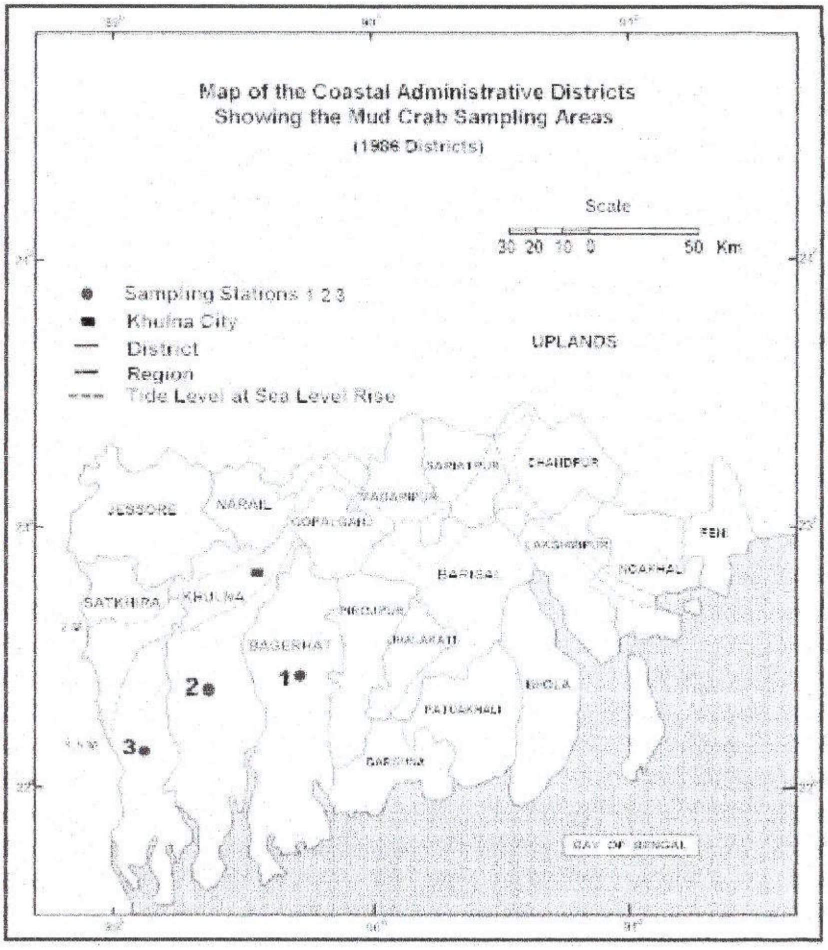
2.03 Materials and Methods:

2.03.1 Location of study area: Mud crab (*Scylla serrata*) samples were collected from 2 locations in the SW region, namely Vaga of Bagerhat and Munshigonj of Satkhira districts (Map - 1). Vaga and Munshigonj are approximately 40 and 150 km from Khulna district headquaters respectively. Vaga of Bagerhat and Munshigong of Satkhira are located in the low and high saline zone of the Sundarban mangrove forest respectively (Karim, 1994).

2.03.2 Sample collection: Male and female specimens of *Scylla serrata* were collected randomly from the Sundarbans mangrove swamps at 2 different localities Vaga of Bagerhat and Munshigong of Satkhira districts using baited long line (Don) in live condition at monthly interval between January and December 2001. Collected samples were transported in jute bags and carried by bus to the Laboratory of Fisheries and Marine Resource Technology (FMRT) Discipline of Khulna University and kept in deep freeze at –18°C prior to analysis.

2.03.3 Sample preparation: Preserved samples were dissected usually within 24 hours and the period between freezing and dissection never exceeded 3 days. Frozen specimens were defrosted at room temperature and the excess water; and dart were removed by using blotting paper.

2.03.4 Laboratory analysis: The external carapace width (ECW) of the individual crabs was measured (between tips of ninth antero lateral spines) by using a verneer calipers nearest to 1 mm. The total body weight of individual crabs was taken by using a single pan balance nearest to 0.1g. The sex of individuals was determined on the basis of eye observation. Crabs with widen abdomen were identified as female and specimen with narrow abdomen were considered as male (Knuckey, 1996).



Map-1. Location of mud crab sampling stations in the SW region of Bangladesh.

2.03.5 Size frequency distribution: The males and females were separated and grouped into different size classes at 10 mm interval. Monthly size-frequency distribution was estimated by plotting the frequencies of male and female crabs separately against their corresponding size-class for different months. While the size frequency distribution by size of males and females was estimated by plotting frequencies against corresponding size class for male and female respectively.

2.03.6 Sex ratio: Sex ratio is the ratio of the males to females of a given population. It was estimated by the formula:

$$SR = \frac{\text{No. of female crab}}{\text{No. of male crab}} \quad \text{(King, 1997).}$$

Sex ratio was estimated in two ways. Firstly number of male and female in percentage was plotted against months. Secondly numbers of male and female was plotted against size group.

2.03.7 Length-weight relationship: The length-weight relationship in *S. serrata* was estimated by the following relationship (LeCren, 1951):

$$W = aL^{n} \text{ ---------------------- } \quad (I)$$

Where, a = a constant or intercept; n = an exponent or slope.

The exponential form of relationship in formula (I) can be expressed in the logarithmic from:

$$\text{Log } W = \text{Log } a + n \log \text{ ----- } \quad (II)$$

This formula has been followed in the present study. The values of 'a' and 'n' were calculated for length-weight relationship using the log-log relationship in formula (II). In the present experiment, external carapace width (ECW) is regarded as length (L).

The values of log 'a' and 'n' in formula (II) were calculated by using the following mathematical relationship (Lagler, 1956).

$$\text{Log a} = \frac{\sum \text{Logw.} \sum (\text{Log L})^2 - \sum \text{LogL.} \sum (\text{LogL. LogW})}{N\sum (\text{LogL})^2 - (\sum \text{LogL})^2}$$

and $$n = \frac{\sum \text{Logw} - (\text{N.Loga})}{\sum \text{LogL}};$$

Where, W = body weight in gram (g);

L = length (mm) i.e. external carapace width (ECW) in mm;

N = sample size.

In calculating the co-efficient of regression for y (=W) on x (= ECW), the least square method was followed and the co-efficient of correlation 'r' was calculated from the formula:

$$r = \frac{\sum xy - \frac{\sum x. \sum y}{N}}{[\{\sum x^2 - \frac{(x)2}{N}\} \{\sum y^2 - \frac{(\sum y)2}{N}]^{1/2}}$$

The significance of 'r' is tested by 't' test, 't' was calculated by formula

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \text{ with d. f.}$$

Where n = sample number and r =correlation co-efficient

Condition factor: It was estimated by using the following formula:-

$a = (W/L^b)*1000$ (Jennings *et al.*, 2001);

where a = condition factor; W = body weight; L = ECW;

b = power of the length weight equation.

Relative condition factor was calculated by using the following formula:

$K_n = W / W'$

Where,

W = Observed weight in the length weight relationship equation

W′= Calculated weight in the length weight relationship equation

2.04 Result:

2.04.1 Size frequency distribution: A total of 866 male and 697 females between 30 and 140 mm ECW were analyzed in the present study. The frequency distribution of male and female mud crabs in different size class from the SW region is shown in Table: 2.01. The size of male crabs started from 30-40 mm ECW and ended at 130-140 mm ECW with a mode at 80-90 mm. While size of female crabs was found to vary from 30-40 to 110-120 mm CW with a mode at 70-80 mm ECW size class. The maximum frequency in female at 70-80 mm size class was more than two times higher than the frequency of males in the same size class (Fig: 2.01). However, the modal size class in male (80-90 mm) was higher than the female (70-80 mm) size class.

The maximum and minimum size of male crab in SW region was found to be 131mm and 36mm ECW respectively. For female, the maximum ECW value was 115 mm and the minimum was 32mm. In South Western Region, highest frequency of male was found 216 (24.942%) at the 80-90 mm size class and the lowest frequency 2 (0.231%) at 130-140 mm size class. The highest frequency of female was 336 (48.207%) at 70-80 mm size class and the lowest was 1 (0.143%) at 110-120 mm size class (Table: 2.01).

Table: 2.01 The size frequency distribution of *S. serrata* from south western region of Bangladesh..

Size class	Male	Female	Male %	Female %
30-40	3	13	0.346	1.865
40-50	52	3	6.005	0.430
50-60	80	16	9.238	2.296
60-70	107	70	12.356	10.043
70-80	160	336	18.476	48.207
80-90	216	174	24.942	24.964
90-100	155	66	17.898	9.469
100-110	52	18	6.005	2.582
110-120	34	1	3.926	0.143
120-130	5	0	0.577	0
130-140	2	0	0.231	0
Total	866	697	100	100

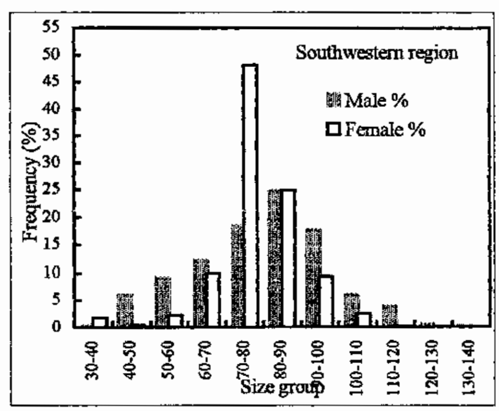


Fig: 2.01 The size frequency distribution of *S. serrata* from south western region of Bangladesh.

The maximum and the minimum size of male in low saline zone (Vaga, Bagerhat) was found to be 130mm and 36mm ECW. In case of female maximum and minimum value of low saline zone was 110 mm and 32 mm ECW. In high saline (Munshigonj, Satkhira) zone for male it was 131mm and 38mm respectively. For female the maximum and the minimum value of ECW was 115 mm and 32 mm respectively. The maximum and the minimum value of the two locations was to be 131 mm (High saline zone, male) and 32 mm (high saline zone female) respectively.

In low saline zone the highest frequency (144, 24.828%) of male was found at 80-90 mm size class and the lowest (02, 0.345%) at 30-40 mm size class. While for female the highest frequency (226, 47.780%) was found at 70-80 mm size class, and the lowest (3, 0.634%) at 40-50 mm size class. Female mud crab was absent above 110 mm size class (Table: 2.02, Fig: 2.02).

In high saline zone the modal frequency for male crabs (72, 25.35%) was recorded at 80-90 mm size class and the lowest (1, 0.55%) at 30-40 mm size class. No male crab was recorded for the 120-130 mm size class.

Table: 2.02 The size frequency distribution of *S. serrata* from low saline zone of Bangladesh.

Size class	Male	Female	Male %	Female %
30-40	2	7	0.344	1.480
40-50	46	3	7.904	0.634
50-60	52	9	8.935	1.903
60-70	62	48	10.653	10.148
70-80	98	226	16.838	47.780
80-90	144	117	24.742	24.736
90-100	105	49	18.041	10.359
100-110	41	14	7.045	2.960
110-120	27	0	4.639	0.000
120-130	5	0	0.859	0.000
Total	582	473	100%	100%

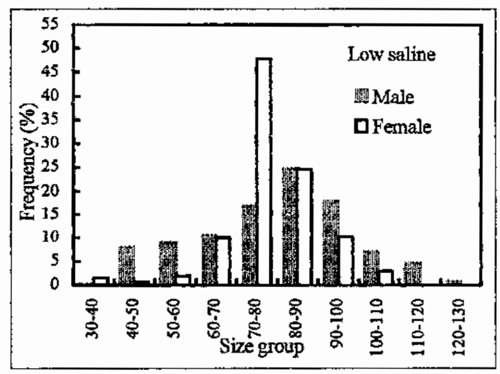


Fig.: 2.02 The size frequency distribution of *S. serrata* from low saline zone (Vaga, Bagerhat) of Bangladesh.

Table: 2.03 The size frequency distribution of *S. serrata* from high saline zone of Bangladesh.

Size class	Male	Female	Male	Female
30-40	1	6	0.35	2.68
40-50	6	0	2.11	0.00
50-60	28	7	9.86	3.13
60-70	45	22	15.85	9.82
70-80	62	110	21.83	49.11
80-90	72	57	25.35	25.45
90-100	50	17	17.61	7.59
100-110	11	4	3.87	1.79
110-120	7	1	2.46	0.45
120-130	0	0	0.00	0.00
130-140	2	0	0.70	0.00
Total	284	224	100%	100%

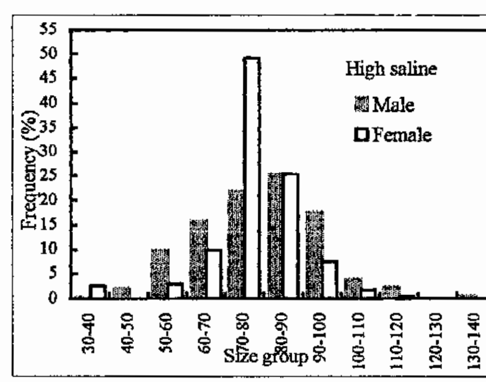


Fig: 2.03 The size frequency distribution of *S. serrata* from high saline zone (Munshigong, Satkhira) of Bangladesh.

The modal frequency (110, 49.103%) for the females was found at 70-80 mm size class. Female mud crab was absent at 40-50mm size class and above 120 size classes (Table:

2.03 & Fig: 2.03). The size of male and female crabs was higher in low saline zone than in high saline zone.

2.04.2 Sex Ratio:

(i) Sex ratio by month: The overall sex ratio in the mud crab from the SW region of Bangladesh was found to be 1: 0.81 (M: F). A higher ratio of male crabs over females was observed throughout the year except in May and December. The highest and the lowest sex ratio was found in the month of May (1.561) and July (0.408) respectively (Table: 2.04 and Fig: 2.04).

Table: 2.04 Sex ratio by month of *S. serrata* from Southwestern region of Bangladesh.

Month	Male	Male (%)	Female	Female (%)	Sex ratio
J	58	53.21	51	46.79	0.879
F	65	55.56	52	44.44	0.800
M	69	52.67	62	47.33	0.899
A	66	54.10	56	45.90	0.848
M	66	39.05	103	60.95	1.561
J	92	59.74	62	40.26	0.674
J	125	71.02	51	28.98	0.408
A	69	61.61	43	38.39	0.623
S	70	61.40	44	38.60	0.629
O	92	52.87	82	47.13	0.891
N	61	53.51	53	46.49	0.869
D	33	46.48	38	53.52	1.152
Total	866		697		1:0.81

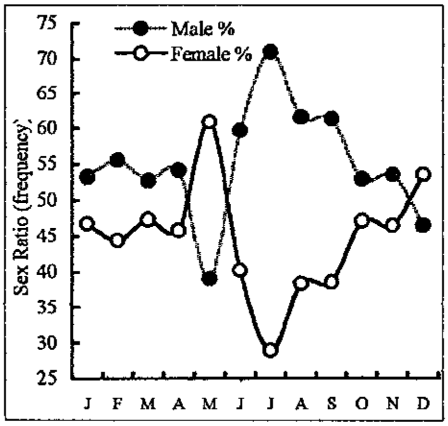


Fig: 2.04 Sex ratio by month of *S. serrata* from Southwestern region of Bangladesh.

Table: 2.05 Sex ratio by month of *S. serrata* from low saline zone of South western region of Bangladesh.

Month	Male	Male (%)	Female	Female (%)	Sex ratio
J	39	50.65	38	49.35	0.974
F	35	53.03	31	46.97	0.886
M	49	55.68	39	44.32	0.796
A	44	55.70	35	44.30	0.795
M	33	35.87	59	64.13	1.788
J	64	54.70	53	45.30	0.828
J	107	74.83	36	25.17	0.336
A	45	59.21	31	40.79	0.689
S	49	60.49	32	39.51	0.653
O	56	53.33	49	46.67	0.875
N	39	49.37	40	50.63	1.026
D	22	42.31	30	57.69	1.364
Total	582		473		1:0.81

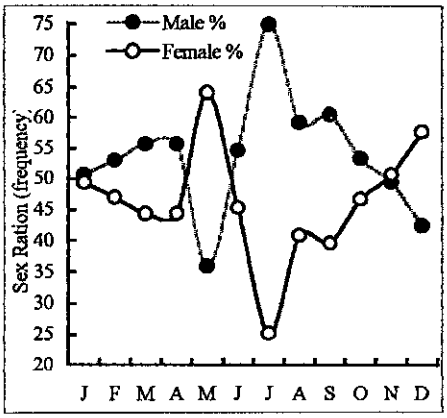


Fig: 2.05 Sex ratio by month of *S. serrata* from low saline zone of South western region of Bangladesh.

