

BIONOMICS OF *NOTOPTERUS NOTOPTERUS* (PALLAS, 1769)



THESIS SUBMITTED TO
THE UNIVERSITY OF RAJSHAHI, BANGLADESH
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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DEDICATED

In Memory of My Father

Whose death-
makes me firm to follow his ideology.

In Memory of My Uncle

(Mohammad Ali Siddiquee)

Being a friend and philosopher-
who showed me the way of life.

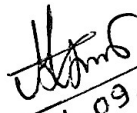
And

My Mother

Her earnest pray-
placed me at my present position.

DECLARATION

I do hereby declare that, the research work submitted as a thesis entitled “**BIONOMICS OF *NOTOPTERUS NOTOPTERUS* (PALLAS, 1769)** in the Department of Fisheries, University of Rajshahi for the Degree of Doctor of Philosophy is the result of my own investigation. The thesis or part of it has not been submitted to any other University or Institution for any degree.


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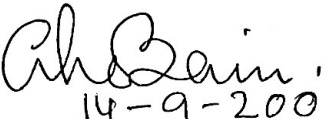
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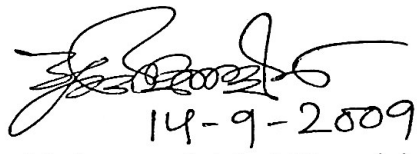
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-Mohammad Manjurul Alam

ABSTRACT

The bionomical study of *N. notopterus* is carried out during January, 2005 to December, 2006. The present research findings are presented in 195 pages including 22 tables, 36 figures and 13 plates. The relationship model equations among different body length parameters are found highly significant. The growth curve model (GCM) for summer, rainy and winter season is established as $TW=0.00771 TL^{3.045}$, $TW=0.00441 TL^{3.219}$ and $TW=0.00884 TL^{2.998}$ respectively where in male, female and combined sexes it is established as $TW=0.00781 TL^{3.031}$, $TW=0.00844 TL^{3.022}$ and $TW=0.00813 TL^{3.026}$ respectively and found highly significant to assess the growth variation of the population. The species showed female dominating distribution including homogeneity in yearly distribution. The Fulton's, allometric and relative condition factors showed variation in different season and sex maintaining a similar pattern indicating gradual development of gonad in relation to the sexual cycle. The fish feed on a large variety of food items viz. fish and body parts (16.89%), crustaceans (20.43%), aquatic insects (20.01%), annelids (2.19%), molluscs (1.41%), debris and mud (16.68%), semidigested mater (11.49%), plant and plant parts (9.60%) and gravel and stones (1.30%). The TL-ACL relationship model equation is established as $ACL = 2.065 + 0.326 TL$ which was positively correlated and statistically significant. The average value of TL-ACL ratio (1:0.43) revealed carnivorous habit of the fish. The gonads are found unpaired having short ducts which originate from the left abdominal cavity beside the alimentary canal and bellow the kidney. The mean length and weight of ripe ovary are found as $4.37 \pm SE0.05$ cm and $16.37 \pm SE0.56$ g respectively. The ova are found larger with a mean diameter of 3.07 ± 0.02 mm in ripe stage. The fish is low fecund and the absolute fecundity is ranged from 651 to 2250 with a mean of 1598.18 ± 42.47 . The breeding period extend from May to September. No methodical marketing channels are observed for *N. notopterus*; channels that have been observed comprise a few intermediaries (e. g. 'Farias', 'Beparis', 'Aratdars' and Retailers) in between fishermen and the consumers. Benefit of fishermen is correlated with the length of marketing chain. The average retail price is found to vary due to season and marketing costs. The fish is able to breed naturally in stagnant water of carp polyculture system. The sandy-loam soil of the pond, submerged vegetation and suitable water quality enhanced the breeding process though random operational activity of carp polyculture system destroys breeding grounds and hampers parental care. But the findings of two years trial conclude for strong potentiality of natural breeding of *N. notopterus* which may play an important role in production and conservation of the species.

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Chapter One

GENERAL INTRODUCTION

Chapter One

GENERAL INTRODUCTION

Background of the Study

Research in fish biology, both in the marine and freshwater is becoming prominent all over the world. In recent years climate change has become recognized as the foremost environmental problem of the twenty-first century, and a subject of considerable debate (Cowie, 2007). This change of climate seriously has been affecting both the terrestrial and aquatic organisms. Fisheries biologists and managers are therefore increasingly asking about aspects of ecology, behaviour, evolution and biodiversity that were traditionally studied by people working in very separate fields. This has highlighted the need to work more closely together in order to help ensure the future success both in management and conservation of natural population (Hart and Reynolds, 2002). So, the world is literally being "turned on its eyes" to the biological research and calling for cooperation and partnerships between biologists and many other professional and cultural groups in the community that we may individually and collectively minimize the horrendous destruction of our planet.

Fish have great significance in the life of mankind, being an important natural source of protein and providing certain other useful products as well as economic sustenance to many nations (Royce, 1972). It is a well known fact that the knowledge on fish biology particularly on morphometry, length-weight relationship, condition factor, food and feeding habit, reproduction, etc. is of utmost important not only to fill up the lacuna of our present day academic knowledge but also in the utility of the knowledge in increasing the technological efficiencies of the fishery entrepreneurs for evolving judicious pisciculture management. For developing fishery, it is necessary to understand their population dynamics how fast they grow and reproduce, the size and age at which they spawn; their mortality rates and its causes, on what they prey upon along with other biological processes. So, obviously it can be said that the knowledge of fish bionomics particularly the comprehensive study of biology of a fish in relation to its environment will act as a "Key Factor" for the development of fishery science.

Objectives of the Study

The objectives of the research are-

- To establish the relationship among different morphological characters of the species.
- To establish growth curve models for the assessment of seasonal and sex dependent growth variation.
- To expose the secret of food and feeding habit.
- To know the reproductive status and behaviour of the species.
- To find out the marketing status of the species.
- To assess the mode of life and population growth in carp polyculture system.

All together the ultimate objective of the study is to increase the production of animal protein in order to sustain the growing population utilizing the large areas of unproductive idle water bodies providing guideline relationship between biological aspects and fish culture.

Justification of Species Selection

The bionomical study is a basic requirement for the successful management of fish population. We have 260 of freshwater and 415 of marine fish species having a glorious prospect in this sector. The proper management of these resources can play a vital role in supplying protein and employment to the people. In Bangladesh a few selected fresh and marine water fish species are in under culture though many of these species can be taken under culture scheme to increase the gross production of fish. For the scanty research record of these species, our farmers are not interested to culture them. The fish *Notopterus notopterus* has a huge potentiality to play role in commercial use. The Flesh of the fish is nutritious and refers as diet for patients. It grows well in seasonal ponds and has no risk of over population density due to its low fecundity, and naturally breeds in stagnant water and do not harm the culturable fish rather helps to increase productivity by controlling the unwanted small fishes, insects, zooplanktons etc. The fish is

relatively high priced due to its special use as “Baked Meat”, a delicious food item for the rich and able to provide good sports to anglers and is referred as game fish. The species is also regarded as aquarium fishes for its exceptional morphological characters specially the undulating movement of its anal fin (Source: www.fishbase.org and personal investigation). Considering all these potentialities the research work is proposed to study the bionomical aspects of *Notopterus notopterus*.

Geomorphology of the Study Area

The geomorphology and effects of environmental parameters greatly influence the nature and pattern of the population of a locality. Such information is of immense importance in the study of biological aspects of any species. The Rajshahi district is situated in the latitude between $24^{\circ}24'$ and $24^{\circ}40'N$ and the longitudes between $88^{\circ}30'$ and $88^{\circ}50'$ E (Source: http://en.wikipedia.org/wiki/Rajshahi_District). The district is bounded by Naogaon district on the north; West Bengal of India, Kushtia district and the Ganges on the south; Natore district on the east and Nawabganj district on the west (Fig. 1.1).

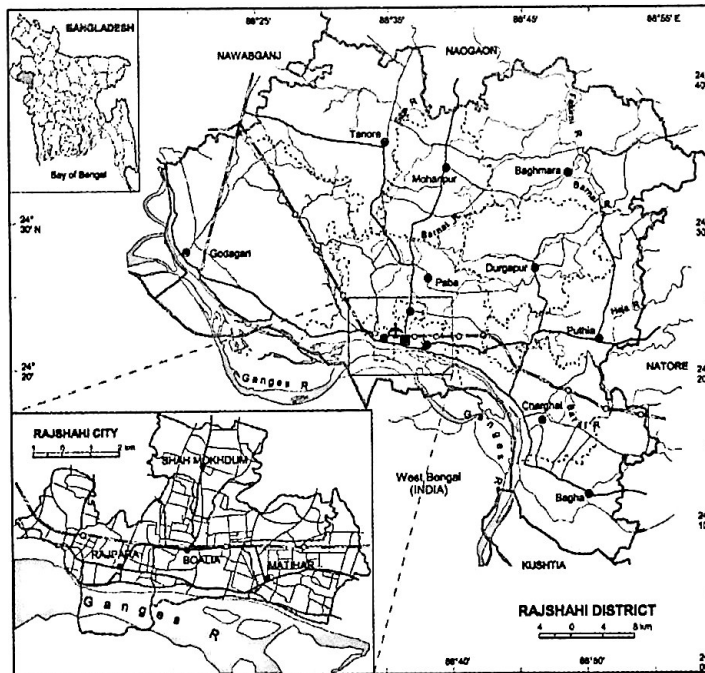


Fig. 1.1: The geomorphology of Rajshahi district (Source: Banglapedia, 2003).

Physical and Climatic Features of the Study Area

This district is described as having tropical monsoon weather with relatively high temperature fluctuations moderate rain fall is less than 1500mm and it is considered to fall in the dry zone of Bangladesh. The relative humidity is at the maximum during monsoon. The air temperature fluctuates in summer around 30°-44° C and in the winter 4.5°-20° C (Source: Rajshahi Meteorological Station, 2008).

Water Resources of the Study Area

The land area of Rajshahi district is 240,701 ha of which 16.98% is considered as water resources (Source: District Fishery Office Rajshahi, 2008). The district is fortunate with 10 rivers (*viz.* Fakirni-Baranai, Shiba-Baranai, Mahananda, Pagla, Musa Khan, Ganges, Baranai, Hoja, Godari and Gumani) and vast water resources like beels, flood plains, ponds, canals etc. (Banglapedia 2003). The Padma is the main river of Rajshahi which flows close to the Rajshahi city and continues to the south-eastern direction over a distance of 145 km (Banglapedia 2003). The river plays a potential role in fisheries sector of Rajshahi. The river is originated from the Ice berg “Gongotri of Himalayas” and named river “Ganga” in India. After wandering over a distance of about 2290 km in the Indo-Gangetic plains in the state Uttar Pradesh, Bihar and West Bengal it enters Rajshahi as “Padma” and passes through the plains of Rajshahi to join the “Jamuna” at Goalanda then with “Meghana” at Chandpur and then ultimately falls into the Bay of Bengal (Banglapedia, 2003).

Profile of the Species

Valid Scientific Name: *Notopterus notopterus* (Pallas, 1769)

Synonyms:

Gymnotus notopterus Pallas, 1769

Notopterus notopterus (Pallas, 1769)

Notopterus kapirot Lacepède, 1800

Mystus kapirot (Lacepède, 1800)

Notopterus kopirot Lacepède, 1800

Clupea symura Bloch & Schneider, 1801

Mystus badgee Sykes, 1839

Notopterus bontianus Valenciennes, 1848

Notopterus pallasii Valenciennes, 1848

Notopterus primaevus Günther, 1876

Notopterus osmani Rahimullah & Das, 1991

English names: Feather back, Knife fish

Local names: Foli, Foila, Folui, Kanla, Folai, Folo, Kana Foli

Etymology and Naming: (Gr. noton=back and Gr. pteron=wing, fin). Featherbacks are easily identified by their razor sharp long anal fin which beings just behind the head and extend along the under surface of the body to tip of caudal fin. In the centre of the back there is a small feather like slender dorsal fin (Plate 1.1), from which the fish derives the name “Featherback” (Talwar and Jhingran, 1991).

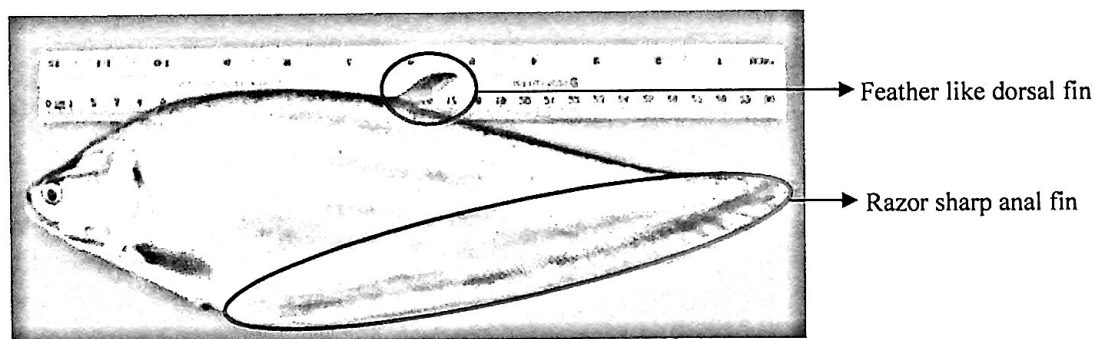


Plate 1.1: Displaying the razor sharp long anal fin and feather like slender dorsal fin of *N. notopterus*

Classification:

Kingdom: Animalia

Phylum: Chordata

Sub-Phylum: Vertebrata

Super Class: Pisces

Division: Gnathostomata

Class: Osteichthyes

Sub-Class: Actinopterygii

Super Order: Teleostei

Order: Clupeiformes ✓

Family: Notopteridae

Genus: *Notopterus* Lecepede, 1800

Species: *N. notopterus* (Pallas, 1769)

Generic Characters: Body oblong, strongly compressed and finely scaled; caudal region long and tapering. Abdomen with a double series of 28-46 spines. Head compressed and cavernous, with large membranous opercular flap. Cleft of mouth moderate and lateral; teeth small on jaws, also on palate and tongue. Pharyngeal teeth absent. Gill membranes confluent at bases, but free from isthmus. Adipose fin absent. Dorsal fin short and tuft-like, situated in the caudal region; originating far behind the origin of anal, with 7 to 10 rays. Pelvic fins rudimentary and are united at their bases, situated a little before the anal and originate in advance of the origin of the dorsal fin. Anal fin very long and ribbon-like, razor-sharp with 100 to 135 rays, confluent with small unforked caudal fin (Srivastava, 1968; Menon, 1974; Misra, 1976; Talwar and Jhingran, 1991); (Plate 1.2 and Plate 1.3).

Description of the species: Fin formula- D. 7-8; P₁. 15-17; P₂.5-6; A.99-104. (Rahman, 2005). Body deeply compressed, dorsal and ventral profiles convex. Both jaws almost equal. Maxilla reaches below middle of orbit. Upper jaw formed by premaxillaries medially and maxillaries laterally. Anterior nostrils with a tube,

posterior ones are holes in front of upper edge of eye. Preorbital serrated. Lower outer and small inner rows of teeth on each jaw; those on palate and vomer in villiform rows. Tongue with rows of strongly curved hook-like teeth. 28-33 pairs of spines along abdomen. Mouth moderate, maxilla extends to midorbit. Lateral line complete with 230-240 scales in lateral series. Scales minute, considerably larger on opercles than on body. 28-31 bony scales between throat and pelvic origin. Anal fin densely scaled. Small tuft-like dorsal fin situated slightly nearer to snout tip than to base of caudal. Pelvics small, united, situated close to vent. Ribbon-like anal fin extends for more than $\frac{2}{3}$ rd of body length confluent with a very small caudal fin (Talwar and Jhingran, 1991; Rahman, 2005). Head 4.3-4.5 in standard, 4.7-5.0 in total length. Height 3.4-3.8 in standard, 3.7-4.2 in total length. Eye 5.0-6.5; snout 1.2-1.3; interorbital 1.2-1.3 (Rahman, 2005). Some of these characters are displayed in Plate 1.2 and Plate 1.3.

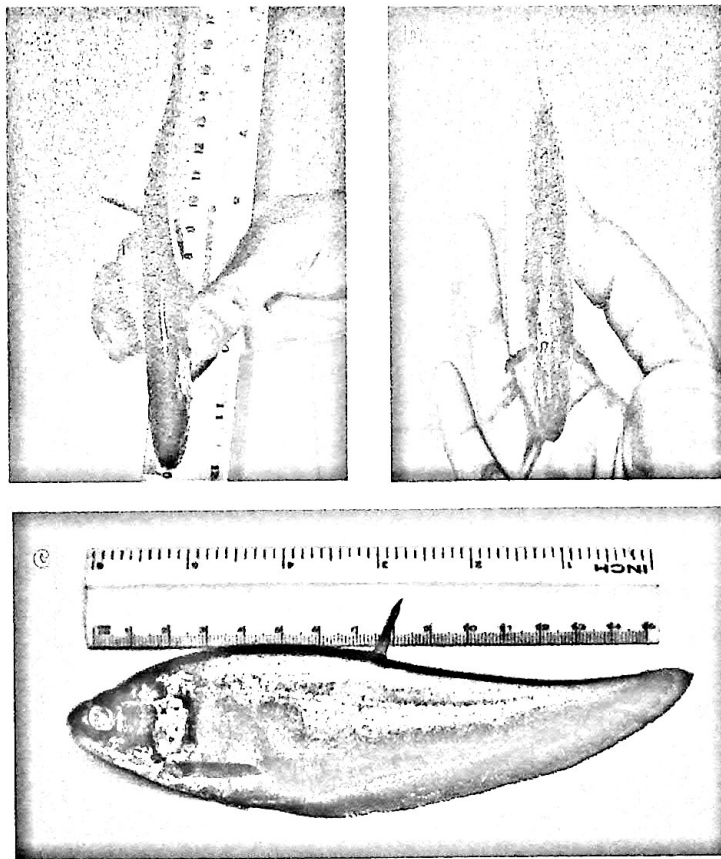


Plate 1.2: A featherback showing deeply compressed body than its flattened structure (a. dorsal view, b. frontal view c. lateral view).

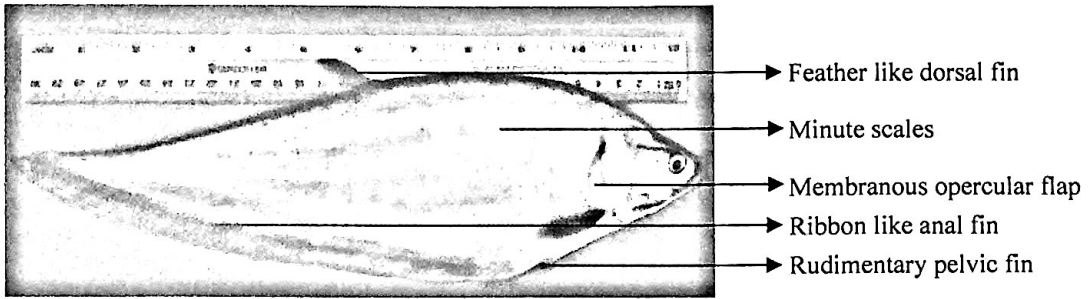


Plate 1.3: A featherback showing several morphological identities while described the generic and species characters.

Colour varies according to ecological conditions. Specimens from clear streams and rivers are silvery-white with numerous fine grey spots on body and head. Those from the thick vegetation are dark greenish black in colour (Plate1.4). Some of the specimens are darkest along the back (Bhuiyan, 1964; Srivastava, 1968; Talwar and Jhingran, 1991; Rahman, 2005).

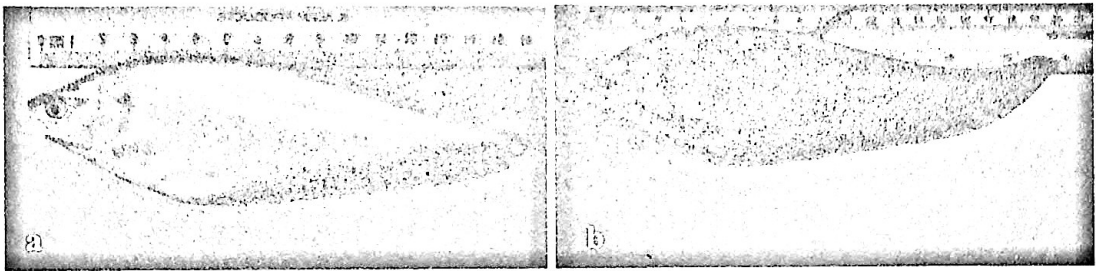


Plate 1.4: Colour variation in featherback due to ecological condition (a. specimen from clear stream b. specimen from thick vegetation).

The largest *N. notopterus* was recorded 60 cm by Day, 1889 in India. In Bangladesh the largest specimen measuring 35.5 cm in total length and weighting about 315g was recorded by Rahman (2005) from Gacher Dahar Beel of Sylhet district.

Habits: Demersal, carnivore, piscivore, predator (Source: www.fishbase.org).

Habitat: Inhabits chiefly in standing and sluggish waters of rivers, canals, floodplains, lakes, reservoirs, ponds and sometimes in brackish water (Source: www.fishbase.org).

Food and Feeding Habits: Feeds on aquatic insects, crustaceans, molluscs, shrimps, small fishes and some young roots of aquatic plants. Active during twilight and night (Source: www.fishbase.org).

Reproduction: Colonizes and breeds seasonally during rainy days and migrates back to permanent waters in dry season. Breeding takes place in stagnant or running waters in the rainy season. Eggs are laid in small clumps on submerged vegetation. A female measuring 21-25 cm usually lays 1,200-3,000 eggs (Source: www.fishbase.org).

Distribution: The species is distributed in Pakistan; Indus, Ganges-Brahmaputra, Mahanadi, Krishna, Cauvery, and other river basins in southern India; Myanmar; Cambodia; Vietnam; Irrawaddy, and Salween; Meklong, Chao Phraya, Mekong and virtually all coastal river basins of peninsular Thailand and Malaysia; Sumatra and Java; and all over Bangladesh presented in Fig. 1.2 According to Srivastava, 1968; Menon, 1974; Misra, 1976; Day, 1889; Talwar, and Jhingran, 1991; Rahman, 2005.

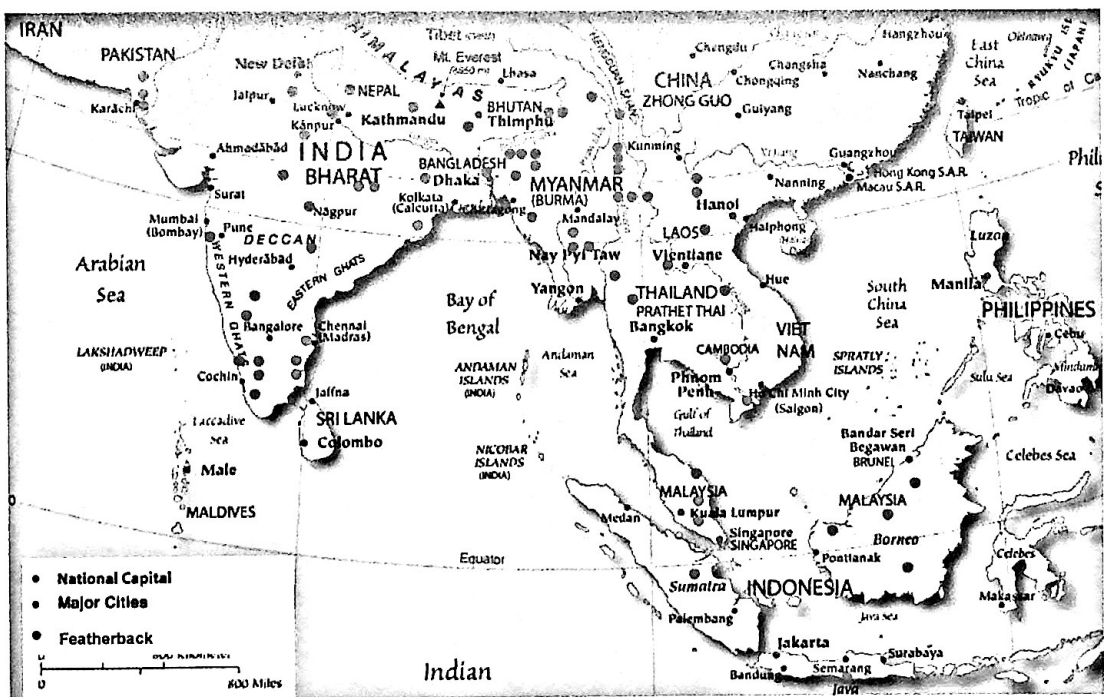


Fig. 1.2: Distribution of featherback in oriental region
(Source of Map: http://www.nationsonline.org/maps/south_east_asia_map.jpg)

Global Importance: commercially important for aquaculture and ornamental or game fishery (Source: www.fishbase.org).

Economic Importance: The flesh is of good flavoured but full of small bones; and in considerable demand. Flesh is specially used to make “Baked Meat”, a delicious food item for the rich. Though bionomics and breeding of *N. notopterus* have been investigated by several works, no worthwhile attempt towards its culture has been made. It provides good sports to anglers and is regarded as game fish of considerable mean value. The species is treated as an aquarium fish for its exceptional morphological characters and swimming by undulatory movement of body and anal fin as a single unit.

Status and conservation: The fish is not yet been treated as a threatened fish in IUCN red list but loosing existence due to modern carp culture while preparing ponds by dewatering and killing of predatory fishes by poisoning. As a result the species is loosing its feeding and breeding ground day by day. More attention should be taken for its existence and conservation.

Chapter Two

MORPHOMETRIC AND MERISTIC ANALYSIS

Chapter Two

MORPHOMETRIC AND MERISTIC ANALYSIS

2.1 Introduction

There are many isolated disciplines in fish biology, of which the study of morphology is inseparably related to study of the mode of life of the organism. In fact, the size and shape are fundamental to the analysis of variation in living organisms and morphological variations even in the same species most often related to the varied environmental factors (Grant and Spain, 1977).

Proper identification of fishes is of great importance to fisheries management but it is often difficult to attain. Fishes having confusing characters are not easy to identify even with the aid of carefully prepared keys where hybrids are not treated in most cases. Needless to say, scientific work required the finest identifications where correct procedure can avoid the confusion of identification.

In many fishes, changes in the relative growth of the various body proportions are known to occur at different stages of development, particularly at sexual maturity (Shafi and Quddus, 1975). But all living animals have a tendency to maintain symmetrical growth of its different body parts in relation to one another. It is generally known that all the body parts are dependent on the total length of the body *i.e.* growth of the body parts are proportional to the growth of the total length. But the total length of the body is not dependent on all other body parts. So, morphometric measurements of fishes and the study of statistical relationship among them are essential for taxonomic study of a species (Tandon *et al.* 1993).

According to Vladykov (1934) morphometric and meristic characters of fishes can be divided into three categories. The first category includes those characters which have very low ranges of body proportions and are genetically controlled. The second includes those having wide ranges of proportions and showing impact of the hydrological conditions. The third is the intermediate category which includes those characters partly controlled by the environment. Vladykov (1934) further classified the characters into two categories. Some characters show wide range and

thus can be controlled by the environment; others show narrow range and are said to be controlled genetically. The former are labeled as plastic characters and the later as non-plastic. In the above point of view the characters of first category in former classification can be considered as non-plastic characters and remaining characters of other two categories can be included under plastic characters, and hence can be utilized for differentiation of stocks or subspecies.

In recent years the significance of the statistical relationship of the morphometric characters has also been recognized in all taxonomic and systematic studies. The principle underlying this method is based on the assumption that “Under condition of partial or complete isolation of groups of fish, slight differences in body proportion or meristic characters will be preserved in each group” (Ahlstrom, 1957). The small difference in meristic or morphometric characters may not be apparent in case of individual specimens but average of a large sample may show it clearly and the significance of the differences between the average of two samples or groups can be tested statistically based on the theory of probability.

The size frequency distribution method is based on the assumption that size of individuals of the same age group in a population of fish approximately has normal distribution. With advance in age the rate of growth slows down and as a result the modes will frequently overlap. Uniform rate to growth can not be expected throughout the life span of the individual. It is well known that in earlier stages the growth rates are much higher than in later stages.

Growth of fish may be described in terms of changes in length, width or any other linear dimensions as well as by weight (King, 1995). In fish studies, fish length is often more rapidly and easily measured than mass. Thus knowing the length–weight relationship makes it more convenient to determine mass where only the length is known (Froese and Pauly, 1998). The length-weight relationship is an important tool in fish biology, physiology, ecology and fisheries assessment (Oscor *et al.*, 2005). Length–weight relationships for fish have been used extensively to provide information on the condition of fish, their isometric or

allometric growth, in the analysis of ontogenic changes, to compare life histories of fish species between regions as well as other aspects of fish population dynamics. In fisheries biology, length–weight relationships are useful for the conversion of growth-in-length equations to growth-in-weight for use in stock assessment models and to estimate stock biomass from limited sample sizes (Binohlan and Pauly, 1998; Koutrakis and Tsikliras, 2003; Valle *et al.*, 2003; Ecoutin *et al.*, 2005).

On the other hand the length-weight relationship of fish has theoretical and practical application in fishery biology. The study of length-weight relationship is mainly directed to two objectives: first, to establish a mathematical relationship between two variables *i.e.*, length and weight, so that if one is known, the other can be computed; and second, to measure the variation from the expected weight for length of individual or group of fish (Steeby *et al.*, 1991).

The length-weight relationship is also a useful tool for fish culturists. When large numbers of fishes must be individually sampled, it is faster and often more convenient to determine the fish length rather than weight (Steeby *et al.*, 1991). This relationship is also used in commercial sales and population assessment (Steeby, 1995). According to LeCren (1951) and Tandon (1961) the length–weight relationship is helpful in the determination of spawning season, well being on set of sexual maturity etc. The application of length-weight relationship in fishery biology solves various problems concerned with the life history of fishes. Besides providing a mathematical relationship between length and weight of fish as a means of introversion, such a relationship also yields information on the general well being of the fish, variation in growth, size at first maturity, gonad development and breeding season (Chatterji *et al.*, 1977), and seasonal changes in their specific gravity (Tester, 1940).

The changes in weight in relation to length are generally not on the basis of specific gravity but due to changes in the body form or volume, because usually equilibrium is maintained between the density of the organisms and that of the surrounding water. LeCren (1951) applied the term “condition” as a general term

for the analysis of length-weight relationship with a view to find out the variations from expected weight for length of individuals as indicating relative fatness or plumpness, robustness, degree of well being etc. In order to express the relative well being of the individuals very often the cube law relation of the length-weight relationship is used and called as the 'condition factor' or 'coefficient of condition' or the 'ponderal index' (Hile, 1936; Thompson, 2004). The condition factor is also used to measure the effect of environment improvements including stocking (Cooper and Benson, 1951).

Though *N. notopterus* is not common, it has an excellent demand to the consumers. But information on the morphometry of this species is not satisfactory to fulfill the study of bionomical need of the species. Considering the basic need of morphometric and meristic analysis along with other biological studies for successful farming and economic exploitation of the species, the chapter has been planned and analyzed critically to every possible aspect of the morphometric and meristic analysis and condition factor of the species.

2.2 Review of Literature

It is very essential to review the previous research works before conducting a study. Though the observations on morphometric and meristic analysis and condition factors of different fishes are available all over the world but the literature on the morphometric and meristic analysis of *N. notopterus* is scanty. Some important works related to the present chapter are mentioned below:

Acosta *et al.* (2004) found that the parameter 'b' of nonlinear least squares of weight-length data ranged from 1.41 to 3.68 for 33 species representing 14 families of fishes from Gulf of California (Mexico) which can be used for several biological or fishery purposes to enable the derivation of weight estimates from given a value of length or vice versa. 1

Agboola and Anetekhai (2008) established the length–weight relationships for 35 fish species from the Badagry creek, Lagos, Nigeria and found the values of the parameter b are within the expected range of 2.5–3.5.

Aguirre *et al.* (2008) calculated the length–weight relationship of 21 species of fish from a coastal lagoon in the southwestern Gulf of California and found no differences between sexes in any species. The slope (b) showed values between 2.5 and 3.5.

Alam *et al.* (1994a) observed that the total length of males of *Ailia coila* ranged from 50 to 155 mm and total weight 0.2 to 17g where in female the values were ranged from 56 to 169 mm and 0.3 to 22.8g respectively. The higher values of regression coefficient (n) revealed that the length-weight relationships of the species followed the cub law and may be affected by the general condition of appetite and gonadal contents of the fish.

Arshad *et al.* (2008) found that the 'b' values of five fish species from sea grass beds of the Sungai Pulai estuary, Peninsular Malaysia ranged from 2.535 to 3.089 with determination coefficients (r^2) >0.85 . Total length–standard length relationships of the same fishes were highly significant ($r^2 > 0.85$, $P < 0.001$).

Balart *et al.* (2006) observed the length–weight relationships of 33 cryptic reef fishes from the southwestern Gulf of California and stated that the ‘b’ values varied between 2.63 and 3.61 which indicate the isometric growth.

Bhuiyan and Biswas (1982) studied the morphometry of *Puntius chola* and found very significant co-relationships among total length and different body lengths. The mean values of condition factor (K) and relative condition factor (K_n) were as 1.4662 and 1.001 respectively.

Bouchon-Navaro *et al.* (2006) calculated the weight–length relationships (WLR) for 50 fish species from the sea grass beds of Guadeloupe and Martinique and presented the ‘b’ of the WLR varied between 2.63 and 3.61 and showed a mean value of 3.07 ($SE \pm 0.06$).

Britton and Davies (2007) studied the length-weight relationships of *Pseudorasbora parva* and found that the length of fish ranged from 2.5–11.8 cm. They also stated that the ‘b’ ranged between 2.76 and 3.32 and across all lakes, the relationship was $W=0.011L^{3.03}$, with weight in gram and length in cm.

Cicek *et al.* (2006) estimated the length–weight relationships (LWR) for 31 teleost fish species caught in the Babadillimani Bight on the western entrance of Mersin Bay, Turkey. They found the ‘b’ values varied from 2.662 to 3.395 with a mean of 3.024 (± 0.166).

Dadzie *et al.* (2008) analyzed the morphometric parameters of the black pomfret, *Parastromateus niger* from the Arabian Gulf and found the following length-length relationships: $TL = 0.63 + 1.15SL$ (females), $TL = 0.94 + 1.14SL$ (males) and $TL = 0.75 + 1.15SL$ (both sexes including juveniles). The 95% CI of the exponent in length-weight relationship varied from 2.788 to 2.796 in females, 2.726 to 2.732 in males, 2.779 to 2.784 for both sexes and 2.590 to 2.613 in juveniles, all indicating negative allometric relationship.

Dulčić and Glamuzina (2006) observed the length–weight relationships for fish species from three eastern Adriatic estuarine systems. The values of the parameter ‘b’ mostly remained within the expected range of 2.5–3.5 that indicate isometric growth.

Dulčić *et al.* (2003) worked on the Age, growth and mortality of *Spicara smaris* and found that the total lengths of the fish ranged from 6.3 to 19.8 cm, and the weight from 2.2 to 78.3 g. The slopes (b values) of the length–weight regressions indicated negative allometric growth for females ($b = 2.8 \pm 0.03$) and isometric growth for males ($b = 3.08 \pm 0.04$). The overall sex ratio was 1:4.1 in favour of females.

Esmaeili and Ebrahimi (2006) studied the length–weight relationships of 24 freshwater fish species of Iran and found significant length–weight relationships with high correlation coefficient for all species. The value of the parameter ‘b’ varied between 2.881 and 3.545.

Ferreira *et al.* (2008) estimated the weight–length relationships for 18 species from the Madeira archipelago where the parameter ‘b’ ranged between 2.737 in *Polyprion americanus* and 3.674 in *Benthodesmus simonyi*.

Froese (2006) done the meta-analysis which explores weight–length relationships of the type $W = aL^b$ for 1773 species of fishes. It shows that 82% of the variance in a plot of log ‘a’ over ‘b’ can be explained by allometric versus isometric growth patterns and by different body shapes of the respective species. Across species median $b = 3.03$ is significantly larger than 3.0, thus indicating a tendency towards slightly positive-allometric growth in most fishes. The expected range of $2.5 < b < 3.5$ is also confirmed in the study.

Haniffa *et al.* (2006) studied the length–weight relationships of *Channa punctata* where the total length varied from 5 to 27 cm. They stated that there is no significant difference in the length–weight relationship as a function of sex in the Siruvani, Vellaru and Cauvery populations, whereas there is a significant difference between males and females in the Tamirabarani population, indicating non-homogeneity of these relationships.