Table: 2.06 Sex ratio by month of *S. serrata* from high saline zone of South western region of Bangladesh.

Month	Male	Male (%)	Female	Female (%)	Sex ratio
J	19	59.38	13	40.63	0.684
F	30	58.82	21	41.18	0.700
M	20	46.51	23	53.49	1.150
A	22	51.16	21	48.84	0.955
M	33	42.86	44	57.14	1.333
J	28	75.68	9	24.32	0.321
J	18	54.55	15	45.45	0.833
A	24	66.67	12	33.33	0.500
S	21	63.64	12	36.36	0.571
O	36	52.17	33	47.83	0.917
N	22	62.86	13	37.14	0.591
D	11	57.89	8	42.11	0.727
Total	284		224		1:0.79

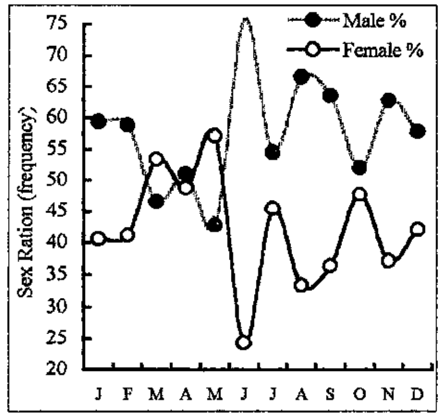


Fig: 2.06 Sex ratio by month of *S. serrata* from high saline zone of South western region of Bangladesh.

Table: 2.07 Sex ratio by size of *S. serrata* from Southwestern region of Bangladesh.

Size class	Male	Male (%)	Female	Female (%)	Sex ratio
30-40	3	18.75	13	81.25	4.333
40-50	52	94.55	3	5.45	0.058
50-60	80	83.33	16	16.67	0.200
60-70	107	60.45	70	39.55	0.654
70-80	160	32.26	336	67.74	2.100
80-90	216	55.38	174	44.62	0.806
90-100	155	70.14	66	29.86	0.426
100-110	52	74.29	18	25.71	0.346
110-120	34	97.14	1	2.86	0.029
120-130	5	0.00	0	0.00	0.000
130-140	2	100.00	0	0.00	0.000
Total	866		697		0.81

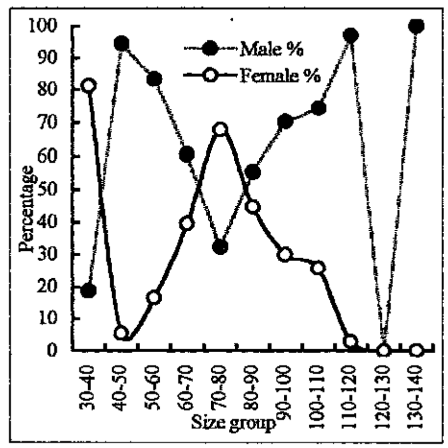


Fig: 2.07 Sex ratio by size of *S. serrata* from Southwestern region of Bangladesh.

The sex ratio of *S. serrata* in low saline zone was estimated to be 1:0.81 (M: F). The higher ratio of male crabs over females was observed throughout the year except in May and December (Table: 2.05). While it was 1:0.79 in the high saline zone. The ration of male crabs was higher throughout the year in the high saline zone except in March and May (Table: 2.06).

(ii) Sex ratio by size: In SW Region the frequency of male crab was higher between 50-60 mm and 110-120 mm size classes while female crab was dominated between 60-70 and 90-100 mm size classes (Table: 2.07). According to the size class distribution, the ratio of males was dominated throughout the entire size class except the 30-40 mm and 70-80 mm where the number of females was higher than the males (Table: 2.07). The ratio of male was found to be highest at 110-120 mm size class (Table-2.7). The ratio of males was found to be increased from 80-90 mm to 130-140 mm size classes (Table: 2.07).

Table: 2.08 Sex ratio by size of *S. serrata* from low saline zone from South western region of Bangladesh.

Size class	Male	Male (%)	Female	Female (%)	Sex ratio
30-40	2	22.22	7	77.78	3.500
40-50	46	93.88	3	6.12	0.065
50-60	52	85.25	9	14.75	0.173
60-70	62	56.36	48	43.64	0.774
70-80	98	30.25	226	69.75	2.306
80-90	144	55.17	117	44.83	0.813
90-100	105	68.18	49	31.82	0.467
100-110	41	74.55	14	25.45	0.341
110-120	27	100.00	0	0.00	0.000
120-130	5	100.00	0	0.00	0.000
Total	582		473		0.812

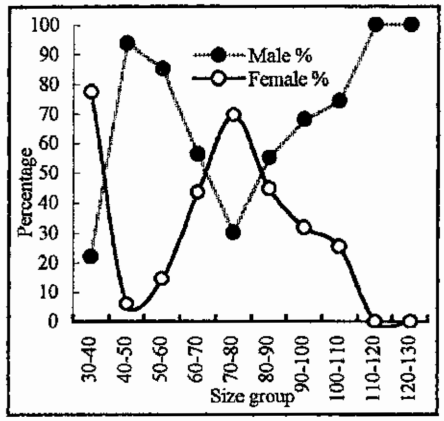


Fig: 2.08 Sex ratio by size of *S. serrata* from low saline zone from Southwestern region of Bangladesh.

Table: 2.09 Sex ratio by size of *S. serrata* from high saline zone from Southwestern region of Bangladesh.

Size class	Male	Male (%)	Female	Female (%)	Sex ratio
30-40	1	14.29	6	85.71	6.00
40-50	6	100.00	0	0.00	0.00
50-60	28	80.00	7	20.00	0.25
60-70	45	67.16	22	32.84	0.49
70-80	62	36.05	110	63.95	1.77
80-90	72	55.81	57	44.19	0.79
90-100	50	74.63	17	25.37	0.34
100-110	11	73.33	4	26.67	0.36
110-120	7	87.50	1	12.50	0.14
120-130	0	0.00	0	0.00	0.00
130-140	2	100.00	0	0.00	0.00
Total	284		224		0.79

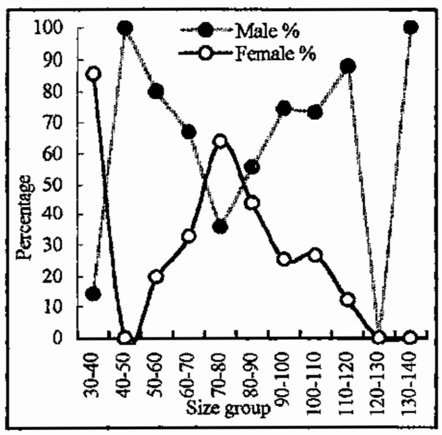


Fig: 2.09 Sex ratio by size of *S. serrata* from high saline zone from SW Region of Bangladesh.

In low saline zone, according to size class distribution the ratio of males was dominated over females in all size classes except the 30-40 and 70-80 mm size classes (Table: 2.8 and Fig: 2.08). The mode (72) for male was found at size class of 80-90 mm. (Table: 2.09), while the modal frequency for female was recorded at 70-80 mm size class.

In high saline zone the number of male crab was higher between 50-60 mm size class and 100-110 mm size class while female crab was dominated between 60-70 and 90-100 mm size classes (Table: 2.09). According to size class distribution, the ratio of males was dominated through the size class except 70-80 mm where the number of females was dominating over the males (Table: 2.09). The ratio of male was found highest at 110-120 mm size class (Table: 2.09). The ratio of males was found to be steadily increased from 90-100 mm to 130-140 mm size classes (Table: 2.07). The sex ratio of male to female by size class was found to be homogenously distributed i.e.1:1 ratio in both the low and high saline zones at 5% level of significance.

2.04.3 Length-weight relationship: The external carapace width (ECW) and wet body weight relationship was estimated for 866 male and 697 female crabs separately as well as combined. The relationships for male and female crabs collected from the two locations (low saline and high saline) were as follows.

In low saline zone:

Male $W = 0.6775\ L^{1.7903}$ $(r = 0.89; n = 582)$

Female $W = 1.1787\ L^{0.8622}$ $(r = 0.96; n = 473)$

In high saline zone:

Male $W = 0.3322\ L^{2.7998}$ $(r = 0.87; n = 284)$

Female $W = 0.5438\ L^{2.0196}$ $(r = 0.86; n = 224)$

In SW region:

Male $W = 0.3327\ L^{2.7877}$ $(r = 0.89; n = 866)$

Female $W = 1.1138\ L^{1.3104}$ $(r = 0.89; n = 697)$

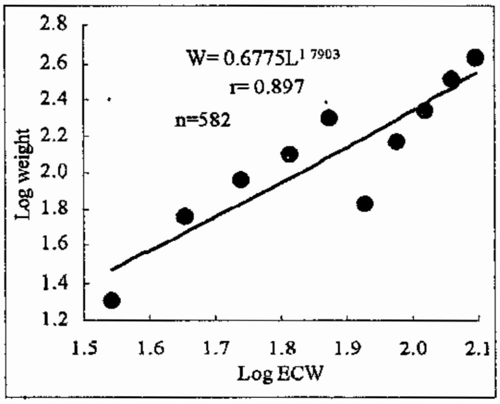


Fig: 2.10 Relationship between ECW and BW in male of *S. serrata* in low saline zone.

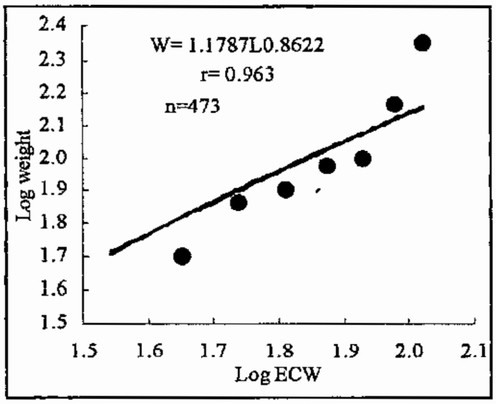


Fig: 2.11 Relationship between ECW and BW in female of *S. serrata* in low saline zone.

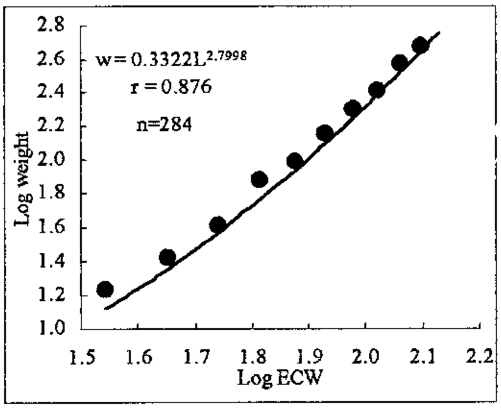


Fig: 2.12 Relationship between ECW and BW in male of *S. serrata* in high saline zone.

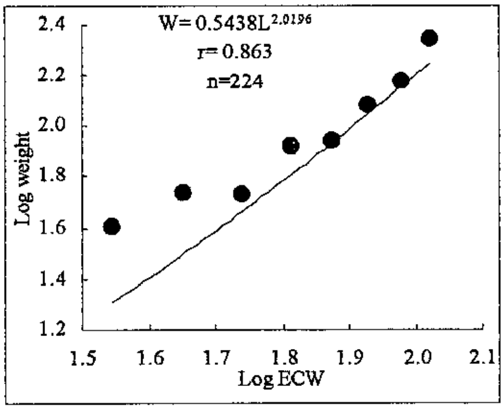


Fig: 2.13 Relationship between ECW and BW in female of *S. serrata* in high saline zone.

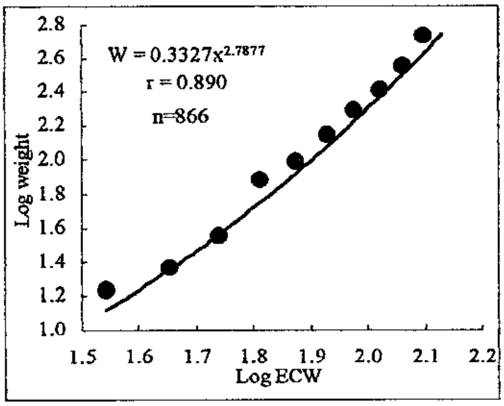


Fig: 2.14 Relationship between ECW and BW in male of *S. serrata* in SW region.

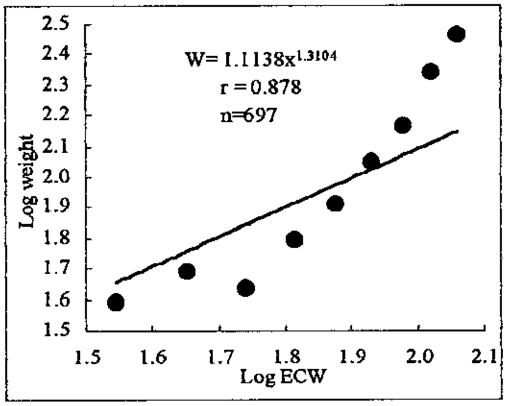


Fig: 2.15 Relationship between ECW and BW in female of *S. serrata* in SW region.

The combined ECW-weight relationship for male and female was estimated as follows

In low saline zone:

$$W = 0.6775L^{1.7903} \qquad (r = 0.85; n = 1055)$$

In high saline zone:

$$W = 0.9962\, L^{1.144} \qquad (r = 0.97; n = 508)$$

In SW region:

$$W = 1.2491\, L^{1.467} \qquad (r = 0.94; n = 1563)$$

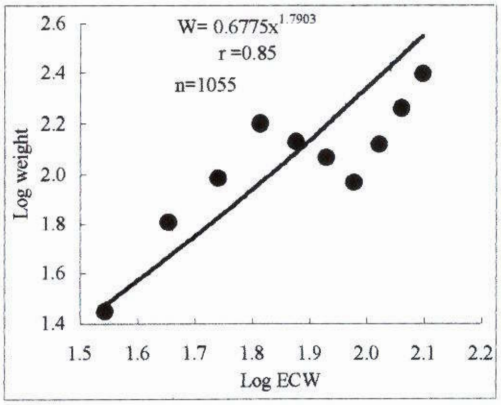


Fig: 2.16 Relationship between ECW and BW in combined sex of *S. serrata* in low saline zone.

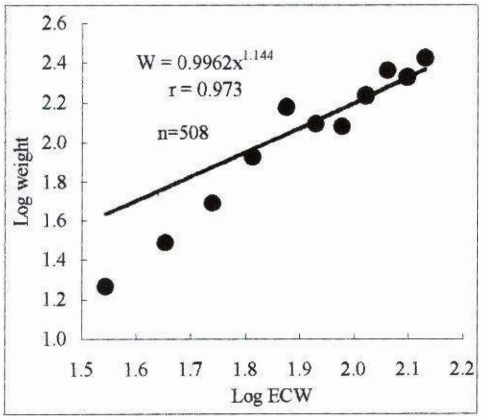


Fig: 2.17 Relationship between ECW and BW in combined sex of *S. serrata* in high saline zone.

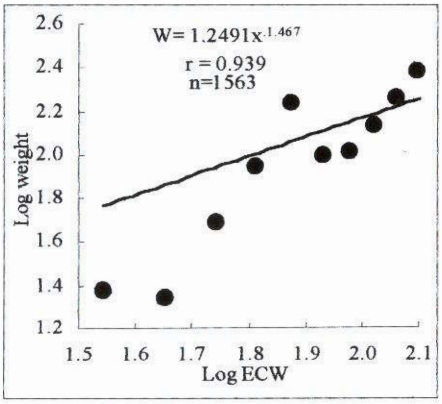


Fig: 2.18 Relationship between ECW and BW in combined sex of *S. serrata* in SW Region.

2.04.4 Relative condition factor: The relative condition factor was estimated sex wise and combined from the average weight of several specimens in 10mm size class. The results are presented in Fig- 2.19, 2.20 and 2.21. The relative condition factor was found to fluctuate by size class in both sexes. In low saline zone, the K_n values for male and female crabs were found to vary from 0.4535 to 1.7305 and 0.87 to 1.9 respectively. In high saline zone, the K_n values for male and female crabs were in range from 0.891 to 1.6 and 0.944 to 1.704 respectively. When the regional data were pooled together, the K_n values for male and female crabs were found to vary from 0.887 to 1.687 and 0.93 to 1.594 respectively. For low saline zone males, the first peak in K_n value was at 70-80 size class and the second peak at 120-130 mm size class.

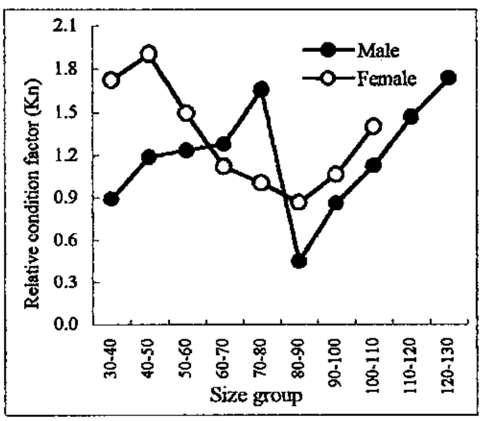


Fig: 2.19 Relative condition factor (K_n) of male and female *S. serrata* in relation to size class in low saline zone.

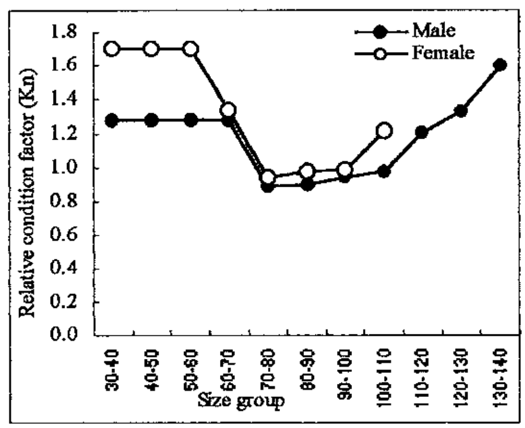


Fig: 2.20 Relative condition factor (K_n) of male and female *S. serrata* in relation to size class in high saline zone.

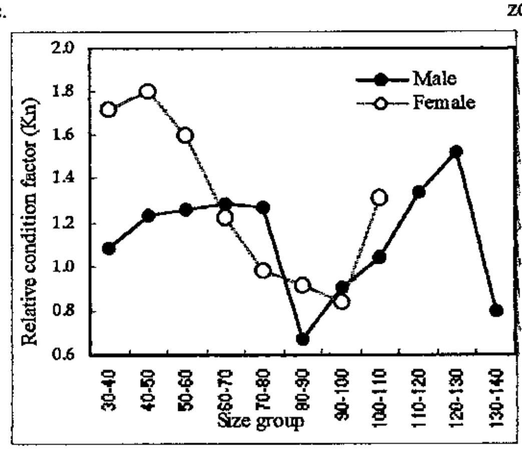


Fig: 2.21: Relative condition factor (K_n) of male and female *S. serrata* in relation to size class in SW Region.

size class and for females, peaks were found to be at 40-50 and at 100-110 size classes. In high saline zone, the highest value was at 130-140-size class for themale while the high values for the female was found at early size classes (30-40 to 60-70). The K_n values in SW region were found to increase after 70-80 size class for both sexes. The peak K_n was found at 130-140 size class for the males and for females it was at 110-120 size class for the females.

2.05 Discussion:

2.05.1 Size frequency distribution: The size of mud crabs caught by the baited line was varied from 30-40 mm to 130-140 mm for males and 30-40 mm to 110-120 mm for females in the SW region of Bangladesh (Fig: 2.01). Mud crabs of 70-80 mm and 80-90 mm size class were fished maximum among female and male population respectively. In low saline zone mud crab size varied from 30-40 mm to 120-130 mm size class for male and 30-40 mm to 100-110 mm size class for female (Fig: 2.02). In high saline zone the range was from 30-40 to 130-140 mm and 30-40 to 110-120 mm size class for male and female respectively (Fig: 2.03). So from the result it can be concluded that in high saline zone, larger crabs are found. The results obtained in the present study indicated that the largest size class in SW Region for male was 80-90 mm (24.942%) ECW and for female the size class was 70-80 mm (48.207%) ECW (Table: 2.01). This result indicate that female mud crabs of 70-80 mm size classes are highest in the population or easily attracted to the baited traps. Crabs from high saline zone were in higher size range than the crabs caught from low saline zone both for male and female population. This may be attributed to huge fishing pressure on mud crab population in the lower saline zone.

Khan and Alam (1992) found that the largest size of crab was 143-145 mm for male and the lowest was 81-85 mm for female in the commercial catches. In the present study the modal class for male and female was 70-80 mm and 80-90 mm respectively. According to Jayamanne (1991), the maximum size of *S. serrata* ranged from 190 mm to 280 mm ECW. The least exploited population size was > 130mm. In the present study 96% of exploited male and 99% of exploited female population was lower than 110 mm ECW. Approximately 50% of harvested female crabs were within 70-80 mm size class while 18.476 % males were within 70-80 mm size class. This result may be due to difference in species of the mud crab stocks in the Sundarbans.

The largest size in low saline and high saline zone was 70-80 mm size class for female and 80-90 mm size class for male which almost agrees with Poovachiranon (1991). The highest exploitation rate of present study has an agreement with the results of Poovachiranon (1992). According to Kathirvel and Srinivasagam (1992), the overall size range (ECW) for the species was 72-205 mm in the inshore sea and 15 to 217 mm in the estuarine areas.

About 17% males were <60 mm ECW in the low saline zone while only 12% males were caught below 60 mm ECW in the high saline zone. Robertson (1996) stated that the size distributions of the catches varied considerably among estuaries. In the present study comparatively smaller size crabs were caught from the low saline zone than the high saline zone. In the present study about 55% of the catches was male in the SW region. Thereby, the size frequency distribution in the present investigation might vary with respect to locations.

2.05.2 Sex ratio:

Sex ratio i.e. ratio between male and female indicates the proportional abundance by sex of the species. Cheewasedtham (1990) stated that the information on sex ratio is important in the interpretation of the population structure and reproductive performance in crustaceans. The ratio embodies the variation in season and size. Quinn and Kojis (1987) reported a variation in sex ratio of *S. serrata* by size and season.

2.05.2(a) Sex ratio by month: The sex ratio in the catch differs to a considerable extent between seasons. Crab abundance appeared to be poor in winter i.e. Sep-January (Khan and Alam, 1992). In the present study, the sex ratio was found to vary with months. The maximum sex ratio *i.e.* dominated females over male population in SW Region (1:1.56), low saline zone (1:1.79) and high saline zone (1:1.33) was found in May whilst the minimum ratio *i.e.* dominated males over female population was found in SW region (1:0.4) in June, low saline zone (1:0.34) and high saline zone (1:0.32) in July (Table: 2.4, 2.5 and 2.6). This result may be attributed as May-July are months of reproductive activities.

Khan and Alam (1992) reported that the catch included 50-55% females during rainy season (April-July) whereas 55-60% of the catch during winter (Sep-January) was male. Poovachiranon (1991) reported that female crab belonging to the size class over 11cm decreased from October–February. The percentage of 9-11 cm animals fluctuated between

42-69%, with the maximum of males being in June and females in November. The minimum catch was in December for the males and in May for the females.
In the SW region the highest male percentage was in the month of July (71.02%), August (61.61%) and September (61.40%). Females dominate in the month of May (60.95%), December (53.52%) and March (47.33%) (Table: 2.4). In low saline zone males dominate in the month of July (74.83%), September (60.49%) and August (59.21%). Again female was found to be highest in May (64.13%), December (57.69%) and November (50.63%) (Table: 2.5). In high saline zone 75.68% (June), 66.67% (July), 63.64% (August) was found in case of male and 57.14% (May), 53.49% (March), 48.84% (April) for female (Table: 2.6). So from the present study June, July, August and September were the peak season for the males and March, April, May, November and December were the peak season for the females. Robertson (1991) reported that the higher percentage of male in the catches constituted 73% (October) and 67% (December) at Mhlanga and 56% of both months' samples at Msimbazi, South Africa.

In the present investigation, male mud crab dominate over males (Fig: 2.7) in most of the months in the SW region. Females dominated over male in May and December (Fig: 2.5) in low saline zone and zone in March and May (Fig: 2.6) in high saline. However the males and female were homogenously distributed at 5% level of significance in the both low and high saline zones.

2.05.2(b) ***Sex ratio by size:*** The highest sex ratio (M: F) was found at 30-40 mm size class in SW region (1:4.33), low saline (1:3.5) and high saline (1:6) zones. It is clear from Table: 2.7 that a comparatively higher ratio of females than males was recorded in smaller size groups.

Poovachiranon (1992) reported the maximum sex ratio in 1:1.29 at 110-130 mm size class whilst the lowest ratio at 1:0.52 in above 130 mm size class. Females with 70-80 mm size class dominated over the males while males dominated over females in all other size classes in the low and high saline zones (Fig: 2.7, 2.8 & 2.9). It means 70-80 mm size class for female in the SW region is the most vulnerable size for harvesting.

Sex ratio was found to vary geographical locations in the present study. Similar results have been reported from Netravati estuary (Ram and Chandramohan, 1978), Cochin backwaters (Kathrivel, 1981), Killai backwaters (Srinivasagam, 1975), Pulicat Lake (Srinivasagam and Raman. 1985) and the inshore and estuarine areas of the Kakinada region (Lalithadevi, 1985) where females dominated over males. While males occurred in greater numbers in the inshore and mud flat areas of Tuticorin (Shanmugam and Bensam, 1980) and Chilika Lake (Mohanty, 1975). Males were dominant in both the low saline and high saline zones in the SW region of Bangladesh.

2.05.3 Length weight relationship:

The ECW-body weight relationship in of male and female *S. serrata* in low saline, high saline and SW region were plotted against their corresponding weight on logarithmic scales and are presented in Figure:2.10 through 2.15.

Figure: 2.14 showed a smooth growth curve for male and an irregular straight line for female crabs in SW region (Fig: 2.15). While the logarithmic relationships between ECW and W in combined sex of *S. serrata* was a straight line (fig: 2.18). In low saline zone the line was slightly curved (Fig: 2.16) and in high saline zone it was straight and regular (Fig: 2.17).

Cheewasedtham (1990) reported that the relationship between CW (mm) and W (g) was $0.097131L^{3.369}$ and $0.559879\ L^{2.559}$ for males and females respectively. According to Poovachiranon (1992), the ECW-weight relationship was $0.0423L^{3.726}$ and $0.3357L^{2.726}$ for males and females respectively from Thailand. Khan and Alam (1991) estimated the relationship between CW and weight for males and females separately as well as combined. The combined relationship was reported at $0.00033L^{2.92}$ for males it was $0.00158\ L^{2.62}$ and for females it was $0.00071\ L^{2.73}$ (Khan and Alam, 1991)

The relationship for male in the present study agrees well with the relationship estimated by Khan and Alam (1991) except for the low saline zone. For female in low saline and SW Region, there was no distinct agreement whilst the relationship for high saline zone was in agreement with Poovachiranon (1992) and Khan and Alam (1991). There was no significant agreement for combine relationship. The variation is to be attributed due to variation in salinity. In high saline zone, the relationship agrees with others. But in low saline zone it does not agree.

Khan and Alam (1991) reported the co-efficient of correlation (r) between the measurements at 0.67, 0.96 and 0.84 for male, female and combined sex respectively. The value of 'r' for male and female were 0.97 and 0.97 respectively (Poovachiranon, 1992). In the present study, the 'r'-value for male in high saline zone (0.87) and SW Region (0.89) were in agreement with Poovachiranon (1992). For female *S. serrata* in high saline zone (0.86), the co-efficient of correlation agrees with Khan and Alam (1991). Except high saline zone and SW Region, the r-value for combined sex in low saline zone is in agreement with Khan and Alam (1991). However, there is overall positive correlation lies between length (ECW) and body weight for both sexes ($r = 0.94$)

In low saline zone, the correlation between (ECW) and body weight was significant for male and insignificant for female at 5% level. The correlation between combined length and weight in low saline zone was significant (Appendix: 13). While, in high saline zone, highly significant correlation ($r = 0.97$) between length and weight was found for female and insignificant for male. Moreover, it was not significant for combined ECW and body weight. The 't' test indicates the significant coefficient of correlation between ECW and body weight for female in SW Region whereas an insignificant correlation was found for combined sexes (Appendix: 13).

The discrepancies among the relationship of male and female could be due to sexual variation, salinity and other environmental factors. The variation in the value of 'n' between the present investigation and the reports from overseas may be due to geographical location.

In low saline zone the slope in the regression for females is slightly lower than males. Figure: 2.22 shows better growth performance of male than female crabs in low saline zone.

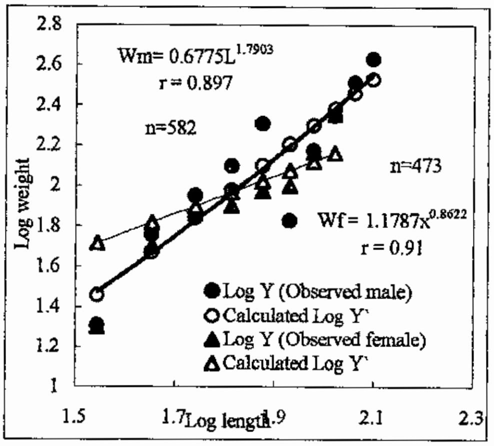


Fig: 2.22 Relationship between L and W of *S. serrata* in low saline zone.

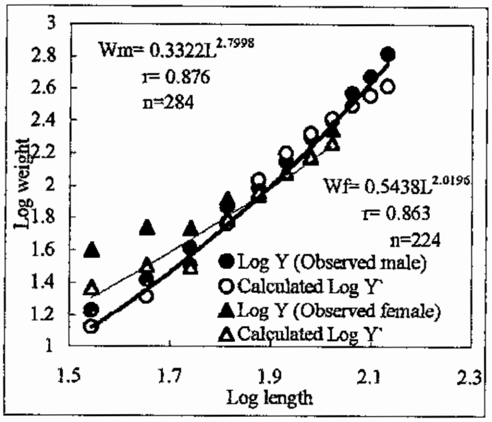


Fig: 2.23 Relationship between L and W of *S. serrata* in high saline zone.

In high saline zone both the male and female growth line showed very close relation (Fig: 2.23). But the males, growth line was higher than the females. In SW, region male and female growth curve showed clear deviation. Male growth line was higher than the females. Therefore, it may be concluded that the growth performance of male were relatively better than female in SW region.

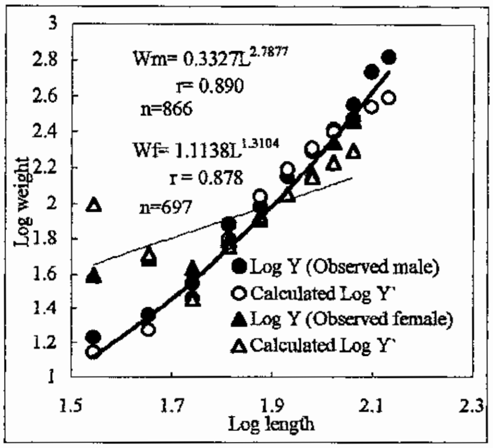


Fig: 2.24 Relationship between L and W of *S. serrata* in SW region of Bangladesh.

Significant variation of growth performance in male and female was seen geographically (in low and high saline zone) at 5% level of significance. Statistically significant variation was also found in growth performance in male and female crabs in SW region of Bangladesh.

Table: 2.10 One way ANNOVA for length-weight according to geographical variation.

Source of variation	df	F value	F critic
Low saline	1079	79.781126	3.85009
High saline	1015	176.87866	3.8506442
SW region	3019	428.79552	3.8444341

2.05.4 Relative condition factor: The present study indicated that the crab at size class of 80-90 for male, female and combined sex were in poor condition. In high saline zone, the K_n values fall drastically after 50-60 size class up to 80-90 size class. The point of inflexion on a curve showing the inflexion in K_n values is a good indicator of the length at which sexual maturity attained. The inflexion point in the present investigation (Fig: 2.21) implies that males and females may attain sexual maturity at 60-70 mm size class.

The variation in K_n values in different locations may be due to size, different maturity stages, sex, partial spawning, food and feeding. In high saline zone male and female become mature early than low saline zone as the higher K_n values were recorded for male and female crabs. The condition of female crabs varied little in comparison with the males. In the present study the variation may be due to salinity, sex and spawning periodicity.

Table: 2.11 One way ANOVA of relative condition factor according to geographical and sexual variation.