Hoque and Hossain (1992) worked on the length-weight relationship and condition factor of the cat fish *Mystus vittatus*. They found that the total length and weight of the fish ranged from 65.31 mm to 132.72 mm and

3.72g to 19.98g respectively. All the relationships were found to be linearly positive. Result of the condition factor shows that the weight of the fish changes in relation to length.

Hossain *et al.* (2006) studied the length–weight (LWR) and length–length relationships (LLR) of the Asian striped catfish, *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae), from the Mathabhanga River of Bangladesh and found that the allometric coefficient ‘b’ of LWR was close to the isometric value ($b=3.058$), although it suggested negative allometric growth for males ($b=2.959$) whilst positive allometric growth for females ($b=3.134$). The results further indicated that the LLRs were highly correlated ($r^2>0.989$, $P<0.001$).

İlkyaz *et al.* (2008) estimated the length–weight relationships for 11 elasmobranch and 51 teleost fish species caught in Izmir Bay, Turkey. The mean b-value was calculated as 3.10 ($SE \pm 0.03$) and only three species were out of range between 2.5 and 3.5.

Karakulak *et al.* (2006) worked on the length–weight relationships for 47 coastal fish species from Gökceada Island in the northern Aegean Sea, Turkey. They estimated the parameter ‘b’ of length–weight relationship ($W=aL^b$) ranged between 2.08 and 3.73. The mean ‘b’ value 3.03 ± 0.052 (SE) was not significantly different from 3.

Kiran *et al.* (2004) studied the Length-weight relationship of feather back, *Notopterus notopterus* (Pallas) from Jannapura pond, Karnataka, India and found that the species has length ranged from 19.1–33.8 cm and weight range from 56.0–358.4g. The length-weight relationship equation was found $\log W = -2.4997 + 3.2721 \log L$ or $W = 0.003164L^{3.2721}$ for male and $\log W = -1.8865 + 2.8483 \log L$ or $0.01298L^{2.8483}$ for female with ‘r’ values 0.8629 and 0.8629 respectively. The values of exponent ‘b’ ranged between 2.8483 and 3.2721 which are nearer to 3.

- Koutrakis and Tsikliras (2003)** worked on the length–weight relationships of 43 fish species from three northern Aegean estuarine systems. They observed that the values of the LWR parameter ‘b’ varies between expected range of 2.5–3.5. The median value was 3.035 and 50% of the b values lay between 2.955 and 3.195.
- Lalèyè (2006)** found linear relationships between total (TL) and standard (SL) lengths for 50 fish species caught in the Ouémé River. The author also observed TL-TW relationship for 52 species and found the ‘b’ values range from 2.331 to 3.519 where the ‘b’ values of 38.5% species were significantly different from 3.
- Mendes *et al.* (2004)** estimated the weight–length (W–L) relationships for 46 fish species captured from the western Portuguese coast where the parameter ‘b’ of the W–L relationship ranged between 2.171 and 3.873, with a median of 3.124. Significant variations in ‘b’ were found at seasonal level for *Mullus surmuletus*, *Pagellus acarne*, *Trachinus draco*, *Sardina pilchardus*, *Scomber scombrus* and between sexes for the *Scyliorhinus canicula*.
- Metin *et al.* (2006)** observed that the males of sampled population of poor cod, *Trisopterus minutus* were 53% where females were 41% with the total length ranged from 10.6–24.8 cm. Length–weight relationships were determined for males, females and combined sexes as $W = 0.007L^{3.16}$, $W = 0.009L^{3.04}$ and $W = 0.007L^{3.14}$ respectively.
- Mir (1996)** studied the length-weight relation of *Barbus canis* and found that the total length and weight of the species ranged from 141–375 mm and 50–750g respectively. The length-weight relationship was not followed by the cube law which indicates the non-isometric growth of fish.
- Miranda *et al.* (2006)** worked on the weight–length (W–L) relationships for 28 cyprinid species collected on the Iberian Peninsula. They found that the values of the exponent ‘b’ in the W–L relationships ranged from 2.78 to 3.47 indicating overall isometric growth.

Mortuza and Mokarrama (2000) stated that the total length of males of *Botia lohachata* ranged from 44.25 to 88 mm with the total weight ranged from 0.805 to 6.45g where in female the values were ranged from 48.80 to 91 mm and 1.006 to 6.54g respectively. The higher values of regression coefficient (n) revealed that the length-weight relationships of the species followed the cube law and may be affected by the general condition of appetite and gonadal contents of the fish.

Moutopoulos and Stergiou (2002) observed the relationships between total (TL), fork (FL) and standard (SL) length for 37 fish species and the relationships between TL and wet weight for 40 fish species from the Aegean Sea (Cyclades; Greece). They found that the relationships between TL, FL and SL were all linear (for all cases: $r^2 > 0.928$) and the values of the exponent 'b' of the length-weight relationships ranged from 2.235 to 3.704.

Oscoz et al. (2005) worked on the weight-length relationships (WLR) for *Salmo trutta*, *Phoxinus phoxinus*, *Chondrostoma miegii*, *Barbus graellsii*, *Barbatula barbatula* and *Gobio gobio* and reported that the 'b' values in the WLR ($W = aL^b$) varied between 2.97 and 3.42.

Özaydın et al. (2007) observed the weight-length relationships for 60 fish species captured from Izmir Bay, Central Aegean Sea. They found the exponent 'b' based on $W=aL^b$ showed a mean value of 3.027 (SE ± 0.03) and more than 50% of the values ranged between 2.912 and 3.189. Only one species, *Cepola macrophthalma*, showed strong negative allometric growth.

Pajuelo et al. (2006b) stated that the total length of *Pagrus auriga* ranged from 120 to 780 mm. The length-weight relationship for all individuals was described by the parameters: $a=0.0086$ and $b=3.014$, when length is given in mm and weight in grams.

Ruiz-Campos et al. (2006) observed the length-weight and length-length relationships by nonlinear least squares of weight and length data for 10 freshwater, estuarine and marine fish species from northwestern Baja California (Mexico) and found that the value of parameter 'b' ranged from 2.50 to 3.61 which indicates isometric growth.

Šantić *et al.* (2006) stated that the 'b' values of length-weight relationships of Mediterranean horse mackerel, *Trachurus mediterraneus* varied during the year with season and condition. The values showed that growth of both males and females was positively allometric, *i.e.* specimens changed shape as they gained weight.

Sinovčić (2004) worked on the growth and length-weight relationships of *Engraulis encrasicolus* and found that the total length of fish ranged from 4.4 to 12.5 and length-weight regression coefficient (b) varied between 2.95 and 3.42 with the regression constant (a) between 2.1 and 6.0 ($\times 10^{-3}$).

Sinovčić *et al.* (2004) described the length-weight and length-length relationships for 10 of the most important pelagic fish species from the Adriatic Sea and found equations for converting size measurements: standard length (SL) and fork length (FL) to total length (TL) and vice versa. Significant relationships were found for all species ($P < 0.001$) with most r^2 values being greater than 0.79.

Tarkan *et al.* (2006) estimated the relation between length and weight for 32 species representing 12 families of fishes from six water resources in the Marmara region of Turkey and observed that the parameter 'b' ranged from 2.66 to 3.56 which indicating overall isometric growth of those fishes.

Tsoumani *et al.* (2006) worked on the length-weight relationships of the cyprinid fish *Carassius gibelio* from the 12 most important lakes of Greece. They found that the values of the exponent b of the length-weight relationships ranged from 2.33 to 3.38, and varied with the trophic state of the lake. In eutrophic lakes these 'b' values were significantly ($P < 0.001$) lower than in oligotrophic or mesotrophic lakes.

Valle *et al.* (2003) obtained the weight-length relationships of 53 fish species representing 21 families where the mean value of exponent 'b' was 2.989 ($SE \pm 0.0304$) and the coefficient of determination was highly significant.

Vaslet *et al.* (2008) reported the weight–length relationships (WLR) for 20 fish species from the mangroves of Guadeloupe where the coefficient ‘b’ in the WLR varied between 2.37 and 3.85, with a mean of 3.15 ± 0.15 .

Yildirim *et al.* (2008) investigated the seasonal variations in Fulton’s condition factor (K) and the length–weight relationship (LWR) for *Capoeta sieboldii* in the upper Çoruh River (Turkey) and found slight seasonal variation in condition, with generally lower values in summer and winter, and higher values in autumn. LWR was calculated as $W = 0.016 \times L^{2.933}$, $W = 0.014 \times L^{3.001}$, and $W = 0.009 \times L^{3.118}$ for males, females, and juveniles, respectively.

Zorica *et al.* (2006) observed the positive allometric growth in length–weight relationship of *Serranus scriba* in the Trogir Bay and found the exponent $b = 3.15$.

2.3 Materials and Methods

Sampling and Laboratory Analysis

Random sampling was done to collect *N. notopterus* at a regular interval of one week from different fish landing centres of Rajshahi, Bangladesh since January 2005 to December 2006 (Fig. 2.1). For the present study a total of 1440 specimens were collected during daytime and precautions were taken to save from spoilage or any damage. After collection the specimens were washed well, confirmed to the species level then tagged and preserved by date in plastic jars with 10% formalin. Different lengths were measured with a precision of 0.01 cm with the help of measuring board fitted with a scale. A fine pointed divider allowed measuring the smaller parts of the body. Weight of the fish was taken with the help of Electronic precision balance Model: KD-300KC to an accuracy of 0.5 g. The specimens were sexed either by the visual observation of secondary sexual characters or macroscopically by dissecting the abdominal cavity for direct observation of the gonads.

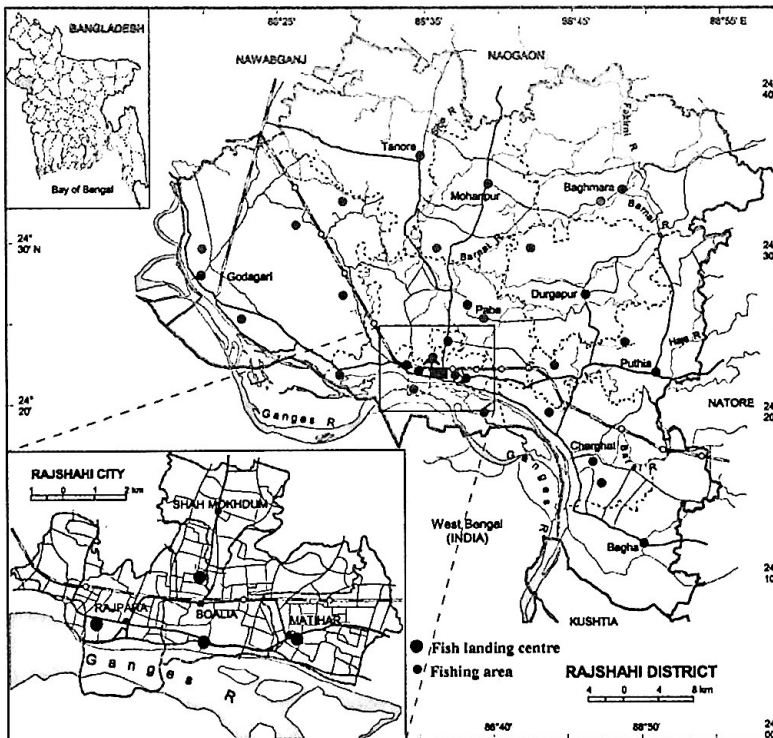


Fig. 2.1: Map of Rajshahi district showing different fish landing centres and fishing areas (Source: Banglapedia, 2003).

Morphometric Measurements

The morphometric measurements are displayed in Fig. 2.2 and the definitions of measurement used in this study are as follows:

Total length (TL): Total length was measured from tip of the snout to the last point of the caudal fin. The specimens were extended on the flat surface of the measuring board and pressure was applied in the region of the abdomen to ensure maximum extension.

Standard length (SL): Standard length was measured from the tip of the snout up to the base of the caudal fin.

Dorsal length (DL): The length between the tip of the snout and the front base of the dorsal fin was measured as dorsal length.

Pectoral length (PL): Pectoral length was measured from the tip of the snout up to the frontal base of the pectoral fin.

Pelvic length (PvL): Pelvic length was measured from the tip of the snout up to the frontal base of the pelvic fin.

Anal length (AL): The length from the snout tip up to the front base of the anal fin was measured as anal length.

Operculum length (OL): This is the length between the snout tip and the frontal base of the operculum.

Head length (HL): The length from the snout tip up to the extreme point of the operculum.

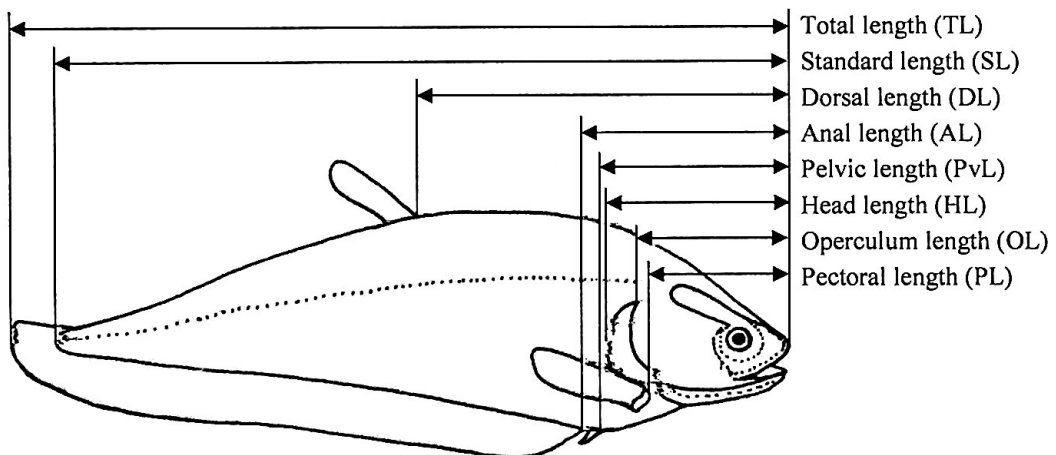


Fig. 2.2: Layout of *N. notopterus* showing different morphometric measurements.

Meristic Counts

The meristic count of dorsal, pectoral, pelvic, anal and caudal fin rays was done for the study of fin ray analysis. The following abbreviations of meristic counts are used in the study:

DFR: Dorsal fin rays

PFR: Pectoral fin rays

PvFR: Pelvic fin rays

ACFR: Anal and caudal fin rays

Statistical Analysis

Determination of Length-Length Relationship Model (LLR-Model)

The length-length relationship models with total length among different body lengths were determined by the method of least squares to fit a simple linear regression model based on two years data as:

$$Y = a + bX$$

Where

Y = various body lengths

X = total length

a = Proportionality constant and

b = Regression coefficient

Determination of Growth Curve Model (GCM)

The seasonal and sex dependent growth curve models are determined based on the exponential equation (LeCren, 1951) plotting two years' data as:

$$TW = aTL^b$$

Where, 'TW' is the total weight (expressed in g); 'TL' is the total length (expressed in cm); 'a' is a coefficient related to body form and 'b' is an exponent indicating isometric growth when equal to 3 and indicating allometric growth when significantly different from 3.

The parameters 'a' and 'b' of the exponential curve were estimated by linear regression analysis over log-transformed data expressed as:

$$\log TW = \log a + b \log TL$$

The values of the constant 'a' and 'b' of the linear regression was determined by the following equations (Rounsefell and Everhart, 1953; Lagler, 1966):

$$\log a = \frac{\sum \log TW \times \sum \log TL - \sum \log TL \times \sum (\log TL \times \log TW)}{N \times \sum \log TL^2 - (\sum \log TL)^2} \text{ and,}$$

$$b = \frac{\sum \log TW - N \times \log a}{\sum \log TL}$$

where, 'N' indicates the number of specimens.

Determination of Condition Factors

The Fulton's condition factor, K was calculated by using the formula, $K = (TW/TL^3) \times 100$. Here, factor 100 is used to bring K close to unity. Whereas, allometric condition factor and relative condition factor were calculated by $K_a = TW/TL^b$ (Zorica *et al.*, 2006) and $K_n = TW/aTL^b$ (LeCren, 1951) respectively. The parameters 'a' and 'b', of the length-weight relationship model which have been used in the calculation of condition factors K_a and K_n were varied among different seasons and sexes. The study period was divided into three major seasons viz. summer (March to June), rainy (July to October) and winter (November to February)

All sorts of statistical analysis and model parameters were calculated by using the computer software SPSS Version 11.5.

2.4 Results and Observations

2.4.1 Frequency Distribution of Length Based Sex

The frequency distribution of length based sex of the collected specimen is observed during the study period. The total length of smallest male and female specimens was recorded as 7.1 and 7.2 cm respectively with the same weight of 3.2g (Plate 2.1). And the largest male and female specimens were recorded as 31.5 cm (weight 261g) and 31.2 cm (weight 278g) in total length respectively (Plate 2.1). The length of fish was grouped in 13 category ranged from 7-9 to 31-33 cm where the male dominated in five groups viz. 7-9, 13-15, 27-29, 29-31 and 31-33. And the females were gradually found to dominate in the rest eight groups (Fig. 2.3). The comparative distribution of male and female specimens of individual year showed similarity to the distribution of total specimens described above (Fig. 2.4).

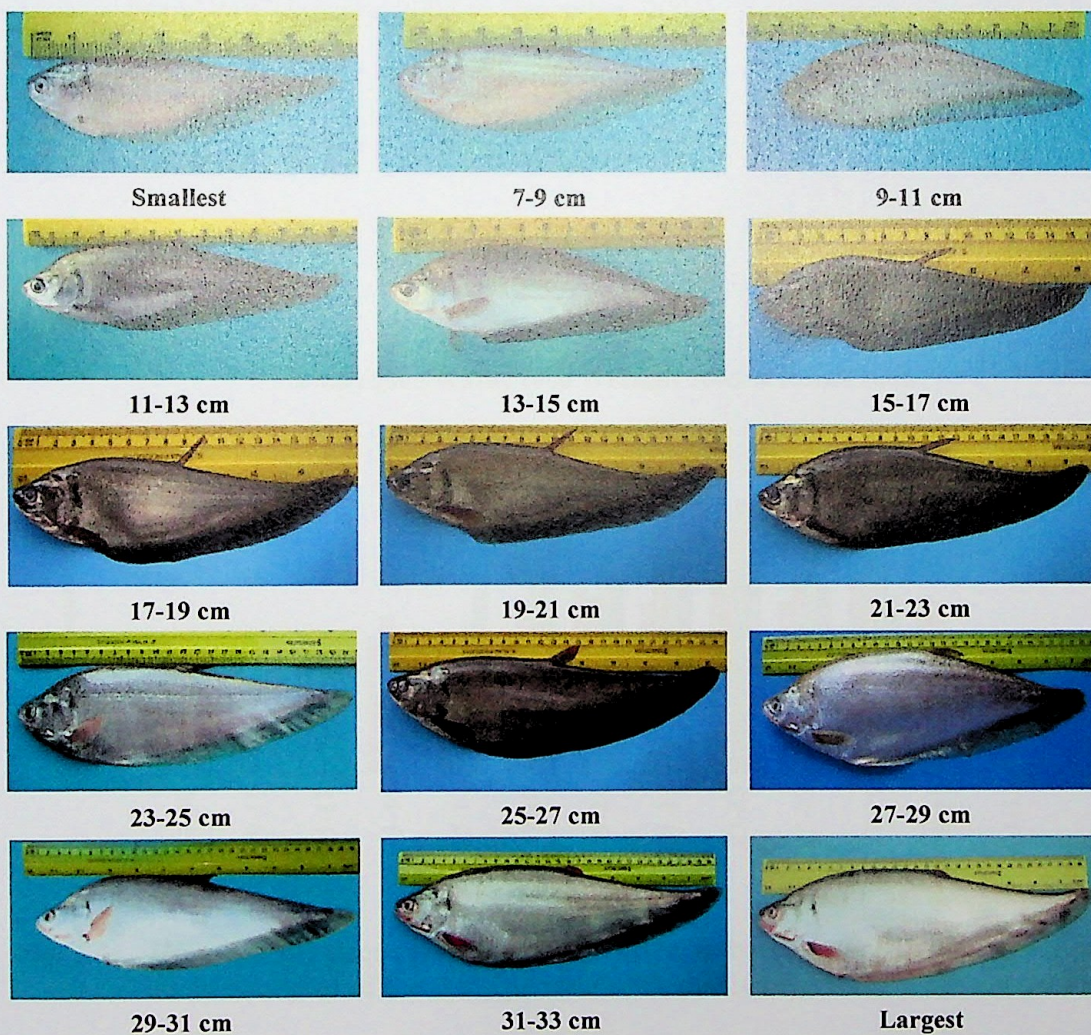


Plate 2.1: Featherbacks of 13 length groups including smallest and largest specimen.

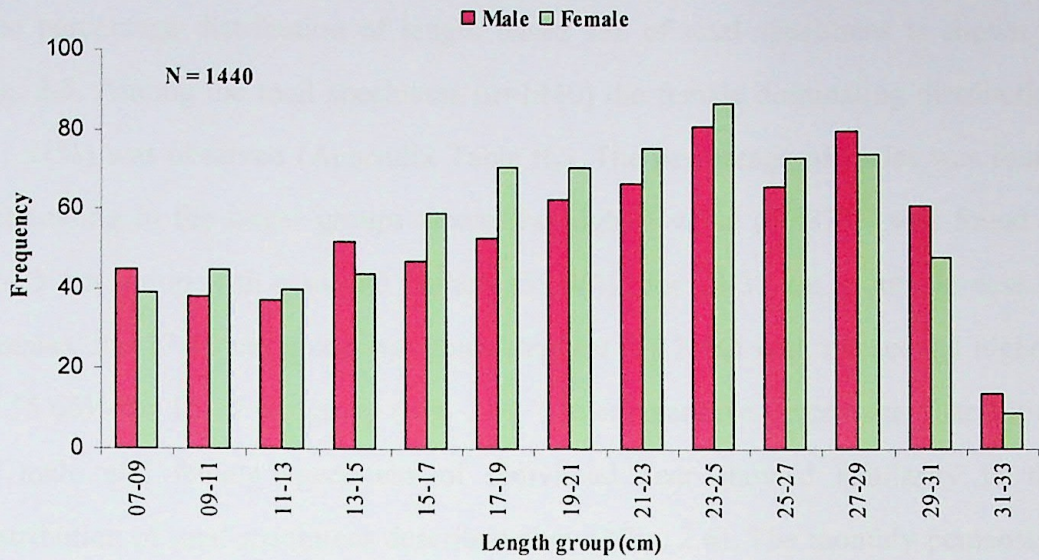


Fig.2.3: Frequency distribution of length based sex of *N. notopterus* based on two years' data (January, 2005 to December, 2006).

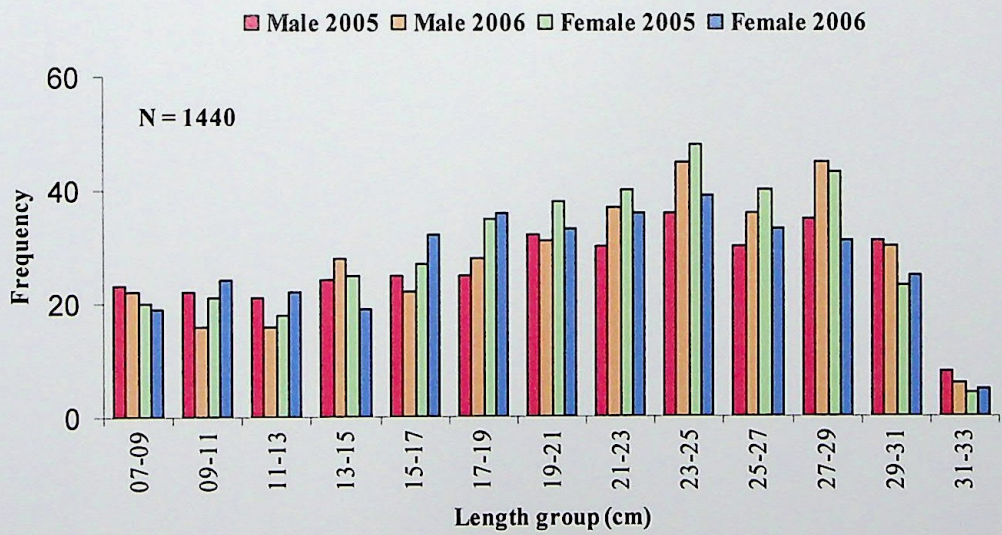


Fig. 2.4: Comparative frequency distribution of length based sex of *N. notopterus* for individual year of the study period (2005 and 2006).

2.4.2 Percentage distribution of length based sex

The percentage distribution of length based sex of total specimens is shown in Fig. 2.5. Among the total specimens (n=1440) the female dominating distribution (51.11%) was observed (Appendix Table II_a). The percentage of males was found dominating in the larger groups where the highest value (60.87%) was found in 31-33 cm group with a second highest (55.96%) for 29-31 cm group. In case of females, the 17-19 cm group was found highest (57.26%) with the second highest of 55.66% for 15-17 cm group (Fig. 2.5). The comparative percentage distribution of male and female specimens of individual year showed similarity to the distribution of total specimens described above (Fig. 2.6). The monthly percentage distribution of male and female specimens was also shown in Fig. 2.7 and 2.8. The monthly pattern of percentage distribution maintained similarity with the overall distribution except several months especially May to October.

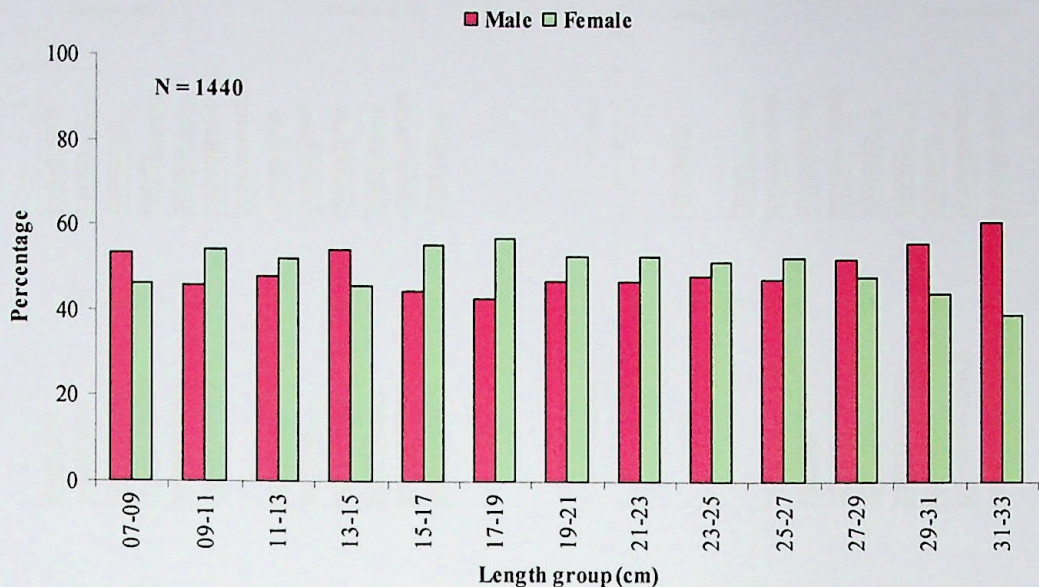


Fig. 2.5: Percentage distribution of length based sex of *N. notopterus* based on two years' data (January, 2005 to December, 2006).

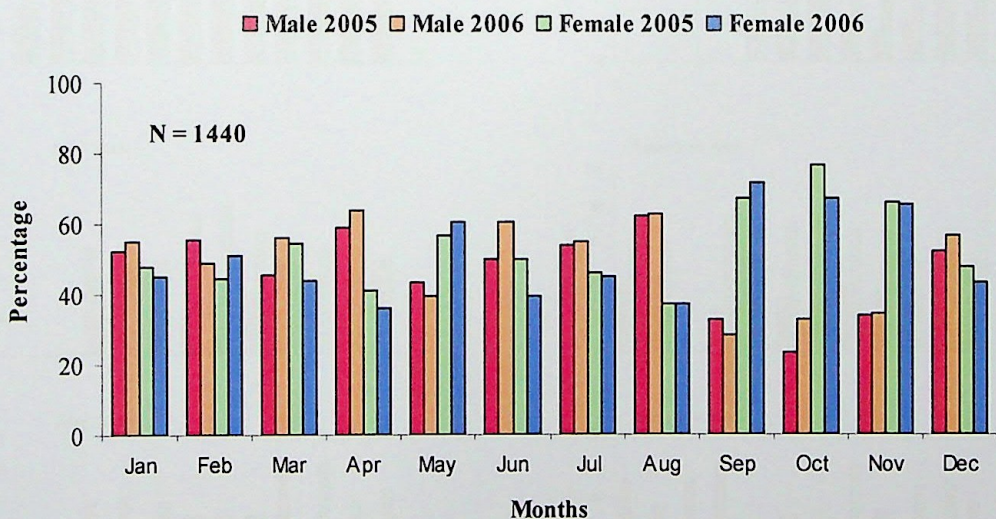


Fig. 2.6: Comparative percentage distribution of length based sex of *N. notopterus* for individual year of the study period (2005 and 2006).

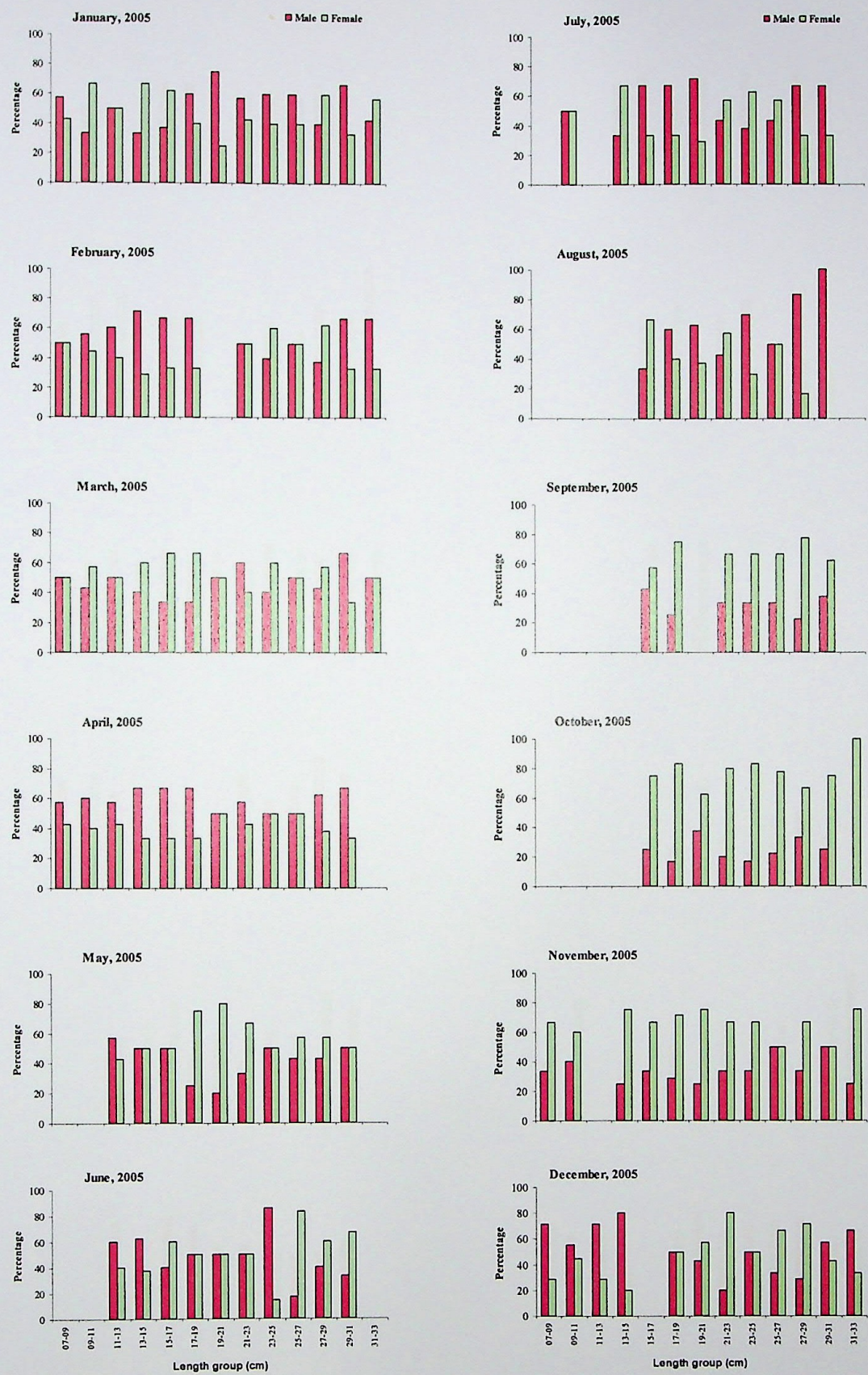


Fig. 2.7: Monthly percentage distribution of length based sex of *N. notopterus* in 2005.

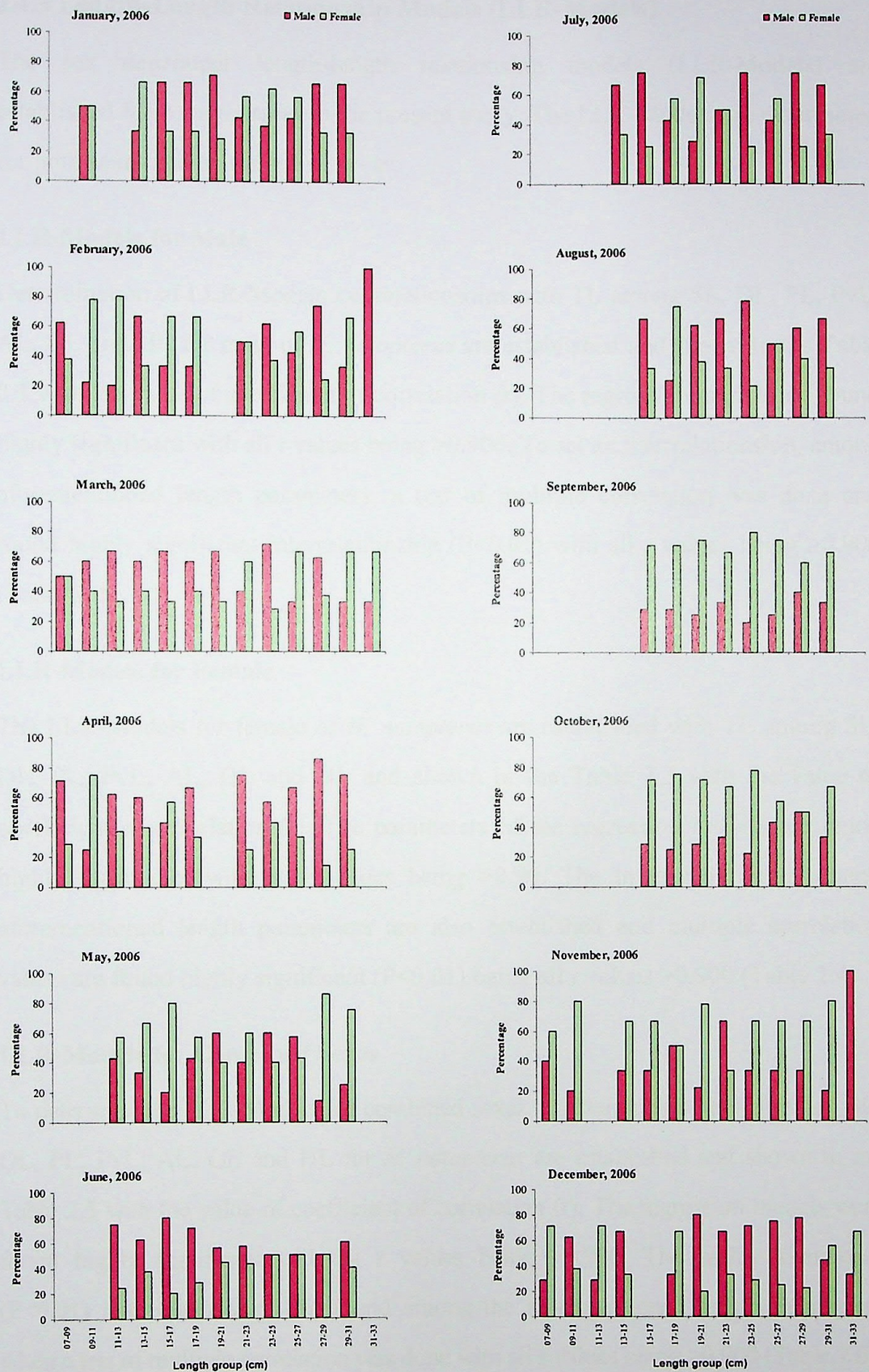


Fig. 2.8: Monthly percentage distribution of length based sex of *N. notopterus* in 2006.

2.4.3 Length-Length Relationship Models (LLR-Models)

The sex dependent length-length relationship models (LLR-Models) are established for *N. notopterus* in the present study. The LLR-Models are determined for both sexes and combined sexes as:

LLR-Models for Male

Determination of LLR-Models *i.e.* relationships with TL among SL, DL, PL, PvL, AL, OL and HL for male of *N. notopterus* are established and shown in the Table 2.1 with the value of coefficient of correlation (r). The regression models are found highly significant with all r values being >0.900 . To set an interrelationship, among aforementioned length parameters, a test of multiple correlation was done and found highly significant interrelationship ($P<0.01$) with all r values being >0.900 (Table 2.2).

LLR-Models for Female

The LLR-Models for female of *N. notopterus* are established with TL among SL, DL, PL, PvL, AL, OL and HL and shown in the Table 2.3 with the value of coefficient of correlation (r). The parameters of the regression models are found highly significant with all r values being >0.90 . The interrelationships among aforementioned length parameters are also established and multiple correlation values are found highly significant ($P<0.01$) being all r values >0.900 (Table 2.4).

LLR-Models for Combined Sexes

To determine the LLR-Models for combined sexes, relationships with TL among SL, DL, PL, PvL, AL, OL and HL for *N. notopterus* are established and shown in the Table 2.5 with the value of coefficient of correlation (r). The regression models were found highly significant with all r values being >0.900 . The highly significant ($P<0.01$) interrelationships are found among the aforementioned length parameters when a test of multiple correlation was done with all r values being >0.900 (Table 2.6).

Table 2.1: Length-length relationship models for male of *N. notopterus* with total length among different body lengths based on simple linear regression equation, $Y = a + bX$ (Mean TL $\pm$ SE = 20.78 $\pm$ 0.26 cm, N = 704).

Relationship Parameters	Mean $\pm$ SE (cm)	Model Equations of the Linear Regression	Coefficient of Correlation 'r'	Percentage with TL
SL	19.02 $\pm$ 0.24	SL = - 0.264 + 0.928TL	0.999**	91.52
DL	10.13 $\pm$ 0.12	DL = 0.009 + 0.487TL	0.998**	48.76
PL	3.44 $\pm$ 0.04	PL = - 0.131 + 0.172TL	0.991**	16.57
PvL	4.49 $\pm$ 0.06	PvL = - 0.571 + 0.243TL	0.991**	21.59
AL	5.19 $\pm$ 0.07	AL = - 0.083 + 0.254TL	0.995**	24.97
OL	4.01 $\pm$ 0.05	OL = 0.164 + 0.185TL	0.992**	19.28
HL	3.68 $\pm$ 0.04	HL = 0.073 + 0.174TL	0.994**	17.73

** Correlation is significant at the 0.01 level.

Table 2.2: Correlation matrix (values of r) of different body lengths of *N. notopterus* in male (P<0.01).

	Total Length	Standard Length	Dorsal Length	Pectoral Length	Pelvic Length	Anal Length	Operculum Length	Head Length
Total Length	1.000							
Standard Length	0.999**	1.000						
Dorsal Length	0.998**	0.998**	1.000					
Pectoral Length	0.991**	0.991**	0.989**	1.000				
Pelvic Length	0.991**	0.991**	0.989**	0.983**	1.000			
Anal Length	0.995**	0.995**	0.993**	0.987**	0.996**	1.000		
Operculum Length	0.992**	0.992**	0.989**	0.988**	0.983**	0.986**	1.000	
Head Length	0.994**	0.994**	0.991**	0.992**	0.985**	0.989**	0.995**	1.000

** Correlation is significant at the 0.01 level.

Table 2.3: Length-length relationship models for female of *N. notopterus* with total length among different body lengths based on simple linear regression equation, $Y = a + bX$ (Mean TL $\pm$ SE = 20.46 $\pm$ 0.24 cm, N = 736).

Relationship Parameters	Mean $\pm$ SE (cm)	Model Equations of the Linear Regression	Coefficient of Correlation 'r'	Percentage with TL
SL	18.75 $\pm$ 0.22	SL = - 0.249 + 0.929TL	0.999**	91.63
DL	9.94 $\pm$ 0.12	DL = - 0.002 + 0.486TL	0.997**	48.60
PL	3.38 $\pm$ 0.04	PL = - 0.069 + 0.168TL	0.990**	16.50
PvL	4.43 $\pm$ 0.06	PvL = - 0.524 + 0.242TL	0.991**	21.65
AL	5.13 $\pm$ 0.06	AL = - 0.027 + 0.252TL	0.995**	25.09
OL	3.95 $\pm$ 0.04	OL = 0.242 + 0.181TL	0.991**	19.32
HL	3.66 $\pm$ 0.04	HL = 0.098 + 0.174TL	0.993**	17.90

** Correlation is significant at the 0.01 level.

Table 2.4: Correlation matrix (values of r) of different body lengths of *N. notopterus* in female (P<0.01).

	Total Length	Standard Length	Dorsal Length	Pectoral Length	Pelvic Length	Anal Length	Operculum Length	Head Length
Total Length	1.000							
Standard Length	0.999**	1.000						
Dorsal Length	0.997**	0.997**	1.000					
Pectoral Length	0.990**	0.990**	0.988**	1.000				
Pelvic Length	0.991**	0.991**	0.988**	0.981**	1.000			
Anal Length	0.995**	0.995**	0.992**	0.985**	0.996**	1.000		
Operculum Length	0.991**	0.991**	0.989**	0.988**	0.982**	0.986**	1.000	
Head Length	0.993**	0.993**	0.990**	0.989**	0.984**	0.988**	0.995**	1.000

** Correlation is significant at the 0.01 level.

Table 2.5: Length-length relationship models for combined sexes of *N. notopterus* with total length among different body lengths based on simple linear regression equation, $Y = a + bX$ (Mean TL $\pm$ SE = 20.62 $\pm$ 0.17 cm, N = 1440).

Relationship Parameters	Mean $\pm$ SE (cm)	Model Equations of the Linear Regression	Coefficient of Correlation 'r'	Percentage with TL
SL	18.88 $\pm$ 0.16	SL = - 0.255 + 0.928TL	0.999**	91.57
DL	10.04 $\pm$ 0.08	DL = 0.004 + 0.487TL	0.997**	48.68
PL	3.41 $\pm$ 0.03	PL = - 0.101 + 0.170TL	0.990**	16.53
PvL	4.46 $\pm$ 0.04	PvL = - 0.542 + 0.242TL	0.991**	21.62
AL	5.16 $\pm$ 0.04	AL = - 0.048 + 0.252TL	0.995**	25.03
OL	3.98 $\pm$ 0.03	OL = 0.202 + 0.183TL	0.991**	19.30
HL	3.67 $\pm$ 0.03	HL = 0.087 + 0.174TL	0.993**	17.81

** Correlation is significant at the 0.01 level.

Table 2.6: Correlation matrix (values of r) of different body lengths of *N. notopterus* in combined sex (P<0.01).

	Total Length	Standard Length	Dorsal Length	Pectoral Length	Pelvic Length	Anal Length	Operculum Length	Head Length
Total Length	1.000							
Standard Length	0.999**	1.000						
Dorsal Length	0.997**	0.997**	1.000					
Pectoral Length	0.990**	0.990**	0.988**	1.000				
Pelvic Length	0.991**	0.991**	0.989**	0.982**	1.000			
Anal Length	0.995**	0.995**	0.992**	0.986**	0.996**	1.000		
Operculum Length	0.991**	0.991**	0.989**	0.988**	0.982**	0.986**	1.000	
Head Length	0.993**	0.993**	0.991**	0.990**	0.984**	0.988**	0.995**	1.000

** Correlation is significant at the 0.01 level.

2.4.4 Modelling of Growth Curve

The relationship between length and weight is influenced by a number of factors. In this study two vital factors viz. season and sex were considered to establish the growth curve model (GCM) of *N. notopterus* plotting two years' length-weight data of the fish. The seasonal and sex dependent GCM of the fish are as follows:

GCM for Summer: Length-weight data of 503 specimens was considered to establish the GCM of summer. The characteristics of total length and weight, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are given in Table 2.7. The result showed that the TL of *N. notopterus* ranged from 7.10-31.30 cm with mean±SE of 20.02±0.26 cm while body weights varied from 3.20-271.00g with mean±SE of 94.75±2.96g (Table 2.7). The result of GCM analysis indicated positive allometric growth $TW=0.00771TL^{3.045}$ (Fig. 2.9). The statistical analysis (t-test) revealed that the GCM with 'b' values ranged from 3.001-3.079 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.997$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as whole in summer.

GCM for Rainy Season: A total of 375 specimens were considered to establish the GCM of summer. The range and mean±SE of total length and weight, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are given in Table 2.7. It is observed that the TL of *N. notopterus* ranged from 14.00-31.00 cm with mean±SE of 23.17±0.24 cm where body weights varied from 25.50-261.00g with mean±SE of 121.89±0.28g (Table 2.7). The result of GCM analysis indicated positive allometric growth $TW=0.00441TL^{3.219}$ (Fig. 2.9). The statistical analysis (t-test) revealed that the GCM with 'b' values ranged from 3.142-3.297 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.995$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as a whole in rainy season.

GCM for Winter: Length-weight data of 562 specimens was plotted to establish the GCM of winter. The details of total length and weight characters, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are shown in Table 2.7. The TL of *N. notopterus* found to vary from 7.10-31.50 cm with mean±SE of 19.48±0.17 cm while body weights ranged from 3.20-278.00g with mean±SE of 94.33±0.20g (Table 2.7). The GCM analysis indicated isometric growth $TW=0.00884TL^{2.998}$ (Fig. 2.9). The statistical analysis (t-test) revealed that the 'b' values of GCM ranged from 2.960-3.036 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.997$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as a whole in winter.

GCM for Male: Length-weight data of 704 males was considered to establish the GCM for male. The characteristics of total length and weight, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are given in Table 2.8. The result showed that the TL of male ranged from 7.10-31.50 cm with mean±SE of 20.78±0.26 cm while body weights varied from 3.20-261.00g with mean±SE of 102.43±2.96g (Table 2.8). The result of GCM analysis indicated positive allometric growth $TW=0.00781TL^{3.031}$ (Fig. 2.10). The statistical analysis (t-test) revealed that the GCM with 'b' values ranged from 3.009-3.052 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.996$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as whole for male.

GCM for Female: Length-weight data of 736 specimens was plotted to establish the GCM for female. The range and mean±SE of total length and weight, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are given in Table 2.8. It is observed that the TL of female ranged from 7.20-31.20 cm with mean±SE of 20.46±0.24 cm where body weights varied from 3.20-278.00g with mean±SE of 100.63±02.82g (Table 2.8).

The result of GCM analysis indicated positive allometric growth $TW=0.00844TL^{3.022}$ (Fig. 2.10). The statistical analysis (t-test) revealed that the GCM with 'b' values ranged from 3.008-3.037 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.998$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as a whole for female.

GCM for Combined Sexes: A total of 1440 specimens were collected to establish the GCM for combined sexes. The details of total length and weight characters, parameters 'a' and 'b' of the relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are shown in Table 2.8. The TL for combined sexes ranged from 7.10-31.50 cm with mean $\pm$ SE of 20.62 $\pm$ 0.17 cm while body weights ranged from 3.20-278.00g with mean $\pm$ SE of 101.51 $\pm$ 2.04g (Table 2.8). The GCM analysis indicated positive allometric growth $TW=0.00813TL^{3.026}$ (Fig. 2.10). The statistical analysis (t-test) revealed that the b values of GCM ranged from 3.013-3.039 which significantly different from $b=3$ ($P<0.01$). The correlation of coefficient value ($r=0.996$) indicates that the relationship is statistically significant and the equation of GCM is applicable to the population as a whole for combined sexes.

Table 2.7: Descriptive statistics and seasonal changes in parameters of the growth curve models for *N. notopterus* based on the exponential equation $W = aL^b$ plotting two years data (January, 2005 to December, 2006).

Season	Total Length Characteristics		Total Weight Characteristics		Parameters of the Relationship				Growth type
	Range (cm)	Mean±SE (cm)	Range (g)	Mean±SE (g)	a	b	bCL _{95%}	r	
Summer	7.1-31.3 (n=503)	20.02±0.26	3.20-271	94.75±2.96	0.00771	3.045	3.011-3.079	0.997	A ⁺
Rainy	14.0-31.0 (n=375)	23.17±0.24	25.5-261	121.89±0.28	0.00441	3.219	3.142-3.297	0.995	A ⁺
Winter	7.1-31.5 (n=562)	19.48±0.17	3.20-278	94.33±0.20	0.00884	2.998	2.960-3.036	0.997	I

Note: n, sample size; a, proportionality constant; b, slope of the relationship; CL, confidence limits; r, correlation of co-efficient; A⁺, positive allometric growth; I, isometric growth.

Table 2.8: Descriptive statistics and sex dependent changes in parameters of the growth curve models for *N. notopterus* based on $W = aL^b$ plotting two years data (January, 2005 to December, 2006).

Sex	Total Length Characteristics		Total Weight Characteristics		Parameters of the Relationship				Growth type
	Range (cm)	Mean±SE (cm)	Range (g)	Mean±SE (g)	a	b	bCL _{95%}	r	
Male	7.1-31.5 (n=704)	20.78±0.26	3.20-261	102.43±2.96	0.00781	3.031	3.009-3.052	0.996	A ⁺
Female	7.2-31.2 (n=736)	20.46±0.24	3.20-278	100.63±2.82	0.00844	3.022	3.008-3.037	0.998	A ⁺
Combined	7.1-31.5 (n=1440)	20.62±0.17	3.20-278	101.51±2.04	0.00813	3.026	3.013-3.039	0.996	A ⁺

Note: n, sample size; a, proportionality constant; b, slope of the relationship; CL, confidence limits; r, correlation of co-efficient; A⁺, positive allometric growth.

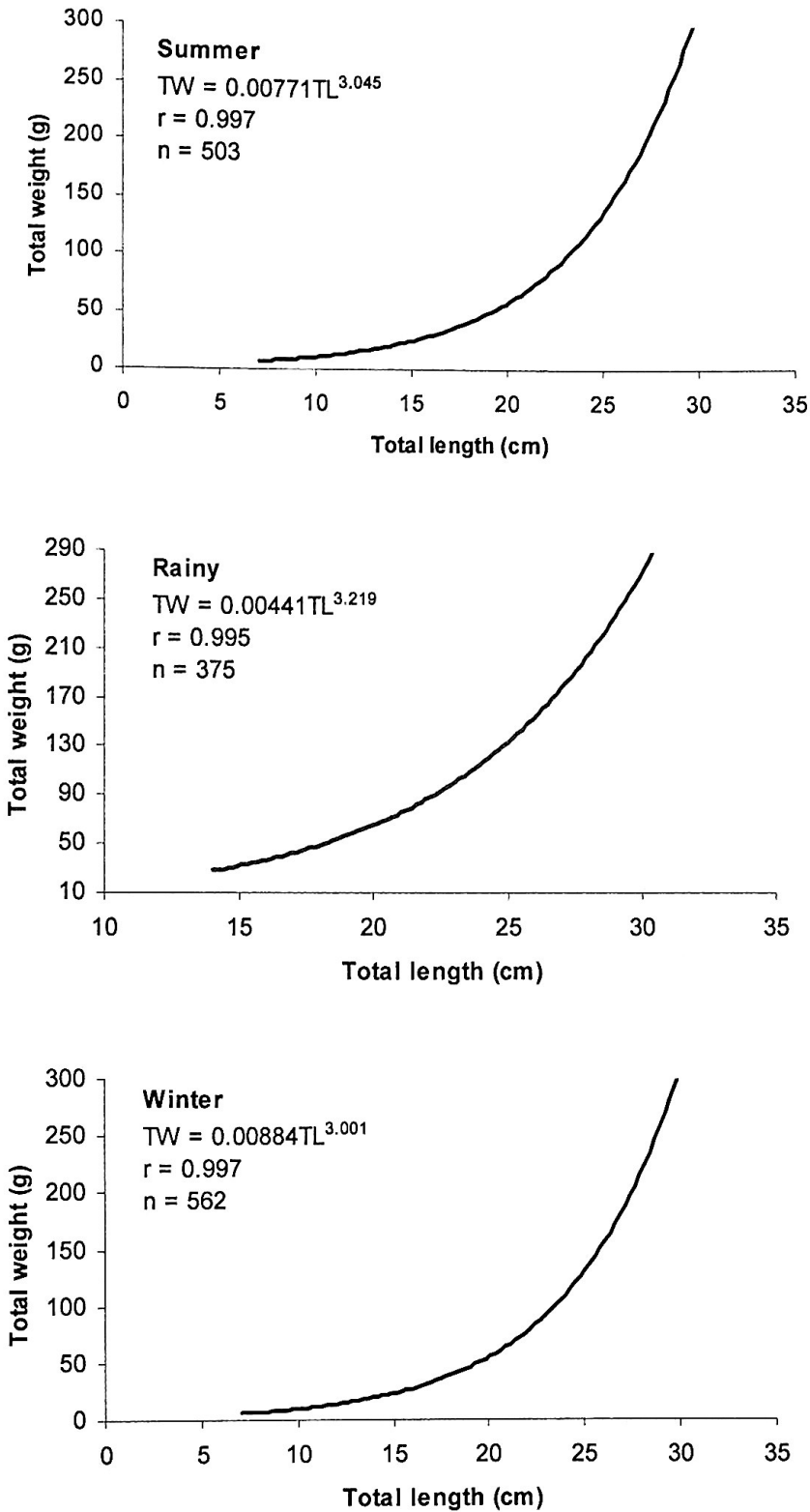


Fig. 2.9: Seasonal changes in growth curve model of *N. notopterus* based on the exponential equation $TW = aTL^b$ plotting two years data (January, 2005 to December, 2006).

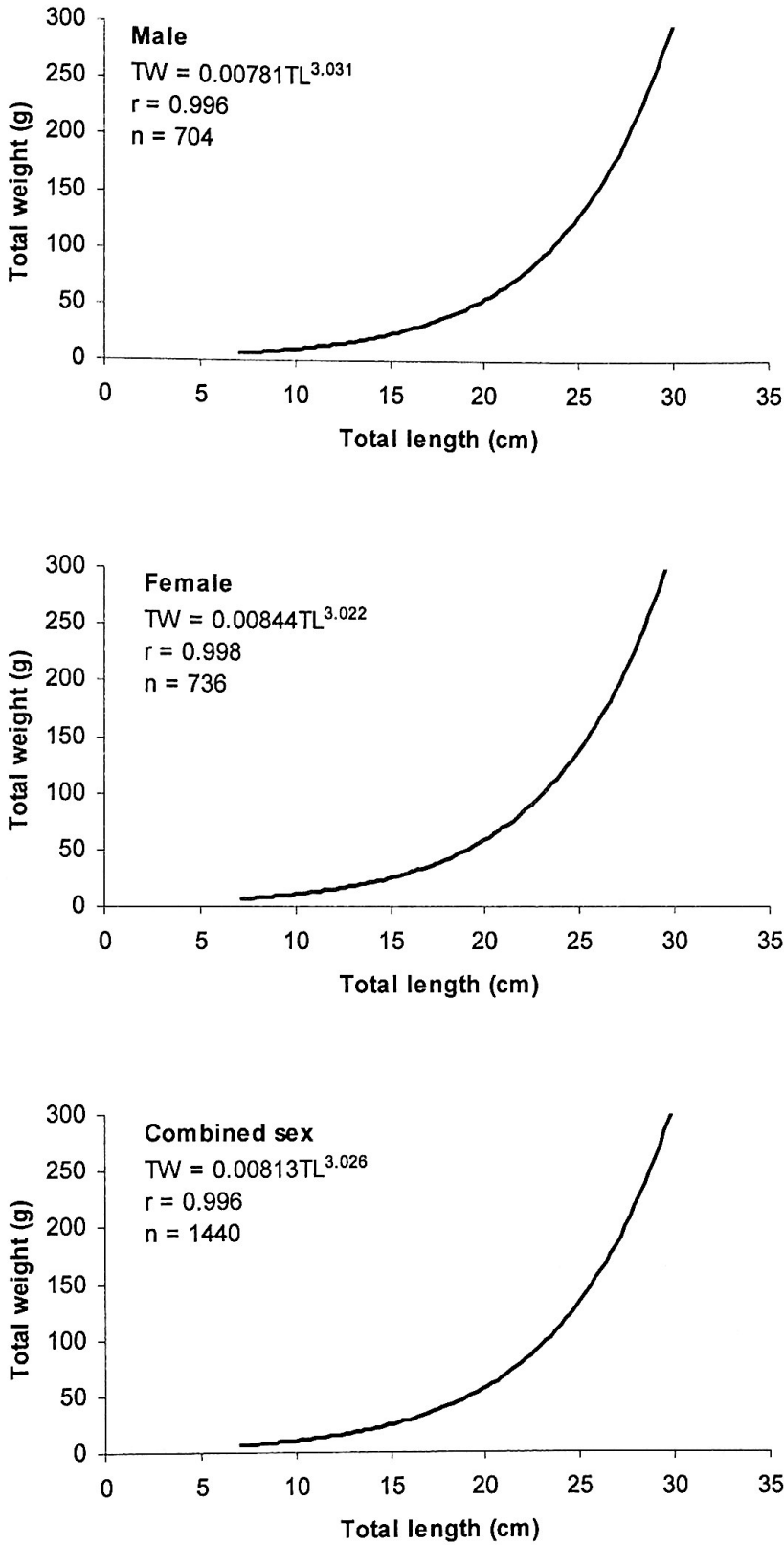


Fig. 2.10: Sex dependent growth curve model of *N. notopterus* based on the exponential equation $TW = aTL^b$, plotting two years data (January, 2005 to December, 2006).

2.4.5 Condition Factors

The Fulton's (K), allometric (K_a) and relative (K_n) condition factors are studied based on season and sex for comparing seasonal changes in nutritional conditions and sex dependent growth of the fish. The obtained result is as follows:

Seasonal variation in K, K_a and K_n : The seasonal variation in K, K_a and K_n are estimated from the 1440 specimens of *N. notopterus*. The average values of K, K_a and K_n for summer, rainy and winter seasons are shown in the Appendix Table II_b. For the comparative study, values of seasonal K, K_a and K_n are plotted against corresponding length groups and presented in Fig. 2.11. It is observed that the Fulton's condition factors (K) showed almost similar growth tendency expressing the cube law among the season with fluctuation in growth in several length groups. In case of allometric condition factors differences are observed in growth conditions showing similar tendency of tend line. The relative condition factors showed similarity in summer and rainy but in winter the growth was different from that of two *i.e.* the fish showed maximum robustness during winter months (November to February).

Sex dependent variation in K, K_a and K_n : The sex dependent variation in K, K_a and K_n are also estimated from the 1440 specimens of *N. notopterus*. The average values of K, K_a and K_n for male, female and combined sexes are shown in the Appendix Table II_c. For the comparative study, values of seasonal K, K_a and K_n are plotted against corresponding length groups and presented in Fig. 2.12. It is observed that the Fulton's condition factors (K) showed almost similar growth tendency expressing the cube law among male, female and combined sexes with fluctuation in growth in all length groups excluding 13-15 cm group. In case of allometric condition factors rhythm was also observed in growth conditions showing similar tendency in both sexes and combined sexes. The relative condition factors for male, female and combined sexes showed variation in 13-15, 15-17 and 17-19 length groups but similarity was also observed in the rest groups.

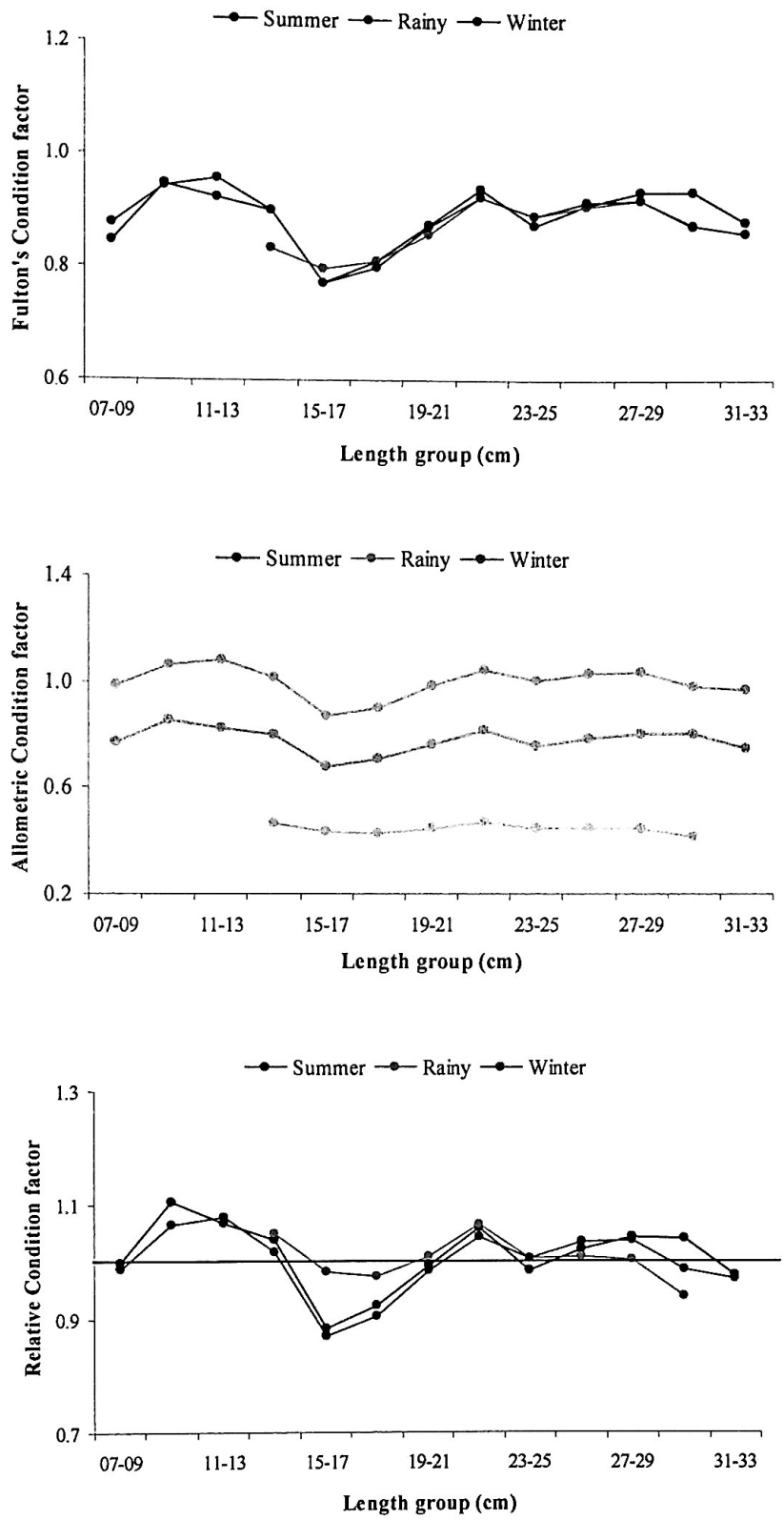


Fig.2.11: Seasonal variation in Fulton's condition factor, allometric condition factor and relative condition factor of *N. notopterus*.

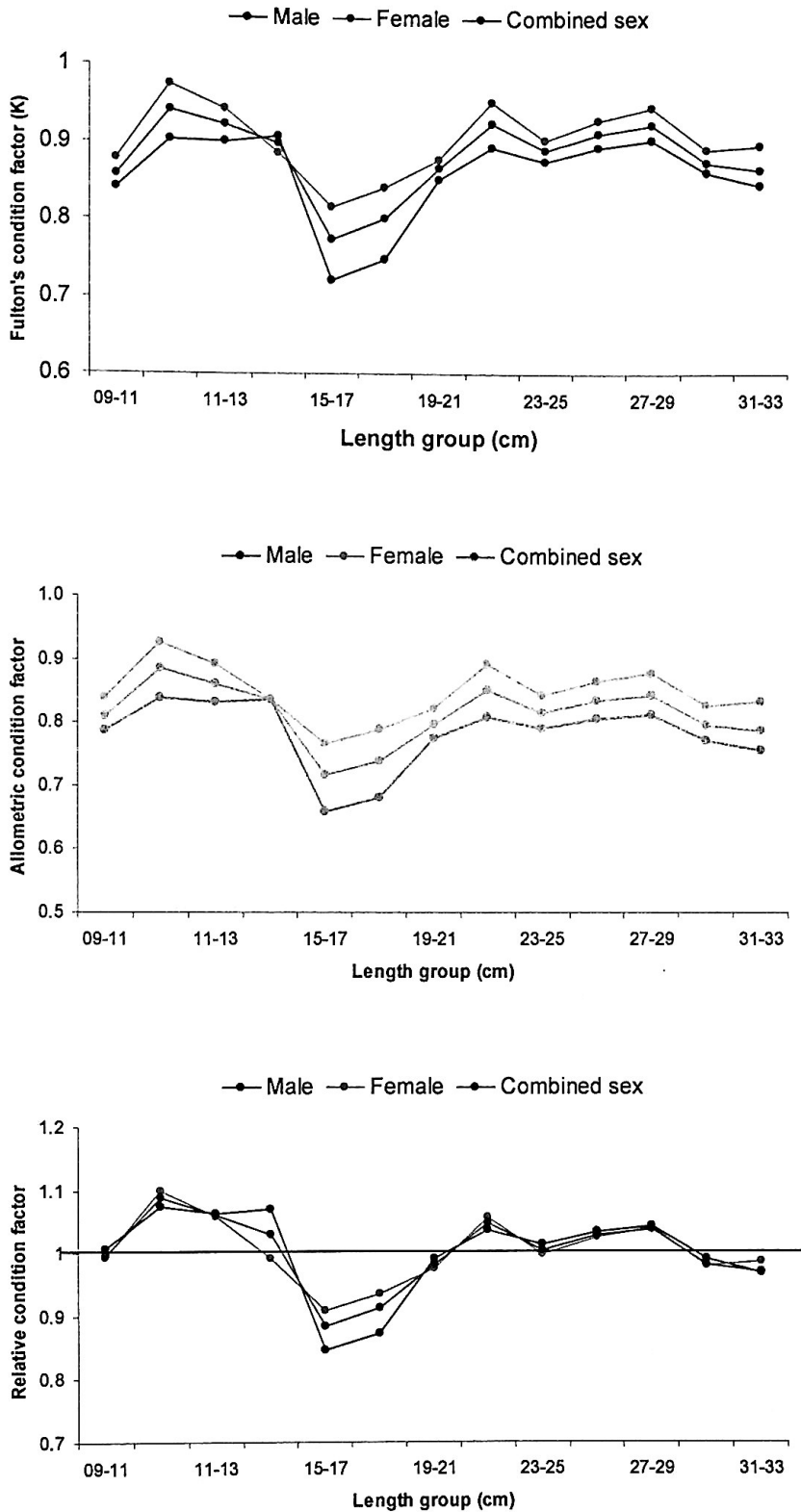


Fig. 2.12: Sex dependent variation in Fulton's condition factor, allometric condition factor and relative condition factor of *N. notopterus*.

2.4.6 Meristic Analysis of Fin Rays

The fins of *N. notopterus* are diversified. The fish has a short and tuft-like dorsal fin, situated in the caudal region far behind the origin of anal fin. Pelvic fins are rudimentary and united at their bases, situated a little before the anal fin and originate in advance of the origin of the dorsal fin. The razor-sharp anal fin is very long and ribbon-like and confluent with a very small unforked caudal fin.

The fin rays of *N. notopterus* are distinct and translucent excluding pelvic. The rays of pelvic fins are very indistinct due to its rudimentary character. The percentage analysis of fin rays is done on the basis of sex and the distribution is observed as follows:

Dorsal fin rays (DFR): The number of DFR ranged from 7-9 and almost similar in structure and height from the dorsal surface (Plate 2.2). The sex based percentage analysis showed that the highest 42.90% males, 44.16% females and 43.54% combined sexes are stands for DFR-8 group where the lowest were 21.90%, 24.86% and 23.40% in male, female and combined sexes respectively for DFR-7 group (Appendix Table II_d; Fig. 2.13).

Pectoral fin rays (PFR): The pectoral fins are simple and morphologically similar in structure both for male and female. Generally the PFR of *N. notopterus* ranged from 15-17 in number (Plate 2.2). In the present study the percentage analysis for individual fin rays of both sexes and combined sexes showed higher value 40.34% in males, 37.50% in females and 38.89% in combined sexes for PFR-17 group where the lowest was as 25.43%, 28.13% and 26.81% respectively for male, female and combined sexes for PFR-15 group (Appendix Table II_d; Fig. 2.13).

Pelvic fin rays (P_vFR): The rays of rudimentary pelvic fins are very indistinct and the number ranged from 5-6 (Plate 2.2). The percentage analysis for individual fin rays of both sexes and combined sexes showed higher value 54.40% in males, 52.04% in females and 53.19% in combined sexes for P_vFR-6 group (Appendix Table II_d; Fig. 2.13).

Anal and Caudal Fin Rays (ACFR): As the anal fin is confluent with caudal fin, a combined study is made for the analysis of the rays of both fins. It is observed that the number of ACFR ranged from 99-110 (Plate 2.2). The percentage analysis for individual fin rays of both sexes and combined sexes revealed that the maximum 15.06% male, 14.81% female and 14.93% combined sexes stands for ACFR-105 group where the minimum stands 5.40% for male, 5.14% for combined sexed at ACFR-99 group and 2.72% for female at ACFR-110 group where variation is observed in ACFR distribution (Appendix Table II_d; Fig. 2.13).

In the present work no significant difference has been observed on the distribution of fin rays among male, female of *N. notopterus*. From the highest value of the percentage analysis of different fin rays the following fin formula is obtained:

Fin Formula: D.7-9; P₁. 15-17; P₂.5-6; (A+C).99-110.

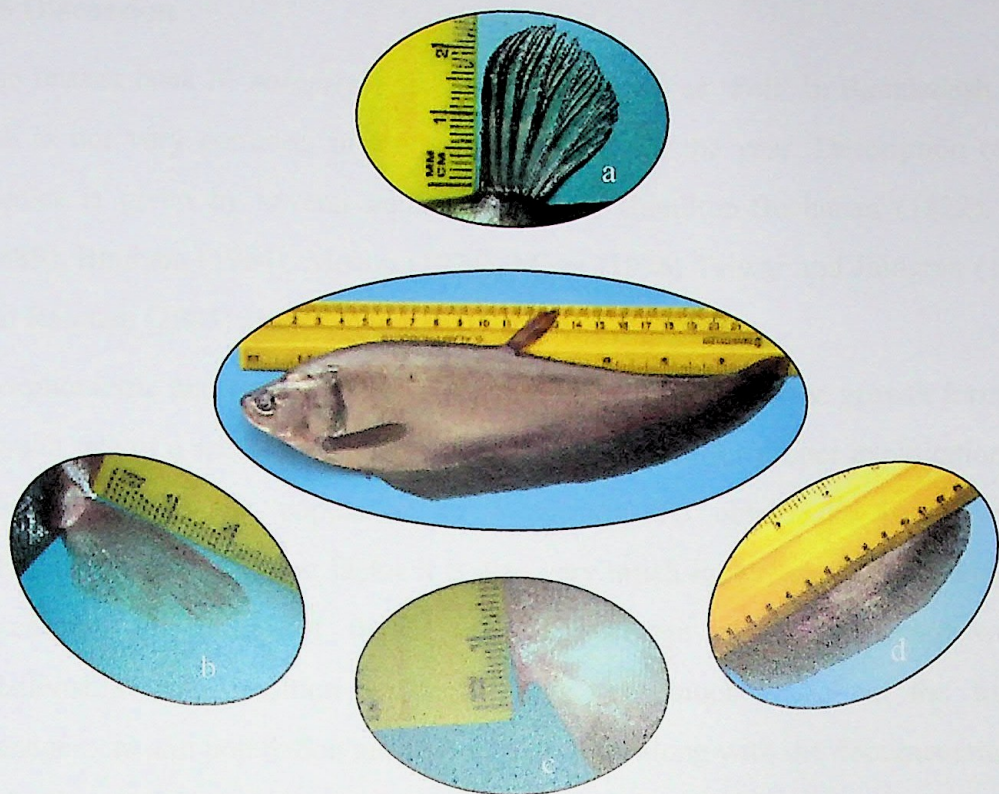


Plate 2.2: Status and position of different fins of *N. notopterus* (a. dorsal fin; b. pectoral fin; c. pelvic fin; d. anal and caudal fin).