Source of variation	*df*	*F*	*F crit*
Low & high saline male	21	0.005926	4.3807518
Low & high saline female	16	0.0002353	4.6001105
Low & high saline zone	21	0.32316	4.380752
SW Male/Female	20	0.8048314	4.4138631

From the above Table: 2.11 we can conclude that there is no significant variation in relative condition between mud crabs (male and female) in low and high saline zones. Variation does not exists K_n values between male and female mud crab in the SW region at 5% level of significance. Therefore, it may be concluded that the condition of mud crabs does not vary in respect to sex and geographical locations in the SW region of Bangladesh.

2.06 Conclusion:

The modal class of harvesting crabs was found to be 70-80 mm size class female and 80-90 mm for male in SW region. The overall sex ratio of mud crab in the SW region was found to be 1:0.80. A significant positive ECW-weight relationship was found in both sexes in low and high saline zone. However the growth pattern in male and female crabs was different for low and high saline areas. Growth performance of male is faster than female. But the relative condition factor indicates no significant variation of overall condition in male and female in the SW region.

Mud crab is a potential aquatic resource of Bangladesh. Present study investigate some important aspects of biology. But more study is essential to know about the spawning season, migration, recruitment, mortality and natural growth rate in order to device a balance management regime for sustainable use of this potential mud crab resource. Intensive study on various aspects of biology such as life history, feeding habits, age of maturation period and duration of spawning etc. is of crucial importance in any fishery management.

Chapter 3: Some aspects of Nutrition

3.01 Introduction:

The mud crab *Scylla serrata* (Forskal, 1755) is one of the most popular and costly seafood in many countries of the Indo-Pacific region (Motoh, 1979) particularly in the South-East Asian countries (Pripanapong and Tongdee, 1998; Piatek, 1981). Its excellent and distinctive flavor makes it one of the most delicious and costly food item (Thongkum, 1988). The mud crabmeat provides an excellent source of nutrition because of its high protein content. It is served as food boiled, roasted, curried, cold with salad and mayonnaise, hot with black pepper, cracked from their shells or eaten whole just after moulting (Warner, 1977; Nandi and Pramanik, 1994). Crab meat is also considered to possess some medicinal value. It is believe to cure asthma and chronic fevers (Chopra, 1935; Chidambaram and Raman, 1994). *Scylla serrata* occurs abundantly in the shallow low saline coastal waters of Bangladesh (Shafi and Quddus, 1982; Bhuyian and Das, 1976). Bangladesh earns considerable amount of foreign exchange though exporting the animal in live condition (Azam *et al.*, 1998). Information on the nutritive value of *S. serrata* is scanty in Bangladesh. Mannan (1977) and Annon (1980) reported the biochemical composition and mineral content some crabs from Bangladesh along with other fishes. Das et al. (1995) reported the proximate composition of moisture, protein, fat, carbohydrate, ash and the calcium and iron contents in the body and claw meat of two portunid crabs, namely *S. serrata* and *Portunus pelagicus*, from the South-Eastern (SE) coast of Bangladesh. Arshadullah (1976) reported the processing of *S. serrata* from Chittagong, Bangladesh. Reports are also available on *S. serrata* and *P. pelagicus* from coastal waters of India and Pakistan (Srinivasagam, 1979; Qasim et al., 1990; George and Gopakumar, 1987). The present study was conducted to report the proximate composition of moisture, protein, lipid and ash contents in different body parts such as body meat, shell, gill, hepatopancreas and ovary of male and female mud crab from 3 different geographical localities of the South-western (SW) region of Bangladesh.

3.02 Literature review:

The crabs belonging to the families Porunidea, Calappidae and Potamonidae are fished and consumed in all the coastal states in India including West Bengal (Nandi and Pramanik, 1994). The Porunid crab *Scylla serrata* is the most common brackish water food crab of India (Nandi and Pramanik, 1994). Due to eating restrictions based on socio-religious geritage, crabs are not the popular food among the majority of people of Bangladesh. But most of the other crustacean species such as shrimps, prawns and lobsters are highly desirable.

Scylla serrata is one of the popular seafood in many parts of the world particularly in the South-East Asian countries. Its excellent and distinctive flavor makes it one of the most delicious and costly food item all over the world (Azam *et al.*, 1998).

The crab meat provides an excellent source of nutrition because of its high protein content. Crab meat is rich not only in protein but also in other nutritive materials, including minerals. It is served as food boiled, roasted, curried, cold with salad and mayonnaise, hot with black paper, cracked from their shells or eaten whole just after molting. The price of newly moulted soft shell crabs are two folds higher than the hard shell crabs in Thiland, Taiwan, Malayasia. It is difficult, unless one is allergic to them; to avoid being delighted by eating crabs (Warner, 1977).

The crab meat is considered to possess some medicinal value. It is believed to cure asthma and chronic fevers (Chidambarama and Raman, 1994; Chopra, 1935). Glucoronoglycans are useful therapeutically for the treatment of many diseases. Crab meat contains high protein levels with all the essential amino acids recommended by FAO/WHO (1973). The waste material consisting of gills, intestines and shells are good raw materials for the preparation of fish meal and high quality chitin and chitosan (Azam *et al.*, 1998). Chitin content in the outer body shell, inner body shell, claw shell and the leg shell are 18%, 23%, 10% and 14% in dry weight respectively (Nair and Madhavan, 1989). About 5,000 tons of chitin is used in Japan each year for purifying edible water from radioactive and heavy metal pollution. It is also used in industry for manufacturing cosmetics, sanitary materials, surgical threads, dairy products etc (Seenath, 1989).

The only available information on the biochemical composition and mineral contents on the crabs of Bangladesh is by Mannan (1977) and the Institute of Nutrition and Food Science (1980). Nutritive values of the mean of edible marine crabs of India have been studied by Pillai and Nair (1973) and Srinivasagam (1979). Das *et. al.*, (1995) reported the proximate composition in terms of moisture, protein, fat, carbohydrate, ash and the mineral contents of calcium and iron in the body and claw meat of two Portunid crabs collected from the coastal waters of the Bay of Bengal. In general the raw white meat (muscle) contains about 20% protein, 1-2% minerals, little fat and hardly any carbohydrate (Warner 1977). The meat of larger crabs, in general, contains more moisture than those of smaller ones (Srinivasagam, 1979).

Among the three major biochemical components of the embryo of *S. serrata*, protein content is the highest, ranging from 44.8% to 73.4%; followed by lipid content, from 14.7% to 19.0%; and carbohydrate content the lowest, ranging from 1.7% to 3.1%. After embryonic development, protein, lipid and carbohydrate content decreased 39.0%, 17.0%, 7.7%, respectively (Wang *et al.*, 1995).

Mathai and Devi (1993) done Biochemical study on the various vital tissues based on growth and development would yield fruitful data which would facilitate better utilization of *Scylla serrata,* commercially important food item.

Prasad and Neelakantan (1988) reported that the abdominal muscle of juvenile female was rich in almost all the tissue components studied. The chelate leg muscle of adult male was rich in lipid components. Collagen, total GAG and elastin concentrations were maximum in the chelate leg muscle of juvenile female. Muscle meat contains higher protein and lower fat values in 51-80 mm size range. A consistent protein and decreased glycogen and fat content are available in sub-adult and adult crabs (81-130 mm CW). Juveniles and sub-adult mud crabs contain more moisture than in adult crabs. The meat of larger crabs, in general, contained more moisture than those of smaller ones (Srinivasagam, 1979).

It is suggested that protein is the main energy sources for the embryonic development of *S.*

serrata, which may be related to its tropical and subtropical aquatic habitat (Wang *et al.*, 1995). While, the haemolymph free sugar level in both groups decreased as ovarian development increased (Elumalai and Balasubramanian, 1997). Molting, nutritional statute, infection, hypoxia and salinity fluctuations are the major factors affecting the relative proportions and total quantities of haemolymph proteins (Depledge and Bjerregaard, 1989).

A few studies have been conducted on mud crab in Bangladesh. Bhuiyan and Das (1976), Mahmood, (1977), Islam (1977), Shafi and Quddus (1982) reported the taxonomy and distribution of mud crabs form Bangladesh. Ecology of crabs has been studied by Islam and Bhuiyan (1982), bio-economics by Khan and Alam, 1992; seasonal abundance and marketing by Ahmed (1991), processing by Arshadullah (1976). Chantarasri (1994) estimated the production and MSY of *S. serrata* from the Sundarban in 1993. Azam *et al.* (1998) reported the status and potential of *S. serrata* in Bangladesh. Saha *et al.* (2000) studied effect of stocking density on brood stock development of *S. serrata* in brackish water ponds. Kamal (2002) reported the fattening technology for the mud crabs from the SW region of Bangladesh.

3.03 Materials and Methods:

3.03.1 Sample Collection: Male and female specimen of *Scylla serrata* were collected randomly from 2 different localities of the SW region *viz.* Vaga of Bagerhat and Munshigong of Satkhira districts in live condition during summer (March-July) and winter months (October-February) in 2001 by using baited long line (Don). Ecologically Bagerhat, Khulna and Satkhira area are known as low saline, moderate saline and high saline zone respectively (Karim, 1994). Collected samples were transported in jute bags and carried by bus to the Laboratory of Fisheries and Marine Resource Technology (FMRT) Discipline of Khulna University and kept in deep freeze at $-18^{o}C$ prior to further analysis.

3.03.2 Laboratory Analysis: Proximate composition of crude protein, crude lipid, moisture and ash were determined in the Fish Nutrition Laboratory of FMRT Discipline, Khulna University, Bangladesh. Preserved animals (at deep fridge) was chilled at 0°C for 24 hours in a refrigerator. Then the animals were allowed to keep in room temperature for 1-2 hours. Excess water from crab body was removed with blotting paper. Then the total body weight of individual animal was measured by using an electric balance nearest to 0.01 g. Different body parts such as gill, meat, external body shell (carapace), hepatopancreas and ovary were dissected out by using scalpel and hammer. Separated wet body parts (gill, shell, meat, hepatopancreas and ovary) were taken on to aluminium foils. After taking the wet weight, the foils were kept in an oven at 60°C until they dried out completely. After that, the samples were kept in a dessicator until a constant weight was found. The dried samples of gill, shell, meat, hepatopancreas and gonad were preserved in airtight plastic bottles in a fridge at 4°C for further proximate composition analysis. For the proximate composition, three replicates were taken for each sample and all the analysis were carried out following Pearson (1976) and, Katsutoshi and Low (1992).

3.03.3 Moisture: Moisture was determined by keeping previously dried different body parts (gill, meat, shell, hepatopancreas and ovary) of *S. serrata* in a thermostat oven at 105°C for 24 hours. Thereafter samples were kept in dessicator for about one hour. The dry weight of each sample was taken in an electric balance.

3.03.4 Crude protein: Total nitrogen was estimated by following the standard Kjeldahl procedure (Pearson, 1976). Crude protein content was obtained by multiplying the total nitrogen value by the conventional factor 6.25 (Pearson, 1976). The results were reported as per cent (%) of dry weight. About 0.2-0.5 g sample was taken in a Kjeldahl flask and about 2 g resolvent (potassium sulfate and mercuric oxide in the ratio of 10:0.7 preserved in an amber glass bottle) was added into the flask. About 5 ml of concentrated sulfuric acid was added in to the flask slowly. Then the flask was kept on to a digestion chamber until a clear color of the digestion mixture appeared. After digestion, the flask was removed from the digestion plant and kept at room temperature until cooling. After cooling the digestion mixture, 0.5g of sandy zinc and 70 ml distilled water were added to the digested mixture. About 25 ml of 33-40% sodium hydroxide (NaOH) solution (containing 1% potassium sulfide) was poured slowly along the flask's inner wall and washed down the remaining solution on the mouth with a small amount of water. The flask was then connected to the distillation apparatus and turned the switch on. Before connecting the sample containing flask with the distillation plant, 10-20 ml of 2% boric acid was taken in another Erlenmeyer flask (conical flask) and 2-4 drops of Tashiro's indicator was added into it. Then the distillation tube was poured into the Erlenmeyer flask so that the end of the glass tube was immersed in the boric acid solution. Distillation procedure was continued for about 30 minutes to obtain about 30 ml distilled solution. After completion of distillation, the solution was titrated against 0.1 N hydrochloric acid (HCl). The protein percentage found was calculated as dry weight of the sample.

$$\% \text{ Total nitrogen } (\% \text{ N}) = \frac{\text{Ttitrant (ml)} \times \text{Strength of titrant} \times 0.0014}{\text{Weight of sample (g)}} \times 100$$

% Crude protein = % N × 6.25 (Pearson, 1976)

3.03.5 Crude lipid: Crude lipid was estimated by Soxhlet method through extracting a weighed quantity of dried sample with acetone in a Soxhlet fat extractor. About 2-5 g of sample was taken in a thimble paper. The thimble paper was poured in into chamber of the Soxhlet apparatus. Before that about 70 ml of acetone was poured in the round shaped flask and put in the extractor and the switch of the extractor was turned on. After 4-5 hours, lipid on acetone was collected from the extractor and evaporated the acetone by placing the flask on a hot plate. The weight of lipid was taken by using an electrical balance nearest to 0.01 g.

3.03.6 Ash: Ash content was determined by igniting previously dried different body parts of male and female mud crab in a muffle furnace. About 2-5 g-dried samples was taken in a porcelain crucible. The crucible with the dried sample was placed in a Muffle furnace for about 18-20 hours at 550°C. After that the crucible was taken out from the furnace and kept in a dessicator for an hour. The weight of the ash of different body parts in the crucible was taken by an electrical balance nearest to 0.01g.

3.03.7 Carbohydrate: Carbohydrate content was determined by deducting the total of protein, lipid, ash, and moisture from one hundred (Das *et al.*, 1995).

3.04 Result:

3.04.1 Moisture:

The moisture content (as percent) found in different body parts of male and female mud crab from low and high saline zone are shown in Table: 3.01. The highest (84.02%) and the lowest (47.71%) moisture content were recorded in the gill and shell tissue respectively.

Table: 3.01 The mean moisture contents in different body parts of male and female mud crabs from low and high saline zone in 2001 (as % dry weight).

Body parts	Low saline zone			High saline zone			Southwestern region (%)
	Male (%)	Female (%)	Mean (%)	Male (%)	Female (%)	Mean (%)	
Gill	82.31	84.49	83.4	84.37	84.89	84.63	84.02
Shell	36.79	50.64	43.71	45.58	57.82	51.7	47.71
Meat	80.14	78.46	79.3	81.73	78.98	80.35	79.83
HP	66.37	72.09	69.23	68.49	68.34	68.42	68.83
Egg	--	54.15	54.15	--	54.3	54.3	54.23

HP: Hepatopancreas.

3.04.1.1 Gill: The moisture content in the gills of *S. serrata* was varied between 82.31% and 84.89%. The maximum moisture content (84.89%) was found in female from high saline zone and the minimum (82.31%) in male from low saline zone (Table: 3.01). No significant variation in moisture content was found between the two saline zones. However, moisture content was found comparatively higher in females than the males in both salinity zones (Fig: 3.03).

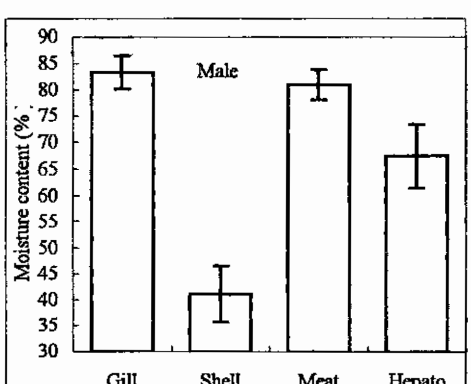


Fig: 3.01 Mean and SD of moisture content in different body parts of male *S. serrata* from the SW region of Bangladesh.

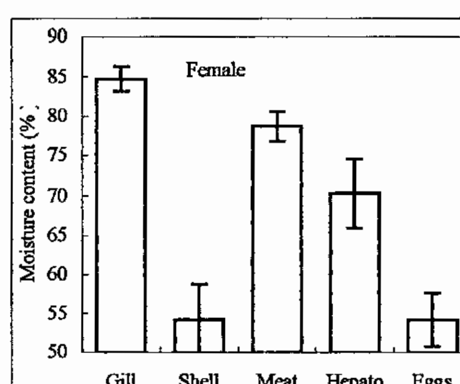


Fig: 3.02 Mean and SD of moisture content in different body parts of female *S. serrata* from the SW region of Bangladesh.