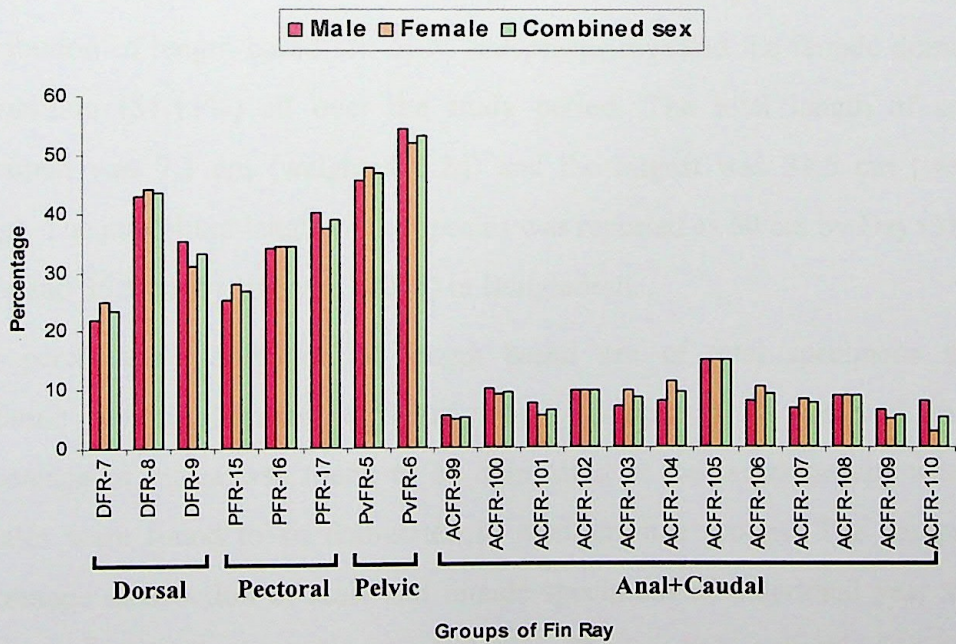


Fig. 2.13: Sex based percentage distribution of *N. notopterus* among different fin ray groups.

2.5 Discussion

The feather back *N. notopterus* is commonly known as ‘Foli’ in Bangladesh. The fish is not very common in the market throughout the year. Description of the species is given by several authors of whom Hamilton-Buchanan (1822), Day (1889), Bhuiyan (1964), Menon (1974), Misra (1976) Talwar and Jhingran (1991) and Rahman (2005) are mentionable.

Morphometric and meristic studies are essential to determine the growth form and growth rate of a species, which is very much important for proper exploitation and management of the population of a species. To obtain the length-weight relationship and condition factor it is also very much important for stabilizing the taxonomic characters of the species. Knowledge about the length-weight relationship and condition factors is also very much useful in the fishery management and population analysis of a species, along with the documentation of the characteristics.

2.5.1 Distribution of Length Based Sex

Frequency and percentage distribution of length based sex of *N. notopterus* were studied to observe the sex dominating status of the species. The frequency distribution of length based sex of *N. notopterus* revealed the female dominating distribution (51.11%) all over the study period. The total length of smallest specimen was 7.1 cm (weighted 3.2g) and the largest was 31.5 cm (weighted 278g). The maximum length of the species was reported as 60 cm by Day (1889) in India and 35.5 cm by Rahman (2005) in Bangladesh.

The percentage distribution of length based sex of total specimens showed rhythmic variation among different length groups. It is observed that the percentage of males was found to be dominated in the larger groups where the females were found to be dominated in medium size groups. The comparative percentage distribution of male and female specimens of individual year showed similarity in distribution of total specimens. The monthly pattern of percentage

distribution of total male and female specimen revealed that the specimen maintained homogeneity in two years distribution except several months especially May to October. To the best knowledge on the basis of published information of *N. notopterus* this type of distribution has not yet been reported by any researcher.

2.5.2 Length-Length Relationship Models (LLR-Models)

All living animals have a tendency to maintain symmetrical growth of its different body parts in relation to one another. It is generally known that all the body parts are dependent on the total length of the body *i.e.* growth of the body parts are proportional to the growth of the total length. But the total length of the body is not dependent on all other body parts (Tandon *et al.*, 1993).

The regression equation of sex dependent length-length relationship models (LLR-Models) are established for *N. notopterus* to assess the symmetrical growth in relation to body length *i.e.* relationships with TL among SL, DL, PL, PvL, AL, OL and HL for male, female and combined sexes. It is observed that the model equation is highly significant with all 'r' values being >0.900 with no significant differences between the sexes. The values of the LLR-Model equation clearly revealed that the lengths of the body parts are proportional to the total length which agreed with Tandon *et al.* (1993). The interrelationship among aforementioned length parameters were also found highly significant ($P < 0.01$) with all 'r' values being >0.900 from the multiple correlation analysis. The findings of LLR-Model analysis of *N. notopterus* are similar to the findings of Bhuiyan and Biswas (1982), Hoque and Hossain (1992) Sinovčić *et al.* (2004), Hossain *et al.* (2006) and Dadzie *et al.* (2008).

2.5.3 Modeling of Growth Curve

The length-weight relationship is an important tool in fish biology, physiology, ecology and fisheries assessment (Oscor *et al.*, 2005). It is originally used to provide information on the condition of fish and to determine whether somatic growth was isometric or allometric (LeCren, 1951; Ricker, 1963). In fisheries biology, length-weight relationships are useful for the conversion of growth-in-

length equations to growth-in-weight in stock assessment models and to estimate stock biomass from limited sample sizes (Binohlan and Pauly, 1998; Koutrakis and Tsikliras, 2003; Valle *et al.*, 2003; Ecoutin *et al.*, 2005).

The length–weight relationship in fishes is affected by a number of factors including habitat, diet, growth phase, season, degree of stomach fullness, gonad maturity, sex, size range, health and general fish condition and preservation techniques (Tesch, 1971). In this study two vital factors *viz.* season and sex were considered to establish the growth curve model (GCM) of *N. notopterus* plotting two years' length-weight data of the fish.

The Seasonal and Sex Dependent GCM: Length-weight data of summer (n=503), rainy (n=375) and winter (n=562) season was considered to establish the seasonal GCM of *N. notopterus*. The result of GCM analysis indicated positive allometric growth $TW=0.00771TL^{3.045}$ with 'b' values ranged from 3.001-3.079 in summer, positive allometric growth $TW=0.00441TL^{3.219}$ with 'b' values ranged from 3.142-3.297 in rainy season and isometric growth $TW=0.00884TL^{2.998}$ with 'b' values ranged from 2.960-3.036 in winter which were significantly different from $b=3$ ($P<0.01$) that adequately adjusted to the exponential model. Among the three seasons the correlation of coefficient values were found 0.997, 0.995 and 0.997 respectively which indicates the equations are statistically significant and applicable to the population as a whole to estimate the seasonal growth variation.

The sex dependent GCM of *N. notopterus* was established considering length-weight data of male (n=704), female (n=736) and combined sexes (n=1440). The result of GCM analysis for males, females and combined sexes indicated positive allometric growth $TW=0.00781TL^{3.031}$ with 'b' values ranged from 3.009-3.052 for male, $TW=0.00844TL^{3.022}$ with 'b' values ranged from 3.008-3.037 for female and $TW=0.00813TL^{3.026}$ with 'b' values ranged from 3.013-3.039 for combined sexes which were significantly different from $b=3$ ($P<0.01$) that adjust adequately to the exponential model. The correlation of coefficient values among the sexes were found 0.996, 0.998 and 0.996 respectively which indicates the GCM equations are statistically significant and applicable to the population as a whole for determining the sex dependent growth variation.

Hile (1936), Martin (1949), Tesch (1971), Bhuiyan and Biswas (1982), Johal *et al.* (1989), Hossain *et al.* (1991b), Hoque and Hossain (1992), Alam *et al.* (1994a), Moutopoulos and Stergiou (2002), Koutrakis and Tsikliras (2003), Kiran *et al.* (2004), Mendes *et al.* (2004), Sinovčić (2004), Oscoz *et al.* (2005), Balart *et al.* (2006), Bouchon-Navaro *et al.* (2006), Cicek *et al.* (2006), Dulčić and Glamuzina (2006), Esmaeili and Ebrahimi (2006), Froese (2006), Karakulak *et al.* (2006), Lalèyè (2006), Miranda *et al.* (2006), Ruiz-Campos *et al.* (2006), Tarkan *et al.* (2006), Tsoumani *et al.* (2006), Britton and Davies (2007), Özaydın *et al.* (2007), Agboola and Anetekhai (2008), Aguirre *et al.* (2008), Arshad *et al.* (2008), Ferreira *et al.* (2008), Vaslet *et al.* (2008) observed that the value of exponent 'b' usually lies between 2 and 4 and an ideal fish maintain the shape $b=3$. The value of 'b' will be exactly 3.0 when the growth is isometric (Allen, 1938; Ricker, 1963). The seasonal and sex dependent 'b' values of the present analysis were found in between 2.960-3.297 and 3.008-3.052 respectively that very close to exact value 3. Therefore, *N. notopterus* do follow the cube law. The reason behind may be the observed specimen were the inhabitants of quite good environment and gravid females were more in the samples (LeCren, 1951).

Sometimes values of exponential 'b' has been observed as <3 or >3 . This is due to the fact that the weight of the fish is affected by the time of the year, food, and spawning condition or because of the market difference between the same populations in different years. An example of this is *Cisco* in the northern Wisconsin, USA, where neighboring lake inhabitants had 'b' values in different years as follows; Muskellunge Lake, 1.38-2.05; Trout Lake, 2.31-2.78, Silver Lake, 3.32-3.45 and Char Lake 3.51-3.68 (Hile, 1936). On the other hand LeCren (1951) observed the perch from larval condition to the adult and reported that the average value of 'b' ranged between 3.01 and 3.59 (3.59 for larval and 3.01 for 0 to 1 year old fish, 3.20 for immature females of 2 year or more, 3.28 for mature males and 3.40 for mature females); Dulčić *et al.* (2003) observed the 'b' values 2.8 ± 0.03

for female and 3.08 ± 0.04 for male in *Spicara smaris*; Hossain *et al.* (2006) found 'b' values 2.959 for males and 3.134 for females in *M. vittatus*; Yildirim *et al.* (2008) recorded 'b' values 2.933 for males, 3.001 for females, and 3.118 for juveniles in *Capoeta sieboldii*; Dadzie *et al.* (2008) found the 'b' values at the 95% confidence limit which ranged from 2.788-2.796 for female, 2.726-2.732 for males, 2.79-2.784 for both sexes and 2.590-2.613 for juveniles in *Parastromateus niger*. Workers like Mia (1984), Azadi *et al.* (1990), Hoque and Hossain (1992), Alam *et al.* (1994a), Mir (1996), Mortuza and Mokarrama (2000), Haniffa *et al.* (2006), Santic *et al.* (2006) obtained such results in different fishes.

2.5.4 Condition Factors

The condition factors are the indicator of the general condition of a fish or shellfish, such as the degree of well being, relative robustness, plumpness or fatness in numerical terms (Doha, 1970; Hossain, 1976). The value of the condition factors increase with gradual development of the reproductive system, vary from species to species and are never constant (Lagler, 1966). According Šantić *et al.* (2006), condition factor remains constant during pre-spawning period, decrease in spawning period and becomes lowest immediately after spawning. In the present study the Fulton's (K), allometric (K_a) and relative (K_n) condition factors showed clear variation in different season and sex and maintained fairly same patterns and high correlations among them. But in winter months (November to February) the fish showed maximum robustness due to availability of food in early winter that indicates the suitability of fishing time. The result is also found in *Puntius chola* (Bhuiyan and Biswas, 1982), *Heteropneustes fossilis* (Mia, 1984), *Amblypharyngodon mola* (Afroze *et al.*, 1992), *Mystus vittatus* (Hoque and Hossain, 1992), *Puntius stigma* (Islam and Hossain, 1992), *Ailia coila* (Alam *et al.*, 1994a), *Barbus canis* (Mir, 1996), *Chanda ranga* (Iqbal *et al.*, 1995-1996), *Botia lohachata* (Mortuza and Mokarrama, 2000), *Trachurus mediterraneus* (Šantić *et al.*, 2006), *Parastromateus niger* (Dadzie *et al.*, 2008).

2.5.5 Meristic Analysis of Fin Rays

Similar to morphometric characters the meristic characters did not show any significant difference between the males and females of *N. notopterus*. Talwar and Jhingran (1991) reported that the range of dorsal, pectoral, pelvic, anal and caudal fin spines and rays are D.7-9; A+C.100-110; V.5-6; Rahman (2005) reported that the range of spine and fin rays of dorsal, pectoral, pelvic, anal and caudal fins are D. 7-8; P₁.15-17; P₂.5-6; A.99-104. Bhuiyan (1964) reported that the range of spine and fin rays of dorsal, pectoral, pelvic, anal and caudal fins are D. 7-8; P. 17; Ac.119-130; Srivastava (1968) reported that the range of spine and fin rays of dorsal, pectoral, pelvic, anal and caudal fins are D. 8 (1/7); P.17; V. 6; A.100; C.19. In the present investigation possible extensive analysis has been carried out as D. 7-9 (Peak 8); P₁. 15-17 (Peak 17); P₂. 5-6 (Peak 6); A+C. 99-110 (Peak 105). Niimi and Morgan (1980) suggested that the variation in the morphometric and meristic characters among the same species may occur due to ecological factors. So, from the above meristic studies more reliable characters have been come out for the taxonomy of the species.

Chapter Three

FOOD AND FEEDING HABIT

Chapter Three

FOOD AND FEEDING HABIT

3.1 Introduction

All living organisms require adequate nutrition for their proper growth and survivability which they must obtain from food. Each starts life with a bit of food received from the parent, but it soon needs to feed itself. It must continue to feed itself regularly with suitable food or die. For some, feeding is almost continuous, for others, feeding is in circadian (*i.e.*, daily or tidal) or seasonal cycles; but for most animals feeding is the dominant activity of their entire lives because their need is constant and the food is usually scarce (Royce, 1972).

It is rarely possible to observe the feeding habit of an aquatic animal under natural condition but study of stomach content of a suitable sample can determine its habitual food or diet. The types of food and the mode of food intake differs species to species even in different stages of life. It may be safely assumed that most fishes are omnivorous even in early life, eating and digesting both plant and animal tissue. As fish grow toward adulthood, however, feeding adaptations develop and the diets of some kinds become highly restricted. Many remain more or less omnivorous throughout life. A few become plankton feeders at an early stage and remain so. Some become highly herbivorous, others carnivorous. Some species are cannibalistic. Certain assume parasitic feeding habit as adults (Lagler, 1966). So, a great variation is seen with food and feeding habits of different species of fish. Variation is also seen in the feeding patterns of fishes at different stages of life, season to season, month to month and even within a day.

It is not an easy task to identify each organism in the stomach and either weight it or determine its volume. Complications arise when animals feed irregularly; regurgitate the most recently eaten items during capture; and show variation in the rate of digestion. But the dietary studies are essential to understand how fishes live and grow, what foods may influence their abundance and distribution and the relative quality of feeding conditions (Royce, 1972).

For successful fish farming a thorough knowledge of the food and feeding habit of the selected species of fish is essential, to ensure the proper utilization of all the available food in the water at different ecological niches. The study of food and feeding habits of fishes is important for selecting a group of fish for raising in ponds and impoundments, where they will not compete with others for food but will live in association and utilize the maximum available food.

The *N. notopterus* is a carnivore fish being active during twilight and night; and inhabits in standing and sluggish waters of lakes, floodplains, canals and ponds all over Bangladesh (Rahman 2005). A scanty research work has been done regarding the food and feeding habit of the species which is not satisfactory to provide the basic information. Considering the actual need, the research work is aimed to obtain some knowledge about food and feeding habit of *N. notopterus*; will help to select such species for culture and produce an optimum yield by utilizing all the potential food of the water bodies without any competition.

3.2 Review of Literature

A large number of works had been done on the food and feeding habits of different fishes of the world. Gross morphological reports on the modification of feeding structures in relation to feeding habit had also been described by Lagler (1966). A brief review of available literature of feeding habits of fishes has given below:

Acuna *et al.* (2007) observed the feeding habit of Brazilian codling, *Urophycis brasiliensis* and identified a total of 24 prey species in the stomach content. The shrimp *Artemesia longinaris* was found to be highest (89.9%) followed by *Cynoscion guatucupa* (4.3%) where molluscs were found marginally (0.01%).

Alam *et al.* (2002a) observed that the fish *Tor putitora* is omnivore with higher feeding preference for plant material than for animal material. The dominant food groups recorded in the gut contents were Cyanophyceae, Bacillariophyceae and Chlorophyceae. The fish was found to explore the food substances from all the layers of the water body.

Alam *et al.* (2002b) stated that the fish *Gudusia chapra* feed on a range of food items including phytoplankton, zooplankton and detritus. Food analysis by point method indicated that the fish feed mainly on detritus and phytoplankton. Diel pattern study showed that the fish has two peaks of feeding activity; one is at 10:00 hour and another is at 18:00 hour.

Alp *et al.* (2008) studied on the diet composition and prey selection of pike (*Esox lucius*) and found that the diet of the fish included 10 prey fish species, two Crustacean, four Insects, one Hirudinae and one Amphibia. Feeding activity varied by season and ontogeny. Stomach fullness and the percentage of fish with prey were highest in spring in small groups, while feeding intensity was lowest in winter in large groups.

Anastasopoulou and Kapis (2008) found that the *Chlorophthalmus agassizi* of the North Ionian Sea shows a mixed feeding strategy, exploiting a wide range of prey including mesopelagic, benthic and endobenthic organisms. Crustaceans and fishes were found as dominant food items in the diet year round. Diet composition showed slight seasonal fluctuations which were correlated with food availability and reproductive activity.

Banu et al. (1993) observed the food items of *Hypophthalmichthys molitrix* and found that the fish is planktophagous and surface feeder. They found different food items like blue-green algae, green algae, diatoms, protozoa, rotifers, cladocerans and copepods from the gut content of the fish.

Bhuiyan and Islam (1988) worked on the seasonal variation in the percentage composition of the food of *Xenentodon cancila* and collected different food items viz. fishes, crustaceans, aquatic insects, semi-digested food items and unidentified food materials from the stomach of the fish. They also found that the fish shows active feeding from September to March where the feeding activity was low from June to August.

Bhuiyan et al. (1992) worked on the food feeding habit of *Aspidoparia morar* and found that the food items of the fish includes algae, plant parts, crustaceans, aquatic insects, debris and detritus, sand and mud and unidentified materials. They also stated that the fish shows active feeding from March to August where it was poor from November to February.

Bhuiyan et al. (1994) found that the fish *Rhinomugil corsula* is omnivorous and mainly consume rotifers, crustaceans, insects, debris and detritus, algae, higher plant parts and other food particles. They also observed the seasonal changes of food and feeding habit of the species.

Bhuiyan et al. (1997) observed that *Clupisoma atherinoides* is a carnivore fish; feeding mainly on crustaceans, aquatic insects, protozoans, debris and detritus, higher plant parts and algae.

Bhuiyan *et al.* (1998) worked on the food and feeding habit of *Puntius gonionotus* and stated that the fish is planktivorous and mainly fed on algae, aquatic plants, rotifers, higher plants, debris and detritus, aquatic insects, protozoans and crustaceans.

Bhuiyan *et al.* (1999b) worked on the food and feeding habit of *Mugil cephalus* and found that the fish is herbivore. The adult fishes were found to feed poorly from November to January while the immature fishes feed actively in all the rest months of the year. The food items were found as algae, higher plant parts, protozoans, crustaceans, debris, sand and mud; and unidentified food materials.

Chrisafi *et al.* (2007) observed the feeding habits of sand smelt, *Atherina boyeri* identified 15 important items belonging to six major groups: crustacean (copepods, cladocera), mollusca (bivalve: larvae), insects (larvae), cestode worms and finfish (fry and eggs). Seasonal changes in diet composition were found where larvae of bivalve (33.8%) were dominated in January to May; and copepods (26.4%) and cladocera (24.2%) were dominated in June to December.

Collins *et al.* (2008) worked on the distribution, total length frequency and diet of *Patagonotothen guntheri*. They found that the growth is slow and the fish is primarily a pelagic feeder. The diet of smaller fish was dominated by copepods, predominantly *Rhincalanus gigas*, whilst larger fish principally consumed the pelagic hyperiid amphipod, *Themisto gaudichaudii* and Antarctic krill *Euphausia superba* including benthic prey.

Dadzie *et al.* (2000) studied the food habits of the silver pomfret, *Pampus argenteus* and found a broad spectrum food contents in the stomach of the fish where Crustacea were (45%), Bacillariophyta (21%), Mollusca (11%), fish scales (10%), and fish eggs and larvae (3%). In summer the species fed on a wider variety of food items than in winter. Analysis of monthly variations in stomach fullness indicated that feeding intensity fluctuated throughout the year, with lower during August and September, corresponding to the spawning period.

Hossain et al. (1990) stated that *Notopterus notopterus* is a carnivore fish and shows slackened feeding activities in the breeding season. It is also stated that the feeding activity of adult female increases in the late spawning season. The maximum fullness of the stomachs was observed in November and highest emptiness was recorded in March and in September. The occurrence of food items of the fish was found as crustaceans (25.09%), fishes (17.41%), insects (14.95%), debris and mud (14.51%), plant parts (20.18%), algae (0.40%), protozoans (0.11%), annelids 0.96%), mollusks (0.47%) and semi-digested matter (5.91%).

Islam (2002) observed that *Glossogobius giuris* feeds on small fishes and their larvae, insects, crustaceans and mollusks in their per-adult stage but in the adult stage the food items are identified as fishes, crustaceans, mollusks and insects. The species is piscivorous and cannibal all over the life. Males are found to be more cannibal than the female.

Islam et al. (1999) observed that the fish, *Colisa fasciata* is a column as well as bottom feeder and planktonivorous. It feeds more or less in all the months of the year and reduce feeding during spawning period. The major food items are identified as algae, plant parts, crustaceans, aquatic insects, protozoans, annelids and debris and detritus.

Karmaker and Das (2001) stated that the fish *Lates calcarifer* fed on *Mugil*, *Gobids*, *Anguilla*, *Setipinna*, *Anchoviella*, *Gazza*, *Arius*, *Penaeus*, *Metapenaeus* and *Nematopalemon*. Active feeding intensity was observed in August and the lowest in December and January. Special food preference in relation to size variation of the fish was not observed.

Knutsen et al. (2001) observed that the food of migratory *Salmo trutta* varied significantly with age, season and habitat of the fish. The main prey categories in terms of frequency of occurrence were fishes followed by crustaceans, surface insects and polychaetes. Seasonal variation in diet and within habitats was found, supporting the view that brown trout is an opportunistic feeder.

Kovacic (2001) stated that roule's goby, *Gobius roulei* is a predator and picker, feeding mostly on mobile benthic fauna, including bivalves, gastropods, polychaets, pagurids, mysids, gammarids and fishes.

Morley et al. (2004) studied the biology of *Macrourus holotrachys* and found that the fish is a benthopelagic predator and scavenger which feeds on a wide range of fishes and invertebrates.

Mustafa and Ahmed (1979) stated that the food of *N. notopterus* consists of mainly plankton which includes protozoans, crustaceans and algae together with insects and small quantities of other items along with debris and mud. The percentage composition might be as 21% protozoans, 20.50% crustaceans, 29% plants, 6.50% insects, 2.8% debris and mud, 8% fish, 4% fish remaining, 5% animal remaining, and very smaller proportion of rotifers and annelids.

Nabi (1993) worked on the daily feeding periodicities of *Macrognathus aculeatus* in Chalan Beel water and found that the fish is nocturnal. They have also found the empirical relationship between the feeding activities of first night and late night with seasonal changes of day length and water temperature.

Pilling et al. (2001) stated that the patagonian toothfish, *D. eleginoides* is an opportunistic carnivore. They found a wide range of prey items in the stomachs of *D. eleginoides* which was restricted in location and depth. The study confirms that feeding habits depend on the local availability of food items, as well as factors such as depth and predator size.

Richardson et al. (2000) stated that the females and juveniles of *Holohalaelurus regani* were generally found in shallower water than males. The fish is a generalist feeder, with the diet comprising teleosts, crustaceans and cephalopods.

Šantić et al. (2005) observed the feeding habits of the horse mackerel, *Trachurus trachurus*, on respect to fish size and season. They found 49.7% empty stomach among stomachs examined in the study period. This percentage varied significantly with season; the maximum number of empty stomachs was observed during January (80%) and February (82%) and a minimum number observed during July (15%) and August (19%). A total of 30 different prey species belonging to five major groups were identified in the stomach contents.

Sever *et al.* (2006) observed that in terms of percentage of weight fishes were the main food of *Scomber japonicus* during summer and autumn. Thaliaceans (*Salpa* sp.) constituted the most important food source in winter, whereas planktonic crustaceans (Amphipoda, Copepoda) were the main prey during spring.

Skoglund and Barlaup (2006) studied the feeding habits of brown trout *Salmo trutta* fry during the critical first feeding period in a natural spawning and nursery stream and found a low proportion of the fry initiated exogenous feeding before emergence from the gravel, and while having nearly 30% of the yolk sac remaining. The degree of stomach fullness revealed that feeding was more efficient after a territory had been acquired. The diets of the young fry were dominated by chironomid larvae, followed by zooplankton and Plecoptera larvae.

Slotte *et al.* (2006) studied the egg cannibalism in Barents Sea capelin, *Mallotus villosus* and found that the stomachs of the fish were either empty or contained eggs, often mixed with sand. The occurrence of cannibalism increased with stage of maturity, being highest in spent fish, and higher in males than in females. At similar stomach fullness, the females had consumed more eggs than the males.

Tanaka *et al.* (2006) studied the feeding habits and gill raker morphology of three major planktivorous pelagic fishes viz. Japanese anchovy *Engraulis japonicus*, Pacific round herring *Etrumeus teres* and Japanese jack mackerel *Trachurus japonicus* in the summer months of 2001. The diet of the Japanese anchovy mainly consisted of Oncaeidae copepods, while the diets of the Pacific round herring and Japanese jack mackerel were dominated by calanoid copepods at all stations.

Xue, *et al.* (2005) studied the stomach contents of *Pseudosciaena polyactis* and found that small yellow croaker was a carnivorous predator and crustaceans were the most important prey. Feeding activity was highest in autumn and lowest in spring and winter. Decapods were more important in summer, whereas euphausiids were more important during other seasons.

3.3 Materials and Methods

Sampling and Laboratory Analysis

Sampling was done fortnightly to collect *N. notopterus* from different fish landing centres of Rajshahi, Bangladesh and directly from the fisherman of the study area since January 2005 to December 2006. A total of 430 specimens were collected during daytime. Just after collection the live fishes were killed and 5-10% formalin solution was injected into the stomach of all the fishes in order to stop digestion and rotting of food items. The specimens were then tagged and finally preserved in 10% formalin for laboratory investigation.

To investigate the feeding intensity, the stomachs were dissected out and fullness of stomach was studied based on the following empirical scale presented in the Table 3.1.

Table 3.1: Description of five empirical scale of the stomach fullness used in this study

Fullness Category	Description
Empty stomach	Stomach barely bloated with no or few prey
Semi-empty stomach	Stomach slightly bloated with few amount of prey
Semi-full stomach	Stomach bloated with considerable amount of prey
Moderately full stomach	Stomach sufficiently bloated with large amount of prey
Full stomach	Stomach immensely bloated with large amount of prey

Stomach contents were examined under simple and compound microscope as required and the food items were identified to the species level whenever possible depending on the stage of digestion. Monthly and length group wise percentage composition of stomach contents were analyzed by gravimetric method (Lagler, 1966) and percentage of occurrence method (Hynes, 1950).

The stomach contents were also noted and weighted to determine the monthly feeding intensity in relation to sexual cycle by calculating Gastro Somatic Index (GaSI) using the following formula:

$$\text{Gastro Somatic Index (GaSI)} = \frac{\text{Weight of the stomach content}}{\text{Weight of the fish}} \times 100$$

Total length (TL), alimentary canal length (ACL) and weight of the fish was taken to an accuracy of 0.01cm and 0.1g. The TL-ACL relationship model was established by the method of least squares to fit a simple linear regression model based on two years data as:

$$Y = a + bX$$

Where

Y = Alimentary canal length

X = total length

a = Proportionality constant and

b = Regression coefficient

Calculations: All sorts of statistical analysis were done by using the computer software SPSS Version 11.5.

3.4 Results and Observations

It is painstaking and challenging work to observe the food and feeding habit of an aquatic animal under natural condition but study of stomach content of a suitable sample can determine its habitual food or diet. The types of food and the mode of food intake are not constant throughout life. A great variation is seen in feeding pattern of different species even in an individual in different stages of life, season to season, month to month and even within a day.

However, the present investigation deals with the 430 stomach contents of *N. notopterus* to determine the food and feeding habit of the fish. The following aspects of food and feeding habit were observed during the study period:

3.4.1 Feeding intensity

a) Overall intensity: The overall feeding intensity was carried out based on the stomachs contents of 430 specimens. It is observed that 25.63% stomachs were full, 32.07% were moderately full, 26.24% were semi-full, 16.06% were semi-empty and 0.00 % was empty allover the study period (Plate 3.1; Fig. 3.1). Fishes with full, moderately full and semi-full stomachs were considered to feed actively and fishes with semi empty and empty stomachs were considered to feed inactively. The overall percentage occurrence reveled that 83.94% fish showed active feeding during the study period.

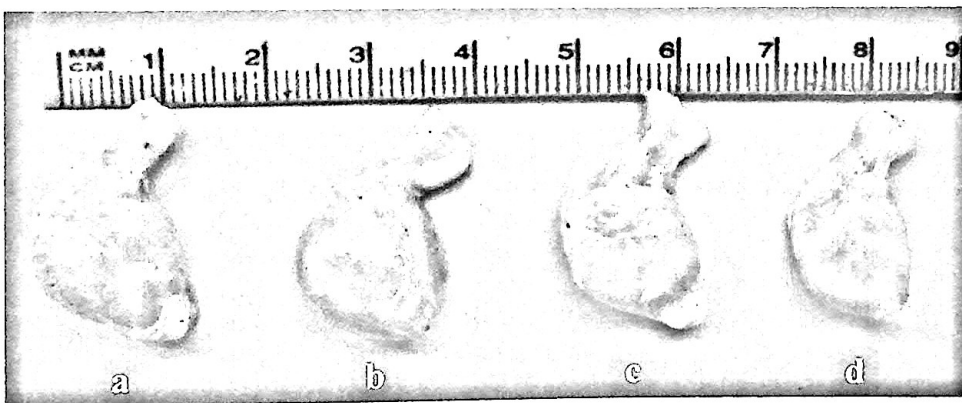


Plate 3.1: Showing the fullness category of stomach (a. full; b. moderately full; c. semi full; d. semi empty).

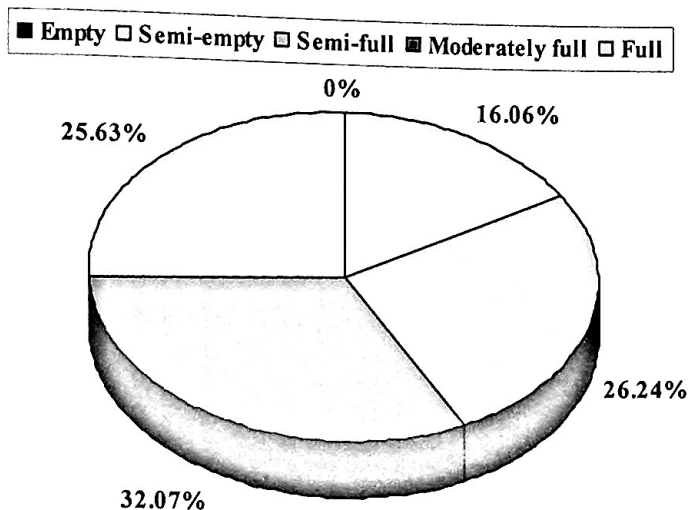


Fig. 3.1: Overall percentage of fullness of stomach of *N. notopterus*

b) Monthly intensity: The monthly feeding intensity analysis was done based on two years' data. It is observed that the comparative higher value of full stomachs were found from August to February, moderately full stomach were found from August to May, semi-full stomach were found from November to April and semi-empty stomach were found from May to July. It is remarkable that there were no empty stomach recorded during the study period. The result revealed that the fish showed monthly variation in feeding intensity. Detailed results are shown in Fig. 3.2.

c) Length group-wise intensity: Two years data analysis for length group-wise feeding intensity of *N. notopterus* revealed that the comparative higher percentage values of full stomachs were found in bellow 10, 10-15, 15-20 and 20-25cm groups; moderately full stomachs were found in bellow 10, 10-15, 15-20, 20-25 and 25-30cm groups; semi-full stomachs were found in 10-15, 15-20, 20-25, 25-30 and Above 30cm groups; and semi-empty stomachs were found in 20-25, 25-30 and Above 30cm groups (Fig. 3.3). The result clearly revealed that the feeding intensity was different among the length groups and the size of fish plays a vital role in active feeding which may be related to reproductive activity.

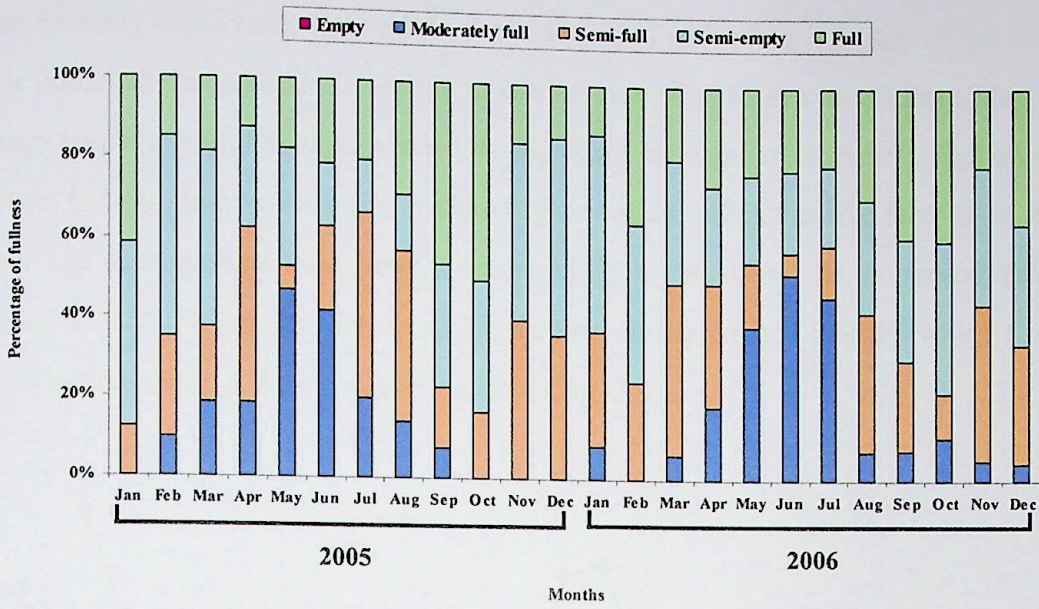


Fig. 3.2: Monthly percentage of fullness of stomach of *N. notopterus* (2005 to 2006)

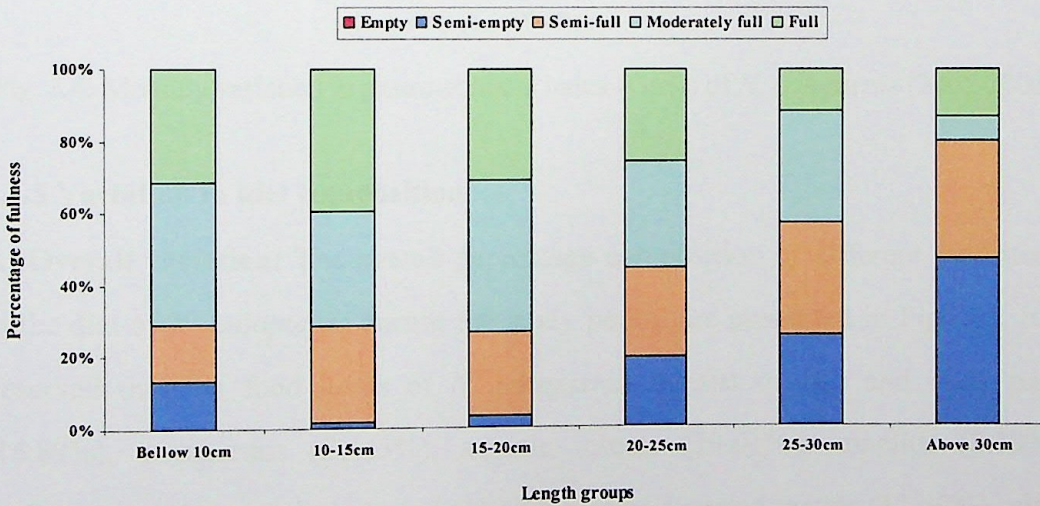


Fig. 3.3: Percentage of fullness of stomach in different length groups of *N. notopterus*

3.4.2 Gastro-somatic Index (GaSI) in Relation of Sexual Cycle

The monthly GaSI value showed rhythmic variation in feeding intensity of the fish. It is observed that comparatively the lower values of GaSI were found from May to August and the higher values were found from September to April. The lower values indicate inactive feeding and the higher values indicate active feeding of the fish. The cause behind these, the variations in GaSI values may be the reproductive periodicity of the fish that shows active feeding during pre and post spawning time and inactive feeding during spawning time (Fig. 3.4).

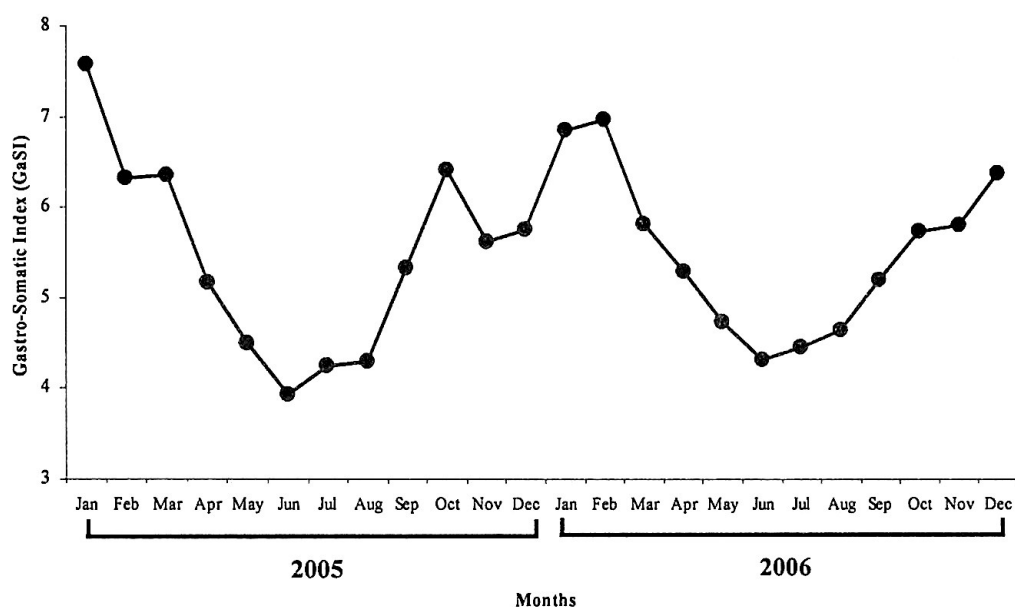


Fig. 3.4: Monthly variation in gastro-somatic index (GaSI) of *N. notopterus* (2005-2006).

3.4.3 Variation in diet composition

A) Overall variation: The overall percentage composition of different food items in the diet of *N. notopterus* during the study period are presented in Fig. 3.5. It is observed that the food items of *N. notopterus* consist of fish and body parts (16.89%), crustaceans (20.43%), aquatic insects (20.01%), annelids (2.19%), molluscs (1.41%), debris and mud (16.68%), semi-digested matter (11.49%), plant and plant parts (9.60%) and gravel and stones (1.30%).

c) Annelids

The food items of annelids were observed from February to October in small proportion which consisted of *Chaetogaster* (0.58%), *Aeolosoma* (1.15%) and *Branchiura* (0.46%). The highest and lowest percentage of this food items were recorded as 3.23% in July 2006 and 1.07% in October 2006 respectively (Table 3.2 and Fig. 3.6).

d) Molluscs

The molluscan food items were represented by 0.85% *Anisus* (not found in January) and 0.56% *Lymnea* (not found in December). The highest (3.13%) percentage of this food item was observed in July 2005 with an average of 1.41% (Table 3.2 and Fig. 3.6).

e) Debris and Mud

The percentage of debris and mud of the stomach content ranged from 12.41- 23.04 with an average of 16.68. The values indicate that the fish took considerable amount of debris and mud in their diet ((Table 3.2 and Fig. 3.6).

f) Semi-digested matter

The semi-digested matter consisted of all the food particles which lost their characteristics due to the activity of digestive tract. This item was found in considerable amount ranging from 10.06-14.03% with an average of 11.49% (Table 3.2 and Fig. 3.6).

g) Plant and Plant Parts

Remarkably the leaves, stems and young roots of lower and higher plants are observed in the stomach of the fish as a considerable proportion which ranged from 7.04-11.91% with an average of 9.60 (Table 3.2 and Fig. 3.6). The proportion of this food content may confused anyone while observe the ratio of TL : ACL.

h) Gravel and stones

The gravel and stones are found astonishingly in the stomach content of *N. notopterus*. It is observed that the fish included this item in its diet throughout the year. The percentage of this food item ranged from 0.26-2.82 with an average of 1.30 (Table 3.2 and Fig. 3.6).

B) Length group-wise variation

A gradual variation is observed in percentage composition of different food items among different length groups of *N. notopterus* as:

a) Fish and body parts

The percentage of fish food items were found highest in the stomach of the fish as 20.92 in “above 30cm group” and the next followed by 20.58 in 25-30 cm group. The lowest 10.82% was observed in the smallest length group (bellow 10cm) during the study period. The result reveled that predation on fish is observed more in larger fish groups comparatively (Table 3.3 and Fig. 3.7).

b) Crustaceans

The crustaceans showed no remarkable variation in the stomach content of the fish. The percentage variation is stands between 19.56 and 20.82 among the length groups. However, these two values were observed in “bellow 10cm” and 20-25cm groups respectively (Table 3.3 and Fig. 3.7).

c) Aquatic Insects

Like crustaceans no remarkable variation is observed for aquatic insects among different length groups. It is observed that the percentage variation for aquatic insects lies between 19.19 and 20.75 (Table 3.3 and Fig. 3.7).

c) Annelids

The highest percentage of annelids was observed as 2.39 in 25-30cm group where the lowest was 1.84 in 10-15cm group. The scattered variation in percentage distribution of this item among different length groups reveled that the length factor has no significant effect on the consumption of annelids (Table 3.3 and Fig. 3.7).

d) Molluscs

The percentage of molluscs was ranged between 0.76-1.92%. Gradual increment is observed in percentage composition of this food item with the increment of length (Table 3.3 and Fig. 3.7).

e) Debris and Mud

The highest percentage of debris and mud was observed as 20.22 in bellow 10cm group where the lowest was 15.19 in 25-30cm group. It is observed that the consumption of debris and mud reduces in accordance with the increase of length (Table 3.3 and Fig. 3.7).

f) Semi-digested matter

The variation in percentage distribution of semi-digested matter was ranged between 11.23 and 12.64. The highest percentage was recorded in bellow 10cm group where it was found lowest in 20-25cm group (Table 3.3 and Fig. 3.7).

g) Plant and Plant Parts

Plant and plant parts are found as a considerable proportion in the stomach content of the fish. It is observed that the higher the percentage of plant and plant parts the lower the length group *i.e.* the fish reduces the consumption of this food item with the increase of its length (Table 3.3 and Fig. 3.7).

h) Gravel and stones

An exceptional food item, "gravel and stone" was observed in the stomach of the species. It is observed that the stomach of the larger fishes content comparatively more amount of this food item. The highest percentage of this food item was recorded 1.91 in above 30cm length group where the lowest 0.79 in 10-15cm group (Table 3.3 and Fig. 3.7).

Table 3.2: Detailed percentage composition of food items of *N. notopterus* based on the stomach content of 430 specimens from 2005-2006

Group name	Name of food organisms	Recorded months	Individual percentage	Total percentage
Fish and body parts	<i>Puntius</i>	Jan to Dec	2.51	16.89
	<i>Amblypharyngodon</i>	Sep to Feb	1.57	
	<i>Esomus</i>	Aug to Nov	1.15	
	<i>Chanda</i>	Jul to Dec	1.24	
	<i>Pseudambassis</i>	Jan to Dec	0.85	
	<i>Danio</i>	Aug to Feb	1.45	
	<i>Chela</i>	Aug to Dec	0.56	
	Fish scale/body parts	Jan to Dec	7.56	
Crustaceans	<i>Daphnia</i>	Jan to Dec	1.15	20.43
	<i>Cyclops</i>	Jan to Dec	1.23	
	<i>Cypris</i>	Jan to Dec	1.37	
	<i>Mysis</i>	Jan to Dec	1.42	
	<i>Diaptomus</i>	Jan to Dec	0.88	
	Prawns	Jan to Dec	9.23	
	Larvae	Jan to Dec	5.15	
Aquatic Insects	<i>Belostoma</i>	Jan to Dec	1.90	20.01
	<i>Chironomus</i>	Jan to Dec	1.73	
	<i>Halipus</i>	Jan to Dec	1.87	
	<i>Regimbartia*</i>	Jul to Feb	1.69	
	<i>Libellula</i>	Jan to Dec	0.88	
	<i>Notonecta*</i>	Jul to Mar	2.53	
	<i>Epecordulea</i>	Jan to Dec	2.17	
	Larvae, nymph and pupae	Jan to Dec	7.24	
Annelids	<i>Chaetogaster</i>	Mar to Oct	0.58	2.19
	<i>Aeolosoma</i>	Feb to Oct	1.15	
	Branchiura	Feb to Sep	0.46	
Molluscs	<i>Anisus</i>	Feb to Dec	0.85	1.41
	<i>Lymnea</i>	Jan to Nov	0.56	
Debris and Mud	-	Jan to Dec	-	16.68
Semi-digested matter	-	Jan to Dec	-	11.49
Plant and plant parts	Leaves, stems and roots	Jan to Dec	-	9.6
Gravel and stones	-	Jan to Dec	-	1.3

Note: * means harmful

Table 3.3: Percentage composition of food items of *N. notopterus* in different length groups.

Size groups	Ratio TL: ACL	Percentage of food items								
		Fish and body parts	Crustaceans	Aquatic Insects	Annelids	Molluscs	Debris and Mud	Semi- digested matter	Plant and plant parts	Gravel and stones
Bellow 10cm	180.52	10.82	19.56	19.90	2.15	0.76	20.22*	12.64*	12.46	1.50
10-15cm	180.51	12.67	19.71	19.66	1.84	0.91	19.47	12.10	12.85*	0.79
15-20cm	180.47	17.25	20.39	19.49	2.04	1.03	16.83	11.26	10.44	1.26
20-25cm	180.42	17.14	20.82*	20.75*	2.27	1.73	16.04	11.23	8.66	1.37
25-30cm	180.41	20.58	20.48	19.79	2.39*	1.47	15.19	11.30	7.28	1.54
Above 30cm	180.40	20.92*	20.44	19.19	1.99	1.92*	15.55	11.55	6.53	1.91*
Mean±SE	180.43	16.56 ±1.67	20.23 ±0.20	19.8 ±0.22	2.11 ±0.08	1.30 ±0.19	17.22 ±0.87	11.68 ±0.23	9.70 ±1.08	1.40 ±0.15

Note: * means the highest value

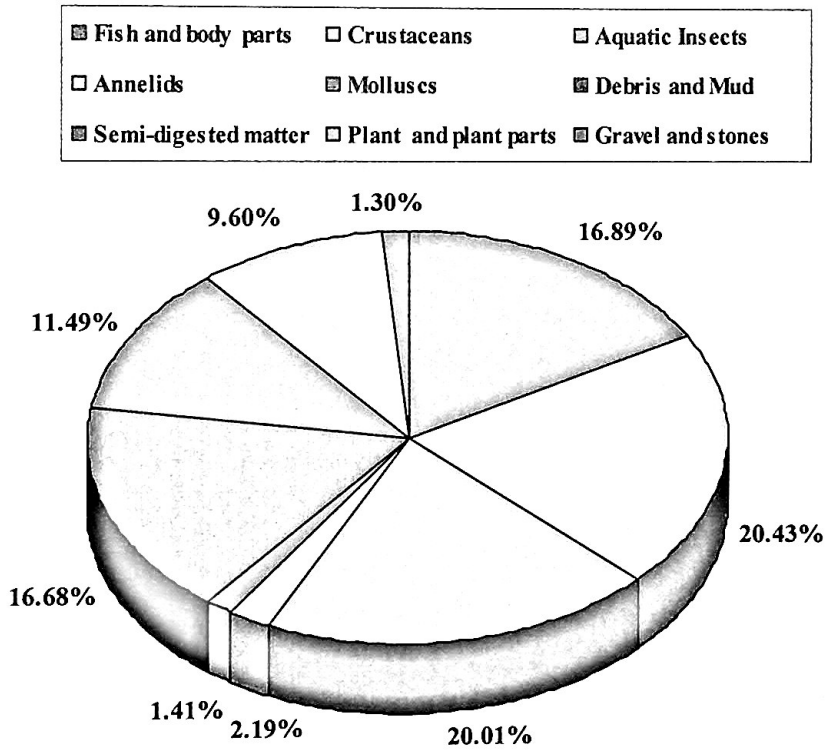


Fig. 3.5: Mean variation in percentage composition of food items of *N. notopterus*

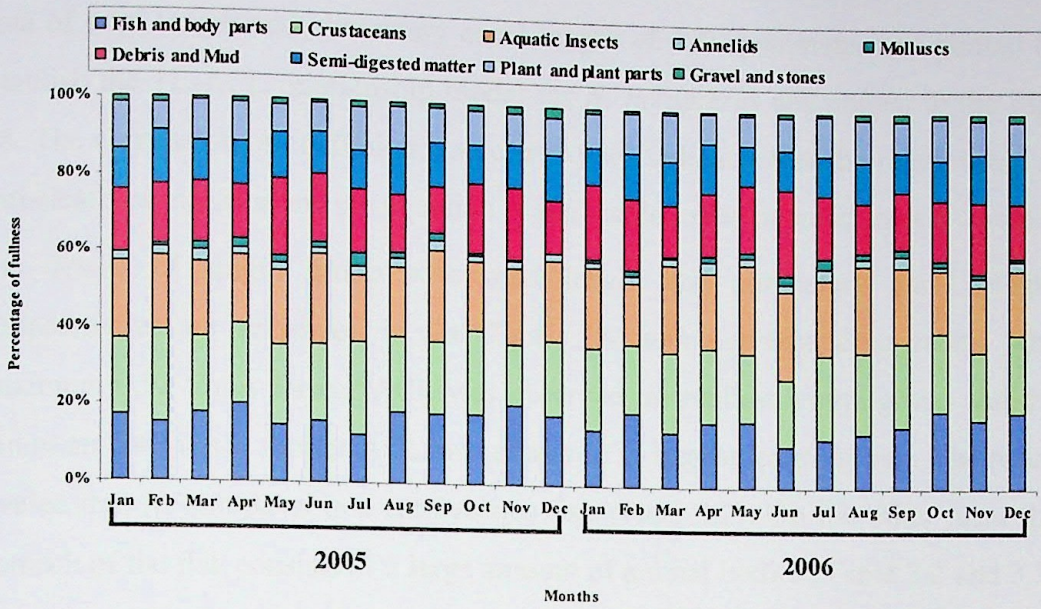


Fig. 3.6: Monthly variation in percentage composition of different food items of *N. notopterus* (2005-2006)

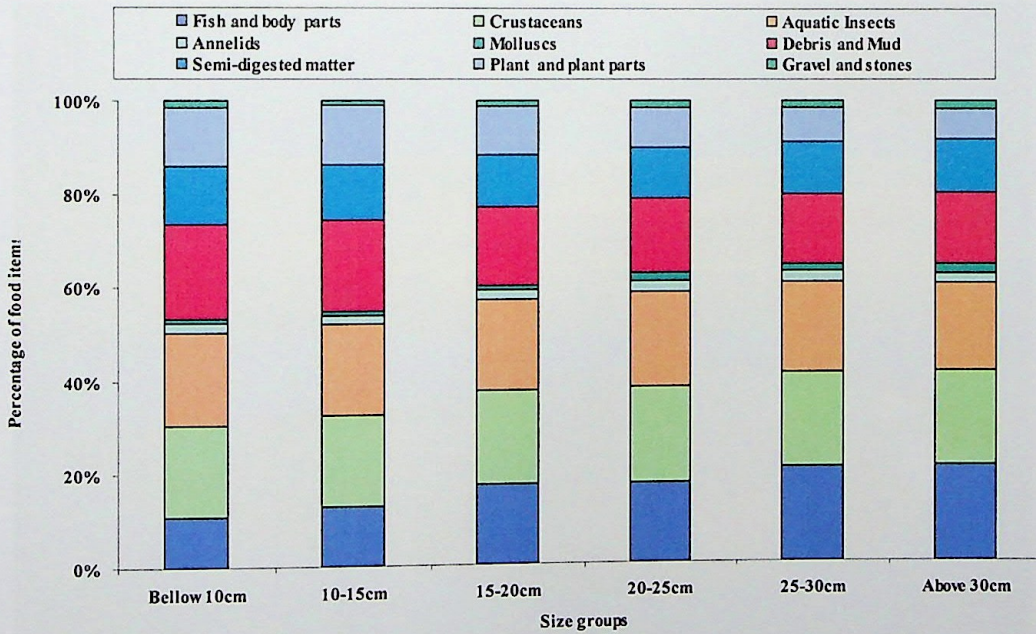


Fig. 3.7: Percentage composition of food items of *N. notopterus* in different size groups.

3.4.4 TL-ACL Relationship Model and Feeding Habit

Data of total length and alimentary canal length of 430 specimens was plotted to establish the TL-ACL relationship model for *N. notopterus* and shown in the Fig. 3.8. The correlation of coefficient value ($r=0.986$) indicates that the relationship is statistically significant and the equation is applicable to the population as a whole.

The details of length group wise total length and alimentary canal length characteristics are presented in the Table 3.4 with corresponding ratios. The maximum 0.52 times shorter ACL was observed in smallest length group and the minimum 0.40 times shorter ACL was observed in largest length group. The result revealed that *N. notopterus* is a carnivorous fish (Plate 3.2). On the other hand the stomach of the fish consists of a large amount of animal bodies (Table 3.2 and 3.3) which confirmed the carnivorous habit of the species earlier. Besides, some characters like spinous gill raker; teeth on each jaw, palate, vomer and tongue strongly recommend the carnivorous habit of the fish. The result also revealed that the length of ACL decrease in relation to increase of its TL *i.e.* the fish becomes more carnivore at adult hood.



Plate 3.2: A featherback having TL of 17.5cm and ACL of 8cm represents 1:0.46 TL-ACL ratio indicating carnivorous habit of the fish.

Table 3.4: Descriptive statistics and relationship between total length (TL) and alimentary canal length (ACL) of *N. notopterus*.

Size group (cm)	No. of observation	Total length (cm)		Alimentary canal length (cm)		Ratio TL:ACL
		Range	Mean±SE	Range	Mean±SE	
Bellow 10	36	7.00-9.90	8.38±0.13	3.50-5.30	4.36±0.07	1:0.52
10-15	57	10.00-14.90	12.66±0.17	5.00-7.50	6.36±0.08	1:0.50
15-20	88	15.00-19.50	17.39±0.14	7.00-9.00	7.93±0.05	1:0.46
20-25	110	20.00-24.80	22.67±0.14	8.50-10.70	9.42±0.05	1:0.42
25-30	111	25.00-29.60	27.54±0.14	9.60-12.30	10.94±0.06	1:0.40
Above 30	28	30.00-31.50	30.39±0.08	11.50-12.50	12.05±0.06	1:0.40
Total	430	7.00-31.50	20.85±0.32	3.50-12.50	8.85±0.11	1:0.43

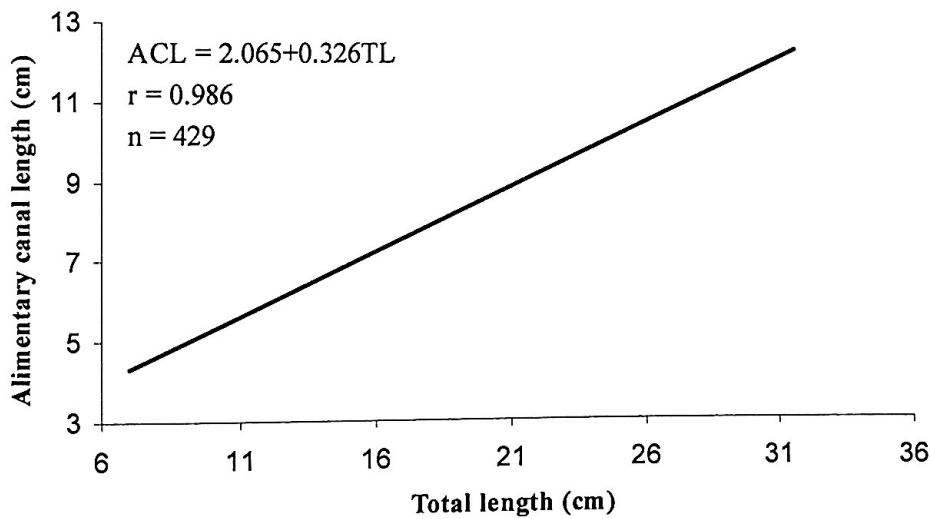


Fig. 3.8: TL-ACL relationship model of *N. notopterus* based on simple linear regression equation ($Y = a + bX$).

3.5 DISCUSSION

Knowledge about food consumption and food composition is of importance in studies of fish stocks. Fish growth, and thus the productivity of a fish stock, depends on the availability of food. Knowledge of the main food sources of the different species of a fish community will provide insight into the food web and consequently into the inter-relationships of the species. Information on food composition can be obtained by analysis of stomachs and intestines (Witte and Densen, 1995). The present study dealt with the stomach content of *N. notopterus* and exposed the secret of food and feeding habit of the fish. The result revealed that the fish fed on a large variety of food items viz. fishes, crustaceans, aquatic insects, annelids, molluscs, debris and mud, plant and plant parts; and gravel and stones showing various feeding intensity.

3.5.1 Feeding intensity

The percentage analysis of fullness of stomach indicates that the fish *N. notopterus* feeds throughout the year. The overall feeding intensity of the fish revealed that almost 83.94% fish feed actively from September to April with a peak during October to March, while post spawning period and the least feeding intensity during peak spawning period from May to July. The length group-wise data also showed highest intensity of feeding in smaller to middle length groups but comparatively lower in larger length groups.

The GaSI is an important parameter to determine the feeding intensity. The GaSI analysis also showed similar feeding intensity in relation to sexual cycle of the species. Hossain *et al.* (1990) stated that *N. notopterus* is a carnivore fish and shows slackened feeding activity in the breeding season and feeding activity of adult female increases in the late spawning season. The maximum fullness of the stomachs was observed in November and highest emptiness was recorded in March and September. The present study again established the findings of Hossain *et al.* (1990). The result also agreed with the findings of Mustafa and Ahmed (1979) in *N. notopterus*,

Bhuiyan and Islam (1988) in *Xenentodon cancila*, Bhuiyan *et al.* (1992) in *Aspidoparia morar*, Hossain *et al.* (1992a) in *Nandus nandus*, Bhuiyan *et al.* (1994) in *Rhinomugil corsula*, Bhuiyan *et al.* (1997) in *Clupisoma atherinoides*, Šantić *et al.* (2005) in *Trachurus trachurus*, Xue *et al.* (2005) in *Pseudosciaena polyactis*; Alp *et al.* (2008) in *Esox lucius*; and partially agreed with the findings of Karmaker and Das (2001), Kovacic (2001), Chrisafi *et al.* (2007) and Collins *et al.* (2008).

3.5.2 Variation in diet composition

The diet composition of fish shows a vast diversity from species to species or even in a species in different stages of life. It is observed that the food items of *N. notopterus* consist of fish and body parts (16.89%), crustaceans (20.43%), aquatic insects (20.01%), annelids (2.19%), molluscs (1.41%), debris and mud (16.68%), semi-digested matter (11.49%), plant and plant parts (9.60%) and gravel and stones (1.30%). All these food items were observed in the stomach content of the fish throughout the year excluding annelids and molluscs. The monthly and length group-wise percentage variation of all these food items were found clearly in the stomach content of *N. notopterus*. These variations were also observed in 1979 by Mustafa and Ahmed in the same species. They reported that the food of *N. notopterus* consists of mainly plankton which includes protozoans, crustaceans and algae together with insects and small quantities of other items along with debris and mud. The percentage composition might be as 21% protozoans, 20.50% crustaceans, 29% plants, 6.50% insects, 2.8% debris and mud, 8% fish, 4% fish remaining, 5% animal remaining, and very smaller proportion of rotifers and annelids. In a research of Hossain *et al.* (1990) earlier reported that *N. notopterus* is a carnivore fish and shows slackened feeding activities in the breeding season. The occurrence of food items of the fish was found as crustaceans (25.09%), fishes (17.41%), insects (14.95%), debris and mud (14.51%), plant parts (20.18%), algae (0.40%), protozoans (0.11%), annelids 0.96%, mollusks (0.47%) and semi-digested matter (5.91%).

Though there is a little dissimilarity exists in the present work and in between these two research groups, it may be concluded that the dissimilarities are avoidable and the diet composition of *N. notopterus* is reestablished.

Similar findings were also observed in *Xenentodon cancila* (Bhuiyan and Islam, 1988), *Nandus nandus* (Hossain *et al.*, 1992a), *Rhinomugil corsula* (Bhuiyan *et al.*, 1994), *Colisa fasciata* (Islam *et al.*, 1999), *Pampus argenteus* (Dadzie *et al.*, 2000), *Holohalaelurus regani* (Richardson *et al.*, 2000), *Sulmo trutta* (Knutsen *et al.*, 2001), *Glossogobius giuris* (Islam, 2002), *Macrourus holotrachys* (Morley *et al.*, 2004), *Scomber japonicus* (Sever *et al.*, 2006), *Atherina boyeri* (Chrisafi *et al.*, 2007) and *Chlorophthalmus agassizi* (Anastasopoulou and Kapiris, 2008).

Besides the result also disagreed with the findings of Banu *et al.* (1993) in *Hypophthalmichthys molitrix*, Bhuiyan *et al.* (1998) in *Puntius gonionotus*, Karmakar and Das (2001) in *Lates calcarifer*, Alam *et al.* (2002a) in *Tor putitora*, Alam *et al.* (2002b) in *Gudusia chapra*, Slotte *et al.* (2006) in *Mallotus villosus*, Tanaka *et al.*, (2006) in *Engraulis japonicus*, *Etrumeus teres* and *Trachurus japonicus*.

3.4.4 TL-ACL Relationship Model and Feeding Habit

The TL-ACL relationship model for *N. notopterus* was established as $ACL = 2.065 + 0.326TL$. The value of correlation of coefficient was found as 0.986 which indicates the relationship is statistically significant and the equation is applicable to the population as a whole.

The ratio between TL and ACL was found maximum 1 ± 0.52 in smallest length group and the minimum 1 ± 0.40 in largest length group. The ratios revealed that *N. notopterus* is a carnivorous fish. On the other hand large amount of animal bodies in the stomach content reconfirmed the carnivorous habit of the species. The gradual decrease of TL-ACL ratio revealed that the fish becomes more carnivore at the adult hood.

Das and Moitra (1956) worked on the feeding habit of *N. notopterus* and found that the stomach is very muscular, large and well developed and the intestine is straight, short and thick walled including TL-ACL ratio as 1:0.60 in *N. notopterus*. They also stated that the food habit of a carnivore fish is correlated with relatively short and muscular alimentary canal. In the present study the characteristics of digestive tract were found completely similar to that of Das and Miotra (1956) which strongly support the carnivorous habit of the fish. Mustafa and Ahmed (1979), Hossain *et al.* (1990) and Azadi *et al.* (1994) had also reported that the *N. notopterus* is a carnivorous fish. The carnivorous characters in fishes were also observed by Bhuiyan and Islam (1988) in *Xenentodon cancila*, Bhuiyan *et al.* (1997) in *Clupisoma atherinoides*, Karmaker and Das (2001) in *Lates calcarifer*, Islam (2002) in *Glossogobius giuris*, Alam (2005) in *Wallago Attu*.

Chapter Four

REPRODUCTIVE BIOLOGY

Chapter Four

REPRODUCTIVE BIOLOGY

4.1 Introduction

Reproduction is the process by which species are perpetuated and by which, in combination with genetic change, characteristics for new species first appear (Lagler *et al.*, 1977). Most aquatic organisms spend much of their lives and energies for reproducing. After a brief juvenile stage, they develop sperms or eggs, spawn, recover, and repeat the process in a cycle that continues until senility or death (Royce, 1972). Continuity of this biological race is maintained by the process of reproduction and failing which they may lead to extinction. So, knowledge about reproduction and reproductive activities are vital and takes a place of paramount importance in studying the biology and life history of any organism.

Reproduction is a physiological phenomenon and it is influenced by several factors such as, genetic, environmental and hormonal factors, either singly or in combination (Marshall, 1965). Before reproduction, several developmental changes occur which affect mainly the development and maturation of the gonads and associated structures concerned with reproduction. These changes are termed as maturation changes or the process of maturation. According to Adiyodi and Adiyodi (1974), sex differentiation is a slow and stepwise process. Sexual development involves the maturation of structural, physiological and behavioural machineries concerned with mating and reproduction, controlled by the sex hormones (Berreut-Bonnenfant and Charniaux-Cotton, 1970) or abiotic and biotic factors (Nikolsky, 1963, Wootton, 1990). Changes in these factors are known to affect spawning success and gonadal development which in turn determines the size or age at which the species attains first sexual maturity (Quatey and Maravelias, 1999).

Environmental parameters, such as day length, temperature, turbidity, availability and nature of food, interspecies and intraspecies social relation may influence the nature and pattern of reproduction and developmental behaviour (Waterman, 1961). The above factors do not appear suitable for an organism throughout the year and, as such, the reproductive activities in aquatic organisms are time oriented and sometimes periodical. Hossain (1989) observed that the critical period of population replenishment is usually so timed by environmental variables or certain condition of water that the young are produced at periods favourable for their survival.

The time or season when the species are normally breeds termed as the breeding or spawning season of that species. The breeding season repeats in cyclic order, in which the organism undergoes maturation changes and they get ready to breed again. The repeated phenomenon is known as the reproductive cycle or sexual periodicity. The reproductive cycle in an organism can be determined by several methods and many workers have studied it in different fishes such as Hossain *et al.*, 1989; Afroze and Hossain, 1990; Hossain *et al.*, 1991a; Nargis and Hossain, 1992; Hoque and Hossain, 1993; Parween *et al.*, 1993; Azadi *et al.*, 1995; Nabi and Hossain, 1996; Alam *et al.*, 1997; Fatema *et al.*, 1997; Yoneda *et al.*, 1998; Bhuiyan *et al.*, 1999a; Sultana *et al.*, 2001; Hossain *et al.*, 2002; Lenhardt and Cakic 2002; Rahman *et al.*, 2002; Alp *et al.*, 2003; Caputo *et al.*, 2003; Grabowska, 2005; Martín *et al.* 2005; Kennedy *et al.* 2006; Zorica *et al.*, 2006; Ferriz *et al.*, 2007; Sulikowski *et al.*, 2007; Kahraman *et al.*, 2008; and Kendall and Gray, 2008.

A precise knowledge of fecundity of a fish is also important to evaluate its life history, commercial catch, artificial propagation, culture practice and proper management of the fishery (Shafi *et al.*, 1978; Afroze and Hossain, 1983; Hossain *et al.*, 1992b; Rahman *et al.*, 2002). The term fecundity can be expressed as the number of eggs present in the ovary that should be laid in a single spawning season. The fecundity of a species is not a constant number which fluctuates within a certain range, which is species specific. Accurate estimation of fecundity is must for studying the population dynamics (Hossain, 1989).

The reproductive capacity of fish population is a function of the fecundity of females (Shafi and Mustafa, 1976). Variation in fecundity is very common among the same species of fish depending on their size, age and environmental conditions (Lagler *et al.*, 1977). Fecundity is also related to length, somatic and gonad weight. In many fishes the relationship of fecundity to length, somatic and gonad weight is curvilinear than linear (Bagenal, 1978). Fecundity is one of the important aspects of the biology and population dynamics of a fish.

Many workers have studied the fecundity of different species of fishes, viz., Afroze and Hossain (1983), Banu *et al.* (1985), Nargis and Hossain (1988), Islam and Azadi (1989), Islam and Hossain (1990), Hoque and Hossain (1993), Alam *et al.* (1994b), Bhuiyan and Afroze (1996), Ellis and Shackley (1997), Hossain *et al.* (1997b), Mustafa *et al.* (1998), Afroze *et al.* (1999), Kovacic (2001), Lenhardt and Cakic (2002), Morley *et al.* (2004), Grabowska (2005), Sindhe and Kulkarni (2005), Kennedy *et al.* (2006), Azzurro *et al.* (2007), Ferriz *et al.* (2007), Glamuzina *et al.* (2007), Knight *et al.* (2007), Dadzie *et al.* (2008), Dadzie and Abou-Seedo (2008), Fazli *et al.* (2008) and Oker *et al.* (2008).

Studies on the sex-ratio on different fishes have been done by Afroze and Hossain (1983), Hossain and Islam (1983), Nargis and Hossain (1988), Islam and Hossain (1990), Rahman *et al.* (1992), Bhuiyan *et al.* (1993), Bhuiyan and Afroze (1996) Alam *et al.* (1996), Lorenzo *et al.* (2002), Oliva-Paterna *et al.* (2002), Pajuelo *et al.* (2006a), Pinheiro *et al.* (2006), Colombo *et al.* (2007), Koc *et al.* (2007), Fazli *et al.* (2008), Filer and Sedberry (2008), Kahraman *et al.* (2008), Mazlan and Rohaya (2008).

An understanding of breeding cycles as they occur in nature is an essential pre-requisite for the initiation of breeding program of the species concerned (Mollah and Tan, 1982). The foregoing literature clearly shows that though there is considerable information on the different aspects of reproductive habits and cycles of some fishes, but there is no comprehensive and comparative account of *N. notopterus*. So, study of reproductive biology of *N. notopterus* is found to be essential in the sense that it may provide information and clues for a tactful and skilful nature of this fish including reproductive system, seasonal maturity, reproductive cycle, fecundity and sex-ratio of the species.

4.2 Review of Literature

There is abundant information in the literature of reproductive biology of fishes. Some important works are mentioned here that related with the present work.

Afroze and Hossain (1983) worked on the fecundity and sex-ratio of *Amblypharyngodon mola* and found that the fecundity of the species ranged from 400 to 8550 with the mean value of 3596.42 ± 150.46 . The male and female ratio of the species was found as 1:6.7.

Afroze and Hossain (1990) worked on the reproductive cycle of *Amblypharyngodon mola* and found that the fish spawns twice a year. The peak breeding months of the species are identified as March and August.

Alam et al. (1996) observed the maturation and spawning of *Setipinna phasa* and found that the fish shows four maturation stages for male and six for female with a prolonged breeding season from October to April. The average sex ratio was observed 1:1.14 which was varied significantly in different months.

Alp et al. (2003) observed the reproductive biology of *Salmo trutta macrostigma* and found that spawning of the fish lasted from November to January. Some 27.7% of the females and 62.5% of the males attained sexual maturity in their second year. The mean fecundity of the sampled population was 554 eggs per fish. The diameter of mature eggs in the spawning season ranged from 3.250 to 5.930 mm, with a 4.146 mm average.

Azzurro et al. (2007) investigated the aspects of gonad morphology, fecundity, atresia and oocyte dynamics of *Siganus luridus* and found that the ovarian development was consistent with the group-synchronous type, and testicular organization was of the unrestricted spermatogonial testis type, with cystic spermatogenesis. Absolute fecundity ranged from 115739 to 740433 oocytes per female. Relative fecundity ranged from 1239 to 3162 oocytes/g, with a mean of 1885 ± 868 oocytes/g.

Barros and Regidor (2002) analysed the spawning period of *Odontesthes bonariensis* using gonadosomatic index (GSI) curves and monthly percentage distributions of maturation stages and found that the fish show a single spawning season with two peaks (late winter and early autumn) within 1 year.

Bhuiyan and Afrose (1996) stated that the fecundity of *Oreochromis nilotica* ranged from 290 to 1265 with a mean of 575.91 ± 296.75 . The number of eggs increased linearly with the increase of body length, body weight, ovary length, ovary weight and ovary breadth. The total male and female ratio was 1:1.31 *i. e.* the females were predominating throughout the year.