3.04.1.2 Shell: The maximum and the minimum values of moisture were found to be

57.82% and 36.79% in the females from high saline zone and in the males from low saline zone respectively. A significant variation in moisture content was found between sexes being higher in females than the males in both the stations (Table: 3.01). The moisture content in the shells was found to vary geographically being lower in low saline zone (43.71%) and higher (51.7%) in high saline zone. (Fig: 3.04)

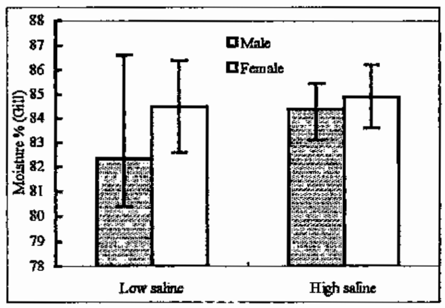


Fig-3.03: Mean and SD of moisture content in gill of *S. serrata* from the SW region of Bangladesh.

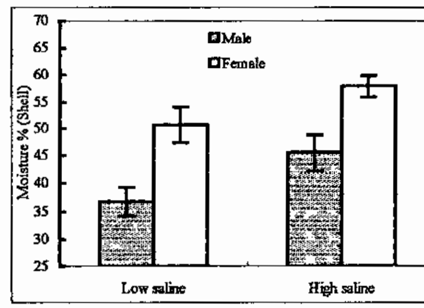


Fig-3.04: Mean and SD of moisture content in shell of *S. serrata* from the SW region of Bangladesh.

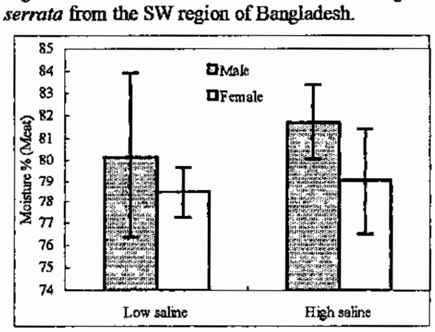


Fig: 3.05 Mean and SD of moisture content in meat of *S. serrata* from the SW region of Bangladesh.

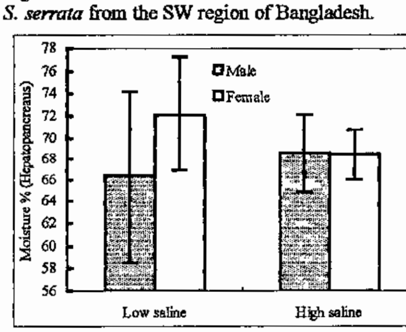


Fig: 3.06 Mean and SD of moisture content in hepatopancreas of *S. serrata* from the SW region of Bangladesh.

3.04.1.3 Meat: The body meat of *S. serrata* contained moisture between 78.46% and 81.73%. The highest (81.73%) and the lowest (78.46) moisture values were recorded in male from high saline zone and female mud crab from low saline zone respectively (Fig: 3.05).

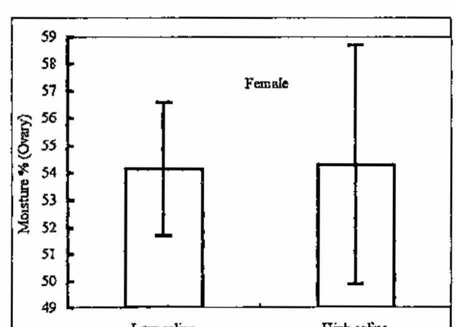


Fig: 3.07 Mean and SD of moisture content in Egg of female *S. serrata* from the SW region of Bangladesh.

No significant variation in moisture content in meat was noticed among geographical locations or between sexes (Table: 3.01). However, mud crabs from low saline zone showed comparatively lower moisture content (79.3%) than the crabs from high saline zone (80.35%).

3.04.1.4 Hepatopancreas: The moisture content in hepatopancreas was found to vary between 66.37% and 72.09%. The maximum and minimum moisture in hepatopancreas of *S. serrata* was recorded in the females (72.09%) and males (66.37%) from low saline zone (Fig: 3.06). No significant spatial or sexual variation in moisture content in hepatopancreas was found in the present investigation (Table: 3.01).

3.04.1.5 Egg: As dissection of male gonad (testis) was difficult, proximate composition of gonad was restricted to the female crabs only. The moisture content of female egg was found to vary between 54.15% and 54.3% (Fig: 3.07). The maximum value was recorded from high saline zone and the minimum from low saline zone (Table: 3.01).

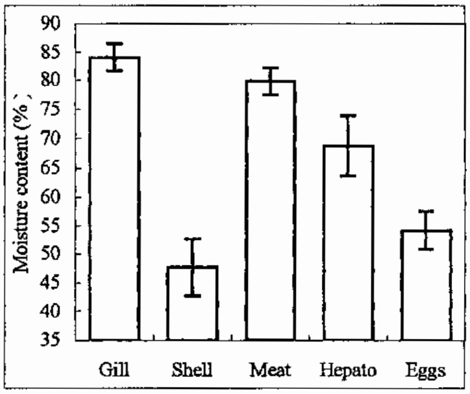


Fig-3.08: Mean and SD of moisture content in different body parts of *S. serrata* from the SW region of Bangladesh.

Among various body parts of *S. serrata*, the maximum (84.02%) moisture content was recorded in gill followed by meat (79.83%), hepatopancreas (68.83%), egg (54.23%) and shell (47.71%) (Fig: 3.08).

3.04.2 Protein:

The mean protein content in different body parts of male and female mud crabs from Bagerhat, Khulna and Satkhira districts are shown in Table: 3.02. the maximum (27.57%) and the minimum (7.86%) protein value were estimated in the egg and shell respectively.

Table: 3.02 Protein contents in different body parts of male and female mud crabs from Bagerhat, Khulna and Satkhira districts in 2001 (as % dry weight).

Body parts	Low saline zone			High saline zone			Southwestern region (%)
	Male (%)	Female (%)	Mean (%)	Male (%)	Female (%)	Mean (%)	
Gill	9.44	8.98	9.21	9.17	9.07	9.12	9.17
Shell	8.55	8.88	8.72	7.49	6.48	6.99	7.86
Meat	16.70	17.52	17.11	14.52	16.65	15.59	16.34
HP	10.73	8.61	9.67	9.4	10.39	9.9	9.78
Egg	--	27.84	27.84	--	27.30	27.30	27.57

HP: Hepatopancreas.

3.04.2.1 Gill: The maximum (9.44%) and the minimum (8.98%) protein content in the gill were recorded in the male and female from low saline zone respectively (Fig: 3.12). A significant variation in protein content in the gill was recorded between male and females. The protein content in gill tissue was higher in males than the females (Table: 3.02). No significant variation in the protein content of gill tissue was observed among the different geographical locations.

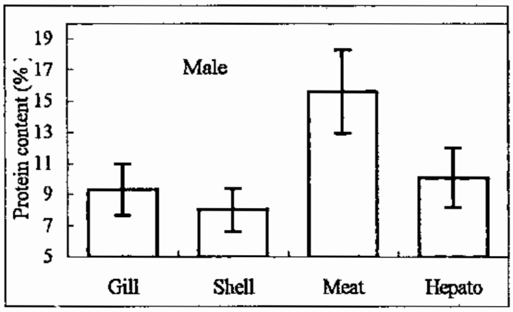


Fig: 3.09 Mean and SD of protein content in different body parts of male *S. serrata* from SW region of Bangladesh in 2001.

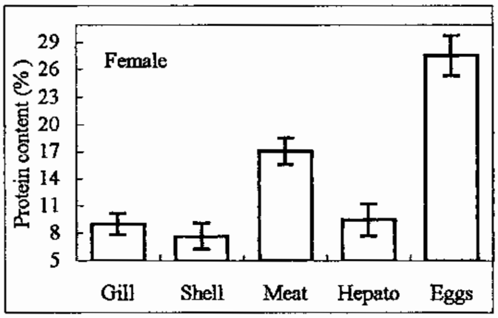


Fig: 3.10 Mean and SD of protein content in different body parts of female *S. serrata* from the SW region of Bangladesh in 2001.

3.04.2.2 Shell: The protein content of the shell (carapace) of mud crab was found to vary between 6.48% and 8.88% in female from high saline zone and female from low saline zone respectively (Fig: 3.13). Low saline zone crabs had significantly higher protein content in their shells than the high saline zone crabs (Table: 3.02).

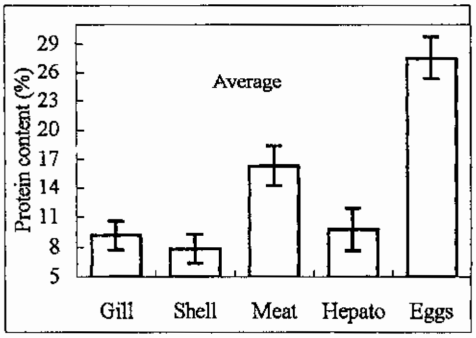


Fig: 3.11 Mean and SD of protein content (%) in *S. serrata* from the SW region of Bangladesh.

No significant variation, however, was observed in protein content among male and female (Table: 2.02).

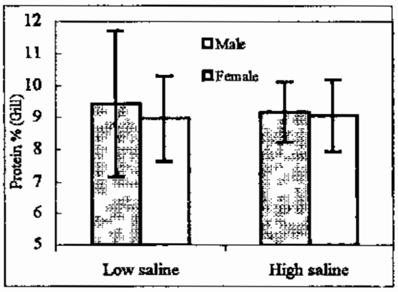


Fig: 3.12 Mean and SD of protein content in gill of *S. serrata* from the SW region of Bangladesh.

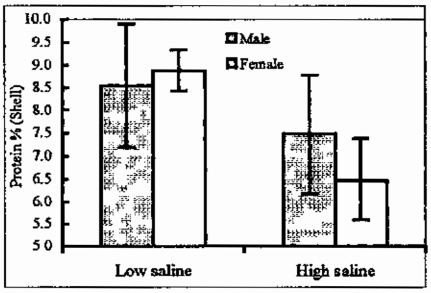


Fig: 3.13 Mean and SD of protein content in shell of *S. serrata* from the SW region of Bangladesh.

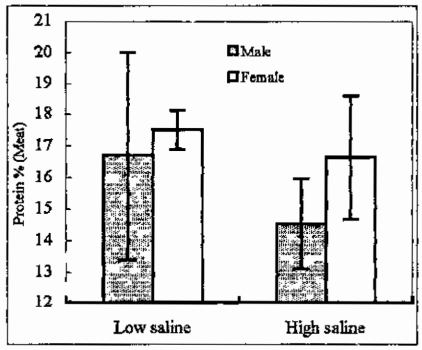


Fig: 3.14 Mean and SD of protein content in meat of *S. serrata* from the SW region of Bangladesh.

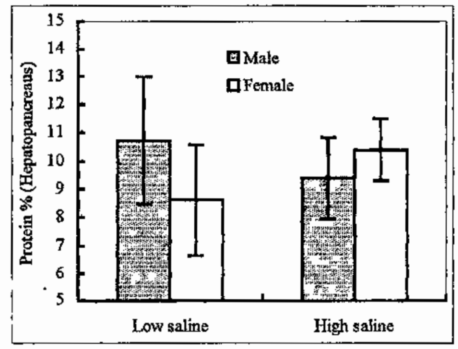


Fig: 3.15 Mean and SD of protein content in Hepatopancreas of *S. serrata* from the SW region of Bangladesh.

3.04.2.3 Meat: The protein content in the body meat of *S. serrata* was found to vary from 14.52% to 17.52% in the males from high saline zone and the females from low saline zone respectively (Table: 3.02, Fig: 3.14). Protein content in the body meat of females were higher than the males. In terms of geographical location the higher protein content was found in low saline zone samples (17.11%) followed by high saline zone (15.59%).

3.04.2.4 Hepatopancreas: The protein content in hepatopancreas was found to vary from 8.61% to 10.73% (Fig: 3.15). The highest and the lowest protein content were found in males and the females from low saline zone respectively (Table: 3.2). In low saline zone, the hepatopancreas of male mud crab had higher protein content than the females from high saline zone. No significant variation in protein content in the hepatopancreas was found between the geographical locations as it varied from 9.67% to 9.90% (Table:3.02).

3.04.2.5 Egg: No geographical variation was noticed in the protein content in the Egg of female mud crabs. It varied between 27.84% and 27.30% (Fig: 3.16) being the highest and the lowest were measured from low and high saline zone respectively (Table: 3.02).

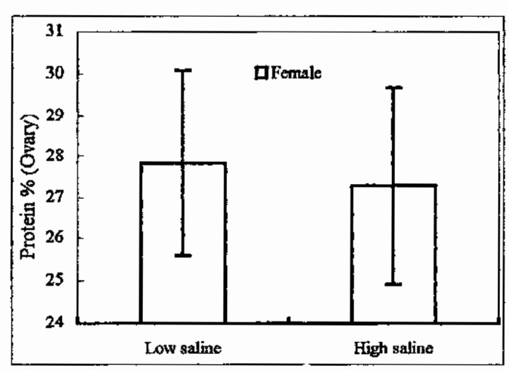


Fig: 3.16: Mean and SD of Protein content in Egg of female *S. serrata* from the SW region of Bangladesh.

The average protein contents in different body parts of mud crabs are shown in Figure: 3.11. Among five different body parts, the highest (27.57%) and the lowest (7.86%)

protein values were recorded in egg and carapace shell respectively. But in case of common body parts highest protein content was in body meat (16.34%). The average protein content in the gills (9.17%) was very close to the protein content in the hepatopancreas (60.49%) in mud crabs (table-3.2). Therefore, the protein content profile in the different body parts of mud crab has been found to be Egg > Body meat > Hepatopancreas > Gill >Shell (Fig: 3.11).

3.04.3 Lipid: The mean fat contents in different body parts of male and female mud crabs from low and high saline zone are shown in Table: 3.03. Hepatopancreas tissue contained the highest (13.67%) and meat tissue contained the lowest (0.34%) lipid content.

Table: 3.03 The fat content in different body parts of male and female mud crabs from low and high saline zone in 2001

Body parts	Low saline zone			High saline zone			Southwestern region (%)
	Male (%)	Female (%)	Mean (%)	Male (%)	Female (%)	Mean (%)	
Gill	0.50	0.71	0.61	0.73	0.61	0.67	0.64
Shell	1.57	1.37	1.47	1.27	1.13	1.2	1.34
Meat	0.32	0.43	0.38	0.37	0.38	0.38	0.38
HP	14.04	12.23	13.14	14.14	14.25	14.20	13.67
Egg	--	3.87	3.87	--	3.92	3.92	3.90

HP: Hepatopancreas.

3.04.3.1 Gill: The maximum (0.73%) and the minimum (0.50%) fat content in the gill tissue were recorded in the males from high saline zone and in the males from low saline zone respectively (Table: 3.03). In terms of geographical variation, crabs from high saline zone showed a comparatively higher fat content than the other locations (Fig: 3.20).

3.04.3.2 Shell: Fat content in the shells of mud crab varied from 1.13% to 1.57%. The maximum (1.57%) and the minimum (1.13%) lipid values were recorded for the males from low saline zone and for the females from high saline zone respectively (Table: 3.03). Male mud crabs contained comparatively higher fat contents in their shells than the females in all the locations (Table: 3.03). Geographically the shells of the mud crabs from low saline zone showed a comparatively higher fat value than the other locations (Fig: 3.21).

3.04.3.3 Meat: The fat content in the body meat of the mud crab varied between 0.32% and 0.43% in the males and females from low saline zone (Table: 3.03). No significant variation in the fat content of body meat between males and females was noticed in the locations. Body meat of female mud crab showed higher fat content than the males (Fig:

3.22). In fat content in the body meat of the mud crabs showed quite same result (Table: 3.03). Lowest fat content was found in meat of mud crab.

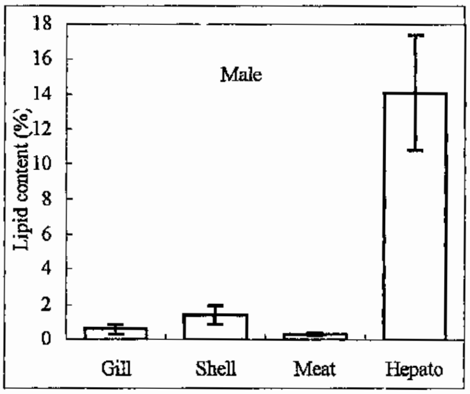


Fig: 3.17 Mean and SD of lipid content in male *S. serrata* from the SW region of Bangladesh.