Bhuiyan and Bhuiyan (1987) studied the fecundity of *Channa striatus* and found that the fecundity of the fish ranged from 1,450 to 23,400 with a mean value of $7,812.2 \pm 1333.9$. They have also found that the same sized fish bears different numbers of eggs in their ovaries.

Bhuiyan et al. (1993) stated that the fecundity of *Aspidoparia morar* ranged from 1431 to 9223 with a mean of 5033.40 ± 1858.93 and the male and female ratio was observed as 1:1.42.

Bhuiyan et al. (1999a) worked on the spawning periodicity of *Clupisoma atherinoides* and found that the spawning season of the fish continued from May to September with a peak in July.

Caputo et al. (2001) found that the paedomorphic goby *Aphia minuta* does not show semelparity. In spring, the mature ovary contains several batches of eggs at different stages of vitellogenesis. Which indicates the breeding season of *A. minuta* is quite long and that spawning takes place at least twice during its short lifespan.

Caputo et al. (2003) found that the pelagic crystal goby *Crystallogobius linearis* is semelparous; and after the first spawning the mature gonads of both males and females appeared to have lost the capability for further spawning. Mature females had very low fecundity (200-700 mature oocytes) and small egg size (0.2-0.55mm).

Coggan *et al.* (1999) stated that *Nezumia aequalis* is one of the most abundant fishes on the upper and middle continental slopes in which sex ratios were close to parity in all depth zones. Ovaries contained five size groups of eggs, the three largest groups being vitelline and contributing 27% of the absolute individual fecundity which was positively correlated with body size and ranged from 9109 to 26 847.

Colombo *et al.* (2007) identified seven developmental stages of ovary of shovelnose sturgeon. They also stated that males reached maturity at a smaller size than females. The sex ratio was not different from 1:1. The fecundity was positively related to body weight.

Dadzie and Abou-Seedo (2008) found four major phases of gonadal development in the black pomfret, *Parastromateus niger* as primary growth phase; secondary growth phase; maturation phase; and spawning phase, followed by the regressed phase. *P. niger* is capable of spawning multiple times throughout the reproductive season lasting from February to September. Batch fecundity was calculated as 2132–2001648 with the mean of 406010.

Dadzie *et al.* (2008) studied the length-length and length-weight relationships of the black pomfret, *Parastromateus niger*, and found that fish shows an allometric relationship in all cases. They also found that the fish spawns in May and June. The fecundity ranged from 71,305 to 3,895,449 eggs and correlated positively with ovary-free body weight, standard length and ovary weight, and negatively with egg size.

Dalela *et al.* (1976) studied the morphohistology of gonads of three teleost fishes; where in *Notopterus notopterus* the gonads were unpaired flat structure, situated ventrolaterally. The testis of the fish was differentiated into anterior and middle functional regions and the posterior nonfunctional region; and the ovary is somewhat oval unpaired structure.

Dalela et al. (1977) studied the reproductive cycle of the gonads of the *Notopterus notopterus* and *Colisa fasciatus* and found that the ovary of both the fishes has same developmental stages. Ovarian cycle is distinguished in the 4 phases depending upon their changes in nucleus. Before spawning the enlargement of the ovary is due to the accumulation of the yolk in the egg. The spawning in both the fishes occurs during late May to August.

Dos et al. (2005) stated that the reproductive period of *P. brasiliensis* extends from August to March, presenting greater activity from October to February. Females reach first maturation at 15.4 cm total length (TL).

Driggers III et al. (2004) studied the reproductive biology of *Carcharhinus acronotus*. Considering the gonado-somatic indices and found that spermatogenesis and vitellogenesis of the fish began after December and mating took place during the end of May and the beginning of June.

Ellis and Shackley (1997) stated that the overall sex ratio (males : females) of *Scyliorhinus canicula* is 1:1.23. Males matured between 490 and 540 mm LT with 50% maturity at 520 mm. Females matured between 520 and 640 mm LT with 50% maturity at 550 mm. Female gonadosomatic index peaked in May. Fecundity increased with fish length. The egg laying season lasted 10 months with a peak in June and July.

Erisman and Allen (2006) studied the reproductive behaviour of a temperate serranid fish, *Paralabrax clathratus* and found that spawning of the fish occurred 32 min before sunset to 120 min after sunset, and both males and females were capable of spawning multiple times during a single evening. Behavioural observations of adults and estimates of spawning periodicity from the collection of females with hydrated oocytes suggested that spawning occurred continuously throughout the summer months and showed no significant relationship with the lunar cycle.

Everson *et al.* (2000) worked on the inter-annual variation in the gonad cycle of *Champscephalus gunnari* and found that the gonadal maturation is closely associated with the time of year. Spawning appears to occur at the same time each year, but the timing of gonadal development is subject to a considerable inter-annual variation.

Fatema *et al.* (1997) stated that *Oxygaster bacaila* shows higher values of gonadosomatic and gonadal length indices in the months of April to August with the peak in June -July. The colouration of ovary was yellow at that period.

Fazli *et al.* (2008) found that the overall male and female sex ratio of golden grey mullet (*Liza aurata* Risso, 1810) in Iranian waters is 1:1.42. They also observed that the reproductive season extended from October to December. Mature gonads were present in 20% of fish at age 3, 63% at age 4, 88% at age 5, and 97% at age 6. Individual absolute fecundity of the golden grey mullet ranged from 113386 to 1470000 million eggs, with a mean ($\pm$ SD) of 451963 ($\pm$ 274,114.2).

Ferriz *et al.* (2007) stated that the reproductive period of *Pseudocorynopoma doriai* is seasonal, occurring from late winter to mid-summer, with another reproductive peak of smaller magnitude in early autumn. The mean monthly GSI in males has a significant correlation with rainfall. First maturity in females was reached within the 42–43 mm standard length class. The mean absolute fecundity was 1286.42.

Filer and Sedberry (2008) found that the females of *Hyperoglyphe perciformis* spawns from September to May with a peak from November to January and the males spawns year round, but had a peak from September to April. The sex ratio (M:F) for this population was 1:1.34.

Gibbs *et al.* (2008) found that the invasive loricariid catfish, *Pterygoplichthys disjunctivus* has cystovarian ovaries, a left ovary that is significantly larger than the right ovary, and is highly fecund. Ovaries contained multiple oocyte size classes and completely spent females were not found, both of which indicate that this species is a multiple spawner.

Glamuzina et al. (2007) found the maximum length 28.04 cm and maximum weight 206.8g of *Chondrostoma knerii* while estimating the length-weight relationship. The correlation between egg number and length and weight was extremely low. The gonadosomatic index distribution showed an inverse proportionality with total length. The fecundity ranged between 2000 and 16000 eggs per female.

Grabowska (2005) observed that spawning of *Neogobius gymnotrachelus* lasted from April to August. Males were on average about 23.3% longer and 53.8% heavier than females. Mean absolute fecundity was 952 eggs per female (361–2236). Egg diameter ranged from 0.140 to 1.558 mm, being of bi-modal distribution, which suggests two or three spawning bouts.

Hoque and Hossain (1993) stated that the fecundity of *Mystus vittatus* varied from 2534 to 60746 with a mean of 19399.609 ± 9177.118 . Positive correlation between fecundity with total length, standard length, body weight, gonadal weight, and gonadal length were observed during the study.

Hossain and Islam (1983) studied the sexual dimorphism and sex ratio of *Clupisoma atherinoides* and found that the species shows distinct sexual dimorphic characters during breeding season. The male and female ratio was found as 29.81:70.19 i.e. the females were predominating throughout the year.

Hossain et al. (2002) studied the reproductive periodicity of *Gonialosa manminna* and observed that the reproductive periodicity of the species starts from January and continues upto June with a peak in April.

Islam and Hossain (1984) worked on the fecundity of Chela, *Oxygaster bacaila* and found that the fecundity of the species ranged from 7,146 to 33,997. The mean number of eggs was calculated as $14,014 \pm 7347.09$ with the fecundity of 1404/g body weight of fish.

Islam and Hossain (1990) stated that the fecundity of *Puntius stigma* varied from 2,475 to 14,461 with a mean of 8635 ± 3790 . The fecundity was calculated as 849 considering the unit weight of the body. The male female ratio was found as 32.33:67.67.

Juchno et al. 2007 stated that the female of spined loach, *Cobitis taenia* spawned multiple times during May to mid- or the end of July. Some had a longer spawning period which lasted until the end of August. Each female could lay several portions of eggs which differed in size and number during the spawning season.

Kahraman et al. (2008) observed that the little tunny, *Euthynnus alletteratus* spawns generally between May and September with the most intensive spawning period between July and August. The sex ratio between male and female was calculated as 1:1.7.

Kendall and Gray (2008) studied the reproductive biology of *Liza argentea* and *Myxus elongatus* and found variation in spawning periodicity for each. They observed that the peak spawning period of *L. argentea* occurred between March and November in Lake Macquarie and January and April in St Georges Basin. In contrast, peak spawning of *M. elongatus* was concentrated between January and March in both estuaries.

Kennedy et al. (2006) stated that relative fecundity of Shovelnose sturgeon ranged from 11220 to 23956 eggs/kg (mean 18156 eggs/kg). Absolute fecundity ranged from 14294 to 65490 eggs/female (mean=30397 eggs/female). GSI values ranged from 9.4 to 27.2 (mean=19.3) and were positively correlated to FL ($r^2=0.18$).

Klein (2007) stated that the maximum age of Mediterranean cardinal fish, *Apogon imberbis* found to be 5 years for both sexes. Both females and males reached maturity at length >5.5 cm, corresponding to 1 year of age. The spawning season ranges from July to October, with a peak in August.

Knight *et al.* (2007) studied the reproductive biology of the Oxleyan pygmy perch *Nannoperca oxleyana* and observed that the species displays sexual dichromatism during the spawning season, with males developing more intense red and brown fin and body colouration, and black pelvic fins. Gonado-somatic indices averaged from 4.1–4.2% for ripe females with the total fecundities of 1323 eggs per fish.

Koc *et al.* (2007) observed that the sex ratio (M:F) of Turkish chub, *Leuciscus cephalus* was 1:1.4, corresponding to 58.4% males and 41.6% females. Significant statistical differences in condition factors between age classes and sexes were not found. Spawning period of this species in the lake was between April and May.

Kovacic (2001) stated that in both sexes of *Gobius roulei* gonad development began in their second year. Fecundity was varied between 1200 and 8000 eggs. The breeding season lasted from April to August.

Latifa *et al.* (2002) observed that the fecundity of *Channa striatus* ranged from 3,454 to 20,568 with an average of $1,172 \pm 5397$. The maturation stage of ovary was recognized as immature, early maturing, late maturing, mature and spent condition.

Lenhardt and Cakic (2002) worked on the seasonal changes in ovaries and testes of *Esox lucius* and found that the active vitellogenesis starts in September at which time the differences between the developing and resting oocytes are even more obvious; and the active spermatogenesis starts in September and lasts for 2 months. Values of absolute fecundity (AF) ranged from 524 to 123896 eggs, and the mean value of relative fecundity was 40.4 ± 12.5 .

Lorenzo *et al.* (2002) stated that *Lithognathus mormyrus* display protandric hermaphroditism. Male : female ratio was unbalanced in favour of males (1:0.85). The reproductive season extended from June to December, with a peak in spawning activity in August–September.

Mabragana *et al.* (2002) studied the reproductive ecology of *S. bonapartii* and found that the right ovary of mature females is larger than the left. Gonadosomatic index and diameter of ovarian follicles of mature females peaked in late spring and was at a minimum from late summer and through the winter.

Martín *et al.* (2005) observed that the relationship between total body mass and total length (TL) of *Psammobatis bergi* was not significantly different between sexes, but females were heavier than males. The reproductive cycle was found to be continuous with a maximum number of females carrying egg cases in warmer seasons.

Mazlan and Rohaya (2008) found that the TL of giant mudskipper, *Periophthalmodon schlosseri* ranges between 10–27.5 cm for males and 14.5–28.5 cm for females. The male and female sex ratio was observed as 1:1.1. Four maturity stages of gonad were described with asynchronous development indicating prolonged spawning season extending from June to October.

Morley *et al.* (2004) studied the biology of *Macrourus holotrachys* and found that the fish is a benthopelagic predator and scavenger which feeds on a wide range of fishes and invertebrates. The ovaries of mature fish had oocytes at all developmental stages. Absolute fecundity ranged from 22,000 to 260,000.

Msiska and Costa-Pierce (1999) studied the reproductive biology of pond-raised *Oreochromis karongae* and found that the fish has a potentiality for multiple spawning in a season. Several peaks of oocyte-size distribution and several maturation stages occurred in the same gonad.

Oker *et al.* (2008) observed that the *Uranoscopus scaber* of the Aegean Sea breeds from March to September, with a peak in May. The maximum batch fecundity (BF) was 58091 with mean 11556 ± 1445 . The BF increased with total length and body weight, excluding the ovaries. They also found a linear relationship between BF and fish size.

Oliva-Paterna *et al.* (2002) stated that *Cobitis paludica* attains maturity at the beginning of their second year life. Male and female ratio was observed as 1:1.64. This multiple spawner start spawning from late March to July.

Ortiz-Ordóñez *et al.* (2007) studied the reproductive cycle of *Ameca splendens* and found six stages of gonadal maturation based on histological and macroscopic characteristics of the gonad. The relative frequency of gonadic stages showed two reproductive peaks from March to May and from September to November.

Pajuelo *et al.* (2006a) stated that the Male : female ratio of coastal fish, *Diplodus vulgaris* is slightly unbalanced in favour of females (1:1.17), although no significant difference of the relation 1:1 was found. A protracted winter spawning season has been identified from November to March, with a peak in spawning activity in December–January. Size of maturity for males and females is attained in the second year of life.

Pajuelo *et al.* (2006b) stated that the total length of *Pagrus auriga* ranged from 120 to 780 mm. The species was characterized by protogynous hermaphroditism. The male: female ratio was in favour of females (1:8.2). The reproductive season extended from September to February, with a peak in spawning activity in October–November.

Parween *et al.* (1993) stated that the breeding periodicity of *Esomus danricus* starts from March and continue upto July with a peak in the months of April and May.

Pinheiro *et al.* (2006) found the male and female ratio of *Bagre marinus* in northeastern Brazil as 1:2.52. The females were separated into four reproductive stages (immature, maturing, mature, and resting). A positive linear relationship was detected between the size of mature females and their fecundity. Clear reproductive progress indicated a spawning period between March and May.

Rahman et al. (1992) worked on the sex ratio of the *Lepidocephalus guntea* and found that the females dominated over the males in all the months excepting July, September, October, November, April and June which concluding that the females are predominant in the month of August, December, January, February, March and May in the natural population of the species. The male and female ratio was obtained as 1:1.61.

Rahman et al. (2002) studied the reproductive periodicity and spawning potentiality of *Rhinomugil corsula* and observed that the species becomes mature at May and starts spawning from June to November with a peak in August. The fish may breed more than once during its five months breeding time, producing a moderate number of eggs related to its body size.

Šantić et al. (2006) stated that the GSI of Mediterranean horse mackerel, *Trachurus mediterraneus* reached maximum values in June and a minimum in December. The condition factor was constant during the prespawning period, lowest immediately after spawning (September), and highest at the end of the recovery phase (December).

Shankar and Kulkarni (2005) found general well being in somatic condition and state of gonadal development during different phases of the reproductive cycle of *N. notopterus*. The condition of fish is influenced by the onset of maturity which indicate the overall condition of the female and male fish seems to get improved towards the approach of maturing and mature stages of the gonads during pre-spawning phases.

Sindhe and Kulkarni (2004) stated that the reproductive cycle of *N. notopterus* can be categorised into immature, developing, maturing, mature, ripe and spent stages on the basis of gonadosomatic index. Liver forms important organ of the body, which has a role in the ovarian development. They found that on exposure to heavy metals at sublethal concentration both gonadosomatic and hepatosomatic index are reduced.

Sindhe and Kulkarni (2005) studied on the fecundity of the freshwater fish, *Notopterus notopterus* in natural and heavy metal contamination; and found that the fish has bigger oocytes and are few in number. They also found that the fecundity has straight line relationship with total length, body weight, ovary length and ovary weight in control fish which did not alter after heavy metal exposure. The result provides the viability of species in only specific environment.

Sulikowski et al. (2007) studied the reproductive periodicity of black-nose sharks *Carcharhinus acronotus* and observed the trends in female reproductive tissues which indicated an annual peak in reproductive activity during June and July. Based on these result, the mating season of black-nose sharks determined as mid-May to July in the Gulf of Mexico.

Sultana et al. (1998) found that the fish *Pangasius pangasius* is bispawner and spawn once in the winger (January-March) and second time in the monsoon and post monsoon (June to November). The fish is highly fecund and produce 85,832.50 eggs per kg of body weight. The fecundity varied from 1,02,600 to 27,50,000 with the mean of $10,69,473 \pm 3,39,323.90$.

Yoneda et al. (1998) studied the reproductive cycle and sexual maturity of the anglerfish *Lophiomus setigerus*. They found that spermatogenesis and vitellogenesis occurred throughout most of the year with spawning from May to November. There were clear seasonal cycles in the gonadosomatic index and hepatosomatic index in females.

Zorica et al. (2006) observed the reproductive biology of *Serranus scriba* from the Trogir Bay and found that 50% of the population of this species sexually matured at 9.3 cm TL; and spawning took place from May to August, with a peak in June and July.

4.2 Materials and Methods

Sampling and Laboratory Analysis

Random sampling was done to collect adult *N. notopterus* at a regular interval of one week from different fish landing centres of Rajshahi, Bangladesh since January 2005 to December 2006. A total of 1225 specimens were collected during day time and precautions were taken to save from spoilage or any damage. After collection, the specimens were washed well, confirmed to the species level and then tagged and preserve by date in plastic jars with 10% formalin.

The total length, standard length and total weight of the specimens were measured as described in chapter 2. The specimens were sexed either by visual observation or by dissecting out the gonads and the numbers of gravid females were recorded.

The gonads of fishes were removed intact and placed in 5% formalin which not only preserved the ovary but made it much easier to separate the eggs from the ovarian wall (Shafi and Quddus, 1974). The length of the ovary was measured with the help of a fine point divider. The weight of gonads was taken with the help of an Electronic balance Model: KD-300KC to an accuracy of 0.01g. Excess moisture of the ovaries was removed by using blotting papers before weighing. The changes of color of the testes and ovary were noted depending on the degree of maturation. During preservation the gonads were properly labeled for subsequent studies.

The mean ova diameter, gonadosomatic index (GSI) and gonadal length index (GLI) was calculated for each month to find out the spawning season. Gonadosomatic index (GSI) and Gonadal length index (GLI) were calculated according to the formula described by Welcomme (1985) and Wootton (1990) as follows:

$$GSI = \frac{\text{weight of the gonad}}{\text{weight of the fish}} \times 100, \quad GLI = \frac{\text{Length of the gonad}}{\text{Length of the fish}} \times 100$$

Ten to fifteen ova were collected at random from the anterior, central and posterior regions of each ovarian lobe by separating them out from the tissue by a fine needle and a brush. These were arranged in several rows on a glass slide and the diameter of individual ova was measured with the help of an ocular micrometer fitted on a compound microscope. The ova diameter was recorded twice in every month.

A total of 607 females were studied for detecting the reproductive cycle. The following methods were applied to study the reproductive cycle of *N. notopterus*:

- 1) Percentage of gravid females against time
- 2) Relative condition factor against time
- 3) Variation in ova diameter
- 4) Gonadal length index (GLI)
- 5) Gonado-somatic index (GSI)
- 6) Colouration of the ovary

A total of 172 gravid females were studied for the estimation of fecundity. The most accurate method of enumeration of fish eggs is by an actual count (Lagler, 1966) which is followed for 12 fishes to estimate the fecundity. Where in others the gravimetric method was followed to determine the fecundity according to Lagler, (1966), Hossain *et al* (1997b) and Latifa *et al.* (2002). The relationship of fecundity with total length (TL), standard length (SL), total weight (TW), gonad length (GL), and gonad weight (GW) were estimated by the least square method.

The sex ratio from the collected fishes was estimated month-wise. The significance of the derivation of sex-ratio from 1:1 on the null hypothesis was tested by the Chi-square test (Snedecor, 1956).

4.3 Results and Observations

Sexual dimorphism

Sex differentiation is an important factor for scientific study of reproductive biology of an organism. The sexual dimorphic characters of *N. notopterus* are very indistinct and the male and female are not easily distinguishable. Generally the fish shows some common sexual dimorphic characters superficially after attaining a minimum total length of 20cm. Unlike many fishes only the secondary sexual characters are observed during the breeding period. The following sexual dimorphic characters of *N. notopterus* were recorded during the study period.

- (i) **Characters of pectoral fin:** Like other fishes, the pectoral fin characters are not distinct in *N. notopterus*. The characters were seemed superficial throughout the year. Although some characters are appeared in acute observation. The pectoral fins of males were found little longer and seemed slightly blackish in colour with comparatively distinct fin rays. In females, the fins are shorter than the male, thin and light orange to reddish in colour with narrow fin rays.
- (ii) **Characters of abdomen and genital papilla:** These characters are only prominent in the breeding period. In males, the abdomen is not bulgy and the genital papilla is thin, muscular, cone-shaped, more pointed and tipped with reddish colour. In female, the abdomen is bulgy, genital papilla is stouter, fleshy, broader, less pointed, v-shaped and not tipped with red colour and the vent protrudes from the body.
- (iii) **Colouration:** The sexual dichromatism is observed between the male and female fishes. The pectoral fins of male are slightly blackish in colour but in female it seemed to be light orange to reddish. In males, the genital papilla is tipped with reddish colour and the defused vent with red colouration where in female the genital papilla is not tipped with red colour.

4.3.2 Reproductive system

Generally the gonads and their associated ducts are the components of reproductive system of a fish. The reproductive system of *N. notopterus* is exceptional and basically different from most oviparous fishes as described bellow:

4.3.2.1 Male reproductive organs

The testis in *N. notopterus* is unpaired, flat-conical structure and situated ventrolaterally and differentiated into anterior and middle functional regions and the posterior non-functional region with its very short duct. It originates from the left abdominal cavity beside the alimentary canal and below the kidney. The colour of the testis is found to vary not only with the maturity of individuals but also with ripeness of gonads (Plate 4.1). The monthly changes in the testis of *N. notopterus* due to maturation process are described in Table 4.1.

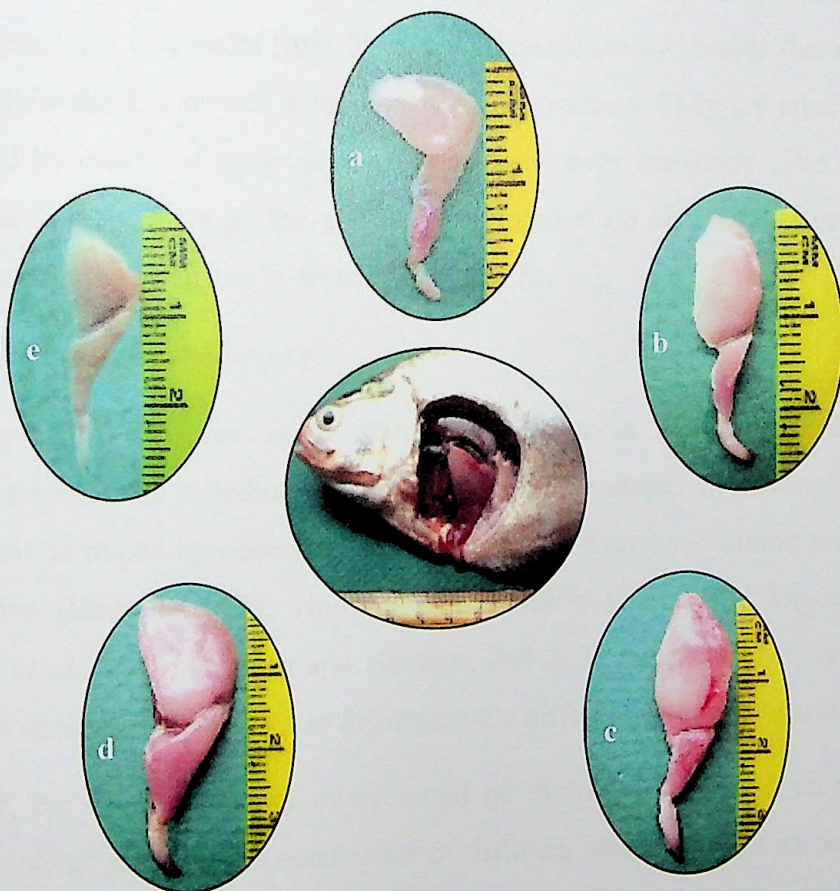


Plate 4.1: Showing the changes of testicular characters in relation to time (a. January-February; b. February-March; c. April-September; d. October; e. October-December).

Table 4.1: Description of monthly changes in testicular characters in relation to time.

Months	Description of testis
January-February:	The testes appeared as a translucent, whitish and thin flattened structure. In the body cavity the gut wall was externally well supplied with fat.
February-March:	The testes were creamy white in colour and a leaf like projection at the outer margin was developing. The width of the testes increased and the fat deposition from the gut wall reduced, presumably utilized in gonadal development (Berra, 1984).
April-September:	In these months, the peak of testicular development was found in most fishes. The testes become large, smooth and whitish-red in colour. The fat from the gut wall was completely disappeared. The tubule walls were found very thin.
October:	In late September, most of the fishes were found with spent, flaccid testes with decreased width of testes.
October- December:	In this month, the testes started to regain their original shape and size. The colour of the testes again changes to white and fat deposition is resumed in the gut wall. This period has been considered as the resting stage of the testes.

4.3.2.2 Female reproductive organs

Like testis, the ovary in *N. notopterus* is also unpaired and situated ventrolaterally. It originates from the left abdominal cavity, beside the alimentary canal, bellow the kidney and somewhat oval in structure. They are attached to the body wall by means of mesovarium, which also cover the ovary. The oviduct is short, which leads through the genital pore situated on an elevated urinogenital papilla behind the anus just in front of the anal fin.

Developmental stages of ovary

Development of ovaries is a spontaneous process that required for the determination of the breeding season of a fish. The stages of maturation of the female can be traced by observing the colour of the ovary and taking the diameter of the ova (Hossain, 1976; Hossain *et al.*, 1989; Hoque and Hossain, 1993; Parween *et al.*, 1993; Hussain and Hossain, 2001). In the present study a total of 607 adult females were studied to determine the different stages of ovaries.

However, the development of ovary could be divided into eleven stages on the basis of colour, size and the occurrence of different stages of eggs as described in the Table 4.2. The stages of ovaries are displayed in Plate 4.2 showing occupying areas of the abdominal cavity.

Table 4.2: Maturation stages of ovary with diagnostic characters in *N. notopterus*.

Stages of maturation	Months	Colour of ovary	Characteristics of ovary
I. Immature	December to January	Whitish	Ovary thin and spherical structure, occupying 30% of the abdominal cavity. Ova are not clearly defined by the naked eye, but can be visible under microscope (Plate 4.2 and 4.3).
II. Maturing-1 (early developing)	February to March	Whitish	Similar to immature stage in external appearance. Colour of the ovary remains still whitish occupying 30-45% of the abdominal cavity (Plate 4.2 and 4.3).
III. Maturing-2 (developing)	March to April	Light-Creamy	Similar to early developing stage in external appearance. Colour of the ovary becomes light creamy occupying 40-45% of the abdominal cavity (Plate 4.2 and 4.3).
IV. Maturing-3 (late developing)	March to April	Creamy	Ovary colour becomes creamy and occupies about 45-55% of the abdominal cavity (Plate 4.2 and 4.3).
V. Mature	May to September	Yellowish	At this stage, the ovary occupies about 55-75% of the abdominal cavity. The colour of the ovary change to yellow. The ovarian wall becomes slightly thin. Immature ova are found together with the mature ova. The colour of the ovary appears to yellowish (Plate 4.2 and 4.3).
VI. Ripe	May to September	Yellow	The colour of the ovary becomes yellow. The ova are seen clearly through the wall of ovary. At this stage ovary occupies 80-90% of the abdominal cavity (Plate 4.2 and 4.3).
VII. Pre- spawning	May to September	Yellow	Similar to ripe stage. TH ovary and oocyte were found in bright yellow coloured. Ooze out with a little pressure on the abdomen (Plate 4.2 and 4.3).
VIII. Spawning	May to September	Dull Yellow	At this stage the he oviduct becomes thinner. The oocyte sometimes found scattered around the genital pore of the female. The ova were detached from the follicle (Plate 4.2 and 4.3).
IX. Post-Spawning	June to September	Dull Reddish	The weight of the ovary reduced about 80% but occupies about 50% of the abdominal cavity. The ovary seemed to be reddish colour (Plate 4.2 and 4.3).
X. Spent	July to October	Pinkish	At the s stage the ovary lost all the oocyte from the ovary. But still contained some ruptured and collapsed post ovulatory follicles and forms irregular series of folds (Plate 4.2 and 4.3).
XI. Resting	October to December	Pinkish	The wall of the tunica contracted and reduced with a corresponding increase in diameter. The size and number of oocyte are also found in appearing condition (Plate 4.2 and 4.3).

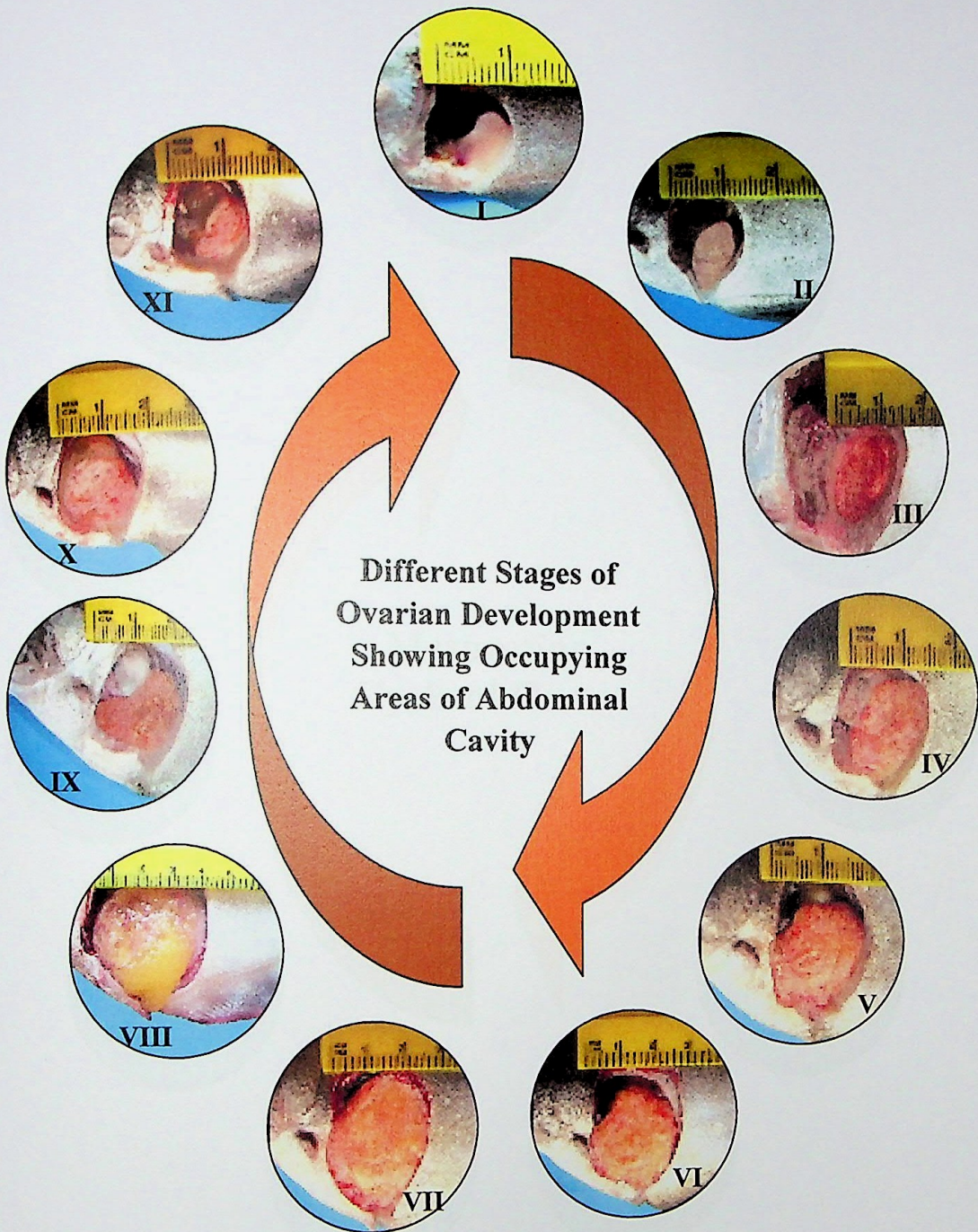


Plate 4.2: Maturation stages of ovary showing occupying areas of the abdominal cavity (I. Immature; II. Maturing-1; III. Maturing-2; IV. Maturing-3; V. Mature; VI. Ripe; VII. Pre-spawning; VIII. Spawning; IX. Post-spawning; X. Spent; XI. Resting).

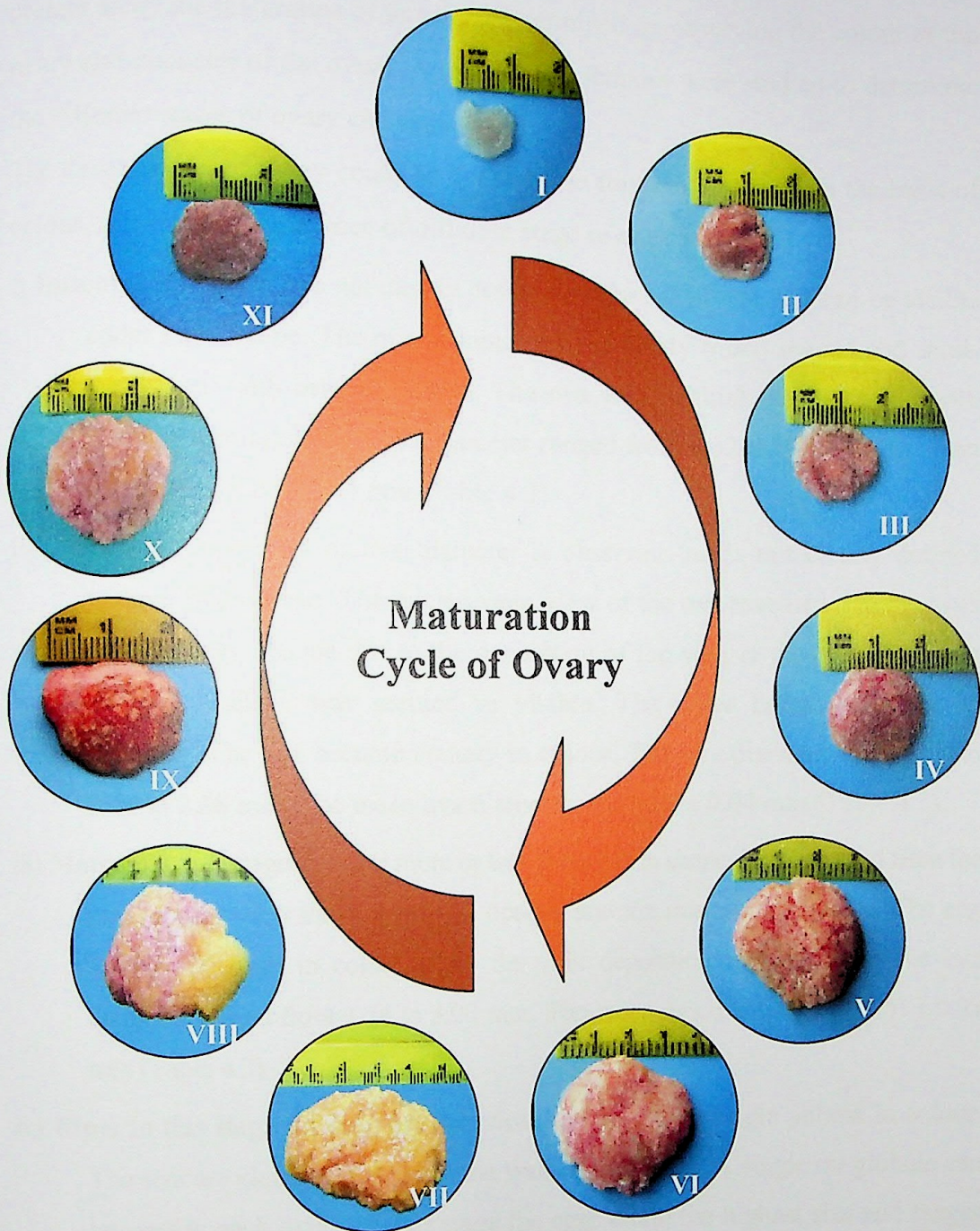


Plate 4.3: Ovarian development of *N. notopterus* in different stages of maturity (I. Immature; II. Maturing-1; III. Maturing-2; IV. Maturing-3; V. Mature; VI. Ripe; VII. Pre-spawning; VIII. Spawning; IX. Post-spawning; X. Spent; XI. Resting).

4.3.3 Maturation stages of ova

The developmental stages and maturation of the ovaries and oocytes are the important parameter for the determination of the breeding season of fish. In the present study the maturation of female is determined by observing the colour of the ovary and diameter of the ovum. A total of 607 females were studied to determine the different stages of ovary and eggs.

The development of ovary could be divided into four major stages on the basis of colour, size and the occurrence of different stage of eggs as

- i) **Immature:** The ova are not clearly defined by the naked eye, but can be visible under microscope. The microscopic ova are nearly round shaped and semi-transparent with central nucleus. The ova were whitish in colour and yolk was not seen at all. The ova diameter ranged from 0.32-0.99 mm with mean diameter of 0.65 ± 0.04 mm (Table 4.3).
- ii) **Maturing:** Increment of ova diameter is observed but is not clearly defined without microscope. The microscopic view of the ova revealed that the eggs were slightly opaque due to the deposition of the yolk at the central portion and the nucleus was seemed to visible. The outer boundary remained irregular. The ova became creamy in colour. The ova diameter ranged from 0.49 to 2.88 mm. The mean ova diameter was 1.26 ± 0.04 mm (Table 4.3).
- iii) **Mature:** In this stage eggs are more or less spherical in shape. It is observed from the microscopic view that the ova are opaque and the nucleus is invisible. The egg turned yellowish in colour when the yolk deposition is completed. The ova diameter ranged from 1.54 to 3.00 mm. The mean ova diameter was 2.63 ± 0.05 mm (Table 4.3).
- iv) **Ripe:** In this stage the eggs are spherical and yellow or bright yellow in colour. The ova are clearly set through the wall of the ovary. A single oil globule can be seen in each ovum. In this stage the eggs attain the highest size and ranges from 2.88 to 3.21mm with a mean of 3.07 ± 0.02 mm (Table 4.3).

A thin transparent layer of ootheca surrounds the eggs. The mature and ripe ova were found towards the periphery and the immature and maturing ova lie towards the centre.

Table 4.3: Variation in ova diameter in different stages of maturity with distinguishing colour

Developmental stages of ova	Ova diameter (mm)			Colour
	Minimum	Maximum	Mean $\pm$ SE	
Immature (N=31)	0.32	0.99	0.65 $\pm$ 0.04	White
Maturing (N=188)	0.49	2.88	1.26 $\pm$ 0.03	Creamy
Mature (N=51)	1.54	3.00	2.63 $\pm$ 0.05	Yellowish
Ripe (N=109)	2.88	3.21	3.07 $\pm$ 0.02	Yellow

4.3.5 Determination of reproductive cycle

The reproductive cycle of fishes depends on various physico-chemical parameters of their habitat. In the rainy season particularly in June and July, after a heavy shower, the physico-chemical condition of water bodies changed abruptly and which, in turn, probably stimulates the spawning of fish. There are various methods to determine the reproductive cycle of a fish.

In the present study, six methods were applied to determine the reproductive cycle of *N. notopterus* as follows

i) Percentage of gravid female against time: The percentage distribution of gravid females was observed from January 2005 to December 2006. The result of two years data revealed that the gravid females of *N. notopterus* occurred during the period from May to September (Fig. 4.1). No gravid females were found in rest of the year. The highest percentage of gravid females were found in the month of June 2005 (89.66%), followed by June 2006 (88.46%), July 2005 (70.37%), July 2006 (68.00%), August 2006 (68.00%) and August 2005 (67.74%).

From the above observation, it may be concluded that *N. notopterus* is an annual breeder and the breeding season extending from May to September.

Limitation of the method

Accurate estimation of the proportion of the gravid females in the natural population is very difficult. The number of gravid females collected may not be the representative of the natural population. So far an accurate estimation of the breeding periodicity of *N. notopterus*, a number of methods has been applied. From the available date it would appear that the breeding season of this species from April to September with a peak in June to July.

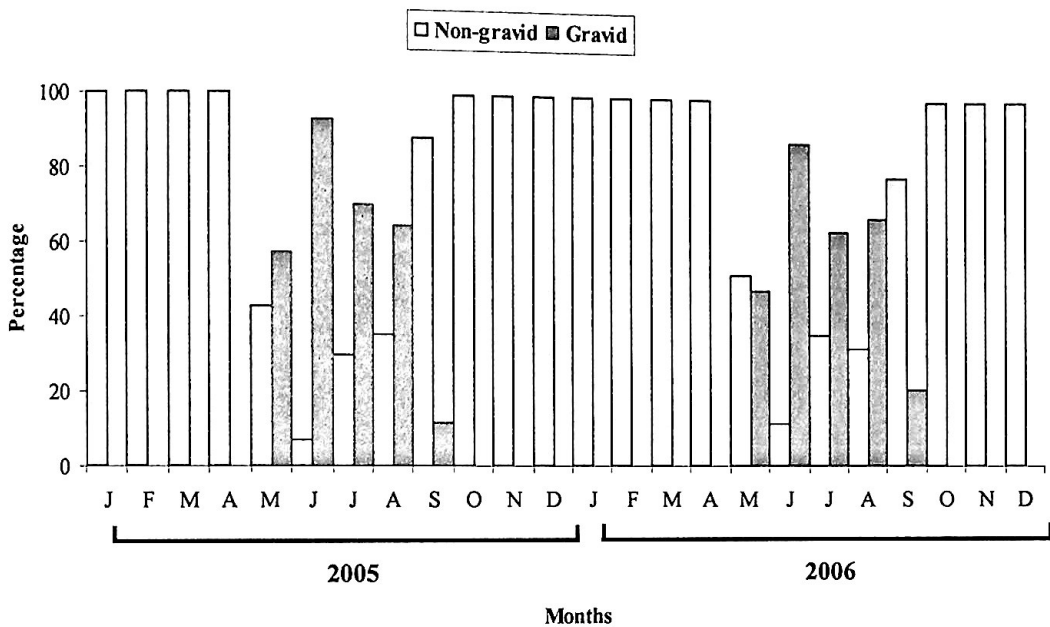


Fig. 4.1: Monthly percentage occurrence of gravid and non-gravid females of adult *N. notopterus* during January, 2005 to December, 2006.

ii) **Relative condition factor against time:** The seasonal changes in weight of adult females are generally the indicator of relative fatness and robustness of a species due to the maturity of the ovary. In the present study the relative condition factor (K_n) of adult females is observed to determine the reproductive cycle of *N. notopterus*. The result revealed that the value of K_n gradually increased during the pre-spawning (January to April) and spawning period (May to September) and decreased in post spawning period (October to December) that shown in Fig. 4.2. These changes occurred only for the rapid growth the ovary which indicates the breeding period of *N. notopterus* from May to September.

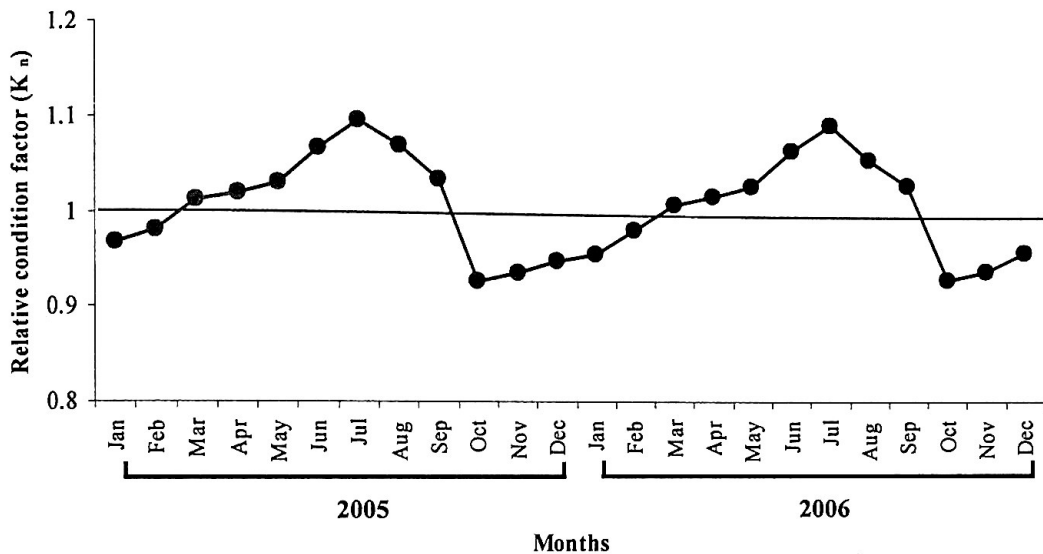


Fig.4.2: Monthly fluctuation in relative condition factor of adult female of *N. notopterus*.

iii) **Diameter of ova:** The monthly variation in ova diameter is an important phenomenon to detect the reproductive cycle of a fish. It is well known that the diameter of ova is highest in the mature and ripe stages of an ovary. The ova with larger mean diameter were found from May to September that showed a distinct fluctuation throughout the year with a meaningful cycle (Fig. 4.3; Table 4.4). These variations are found only in mature female in relation to seasonal cycle.

The month wise ranges of the ova diameters are not so affected by the seasonal variation, but mean values are influenced by the seasonal factors. The reason

behind this is the frequent occurrence of mature and ripe ova from May to September where the maturing and immature ova in the ovary are more frequent in rest of the months. The method revealed that the reproductive activities in *N. notopterus* continue from May to September.

iv) Gonadal length Index (GLI): The length of the ovary increases proportionately in relation to body length and season. GLI was calculated for each individual and monthly average values are shown in Fig. 4.4. The month wise range, mean and standard deviation of the GLI are given in Table 4.4. It can be seen from the Fig.4.4 that the higher values of GLI were obtained during May to September, which indicate the active breeding period of *N. notopterus*.

This method is very useful for the determination of the reproductive cycle, for its simplicity and accuracy, because there is no high sensitive measurement in this method *i.e.* the lengths can easily be measured by using scale and fine point divider.

v) Gonado-Somatic Index (GSI): Not only the length of ovary increase with the appearance of the ripe ova but also the weight of ovary is also increase accordingly. The monthly variation in GSI of *N. notopterus* was observed during the study period because in certain months of the year the mature females bear mature and ripe ovaries, which increases the value of GSI. Such higher values of GSI have been observed during the months from May to September where the values were found considerably low in rest of the months (Fig. 4.5). This variation in GSI only occurs in mature fishes which are reproductively active. After releasing the ripe ova, the length and weight of the ovary is suddenly reduced. So, fluctuations of gonado-somatic index in the same season are also commonly met with. The month wise range and mean of GSI are given in Table 4.4.

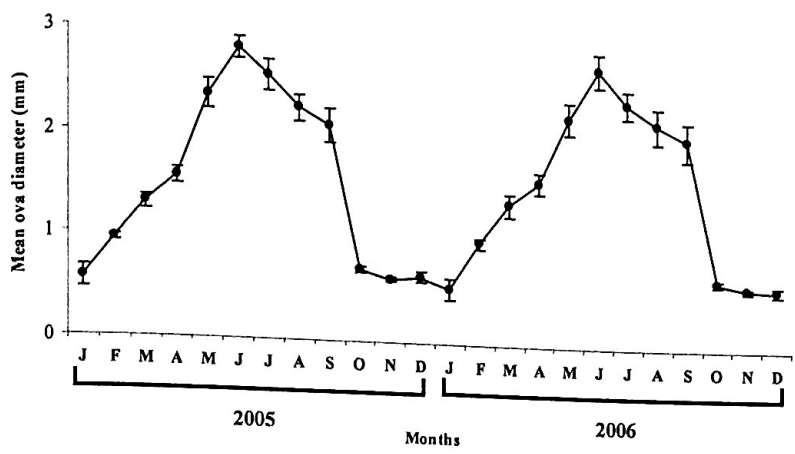


Fig.4.3: Monthly variation in mean ova diameter of *N. notopterus*.

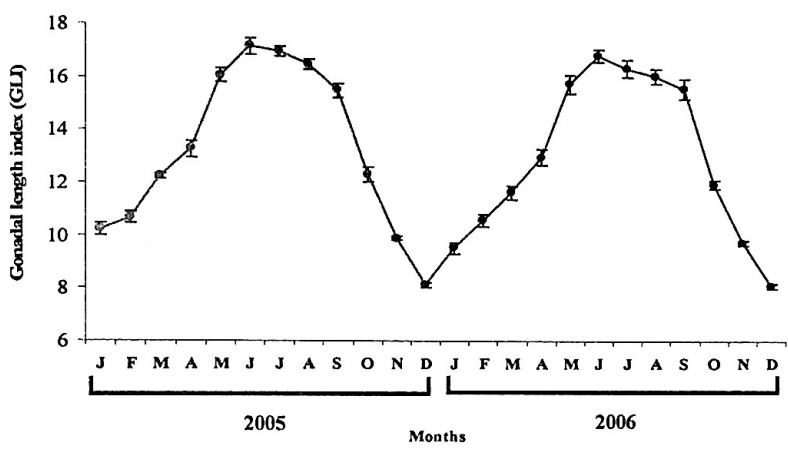


Fig. 4.4: Monthly variation in gonadal length index (GLI) of female *N. notopterus*.

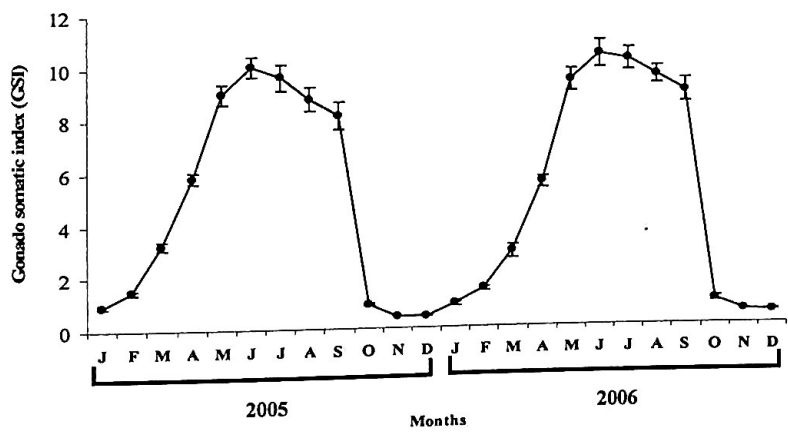


Fig. 4.5: Monthly variation in gonado somatic index (GSI) in female of *N. notopterus*.

Table 4.4: Monthly variation in ova diameter, gonadal length index (GLI) and gonado somatic index (GSI) of *N. notopterus* (N=607).

Year	Month	No. of fish (N)	Ova diameter (mm)			Gonadal length index (GLI)			Gonado somatic index (GSI)		
			Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE
2005	Jan	19	0.32	0.80	0.57±0.11	8.26	12.29	10.23±0.25	0.60	1.65	0.93±0.06
	Feb	26	0.67	1.30	0.94±0.03	8.37	13.38	10.67±0.22	0.79	2.21	1.47±0.07
	Mar	23	0.90	1.98	1.30±0.07	11.19	13.21	12.24±0.11	2.05	4.54	3.22±0.17
	Apr	26	1.03	2.13	1.56±0.07	10.06	15.56	13.28±0.31	4.33	8.18	5.82±0.21
	May	28	0.74	3.20	2.36±0.14	10.48	17.19	16.10±0.26	1.11	12.48	9.02±0.40
	Jun	29	0.73	3.21	2.82±0.11	15.45	18.60	17.21±0.32	1.10	13.47	10.08±0.37
	Jul	27	0.57	3.18	2.57±0.20	14.85	18.43	17.04±0.18	0.67	12.08	9.69±0.51
	Aug	31	0.41	2.71	2.26±0.20	14.40	17.61	16.57±0.19	0.76	11.35	8.85±0.46
	Sep	26	0.45	3.10	2.10±0.17	12.59	16.25	15.59±0.27	0.36	11.07	8.23±0.53
	Oct	28	0.50	0.98	0.70±0.03	10.80	15.77	12.38±0.30	0.33	1.15	0.90±0.05
	Nov	32	0.34	0.81	0.62±0.02	9.20	10.57	9.95±0.07	0.32	0.56	0.43±0.01
	Dec	22	0.35	0.98	0.65±0.05	6.75	9.09	8.16±0.12	0.34	0.70	0.45±0.02
2006	Jan	21	0.41	0.72	0.54±0.10	7.69	11.46	9.58±0.22	0.43	1.44	0.89±0.05
	Feb	23	0.52	1.51	1.00±0.05	7.44	12.61	10.66±0.24	0.68	2.31	1.47±0.09
	Mar	19	0.79	2.10	1.39±0.11	8.89	13.13	11.74±0.26	1.28	5.00	2.91±0.27
	Apr	25	0.98	2.28	1.62±0.10	10.08	15.75	13.12±0.30	3.32	7.29	5.60±0.20
	May	25	0.82	3.14	2.27±0.16	10.67	17.68	15.97±0.36	1.31	12.28	9.55±0.45
	Jun	26	0.82	3.16	2.76±0.16	14.24	19.00	17.11±0.24	1.10	13.76	10.57±0.52
	Jul	25	0.62	3.18	2.43±0.23	13.67	18.75	16.60±0.32	0.64	14.30	10.36±0.43
	Aug	25	0.58	3.18	2.23±0.20	13.23	18.20	16.33±0.28	0.76	11.81	9.74±0.35
	Sep	24	0.52	3.12	2.08±0.19	11.80	17.27	15.85±0.37	0.36	11.25	9.14±0.47
	Oct	25	0.43	1.00	0.68±0.03	10.42	13.50	12.11±0.17	0.30	1.83	0.97±0.11
	Nov	27	0.46	0.79	0.61±0.02	8.63	10.93	9.84±0.11	0.34	0.72	0.53±0.02
	Dec	25	0.31	0.99	0.60±0.04	6.90	8.82	8.15±0.10	0.31	0.66	0.49±0.02

Note: The bold months indicate breeding season

vi) **Colouration of the ovary:** Colour of the ovary changes according to the degree of maturity of the ova. Colour of the ovaries varies from species to species such as green, orange, yellow, brown etc. Gradually the colour becomes more intense and bright with the attainment of maturity, and so it is a helpful method for determining the reproductive cycle of a fish. It is observed that the mature and ripe ovary of *N. notopterus* is yellow to bright yellow in colour. In the present investigation the occurrence of yellow or bright yellow coloured ovary was found from May to September which indicates that these months are the breeding period of *N. notopterus*.

4.3.6 Fecundity

Fecundity is the general term used to describe the number of eggs produced by an individual contained in the ovary. In fishery science, the fecundity is defined as the number of ripe eggs produced by a female individual up to the next spawning. The number of eggs contained in the ovary of a fish is termed the fecundity (Nikolsky, 1963).

4.3.6.1 Estimation of fecundity

For the estimation of fecundity 172 gravid females was taken from the collected samples. It was observed that the absolute fecundity was varied from 651 (for a fish with total length 21 cm and total weight 80 g) to 2250 (for a fish with total length 30.50 cm and total weight 260g). The mean $\pm$ SE of absolute fecundity was 1598.18 ± 42.47 per female (for mean $\pm$ SE of total length 25.41 ± 2.29 cm and mean $\pm$ SE of body weight 157.97 ± 4.17 g). The relative fecundity was ranged from 7.70 to 12.94 with mean $\pm$ SE 10.13 ± 0.08 per gram of body weight (Table 4.5).

The relationship among fecundity and five important variables viz. total length, standard length, total weight, gonadal length, and gonadal weight were established (Fig. 4.6). The descriptive statistics of these variables are also presented in Table 4.6. It is observed that all the relationships were highly significant with 'r' values being >0.900 excluding the relationship between fecundity and gonadal length. In this case the 'r' value was 0.873 which is near to the expected level.

Table 4.5: The range, mean and standard error of total weight, gonadal weight, absolute fecundity and relative fecundity of *N. notopterus* in different length groups.

Size group (cm)	Total weight in (g)			Gonadal weight in (g)			Absolute fecundity F/female			Relative Fecundity F/ g of body weight
	Min.	Max.	Mean $\pm$ SE	Min.	Max.	Mean $\pm$ SE	Min.	Max.	Mean $\pm$ SE	
20-21 (n=19)	68.00	81.00	76.63 $\pm$ 0.98	6.00	8.00	6.75 $\pm$ 0.13	651.00	846.00	734.68 $\pm$ 13.52	9.61
21-22 (n=7)	83.00	105.00	92.00 $\pm$ 3.22	6.20	9.40	7.80 $\pm$ 0.36	714.00	1023.00	845.57 $\pm$ 35.31	9.20
22-23 (n=18)	108.00	120.00	116.94 $\pm$ 0.91	9.98	13.50	11.49 $\pm$ 0.26	1062.00	1553.00	1233.11 $\pm$ 31.19	10.54
23-24 (n=24)	118.00	127.00	123.83 $\pm$ 0.50	9.75	15.00	12.45 $\pm$ 0.29	1035.00	1518.00	1315.46 $\pm$ 29.74	10.63
24-25 (n=24)	126.00	185.00	138.88 $\pm$ 2.47	10.80	20.00	13.93 $\pm$ 0.39	1125.00	2052.00	1437.63 $\pm$ 39.47	10.34
25-26 (n=13)	145.00	170.00	159.77 $\pm$ 2.40	12.50	20.00	16.04 $\pm$ 0.65	1302.00	2061.00	1653.69 $\pm$ 67.21	10.33
26-27 (n=12)	165.00	189.00	182.25 $\pm$ 2.12	13.80	22.00	18.11 $\pm$ 0.71	1395.00	2244.00	1851.75 $\pm$ 74.63	10.15
27-28 (n=15)	184.00	228.00	201.13 $\pm$ 4.19	16.00	22.00	19.39 $\pm$ 0.55	1632.00	2235.00	1944.93 $\pm$ 55.23	9.67
28-29 (n=17)	167.00	232.00	222.71 $\pm$ 3.66	19.60	26.60	23.07 $\pm$ 0.45	2019.00	2556.00	2307.18 $\pm$ 40.84	10.39
29-30 (n=16)	226.00	248.00	237.75 $\pm$ 1.42	18.95	26.00	24.31 $\pm$ 0.54	1890.00	2559.00	2371.31 $\pm$ 49.66	9.97
30-31 (n=7)	246.00	260.00	255.57 $\pm$ 1.82	24.45	25.80	24.84 $\pm$ 0.18	2250.00	2505.00	2383.29 $\pm$ 36.38	9.33

Table 4.6: Relationships between fecundity and other variables (N = 172).

Ordinate	Abscissa	Value of 'a'	Value of 'b'	Value of 'r'
Fecundity (F)	Total length (TL)	- 2883.9	17.64	0.953**
Fecundity (F)	Total weight (TW)	58.002	9.7501	0.958**
Fecundity (F)	Standard length (SL)	- 2720.1	18.553	0.952**
Fecundity (F)	Gonadal length (GL)	- 2444.2	93.938	0.873**
Fecundity (F)	Gonadal weight (GW)	138.12	93.204	0.996**

**Correlation is significant at the 0.01 level.

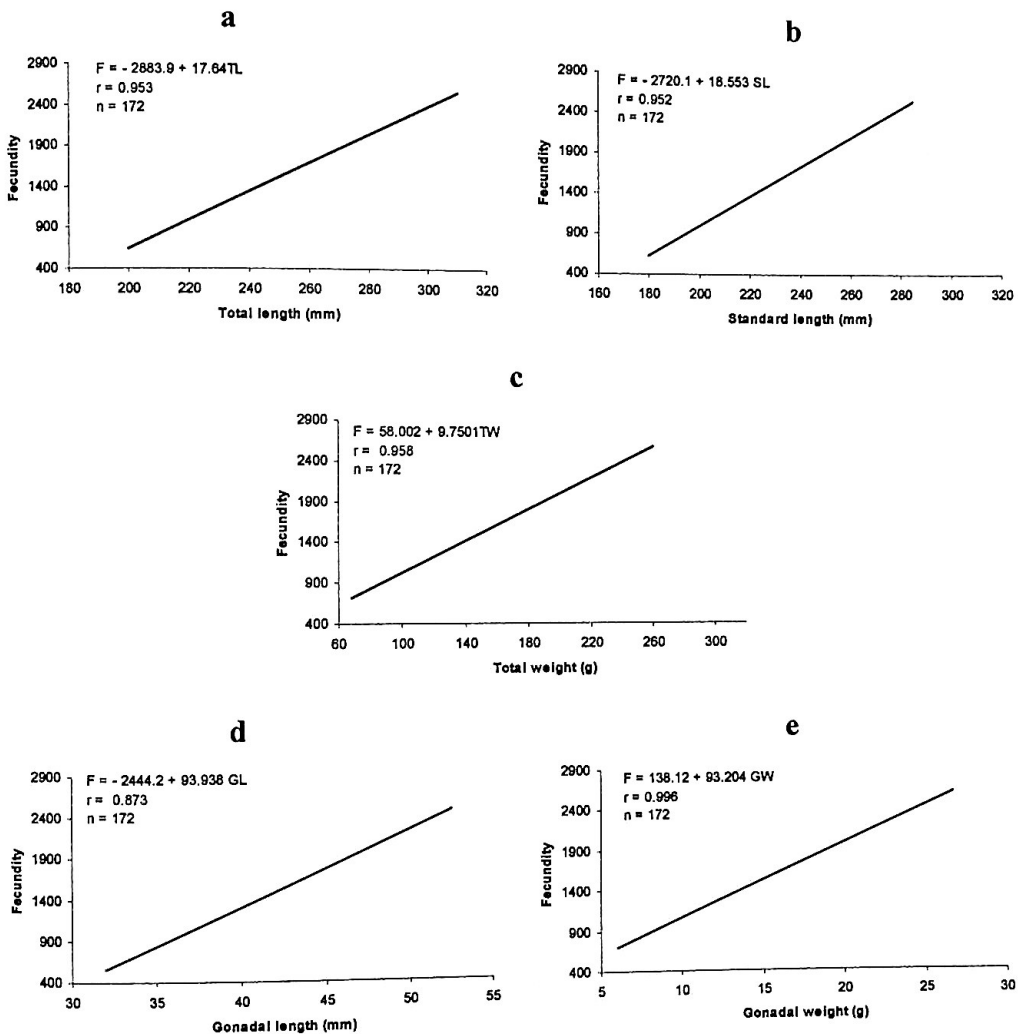


Fig. 4.6: Relationships between fecundity and five variables (a. total length, b. standard length, c. total weight, d. gonadal length, e. gonadal weight) of *N. notopterus*.

4.3.7 Sex- ratio

Sex-ratio for adult *N. notopterus* was determined from 1225 specimens of which 618 were males and 607 were females. The overall sex ratio was found in favour of male i.e. 1:0.98. The month wise male and female ratio was also calculated and found to vary during the study period that shown in Appendix Table IV_a. The males were found mostly predominating all over the year (Fig. 4.7).

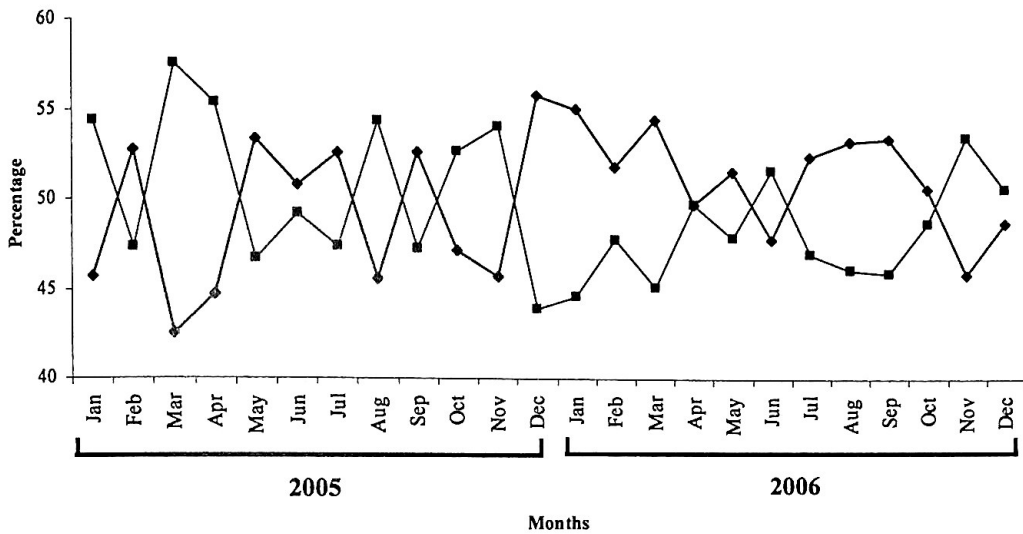


Fig. 4.7: Percentage distribution of adult male and female *N. notopterus*.

The chi-square test was made to see whether the sex difference was statistically significant or not. The test was made from the actual number of males and females. If the population was unbiased in terms of the distribution pattern of the male and female sexes, then the occurrence of the two sexes would be 50% in each case in the random sampling. The results of the test are given in Appendix Table IV_b. The calculated value of total χ^2 was 6.50, the overall χ^2 value was 0.10 and the χ^2 heterogeneity values was 6.40 respectively, which were insignificant.

4.4 Discussion

4.4.1 Sex dimorphism

The sexes are separate in fishes but the sexual dimorphism is not a very common phenomenon (Yadav, 1999). The characteristics of sexual differences or sexual dimorphisms that enable identification of the sexes are classified as primary and secondary sexual characteristics. Primary sexual characters are those, which are concerned actually with the reproductive systems. Testes and their ducts in the male, and ovaries and their ducts in the females constitute primary sexual characters. Secondary sexual characters themselves are really of two kinds: those which have no primary relationship with the reproductive act at all, and those which are definitely accessory to spawning (Lagler *et. al.*, 1977). The secondary sexual characters and accessory structures are necessary for courtship, sexual display and pairing of male and female, simultaneously along with the development of primary sex organs (Yadav, 1999). Some species of fishes exhibit well-marked sexual dimorphisms between the two sexes during their spawning season. It is very difficult to distinguish the sex of many species of fish from their external appearance. Many fishes show virtually no sexual dimorphisms in body shape or colour differences even when spawning. The differentiation of sexes is rather difficult except the breeding season, when the gravid female becomes obvious by the bulged-out belly (Moyle and Cech, 2000). In the present investigation, same sexual dimorphisms have been observed in *N. notopterus* that used to determine the sex of the mature fish. The pectoral fins of male were found little longer than female and slightly blackish with comparatively distinct fin rays. Whereas in female, they look comparatively shorter than the male, thin, light orange to reddish in colour having narrow fin rays.

In the adult males, the genital papilla is thin, muscular, conical shape and more pointed. In the female, genital papilla is stouter, fleshy, broader, less pointed and protrudes from the body. Sexual dimorphism at maturity stage of fishes was determined by Davis (1959) in channel catfish *Ictalurus punctatus*;

Flickinger (1969) in flat head minnow; Breder and Rosen (1966) in bitterling; Wiley and Collette (1970) in 25 families of fish. Huq (1977) examined the six species e.g., *Rita rita*, *Mystus corsula*, *Mystus tengara*, *Ailia coila*, *Clarias batrachus* and *Heteropneustes fossilis* of Bangladesh for finding a practical way of discerning sexes. The size of head and colouration of the body of both sexes of these fishes were identical, but the area of genital pore was quite helpful for identification of sexes. Smith and Bell (1975) used the genital papilla as a key to determine sexes of adult female salmon.

Besides the structure of the genital papilla and the colouration of the body parts shows significant differences between the male and female during breeding season. It was observed that the males and females showed sexual dichromatism during breeding season. Similar condition was also reported by Shafi *et al.* (1978) in *H. ilisha*, Hossain and Islam (1983) in *Clupisoma atherinoides*, Berra (1984) in *P. maraena*, Nabi and Hossain (1996) in *M. aculeatus*, Mabragana *et al.* (2000) in *Sympterygia bonapartii*, Islam (2002) in *G. giuris*, Martin *et al.* (2005) in *Psammobatis bergi*, Knight *et al.* (2007) in Oxleyan pygmy perch *Nannoperca oxleyana*.

4.4.2 Male reproductive organs

The reproductive strategies of fishes are often reflected in the anatomical differences between the sexes. Testes in fishes, generally, are paired structures situated in either side somewhat lateral to and bellow the kidneys (Kumar and Tembhre, 1998). A huge number of works are available in this regard. But the testis of *N. notopterus* is found flat-conical unpaired structure with very short duct which originates from the left abdominal cavity beside the alimentary canal and bellow the kidney. Perhaps this exceptionality exists due to the compressed structure of the body. The result is completely similar to that of Dalela *et al.*, (1976) who reported the unpaired flat gonad in *N. notopterus*. Kumar and Timbhre have also reported the same result in 1998.

Colour and size of the testes vary according to the stage of sexual maturation (Berra, 1984). The testes appeared as a translucent, whitish and thin flattened structure. In the body cavity the gut wall was externally well supplied with fat. Abu-Hakima (1984), Berra (1984) and Nabi and Hossain (1996), described this condition as the immature stage of testicular development in *Acanthopagrus* sp, *P. Maraena* (Gunther) and *M. aculeatus* respectively.

In the successive months, the testes attained maturing (January to April) stages and finally become fully mature or ripe in the month from May to September. The colour and size of the testes also changes accordingly. In these months, the peak of testicular development was found in most fishes. The testes become large, smooth and whitish-red in colour. The fat from the gut wall was completely disappeared.

By late August to September most of the fish are found with spent, flaccid testes and width decreased. Testes started to regain their original shape and size. Colour of the testes again changed to white and fat deposition resumed in the gut wall. This type of developmental changes was reported from a variety of fish species e.g., *C. macrocephalus* (Mollah and Tan, 1982), *M. aeglefinus* (Robb, 1982), *Acanthopagrus* sp. (Abu-Hakima, 1984), *P. maraena* (Berra, 1984), *Amblyphrynogodon mola* (Afroze and Hossain, 1990), *Setipinna phasa* (Alam, *et al.*, 1996), *M. aculeatus* (Nabi and Hossain, 1996), *Clupisoma atherinoides* (Bhuiyan *et al.*, 1999a), *Gobius roulei* (Kovacic, 2001), *Gonialosa manminna* (Hossain *et al.*, 2002), *Esox lucius* (Lenhardt and Cakic, 2002), *A. latus* (Abou-Seedo *et al.*, 2003), *Crystallogobius linearis* (Caputo *et al.*, 2003), *N. notopterus* (Shankar and Kulkarni, 2005), *Siganus luridus* (Azzurro *et al.*, 2007), *Scaphirhynchus platyrhynchus* (Colombo *et al.*, 2007), *Pseudocorynopoma doriai* (Ferriz *et al.*, 2007), *Apogon imberbis* (Klein, 2007), *Ameca splendens* (Ortiz-Ordonez *et al.*, 2007) and *Parastromateus niger* (Dadzie and Abuo-Seedo, 2008).

4.4.3 Female reproductive system

The female reproductive system of *N. notopterus* also comprised of unpaired ovary and its duct. The female gonad exists at the same location as in male. The ovary is oval in structure filled with ova of different sizes. The shape, size and colour of the ovary depend on the stages of maturation of the developing ova. The wall of the ovary is fairly thickened during the non-breeding season and becomes highly vascular during the spawning period.

Depending on the degree of maturation, many authors like Treasurer and Holliday (1981), Hossain (1989), Hussain and Hossain (2001), Azzurro *et al.* (2007), Dadzie and Abou-Seedo (2008) categorized the maturation stages of ovary into ten stages viz. immature, maturing (early developing), maturing (late developing), mature, ripe, pre-spawning, spawning, post spawning, spent and resting. In the present study the maturing stages of ovary were categorized into eleven stages viz. immature, maturing (early developing), maturing (developing), maturing (late developing) mature, ripe, spawning, pre-spawning, post spawning, spent and resting.

The length and weight of immature ovary were ranging from 1.65 to 2.85 cm (mean $2.28 \pm \text{SE } 0.05$ cm) and 0.41 to 1.90g (mean $1.07 \pm \text{SE } 0.06\text{g}$) respectively. The maturing ovary length and weight were ranging from 1.60 to 4.30cm (mean $3.16 \pm \text{SE } 0.04$ cm), and 0.75 to 17.87 g (mean $5.84 \pm 0.30\text{g}$). The mature ovary length was ranging from 3.20 to 4.95 cm (mean $4.13 \pm \text{SE } 0.07\text{cm}$) with weight ranging from 6.00 to 22.90 g (mean $12.51 \pm \text{SE } 0.66\text{g}$). The length and weight of ripe ovary were ranged from 3.20 to 5.25 cm (mean 4.37 ± 0.05 cm) and 6.20 to 26.60 g (mean 16.37 ± 0.56 g) respectively (Appendix Table IV_c).