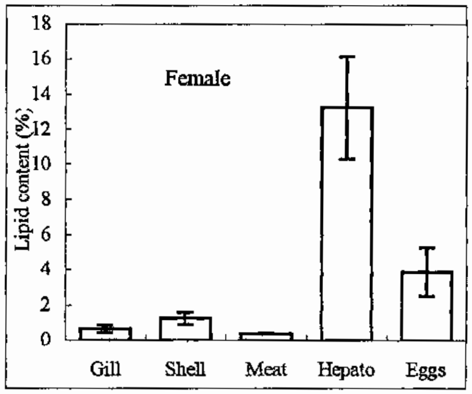


Fig: 3.18 Mean and SD of lipid content in female *S. serrata* from the SW region of Bangladesh.

3.04.3.4 Hepatopancreas: The maximum (14.25%) and the minimum (12.23%) lipid contents in the hepatopancreas was recorded for the females from high saline zone and for the females from low saline zone respectively (Table: 3.03). In terms of spatial variation, mud crabs from high saline zone (14.195%) showed comparatively higher lipid value than low saline zone (13.14) (Fig: 3.23).

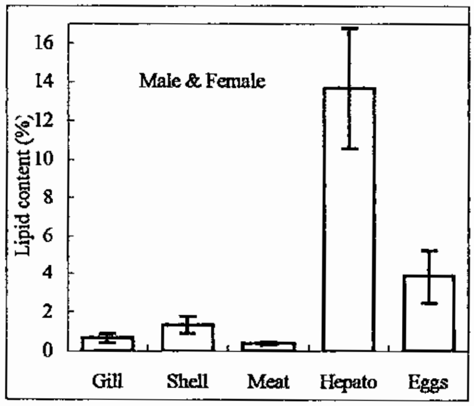


Fig: 3.19 Mean and SD of lipid content in different body parts of *S. serrata* from the SW region of Bangladesh.

3.04.3.5 Egg: The lipid content in the egg of female mud crabs was higher in high saline zone (3.92%) than low saline zone (3.87% (Fig: 3.24). No spatial variation was found in the lipid content of egg from the SW region (Table: 3.03).

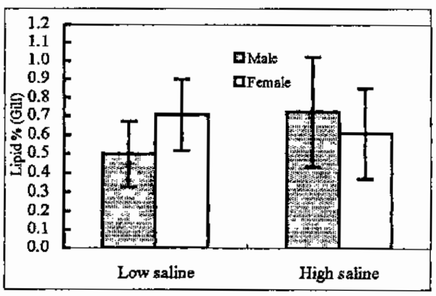


Fig: 3.20 Mean and SD of lipid content in gill of *S. serrata* from the SW region of Bangladesh.

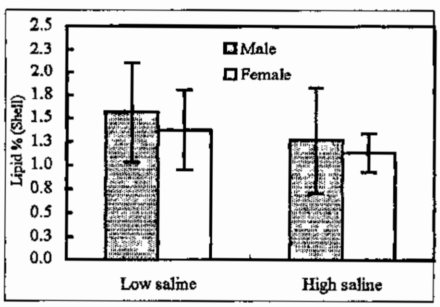


Fig: 3.21 Mean and SD of lipid content in shell of *S. serrata* from the SW region of Bangladesh.

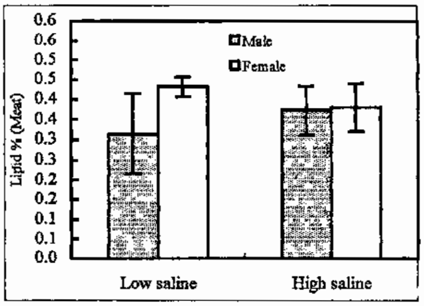


Fig: 3.22 Mean and SD of lipid content in meat of *S. serrata* from the SW region of Bangladesh.

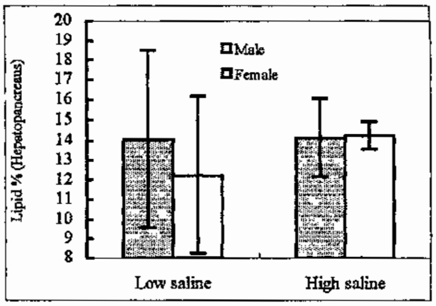


Fig: 3.23 Mean and SD of lipid content in hepatopancreas of *S. serrata* from the SW region of Bangladesh.

The average lipid content in different body parts of mud crabs from the SW region of Bangladesh is shown in Fig-3.19. The maximum lipid content was found in hepatopancreas (13.67%) followed by egg (3.90%), shells (1.34%), gill (0.64%) and body meat (0.38%) (Table: 3.03).

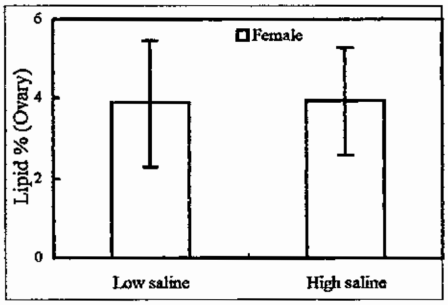


Fig: 3.24 Mean and SD of lipid content in egg of *S. serrata* from the SW region of Bangladesh.

3.04.4 Ash: The mean ash contents in different body parts of male and female mud crabs from low and high saline zone are shown in Table: 3.04. the maximum (33.83%) and the minimum (2.18%) ash content were found in shell and meat tissue of mud crab respectively.

Table: 3.04 Ash contents in different body parts of male and female mud crabs from low and high saline zone in 2001 (as %).

Body parts	Low saline zone			High saline zone			Southwestern region (%)
	Male (%)	Female (%)	Mean (%)	Male (%)	Female (%)	Mean (%)	
Gill	4.15	3.84	4.00	4.15	3.50	3.83	3.91
Shell	43.82	28.64	36.23	36.50	26.34	31.42	33.83
Meat	1.68	2.24	1.96	2.38	2.40	2.39	2.18
HP	3.87	1.92	2.89	4.45	3.14	3.8	3.34
Egg	--	2.47	2.47	--	2.22	2.22	2.35

HP: Hepatopancreas.

3.04.4.1 Gill: The ash contents in the gill tissue of mud crabs were varied from 3.50% to 4.15%. The maximum and the minimum values were recorded in the males from low and high saline zone and in the females from high saline zone respectively (Table: 3.04). The values of ash content in the gill tissue were higher in males than the females in all the locations (Fig: 3.25 & 3.26). In terms of geographical variation, the maximum ash content was found in low saline zone (4.00%), which was followed by high saline zone (3.83%) (Fig: 3.28).

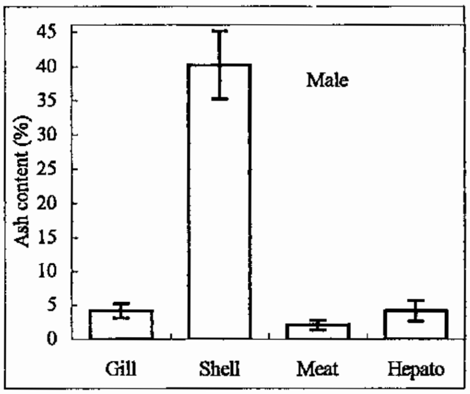


Fig: 3.25 Mean and SD of ash content in male *S. serrata* from the SW region of Bangladesh.

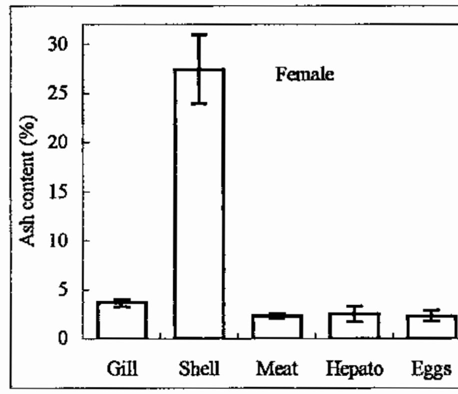


Fig: 3.26 Mean and SD of ash content in female *S. serrata* from the SW region of Bangladesh.

3.04.4.2 Shell: The ash contents in the shells of mud crab were varied between 26.34% and 43.82%. The highest and the lowest values were recorded in males from low saline zone and in females from high saline zone respectively. A significant variation in ash contents was found between male and female mud crabs.

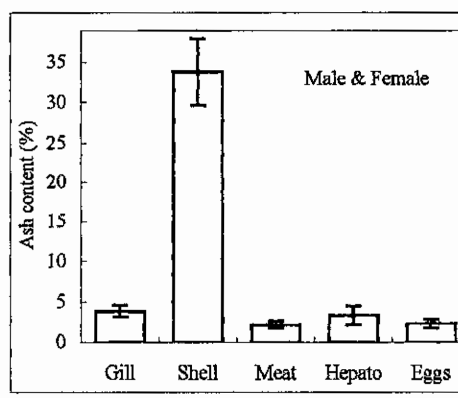


Fig: 3.27 Mean and SD of ash content in different body parts of *S. serrata* from the SW region of Bangladesh.

Males showed comparatively higher ash content than the females in all the regions (Table: 3.04). Low saline zone showed comparatively higher ash content than high saline zone (Fig: 3.29).

3.04.4.3 Meat: The ash contents in the body meat of mud crabs were varied between 1.68% and 2.40%. The maximum and the minimum values were recorded in the females from high saline zone and in the males from low saline zone respectively (Table: 3.04). Ash content in the body meat showed significant sexual variation as the females had a higher ash values than the males in all the locations. Ash content also showed geographical variation being higher (2.39%) in high saline zone and lower in low saline zone (1.96%) (Fig: 3.30).

3.04.4.4 Hepatopancreas: The ash content in the hepatopancreas of mud crabs was varied from 1.62% to 4.45% being the maximum in the males from high saline zone and the minimum in the females from low saline zone (Table: 3.04). A significant variation in the ash contents in hepatopancreas was found between males and females. Male mud crabs showed a higher ash content than the females in all the regions. It also showed geographical variation being the highest in high saline zone (2.39%) and the lowest in low saline zone (2.89%) (Table: 3.4) (Fig: 3.31).

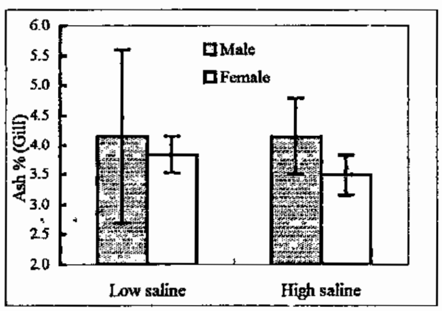


Fig: 3.28 Mean and SD of ash content in gill of *S. serrata* from the SW region of Bangladesh.

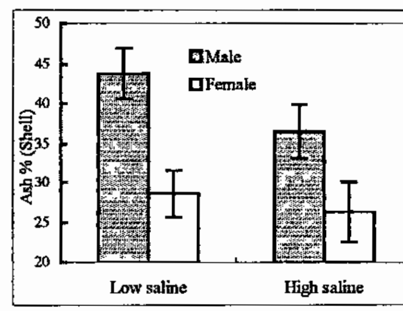


Fig: 3.29 Mean and SD of ash content in shell of *S. serrata* from the SW region of Bangladesh.

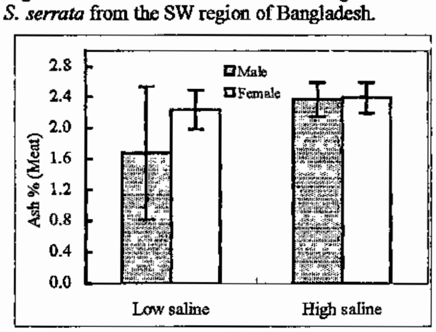


Fig: 3.30 Mean and SD of ash content in meat of *S. serrata* from the SW region of Bangladesh.

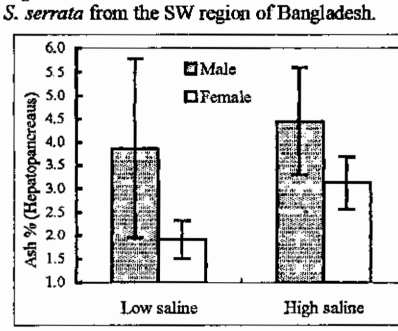


Fig: 3.31 Mean and SD of ash content in hepatopancreas of *S. serrata* from the SW region of Bangladesh.

3.04.4.5 Egg: The ash content in the egg of female crabs was varied between 2.22% and 2.47% being the highest in low saline zone and the lowest in high saline zone respectively (Fig: 3.32).

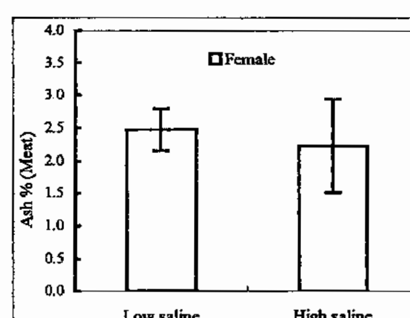


Fig: 3.32 Mean and SD of ash content in egg of female *S. serrata* from the SW region of Bangladesh.

Among the various body parts, the ash content was found to be highest in the shells

(33.83%) and the lowest in the meat (2.18%). The relative contents of ash in different body parts in the mud crab are as follows: Shells>Gills> hepatopancreas> egg> meat.

3.04.5 Carbohydrate: The mean carbohydrate contents in different body parts of male and female mud crabs from low and high saline zone are shown in Table: 3.05. the highest (11.95%) and the lowest (1.04%) carbohydrate were recorded in the egg and meat tissue respectively.

Table: 3.05 Carbohydrate contents in different body parts of male and female mud crabs from low and high saline zone in 2001 (as %).

Body parts	Low saline zone			High saline zone			Southwestern region (%)
	Male (%)	Female (%)	Mean (%)	Male (%)	Female (%)	Mean (%)	
Gill	3.6	1.99	2.80	1.59	1.92	1.75	2.28
Shell	9.27	11.27	10.27	9.19	7.39	8.29	9.28
Meat	1.22	1.01	1.12	0.99	0.93	0.96	1.04
HP	4.99	5.15	5.07	3.48	3.95	3.72	4.39
Egg	--	11.67	11.67	--	12.24	12.24	11.95

HP: Hepatopancreas.

3.04.5.1 Gill: The carbohydrate contents in the gill tissue of mud crabs were varied from 1.59% to 3.60%. The maximum and the minimum values were recorded in the males from low saline zone and in the males from high saline zone respectively (Fig: 3.36). In terms of geographical variation, the maximum ash content was found in low saline zone (2.80%), which was followed by high saline zone (1.75%).

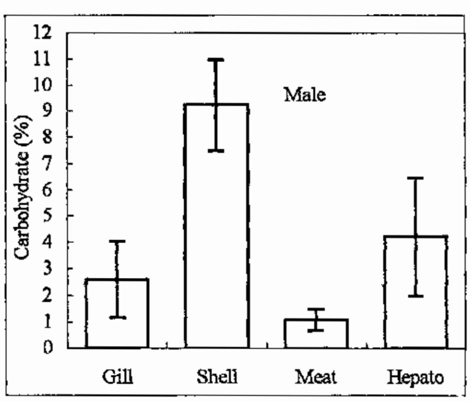


Fig: 3.33 Mean and SD of carbohydrate content in male *S. serrata* from the SW region of Bangladesh.

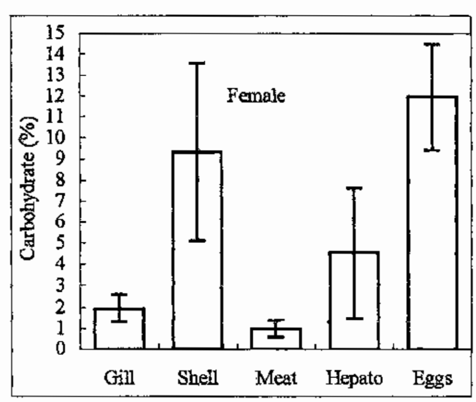


Fig: 3.34 Mean and SD of carbohydrate content in female *S. serrata* from the SW region of Bangladesh.

3.04.5.2 Shell: The carbohydrate content of the shell (carapace) of mud crab was found to vary between 7.39% and 11.27% in female from high saline zone and female from low saline zone respectively (Fig: 3.37). Low saline zone crabs had significantly higher carbohydrate content in their shells than the high saline zone crabs (Table: 3.05). No significant variation, however, was observed in carbohydrate content among male and female. (Table: 3.05).

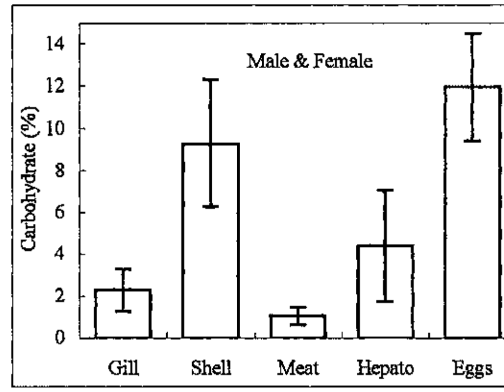


Fig: 3.35 Mean and SD of carbohydrate content in different body parts of *S. serrata* from the SW region of Bangladesh.

3.04.5.3 Meat: The body meat of *S. serrata* contained carbohydrate between 0.93% and 1.22%. The highest (1.22%) and the lowest (0.93%) carbohydrate values were recorded in male from low saline zone and female mud crab from high saline zone respectively (Fig: 3.38). Low saline zone showed higher carbohydrate content in meat than high saline zone. (Table: 3.5). However, female crab showed lower carbohydrate content than male crab (Fig: 3.38).

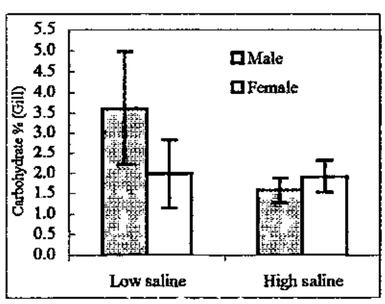


Fig: 3.36 Mean and SD of carbohydrate content in gill of *S. serrata* from the SW region of Bangladesh.

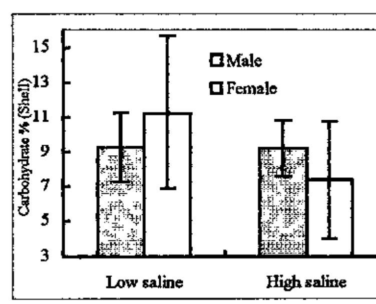


Fig: 3.37 Mean and SD of carbohydrate content in shell of *S. serrata* from the SW region of Bangladesh.

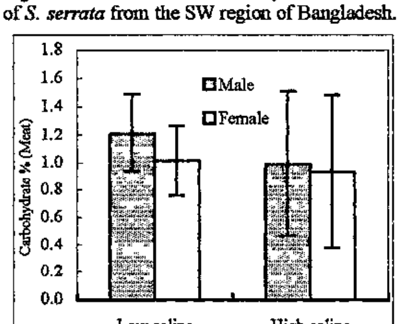


Fig: 3.38 Mean and SD of carbohydrate content in meat of *S. serrata* from the SW region of Bangladesh.

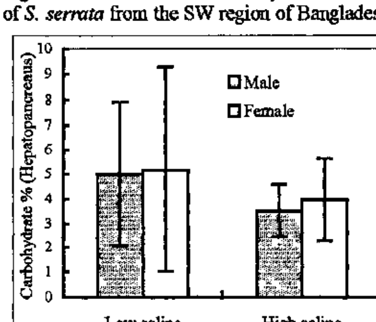


Fig: 3.39 Mean and SD of carbohydrate content in hepatopancreas of *S. serrata* from the SW region.

3.04.5.4 Hepatopancreas: The carbohydrate content in hepatopancreas was found to vary from 3.48% to 5.15% (Table: 3.05). The highest and the lowest carbohydrate content were found in females from low saline zone and males from high saline zone respectively (Fig: 3.39). Both low and high saline zone female crabs had higher carbohydrate content than male. Significant variation in carbohydrate content in the hepatopancreas was found between the low (5.07%) and high saline zones (3.72%) (Table-3.05).

3.04.5.5 Egg: The carbohydrate content in the egg of female crabs was varied between 11.67% and 12.24% being the highest in high saline zone and the lowest in low saline zone respectively (Fig: 3.40).

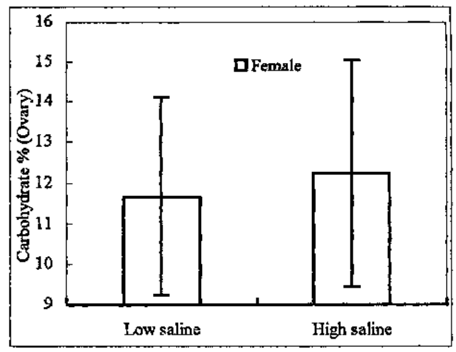


Fig-3.40: Mean and SD of carbohydrate content in hepatopancreas of *S. serrata* from the SW region of Bangladesh.

3.04.6 Proximate composition of different body parts: The proximate composition of gills, shells, body meat, hepatopancreas and egg tissue of mud crab are shown in the Table 3.06 through 3.10 and Figure 3.41 through 3.46.

Table: 3.06 The proximate composition of gill tissue in *S. serrata* from the SW region of Bangladesh.

Gill	Mean	SD
Moisture	84.02	2.38
Protein	9.17	1.43
Lipid	0.64	0.24
Ash	3.91	0.72
Carbohydrate	2.28	1.02

SD= Standard Deviation.

Table: 3.07 The proximate composition of shell tissue in *S. serrata* from the SW region of Bangladesh.

Shell	Mean	SD
Moisture	47.71	4.98
Protein	7.85	1.41
Lipid	1.34	0.45
Ash	33.83	4.2
Carbohydrate	9.28	3

Table: 3.08 The proximate composition of meat tissue in *S. serrata* from the SW region of Bangladesh.

Meat	Mean	SD
Moisture	79.83	2.39
Protein	16.35	2.06
Lipid	0.38	0.07
Ash	2.18	0.47
Carbohydrate	1.04	0.41

SD= Standard Deviation.

Table: 3.09 The proximate composition of hepatopancreas tissue in *S. serrata* from the SW region of Bangladesh.

Hepatopancreas	Mean	SD
Moisture	68.83	5.13
Protein	9.78	2.08
Lipid	13.67	3.1
Ash	3.34	1.16
Carbohydrate	4.39	2.66

Moisture content was found to be highest and lowest in gill (84.02%) and shell tissue respectively (Table: 3.06). Highest and lowest protein content was in egg (27.57%) and shell (7.85%) tissue (Table: 3.07). In hepatopancreas (13.67%) and meat (0.38%) highest and lowest lipid content was found (Table: 3.08). Highest and lowest ash content was found in shell (33.83%) and meat (2.18%) respectively (Table: 3.09). Carbohydrate content was highest in egg (11.95%) and lowest in meat (1.04%) (Table: 3.10).

Table: 3.10 The proximate composition of egg tissue in *S. serrata* from the SW region of Bangladesh in 2001.

Egg	Mean	SD
Moisture	54.23	3.4
Protein	27.57	2.23
Lipid	3.9	1.39
Ash	2.35	0.54
Carbohydrate	11.95	2.52

SD= Standard Deviation.

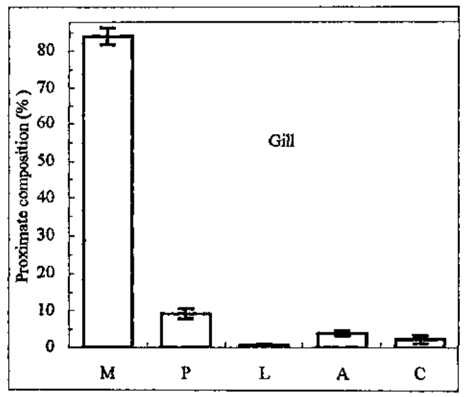


Fig: 3.41:Proximate composition of gill in *Scylla serrata* from the SW region of Bangladesh.

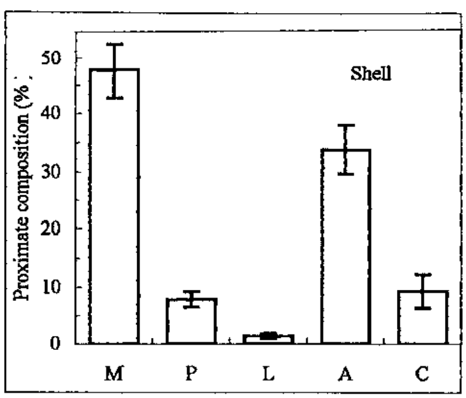


Fig: 3.42 Proximate composition of shell in *Scylla serrata* from the SW region of Bangladesh.

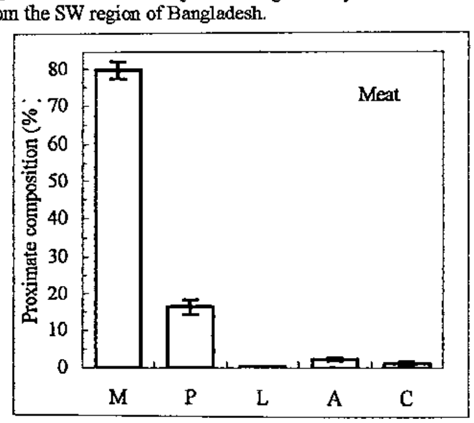


Fig: 3.43 Proximate composition of meat in *Scylla serrata* from the SW region of Bangladesh.

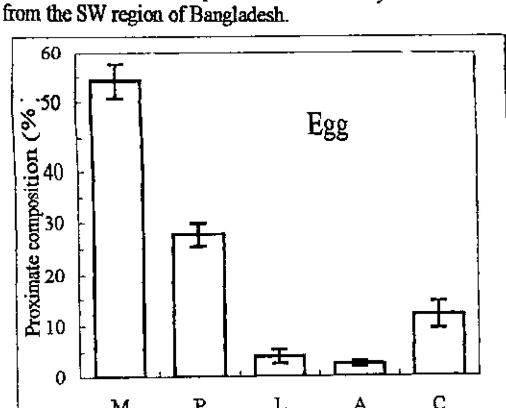


Fig: 3.45 Proximate composition of egg in *Scylla serrata* from the SW region of Bangladesh.

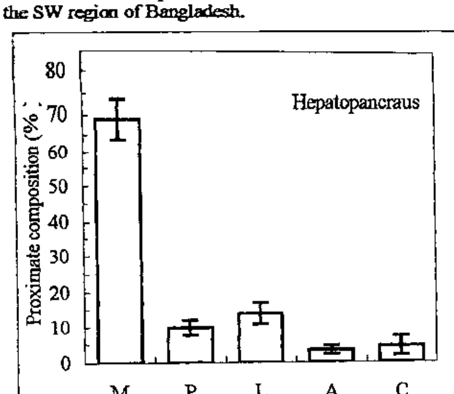


Fig: 3.46 Proximate composition of hepatopancreas in *Scylla serrata* from the SW region of Bangladesh.

M = Moisture, P = Protein, L = Lipid, A = Ash, C = Carbohydrate.

The gill, meat, hepatopancreas of male contained highest protein in monsoon but in post monsoon, the highest content was found in shell whilst the highest protein content in gill, and shell of female was found in post monsoon and the highest contents in meat, hepatopancreas and egg were found in monsoon (Table: 3.12).

The Table: 3.16 indicates that there was significant variation of protein content in gill both for season and sex, while the seasonal variation in other different body parts was not significant for both male and female at 5% level.

3.04.7.3 Ash: Ash content was found highest in shell (34.56±9.04%, 33.09±8.88%) and lowest in meat (2.34±.0.01%, 2.01±0.43%) in both the monsoon and post monsoon (Table: 3.13). Highest standard deviation was found in shell in monsoon and post monsoon. Monsoon values were comparatively higher value than post monsoon (Fig: 3.47)

Table: 3.13 Seasonal variation of ash content in different body parts.

	Monsoon				Post Monsoon			
	Male (%)	Female (%)	Average (%)	SD	Male (%)	Female (%)	Average (%)	SD
Gill	4.51	3.67	4.09	0.59	3.79	3.67	3.73	0.08
Shell	40.95	28.17	34.56	9.04	39.37	26.82	33.09	8.88
Meat	2.35	2.33	2.34	0.01	1.71	2.31	2.01	0.43
HP	4.02	2.50	3.26	1.08	4.30	2.57	3.43	1.22
Egg	–	2.36	2.36	–		2.34	2.34	–

The ash content in gill, shell, meat of male crab was found to be highest in monsoon and hepatopancreas of male contained highest ash in post monsoon whereas shell and meat and egg of female was found to be rich in ash during monsoon but hepatopancreas contained the highest ash in post monsoon and the same ash content was found in gill of female (Table: 3.13).

The statistical analysis (ANOVA) Table represented significant variation of ash content for male in monsoon and post monsoon. Whilst no significant variation was found in other body constituents for male crabs. There was no significant seasonal variation among different body parts of female crabs (Table: 3.16).

3.04.7.4 Lipid: Lipid content was found highest (14.51± 3.01, 12.82± 1.81) in egg in both the seasons. Monsoon showed comparatively higher value than post monsoon (Fig: 3.48). Standard deviation was highest in egg (3.01, 1.81) in both the seasons.

Table: 3.14 Seasonal variation of lipid content in different body parts.

	Monsoon				Post Monsoon			
	Male (%)	Female (%)	Average (%)	SD	Male (%)	Female (%)	Average (%)	SD
Gill	0.72	0.64	0.68	0.06	0.51	0.68	0.59	0.12
Shell	1.27	1.14	1.20	0.09	1.58	1.36	1.47	0.15
Meat	0.37	0.39	0.38	0.02	0.32	0.42	0.37	0.07
HP	16.64	12.38	14.51	3.01	11.54	14.10	12.82	1.81
Egg	–	3.14	3.14	–		4.65	4.65	–

The lipid content in gill, meat, hepatopancreas of male crab was found to be highest in monsoon and shell contained the highest lipid in post monsoon whilst the highest lipid content in gill, shell, meat, hepatopancreas and egg of female was found in post monsoon (Table: 3.14). The seasonal variation of lipid content in gill and hepatopancreas of male was statistically highly significant. In shell and meat lipid content was non significant at 5% level, whereas the variation of lipid contents in different body parts of female was not significant according to season (Table: 3.16).

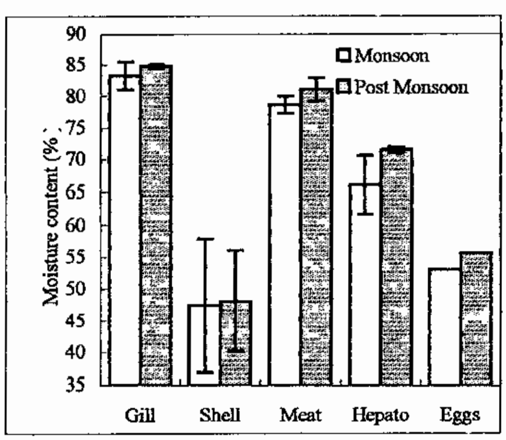


Fig: 3.45: Seasonal variation in moisture content of different body parts.

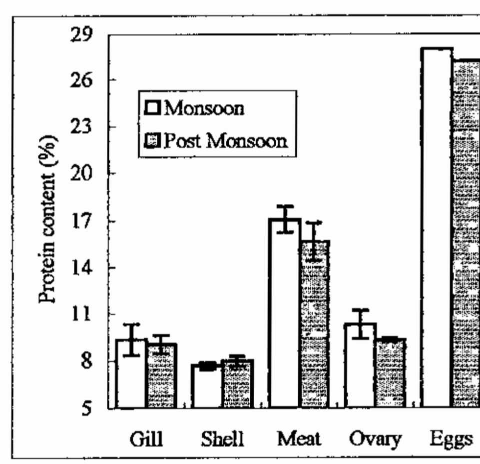


Fig: 3.46 Seasonal variation in protein content of different body parts.

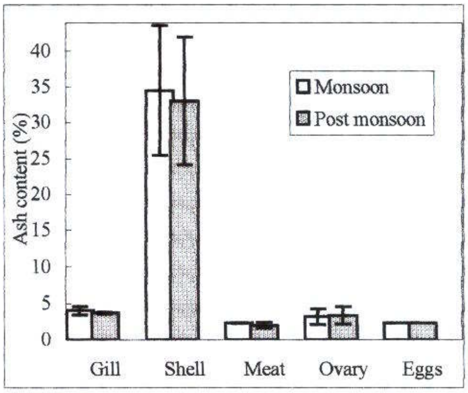


Fig: 3.47 Seasonal variation in ash content of different body parts.

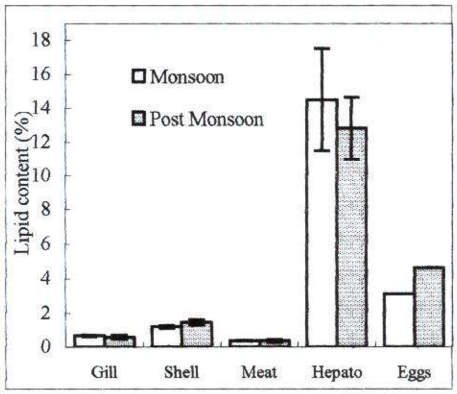


Fig: 3.48 Seasonal variation in lipid content of different body parts.

3.04.7.5 Carbohydrate: Carbohydrate content of gill, shell, meat, hepatopancreas and egg in monsoon and post monsoon was determined according to male and female (Table: 3.15). The highest and lowest Carbohydrate content in monsoon and post monsoon was in egg (13.56%), shell (1.21±0.08%) and in egg (10.35 %), meat (0.86±0.10%) respectively (Fig: 3.49). Highest standard deviation was found in shell (0.66) in monsoon and in shell (0.80) in post monsoon.

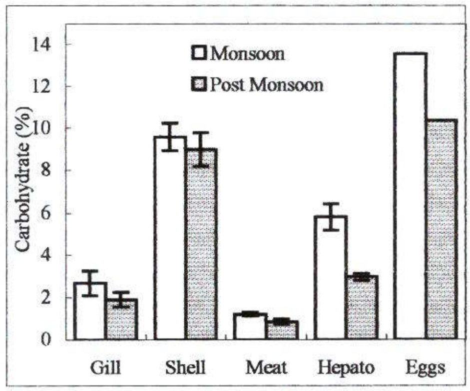


Fig: 3.49: Seasonal variation in carbohydrate content of different body parts.

Table: 3.15 Seasonal variation of carbohydrate content in different body parts.

	Monsoon				Post Monsoon			
	Male (%)	Female (%)	Average (%)	SD	Male (%)	Female (%)	Average (%)	SD
Gill	3.07	2.25	2.66	0.58	2.12	1.66	1.89	0.33
Shell	10.05	9.12	9.58	0.66	8.42	9.55	8.98	0.80
Meat	1.27	1.16	1.21	0.08	0.93	0.79	0.86	0.10
HP	5.38	6.26	5.82	0.62	3.09	2.84	2.97	0.17
Egg	–	13.56	13.56	–		10.35	10.35	–

Table: 3.16 One way ANNOVA for proximate composition of male and female mud crabs in the SW region of Bangladesh.

SV	df	F crit	Moisture		Protein		Ash		Lipid		Carbohydrate	
			Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Gill			*10.335	2.017	*5.287	*5.654	*4.719	0.052	*7.139	0.224	0.316	0.059
Shell			0.754	0.696	0.58	0.204	0.201	0.01	0.129	0.002	1.273	0.641
Meat	17	4.494	*8.278	0.937	3.472	0.452	*6.253	0.734	3.628	0.608	*4.88	0.019
HP			*12.01	0.454	0.942	0.038	0.012	0.655	*21.84	0.296	1.441	*9.247
Egg			–	2.511	–	0.325	–	1.740	–	0.012	–	1.873

* = Significant at 5% level.

The different body parts of male contained highest carbohydrate in monsoon and the carbohydrate content in gill, meat, hepatopancreas of female was found to be highest in monsoon whereas shell of female was found to be rich in carbohydrate value in post monsoon (Fig: 3.49).

The carbohydrate content in the meat of male mud crab was varied significantly by season at 5% level. While the seasonal variation in other different body parts was not significant at 5% level. There was high variation of carbohydrate content in hepatopancreas and no significant variation was found in other body parts of female during monsoon and post monsoon season (Table: 3.16).

3.05 Discussion:

The proximate composition of body meat in the mud crab from different geographical locations in home and abroad is presented in Table: 3.16.

Table: 3.16 Proximate composition of body meat in the mud crab *Scylla serrata* from different geographical locations.

Source	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrate (%)
Srinivasagam, 1979	16.65	F>M	78.38	--	0.15
George and Gopakumar, 1987	20.92F	F>M	80.19 M	5.09	0.67
Das et al., 1995	19.98 F	0.48 F	77.45 F	1.23 F	--
Mannan (1977)	7.3	0.5		0.14	--
INFS (1980)	8.9		83	--	--
Present study	16.35	0.38	79.83	2.18	1.04

M= Male, F= Female. INFS = Institute of Nutrition and Food Science

No study has ever been reported the proximate composition of different body parts of mud crab from Bangladesh. The proximate composition of different body parts such as gills, external body shells (i.e. carapace), body meat, hepatopancreas and egg in the mud crab, *S. serrata*, has been studied for the first time in the subcontinent. Most of the previous studies lack in information particularly on fat, carbohydrate and ash contents (Table-3.16). The methodology followed in the present study is more precise that the previous studies done by various workers (Srinivasagam, 1979; George and Gopakumar, 1987; Das et al., 1995). The results of the present study particularly the proximate composition of body meat is more or less similar to the results provided by the previous workers which indicate that the proximate composition of mud crab do not vary significantly among geographical localities but varies significantly between sexes. Particularly, females posses a higher fat content that the males and that is why the test and hence the demand and price of female mud crab is much higher that the males.

Moisture was found to be the major element in proximate composition as it varied from 78.46% to 80.35% in body meat. The institute of Nutrition and Food Science (1980) reported 83% moisture in meat, which is very close to present study. George and Gopakumar (1987) recorded 80.19% moisture, which confirms the result of the present study. The percentage of protein was varied from 14.52 to 17.52 in the body meat in the present study. Mannan (1977) and the Institute of Nutrition and Food Science (1980) reported 7.3% protein in meat of crab from Bangladesh. George and Gopakumar (1987) reported 20.92% protein in meat of *S. serrata* from India, which shows close agreement with the result of present study. Srinivasagam (1979) reported 12.29% to 16.65% protein in brachyiaran crabs, namely *P. pelagicus, P. sansuinolentus, S. serrata* and *Charybdis cruciata* that corroborate the results of the present study. Mannan (1977) reported 0.5% lipid in his study. Das *et al.*(1995) found 0.48% lipid which fairly agrees with the present observation (0.38%). Srinivasagam (1979) and George and Gopakumar (1987) found higher fat content in female than male. Present study also agrees with the agreement. Mannan (1977) found 0.14% ash content in meat. George and Gopakumar (1987) found 5.09% ash. Das *et. al.*(1995) found 1.23% ash in meat of mud crab which fairly agrees with the present observation. George and Gopakumar (1987) and Srinivasagam (1979) found 0.67% and 0.15% carbohydrate content in meat. In present observation 1.04% carbohydrate was found, which is very close to the previous observation.

Moisture content in shell and hepatopancreas was higher in female than that of male crabs. Body meat contains more moisture in males than the females. No considerable variation was found between low and high saline zone. (Table: 3.01). The highest moisture content was found in the gill (84.02%). Protein content was found highest in egg (27.57%) followed by meat (16.34%). Gill of female contains comparatively high protein value than the males. Mud crab meat (male and female combined) from low saline zone contains comparatively higher protein value than the crab form high saline zone (Table: 3.02). Fat content was found highest in hepatopancreas (Table: 3.03). Male mud crab shell and hepatopancreas contains more ash content than that of female. Meat of males contains lower ash content than the females. Gill and shell of low saline zone contain higher ash content than high saline zone. The meat and hepatopancreas contained higher ash content I high saline zone than the low saline zone (Table: 3.04). The highest carbohydrate content was found in egg (11.95%) followed by shell (9.28%). Carbohydrate content in the hepatopancreas was higher in females than the males (Table: 3.05).

Gill tissue contained the highest value was for moisture (84.02%). In gill lowest value was 0.64% for lipid. Protein percentage was found 9.17% (Table: 3.06). So it can be said that gill of mud crab has a high food value. In shell moisture content was highest followed by ash and carbohydrate. No literature was found to compare the results.

Moisture content in gill, shell, meat, hepatopancreas and egg was found to be higher in post monsoon than monsoon season (Table: 3.11). The variation of moisture in gill was statistically significant in male but insignificant in female. In shell, variation of moisture content was statistically insignificant for both the male and female at 5% level. The variation of moisture content in meat and hepatopancreas was statistically significant in male, but insignificant in female at 5% level. No statistical variation was found for moisture content in the egg in female (Appendix: 6).

Protein content was found higher in all the body parts, except the shell, during monsoon than the post monsoon (Table: 3.12). Statistically the variation of protein content in gill of male and female was significant at 5% level. Protein content of shell, meat and hepatopancreas showed insignificant seasonal variation both in male and female at 5% level of significance (Appendix: 7).

Ash content in gill, shell, meat and egg was higher during monsoon in comparison to post monsoon (Table: 3.13). A significant seasonal variation in ash content in the gill of male was recorded (Appendix: 9). While in female no significant seasonal variation in ash content in different body parts was recorded (Table: 3.16). Lipid content was higher in gill, meat, hepatopancreas and egg during the monsoon than the post monsoon (Table: 3.14).

Lipid content in gill, meat and hepatopancreas of male crab was found to be highest during monsoon. While in the shell lipid content was highest during post monsoon. The highest lipid content in gill, shell, meat, hepatopancreas and egg of female was found in post monsoon (Table: 3.14). The seasonal variation of lipid content in gill and hepatopancreas of male was statistically highly significant and in shell and meat it was insignificant at 5% level whereas the variation in lipid contents among different body parts of female and seasons were not significant (Table: 3.16) (Appendix: 8).

The carbohydrate content in the meat of male crab varied seasonally at 5% level of significance while in other body parts carbohydrate did not vary significantly (Appendix: 10). There was highly significant variation in carbohydrate content of hepatopancreas and no statistically significant seasonal variation was found in other body parts of female (Table: 3.16). Carbohydrate content in the gill, shell, meat, hepatopancreas and egg was higher during the monsoon than the post monsoon season (Table: 3.15). From the above discussion, I found that except moisture all other elements of proximate composition were higher during monsoon season.

3.06 Conclusion:

The result of the present study reveals the food value of mud crab is quite high in comparison to other commercial seafood. The moisture was found as the main constituents in all body parts followed by protein, ash and lipid contents in gills, shells, body meat, hepatopancreas and egg in the mud crab. A prominent variation was noticed in the protein, fat and ash contents in various body parts of mud crab from the SW region. Protein content was highest in egg (27.57%) followed by meat (16.35%). The lipid content of different body parts also revealed that it was the highest in hepatopancreas (13.67%) than the egg (3.9%). Carbohydrate content was highest in egg (11.95%) followed by shell (9.28%). So it can be conclude that mud crab meat can be a better protein source for human consumption. Though egg of female contain more protein content, but it is not available all the year. Again, the other body parts (gill, shell) also contain considerable amount of nutritients that can be a used in poultry, fish and shrimp feed formulation.

Strategies should be developed to change the attitudes among the Muslim communities in Bangladesh in order to develop a stable local market for this valuable aqua-resource.

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Appendix:1 One way ANNOVA test for moisture content.

Source of Variation	SS	df	MS	F	P-value	F crit
			Male			
Gill	55.230	17	55.230	10.335	0.005	
Shell	32.080	17	32.080	0.754	0.398	
Meat	39.516	17	39.516	8.278	0.011	4.494
HP	258.251	17	258.251	12.007	0.003	
			Female			
Gill	9.636	17	9.636	2.017	0.175	
Shell	29.876	17	29.876	0.696	0.416	
Meat	6.528	17	6.528	0.937	0.347	4.494
HP	9.519	17	9.519	0.454	0.510	
Ovary	28.300	17	28.300	2.511	0.133	

Appendix: 2 One way ANNOVA test for protein content

Source of Variation	SS	df	MS	F	P-value	F crit
			Male			
Gill	10.565	17	10.565	5.287	0.035	
Shell	1.572	17	1.572	0.580	0.458	
Meat	17.248	17	17.248	3.471	0.081	4.494
HP	4.381	17	4.381	0.942	0.346	
			Female			
Gill	11.313	17	11.313	5.654	0.030	
Shell	0.497	17	0.497	0.204	0.657	
Meat	1.875	17	1.875	0.452	0.511	4.494
HP	0.117	17	0.117	0.038	0.848	
Ovary	1.767	17	1.767	0.325	0.577	

Appendix:3 One way ANNOVA test for ash content

Source of Variation	SS	df	MS	F	P-value	F crit
			Male			
Gill	3.618	17	3.618	4.719	0.045	
Shell	6.408	17	6.408	0.201	0.660	4.494
Meat	1.811	17	1.811	6.253	0.024	
HP	0.028	17	0.028	0.012	0.916	
			Female			
Gill	0.014	17	0.014	0.052	0.823	
Shell	0.240	17	0.240	0.010	0.920	
Meat	0.127	17	0.127	0.734	0.404	4.494
HP	0.439	17	0.439	0.655	0.430	
Ovary	0.461	17	0.461	1.740	0.206	

Appendix:4 One way ANNOVA test for lipid content

Lipid

Source of Variation	SS	df	MS	F	P-value	F crit
			Male			
Gill	0.520	17	0.520	7.139	0.017	
Shell	0.052	17	0.052	0.129	0.725	4.494
Meat	0.026	17	0.026	3.628	0.075	
HP	108.241	17	108.241	21.843	0.000	
			Female			
Gill	0.010	17	0.010	0.224	0.642	
Shell	0.000	17	0.000	0.002	0.966	
Meat	0.005	17	0.005	0.608	0.447	4.494
HP	3.556	17	3.556	0.296	0.594	
Ovary	0.045	17	0.045	0.012	0.915	

Appendix:5 One way ANNOVA test for carbohydrate content

Source of Variation	SS	df	MS	F	P-value	F crit
			Male			
Gill	0.692	17	0.692	0.316	0.582	
Shell	3.209	17	3.209	1.273	0.276	
Meat	0.569	17	0.569	4.880	0.042	4.494
HP	11.297	17	11.297	1.441	0.248	
			Female			
Gill	0.070	17	0.070	0.059	0.811	
Shell	8.694	17	8.694	0.641	0.435	
Meat	0.005	17	0.005	0.019	0.893	4.494
HP	49.700	17	49.700	9.247	0.008	
Ovary	9.447	17	9.447	1.873	0.190	

Appendix:6 One way ANNOVA test for seasonal variation of different body parts of mud crab for Moisture.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Gill	9.63605	9	9.63605	2.017024	0.174737	4.493998
Shell	29.87645	9	29.87645	0.696177	0.416355	4.493998
Meat	6.528089	9	6.528089	0.937151	0.347418	4.493998
HP	9.519339	9	9.519339	0.453753	0.510172	4.493998
Ovary	28.30027	9	28.30027	2.510687	0.13264	4.493998

Appendix:7 One way ANNOVA test for seasonal variation of different body parts of mud crab for Protein.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Gill	11.31294	1	11.31294	5.654259	0.03022	4.493998
Shell	0.496672	1	0.496672	0.204266	0.657366	4.493998
Meat	1.875339	1	1.875339	0.452488	0.510755	4.493998
HP	0.116806	1	0.116806	0.038078	0.847743	4.493998
Ovary	1.7672	1	1.7672	0.324713	0.576703	4.493998

Appendix:8 One way ANNOVA test for seasonal variation of different body parts of mud crab for lipid.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Gill	0.010272	9	0.010272	0.223985	0.642412	4.493998
Shell	0.000272	9	0.000272	0.001911	0.965677	4.493998
Meat	0.005339	9	0.005339	0.608035	0.44691	4.493998
HP	3.555556	9	3.555556	0.295683	0.594098	4.493998
Ovary	0.045	9	0.045	0.011625	0.915481	4.493998

Appendix:9 One way ANNOVA test for seasonal variation of different body parts of mud crab for Ash.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Gill	0.013889	9	0.013889	0.051969	0.822559	4.493998
Shell	0.240356	9	0.240356	0.010342	0.920263	4.493998
Meat	0.126672	9	0.126672	0.73383	0.404293	4.493998
HP	0.438672	9	0.438672	0.65457	0.430351	4.493998
Ovary	0.4608	9	0.4608	1.739616	0.205754	4.493998

Appendix:10 One way ANNOVA test for seasonal variation of different body parts of mud crab for Carbohydrate.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Gill	0.069689	9	0.069689	0.058886	0.811348	4.493998
Shell	8.69445	9	8.69445	0.640919	0.435105	4.493998
Meat	0.005	9	0.005	0.01881	0.892623	4.493998
HP	49.70045	9	49.70045	9.247465	0.007784	4.493998
Ovary	9.446756	9	9.446756	1.872906	0.190053	4.493998

Appendix:11 χ^2 test for sex ratio according to geographic and size class variation.

sex ratio by month

	df	Stat value	Critic value
Low saline zone	11	1.040	19.675
High saline zone	11	0.105	19.675
SW Region	11	7.753	19.675