The ovaries occupy 30% of the abdominal cavity at the immature stage. But after attaining full maturity (ripe), the ovaries increase in size and occupy 80-90% of the abdominal cavity, showing its external prominency by the swollen abdomen. In this stage the ovaries are richly supplied with blood capillaries and the ovaries look bright. At spent stage, the ovaries are reduced in size like an empty bag and having dull colour. After a short spent phase the ovary starts to regain its original whitish colour and shape rapidly. This condition is observed in the matured females from

October to December. Similar characteristics of ovaries in other fishes were observed during the course of maturation by many researchers of them Dalela *et al.* (1977), Foucher and Beamish (1980), Hossain (1989), Msiska and Costa-Pierce (1999), Hussain and Hossain (2001), Islam *et al.*, (2001), Latifa *et al.* (2002), Alp *et al.* (2003), Kennedy *et al.* (2006), Pinheiro *et al.* (2006), Azzurro *et al.* (2007), Dadzie and Abou-Seedo (2008) and Fazli *et al.* (2008) are renowned.

Actually the maturation process of the ova reflects the maturation characters of the ovaries, which can be divided into 4 stages (Karim and Hossain, 1972), these are immature, maturing, mature and ripe. In immature stage the ova are semi-transparent, nearly round shape having central nucleus with a mean ova diameter 0.65 ± 0.04 mm. In maturing stage the ova slightly increase in size and become slightly opaque due to the deposition of yolk granules. The mean ova diameter was found as 1.26 ± 0.04 mm. In mature stage the ova are spherical and the nucleus, invisible due to the deposition of yolk; the mean ova diameter found as 2.63 ± 0.05 mm. In ripe stage the ova attain their maximum size, brightly coloured and spherical in shape, with a mean ova diameter as 3.07 ± 0.02 mm. These different groups of ova are found in their respective stages of ovaries. In the peak-breeding season, the ripe ovaries are mainly packed with ripe stages of ova.

4.4.4 Reproductive cycle

The time and season when a species normally breed is termed as the “breeding” or “spawning” season of that species. The breeding season repeats in cyclic order, in which the organism undergoes maturation changes and thereby gets ready to breed again. This repeated phenomenon is known as reproductive cycle (Milton and Arthington, 1983).

Reproductive behaviour in most animals is cyclic- more or less regularly periodic; this is so far nearly all fishes. The reproductive act in some fishes occurs only once in a very short lifetime, while in other fishes, it occurs once in a moderately long life span. Several other species spawn more than once in a year more or less

continually (Lagler *et al.*, 1977). After spawning, new group of oocyte is formed which gradually mature to become ready for the next season (Khanna, 1978).

The reproductive cycle in fishes and shellfishes is guided by several environmental factors together with the endocrine activities. Both light and temperature are important factors controlling the maturation of gonads in fishes. Variation in the duration of light and temperature may influence the rate of gonadal development. Most of the stages of reproduction often depend on certain conditions of water movement, e.g. for the liberation of spermatozoa and egg fertilization (Kinne, 1971).

Seasonal changes in the ovaries of teleosts have been studied histologically as well as measuring ova diameter and with the help of gonado-somatic index (Khanna, 1978).

Stephenson (1934) observed 4 types of reproductive cycle in the animals of tropical water which are:

- i. Annual reproductive cycle;
- ii. More than one reproductive cycle in a year;
- iii. Continuous breeder; and
- iv. Discontinuous breeder.

The reproductive activities of most aquatic animals in tropical and sub-tropical areas where environment is relatively uniform throughout the year are controlled at least in part by temperature and length of day light (Hoque and Ahmed, 1993). deVlaming (1972) concluded that temperature appeared to be extremely important in regulating reproductive cycle of cypriniformes. For the enhancement of gametogenesis leading to maturity and spawning, the role of temperature is important (Asahina and Hanyu, 1983; Summers, 1996). However, photoperiod appeared to be more critical than temperature in determine the timing of the reproductive cycle in *Gambusia affinis* (Milton and Arthington, 1983). After heavy shower during monsoon period (late May to early August) some physico-chemical changes in the water bodies probably stimulate the reproductive activities of Indian major carps (Jhingran, 1983).

In the present investigation *N. notopterus* was found to breed during May to September during monsoon rains which decrease the water temperature, increase the dissolve oxygen (DO), and also form a unique fresh environment.

The annual reproductive cycle of marine and freshwater invertebrates could be determined by different methods such as:

- (i) Percentage of ovigerous female against time : (Pollock, 1985 in *A. australis*; Nabi, 1987 in *M. aculeatus*; Afroze and Hossain, 1990 in *A. mola*; Hossain *et al.*, 1991a in *N. nandus*; Hossain *et al.*, 1992b in *O. pabda*; Nargis and Hossain, 1992 in *A. testudineus*; Parween *et al.*, 1993 in *E. danricus*; Alam *et al.*, 1996 in *S. phasa*; Bhuiyan *et al.*, 1999a in *C. atherinoides*; Hussain and Hossain, 2001 in *M. pancalus*; Martin *et al.*, 2005 in *P. bergi*; Juchno *et al.*, 2007 in *C. taenia*; Klein, 2007 in *A. imberbis*; Fazli *et al.*, 2008 in *L. aurata*).
- (ii) Occurrence of larvae: (Chhapgar and Deshmukh, 1964).
- (iii) Appearance of ripe gametes in the gonad (diameter of ova): (Micale *et al.*, 1987; Nabi, 1987; Hossain *et al.*, 1989; Afroze and Hossain, 1990; Hossain *et al.*, 1991a; Nargis and Hossain, 1992; Parween *et al.*, 1993; Azadi *et al.*, 1995; Hussain and Hossain, 2001; Islam *et al.*, 2001; Alp *et al.* 2003; Caputo *et al.* 2003; Grabowska, 2005; Sindhe and Kulkarni, 2005; Dadzie and Abou-Seedo, 2008).
- (iv) Gonado-somatic index (GSI): (Hossain *et al.*, 1989; Afroze and Hossain, 1990; Hossain *et al.*, 1991a; Nargis and Hossain, 1992; Hossain *et al.*, 1992b; Parween *et al.*, 1993; Alam *et al.*, 1997; Barros and Regidor, 2002; Mabragana *et al.*, 2002; Abou-Seedo *et al.*, 2003; Sindhe and Kulkarni, 2004; Kennedy *et al.*, 2006; Šantić *et al.*, 2006; Ferriz *et al.*, 2007; Glamuzina *et al.*, 2007).
- (v) Chemical composition of the gonad and also other organs related to reproduction: (Chandran, 1968 in *Charybdis variegata*; Diwan and Nagabhushanam, 1974 in *Barytelphus canicularis*).

- (vi) Relative condition factor (K_n): (Mallikarjuna, 1966 in *Macrobrachium rosenbergii*; Hossain, 1976 in *Thenus orientalis*; Hossain and Parween, 1982 in *Macrobrachium dayanum*; Nash, 1982 in *Leuseurigolaius friessi*; Nabi, 1987 in *Macrognathus aculeatus*; Karmakar, 1998 in *N. chitala*).
- (vii) Integrated method of analyzing the immature, maturing, mature and spent, ovigerous with respect to virgin and copulated adult female (Haley, 1972 in *Ocypode quadrata*).
- (viii) Maximum indices of abundance of spermatozoa; (Heydorn, 1965 in *Jasus lalandii*; Hossain, 1976 in *T. orientalis*; Nabi, 1987 in *M. aculeatus*; Alam *et al.*, 1997 in *S. phasa*; Hussain and Hossain, 2001 in *M. pancalus*).
- (ix) Maximum egg bearing capacity: (Shyamasundari, 1972 in *C. triaenonyx*; Hossain, 1976 in *T. orientalis*; Afroze and Hossain, 1990 in *A. mola*).
- (x) Gonadal length index (GLI); (Nabi, 1987; Hossain *et al.*, 1989; Afroze and Hossain, 1990; Hossain *et al.*, 1991a; Hossain *et al.*, 1992b; Nargis and Hossain, 1992; Parween *et al.*, 1993; Alam *et al.*, 1997; Hussain and Hossain, 2001; Islam *et al.*, 2001; Barros and Regidor, 2002; Mabragana *et al.*, 2002; Abou-Seedo *et al.*, 2003; Sindhe and Kulkarni, 2004; Kennedy *et al.*, 2006; Šantić *et al.*, 2006; Ferriz *et al.*, 2007; Glamuzina *et al.*, 2007).
- (xi) Colouration of gonad (ovary): (Nabi, 1987; Hossain *et al.*, 1989; Afroze and Hossain, 1990; Hossain *et al.*, 1991a; Hossain *et al.*, 1992b; Nargis and Hossain, 1992; Parween *et al.*, 1993; Alam *et al.*, 1997; Hussain and Hossain, 2001; Islam *et al.*, 2001; Barros and Regidor, 2002; Mabragana *et al.*, 2002; Abou-Seedo *et al.*, 2003; Sindhe and Kulkarni, 2004; Kennedy *et al.*, 2006; Šantić *et al.*, 2006; Ferriz *et al.*, 2007; Glamuzina *et al.*, 2007).
- (xii) Histology and histochemical aids: (Hossain, 1976; Dalela *et al.* 1977; Nabi, 1987).
- (xiii) Neurosecretory activity of certain NS-cells. (Hossain, 1976 in *T. orientalis*).
- (xiv) Isolation of adult female (condition favourable or ecologically good for larvae) from natural population or normal ecological condition (Booolootian, 1966 in *Pachygrapsus crassipes*).

- (xv) Activity of the cement gland (Hossain, 1976 in *T. orientalis*).
- (xvi) Structure and nature of oosetae (Hossain, 1976 in *T. orientalis*).
- (xvii) Structural modification of secondary sexual characters in fin fishes (Hossain, 1989).

From the aforementioned methods, only six (i, iii, iv, vi, x, xi) were applied in the present study to determine the breeding cycle of *N. notopterus*. All the six methods showed that *N. notopterus* breed once in a year which lasts from May to September. Similar results have been obtained in different fishes e.g. Dalella *et al.* (1977) in *N. notopterus*; Afroze and Hossain (1990) in *A. mola*; Hossain *et al.* (1991a) in *N. nandus*; Hossain *et al.* (1992b) in *O. pabda*; Nargis and Hossain (1992) in *A. testudineus*; Parween *et al.* (1993) in *E. danricus*; Alam *et al.* (1997) in *A. coila*; Fatema *et al.* (1997) in *Oxygaster bacaila*; Hussain and Hossain (2001) in *M. pancalus*; Islam *et al.*, (2001) in *S. phasa*; Kovacic (2001) in *Gobius roulei*; Abou-Seedo *et al.* (2003) in *A. latus*; Gonzalez *et al.* (2003) in *B. splendens*; Juchno *et al.* (2007) in *Cobitis taenia*; Klein (2007) in *Apogon imberbis*; Koc *et al.* (2007) in *Leuciscus cephalus*; Dadzie *et al.* (2008) in *Parastromateus niger* and Kahraman *et al.* (2008) in *Euthynnus alletteratus*.

Several dissimilarities were also reported by Hossain *et al.* 2002 in *Gonialosa manminna* (January to June); Lorenzo *et al.*, 2002 in *Lithognathus mormyrus* (June to December); Alp *et al.*, 2003 in *Salmo trutta macrostigma* (November to January); Pajuelo *et al.*, 2006b in *Pagrus auriga* (September to February); Fazli *et al.*, 2008 in *Liza aurata* (October to December); Filar and Sedberry, 2008 in *Hyperoglyphe perciformis* (September to May); Mazlan and Rohaya, 2008 in *Periophthalmodon schlosserri* (June to October); and Oker *et al.*, 2008 in *Uranoscopus scaber* (March to September).

4.4.5 Fecundity

A perfect knowledge on the fecundity of fishes is essential for evaluating the commercial potentialities of its stock, for study of life history, practical culture and actual management of its fishery (Lagler, 1966; Hossain, 1979).

Fecundity appears to bear some relationship to the case according to the eggs (Lagler *et al.*, 1977). For example in poorly fecund fish parental care is highly developed. So, to make the population constant, fecundity does not fluctuate widely due to low mortality rate and predator. Again the fishes with high fecundity show great fluctuation in their abundance. They do not take care of their eggs; the eggs are subjected to several injuries due to excessive temperature, parasitic and predatory attack etc. After spawning most of them do not survive up to hatching.

The study of fecundity of any species is important to have a full understanding of its biology and population dynamics. The study in fecundity is also undertaken to determine the index of density dependent factor affecting the population size (Simpson, 1951; Das, 1977). The fecundity of an individual female varies according to many factors including her egg size, species, food availability, water temperature and season (Lagler *et al.*, 1977). But the estimation of fecundity on the basis of number of ova is not purely accurate (Farmer, 1974), because of the following drawbacks:

- i) Not all the ova contained in an ovary are released,
- ii) Some of the ova are re-absorbed in the ovary, which are known as atretic oocytes (Chubb and Potter, 1984) and
- iii) Constituents of the germinal stand which is present at all the time are retained egg laying

In the present investigation a marked increase in the fecundity was noticed with the increase in total length, standard length, total weight, ovary length and ovary weight, which indicate that the number of eggs increased linearly with the increase of these variables. All the relationships showing values of the regression coefficient are highly significant ($P < 0.01$). Similar results were also reported from different fishes worked out by a number of scientists.

A comparison of correlation co-efficient of fecundity-total length ($r=0.953$), fecundity-standard length ($r=0.958$), fecundity-total weight ($r=0.952$), fecundity-ovary length ($r=0.873$) and fecundity-ovary weight ($r=0.996$) indicated that variation in fecundity could be better in terms total weight and ovary weight than other terms. But this result is disagreed with Ahmed *et al.* (1979) in *C. batrachus*. They found that relationship between fecundity and ovary weight could not be obtained an exact linear relationship, which might be due to the fact that the ova were not uniform in size. However in case of *N. notopterus* the ova were more uniform in size than previous observation as evident from relationship between ovary weight and fecundity.

In *N. notopterus*, the absolute fecundity ranged from 651 to 2250 with mean $\pm$ SE 1598.18 ± 42.47 which revealed that the species is low fecund. The number of eggs produced by a female is dependent on various factors such as size, age and condition (food availability, water temperature, and season) (Lagler *et al.*, 1977). Considering the individual fecundity of the species, it has been found that the same sized fish had different number of eggs in their ovaries. For instance, three specimens of *N. notopterus* had the length of 24cm but the fecundity were 1104, 1284 and 1498 respectively. It is also observed that in some case, fecundity of a fish of larger size is much less than that of a fish of smaller size. Individual physiology of the fishes and their surroundings may be the controlling factors for such variation (Hossain *et al.*, 1997b). This type of variation was also common in other fishes e.g., *Xenentodon cancila* (Bhuiyan and Islam, 1990); *Puntius stigma* (Islam and Hossain, 1990); *A. coila* (Alam *et al.*, 1994b); *S. phasa* (Alam *et al.*, 1997); *P. sophre* (Bhuiyan and Parveen, 1998); *C. idella* (Mustafa *et al.*, 1998); *B. gonionotus* (Bhuiyan *et al.*, 2000); *Gobius roulei* (Kovacic, 2001); *C. striatus* (Latifa *et al.*, 2002); *Salmo trutta macrostigma* (Alp *et al.*, 2003); *Crystallogobius linearis* (Caputo *et al.*, 2003); *M. holotrachys* (Morley *et al.*, 2004); *Siganus luridus* (Azzurro *et al.*, 2007); *Pseudocorynopoma doriai* (Ferriz *et al.*, 2007); *Parastromateus niger* (Dadzie and Abuo-Seedo, 2008); *Parastromateus niger* (Dadzie *et al.*, 2008); *Liza aurata* (Fazli *et al.*, 2008); and *Uranoscopus scaber* (Oker *et al.*, 2008). This is perhaps owing to the variations in the size and heterogeneous distribution of the ova.

4.4.6 Sex-ratio

Knowledge of the sex-ratio of a population is considered essential in the management of a fishery as it will be necessary to devise means of ensuring a proportional fishing of the two sexes. The sex-ratio of *N. notopterus* was in favour of male (1: 0.98) *i.e.*, the male number was more than female. The overall chi-square value, total chi-square value and the chi-square heterogeneity value was insignificant which indicating that the overall number of males was not much higher than the females during the study period. The monthly record revealed that the males were predominating throughout the study period. This type of distribution is rarely observed fish species. A record of similarity is found in *Lithognathus mormyrus* reported by Lorenzo *et al.* in 2002.

In explaining the monthly fluctuation of the male and the female population of *M. rosenbergil*, Patra (1977) reported two factors, *i.e.*, spawning migration and the physico-chemical condition of water, which might have some influences in the variation. Similar explanation has also been made by Costello and Allen (1970) on shrimps and prawns. However, it is not clear that which factor might be responsible in the fluctuation of the male and the female population distribution of *N. notopterus*.

Chapter Five

MARKETING OF N. NOTOPTERUS

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MARKETING OF *N. NOTOPTERUS*

5.1 Introduction

People all over the world prefer fish than animal meat for its different taste, flavour and comparatively low price. So, an unbeaten demand of fish and fisheries products has been persisted worldwide. To make these items available to consumers at the right time and in the right place requires an effective marketing system (Alam, 2001). Kohls (1970) defined marketing as “the business activities involved in the flow of goods and services from the point of initial production until they reach the ultimate consumer.” He also stated that the marketing system lies in between the producer and the final consumer *i.e.*, the activities of the products after the hand of the producer up to the final consumption are treated as ‘marketing system’.

It is said that success of a product depends on a balanced marketing channels in a balanced marketing system. In Bangladesh, there is an ever-increasing gap between supply and demand of fish and fisheries products due to high population growth. To narrow the gap not only the increment of production is required but also the marketing and distribution systems should be improved (ICLARM, 1991; SAARC, 1994). A fisherman or fish farmer usually could not sell their fish in retail markets for many reasons, mainly because of strong non-cooperation and resistance from the middleman. They sell fish by the lot or by species and face one or two 'Nikaries' in his area. Sometimes the middlemen establish their own exclusive trading areas, where other do not interfere or compete openly. This is particularly the case in remote villages. In areas that are well connected by roads and rail, fish farmers contact wholesalers in secondary or higher secondary markets directly and negotiate prices and quantities of fish with the 'Arat's on their own initiatives (Alam, 2001). Intermediaries, particularly Aratdars, face competition from other

whole sellers, which gives the secondary and higher secondary markets an oligopoly-type structure (Alam, 2001). Therefore, it is very important to evaluate the existing demand, supply, price and marketing system of fish to identify market inefficiencies that have negative impact on poor farmers and traders.

Some workers like Kohls (1970), Buksimiar (1977), Sarker (1977), Sabur and Rahman (1979), Dutta (1983), Parween and Hossain (1983), Hossain (1996), Degen *et al.* (2000) and Coates (2001) have been worked on different marketing problems of fishery items.

The present work is aimed to find out the detailed account of the status of potential supply, demand and marketing information of *N. notopterus*, a high demand SIS of Bangladesh.

5.2 Materials and Methods

The study was conducted over a period of 24 months from January, 2005 to December, 2006. The study area consisted of different fish landing centres under Rajshahi City Corporation. The data were collected weekly by survey and interviews, taken from different fish traders and fishermen. The landing percentage of *N. notopterus* considering other fishes was also calculated to know the status of production. The marketing margin included marketing cost and profit or loss of all intermediaries in the marketing chain. To determine the marketing margin, the following formulae are used according to Matin *et al.* (2008):

$$GM_i = PR_i - PP_i$$

Where,

GM_i = Gross margin (Tk/unit weight) for i^{th} intermediary

PR_i = Price received (Tk/unit weight) by i^{th} intermediary

PP_i = Price paid (Tk/unit weight) by i^{th} intermediary

$$NM_i = GM_i - MC_i$$

Where,

NM_i = Net margin (Tk/unit weight) for i^{th} intermediary

MC_i = Marketing cost incurred (Tk/unit weight) by i^{th} intermediary

5.3 Results and Observations

5.3.1 Marketing Channels in Practice

There are some basic principles concerning fish marketing system. During the study period three levels of fish markets viz. primary, secondary and city or terminal markets were observed where the catches fish farmers or fishermen had been found to sell. In these markets, distribution of fish is controlled by a large number of intermediaries through various marketing channels. During the marketing of *N. notopterus* the following intermediaries in different marketing channels were observed:

Fishermen or Growers: The first and base links of a marketing channel are fish farmers or fishermen. They culture fish in ponds or catch fishes from natural resources, throughout or at definite seasons of the year and sell their commodity either directly to the consumers in the nearby market or to any intermediaries (Diagram 5.1).

Farias: 'Farias' are the second link of the marketing channel. Normally, they purchase fish from the producing or fishing areas and supply it to the 'Beparis' (the primary wholesalers) keeping a small profit. Occasionally some 'Farias' directly sell fish in open market. The number of 'Farias' varies on availability of fish landing. During the study period a total of 52 'Farias' were found in the four markets where the highest 23 was observed in Shaheb Bazar and the lowest was 6 in Court Bazar (Fig. 5.1 and Diagram 5.1).

Beparis: Beparis are the third link of the fish marketing channel, mainly gather at the landing centres. They purchase fish from the 'Farias' or directly from the fishermen and sell to the retailers via 'Aratdars'. The investment amount of 'Beparis' varies from medium to high. They often take advance from the 'Aratdars' and finance the 'Farias' and the fishermen. In the study period the number of 'Beparis' in four markets were ranged from 3 to 12 where the highest was recorded in Shaheb Bazar (Fig. 5.1 and Diagram 5.1).

Aratdars: The 'Aratdars' are the fourth link of the marketing channel having license from the proper authority who act as wholesaler as well as commission agent in the market. They usually purchase fishes from Farias and Beparies, sometimes directly from the fish farmers and fishermen. 'Aratdars' normally possess permanent establishments and act in between the 'Beparis' and the Retailers. They help the 'Beparis' to sell their fish and charge a fixed commission on the amount transacted. 'Aratdars' give cash payment to 'Beparis' but supply fishes to retailers on credit by auction. The 'Aratdars' offer a provisional accommodation for the different intermediaries and take a risk for sale after the hand over of fish.

In many cases, arottdars require a large amount of capital investment for financing the 'Beparis' and 'Farias' which is termed as 'Dadon' (bound to sell their commodity to financier). The fishermen often take 'Dadon' for buying crafts and gears or to repair these. Sometimes they take 'Dadon' for their livelihoods also. The highest (13) number of arottdars were recorded in Shaheb Bazar during the study period. There were no arottdar recorded in the Court Bazar (Fig. 5.1 and Diagram 5.1).

Retailers: The retailers are the next link of the marketing channel of any types of markets. They run their profession with fewer amounts of capital investment or without any investment. The retailers purchase fish from the 'Aratdars' and even from the fishermen and sell it directly to the consumers. Sometimes they purchase fish from the 'Aratders' on credit and make payment after selling fishes. The number of retailers is more in the markets, both permanent and seasonal. In some cases the 'Beparis' including fishermen act as retailer depending on the market structure and situation. A total of 152 Retailers were found in four markets during the study period where 87 were in Shaheb Bazar, 26 in Shalbagan, 17 in Court Bazar and 22 in Binodpur Bazar. Hawkers are special retailers found to sell fish from door to door in residential areas of the towns even in the villages (Fig. 5.1 and Diagram 5.1).

Consumers: Consumers are the last link of marketing channel and found in every types of market. They purchase fishes from the retailers for their own consumption. The number of consumers in the market depends on price of fish and their purchasing capacity, quality, quantity and freshness of fish, and position of market near by residence of consumers.

Apparently the consumers of these fish markets are classified in to four categories according to consuming level viz. high class, middle class, institutional and lower class. Generally high-class consumer can purchase the feather back for its high price, middle class consumers hardly buy it but institutional and lower class consumers cannot buy featherback.

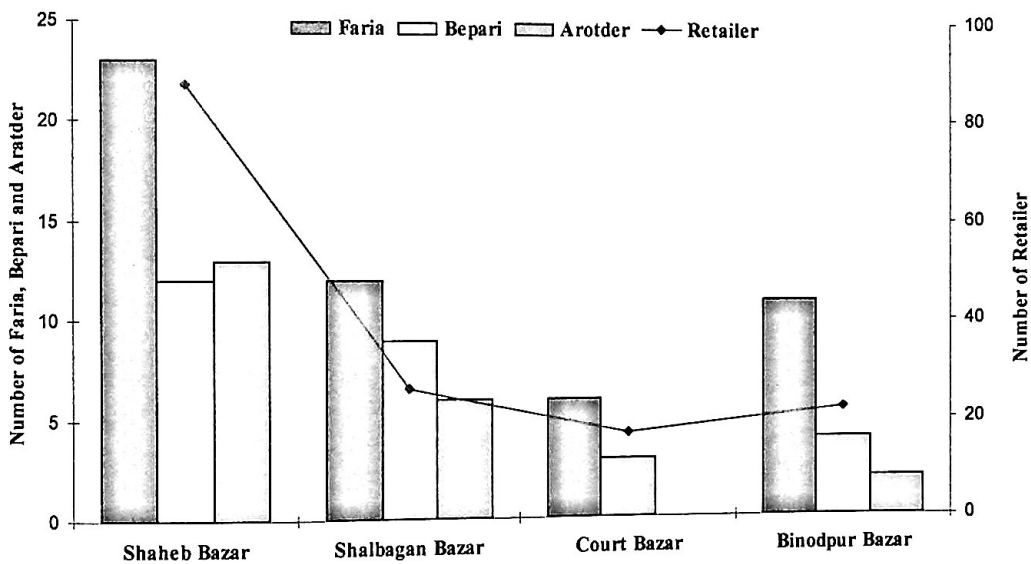


Fig. 5.1: Number of different intermediaries in four fish markets of Rajshahi City Corporation.

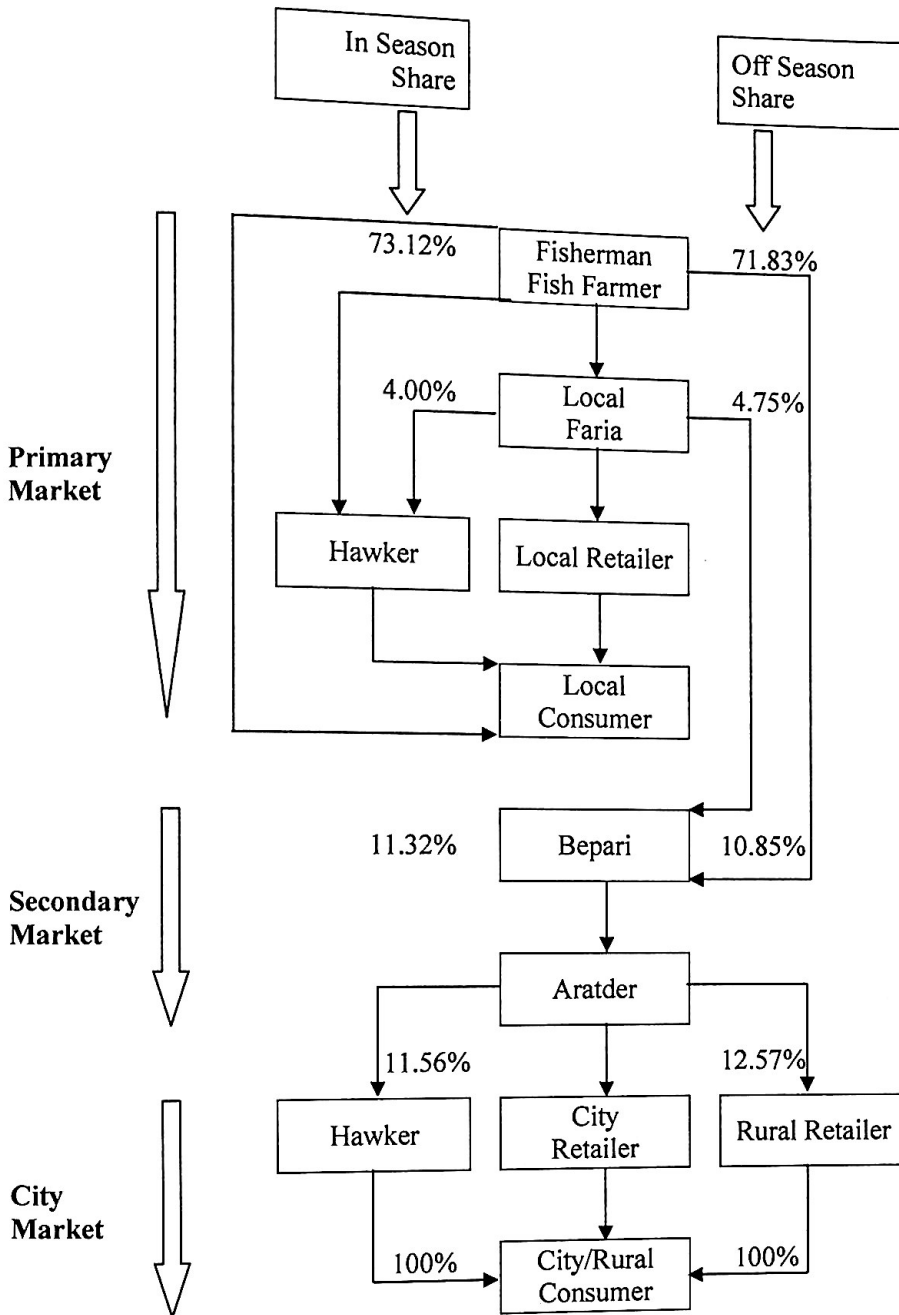


Diagram 5.1: The existing marketing channels showing average in season and off season percentage share of consumers' payment received by growers and different intermediaries.

5.3.2 Landing Statistics and Price Analysis

N. notopterus grows rapidly within a year and forms an important fish food together with other fishes. The available landing of *N. notopterus* was observed from November to February. During the study period the monthly average landing of *N. notopterus* was ranged from 1.93 to 111.33 kg among four fish markets where the highest was recorded in Shaheb Bazar, the biggest fish market of Rajshahi City Corporation. The landing percentage of *N. notopterus* was ranged from 0.02 to 0.18% when compared with total fish landing (Fig. 5.2 and Table 5.1).

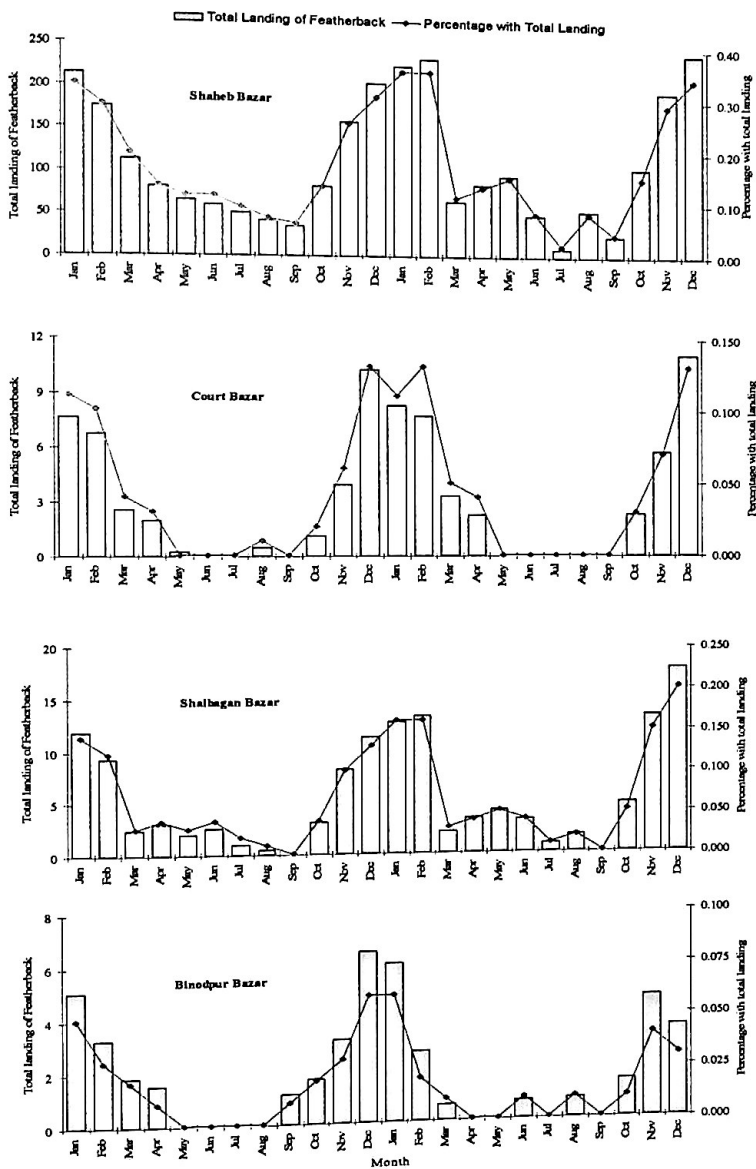


Fig.5.2: Comparative landing of *N. notopterus* in four fish markets of Rajshahi City Corporation.

Table 5.1: Comparative landing statistics of featherback in for fish markets of Rajshahi City Corporation.

Months (2005-2006)	Shaheb Bazar			Court Bazar			Shalbagan Bazar			Binodpur Bazar		
	TLF (kg)	TLOF (kg)	PTL	TLF (kg)	TLOF (kg)	PTL	TLF (kg)	TLOF (kg)	PTL	TLF (kg)	TLOF (kg)	PTL
Jan	213	66192.50	0.32	7.65	7019.25	0.11	11.87	8274.06	0.14	5.07	11032.08	0.05
Feb	174	62252.50	0.28	6.70	6525.25	0.10	9.27	7906.56	0.12	3.29	10542.08	0.03
Mar	111.5	60017.50	0.19	2.55	7001.75	0.04	2.45	8002.19	0.03	1.82	10669.58	0.02
Apr	79.75	60603.75	0.13	1.99	5960.5	0.03	2.98	7825.47	0.04	1.55	10433.96	0.01
May	64.5	59712.50	0.11	0.23	6171.25	0.00	1.97	7464.06	0.03	0.00	9952.08	0.00
Jun	59.75	54452.75	0.11	0.00	5745.5	0.00	2.58	6806.59	0.04	0.00	9075.46	0.00
Jul	50.5	54128.75	0.09	0.00	5012.5	0.00	1.03	6766.09	0.02	0.00	9021.46	0.00
Aug	42	57200.00	0.07	0.50	5720	0.01	0.47	7150.00	0.01	0.00	9533.33	0.00
Sep	35	60207.50	0.06	0.00	5920.5	0.00	0.00	7525.94	0.00	1.15	10034.58	0.01
Oct	82	62198.75	0.13	1.10	6519	0.02	3.13	7774.84	0.04	1.71	10366.46	0.02
Nov	158.5	63680.00	0.25	3.93	7068	0.06	8.23	7960.00	0.10	3.18	10613.33	0.03
Dec	205	67703.75	0.30	10.25	8021	0.13	11.33	8462.97	0.13	6.50	11283.96	0.06
Jan	226.25	64137.50	0.35	8.31	7413.5	0.11	12.75	8017.19	0.16	6.02	10689.58	0.06
Feb	235	66905.00	0.35	7.75	6090.5	0.13	13.33	8363.13	0.16	2.64	11150.83	0.02
Mar	66	61265.00	0.11	3.30	6126.5	0.05	2.07	7658.13	0.03	0.60	10210.83	0.01
Apr	85	64947.50	0.13	2.25	5094.5	0.04	3.33	8118.44	0.04	0.00	10824.58	0.00
May	96.25	65232.50	0.15	0.00	7023	0.00	4.08	8154.06	0.05	0.00	10872.08	0.00
Jun	49	58422.50	0.08	0.00	6242	0.00	3.18	7302.81	0.04	0.70	9737.08	0.01
Jul	10	57680.00	0.02	0.00	5761	0.00	0.87	7210.00	0.01	0.00	9613.33	0.00
Aug	55	66087.50	0.08	0.00	5008	0.00	1.67	8260.94	0.02	0.75	11014.58	0.01
Sep	25	57657.50	0.04	0.00	5565	0.00	0.00	7207.19	0.00	0.00	9609.58	0.00
Oct	106	69327.50	0.15	2.30	6932.5	0.03	4.73	8665.94	0.05	1.43	11554.58	0.01
Nov	198	68990.00	0.29	5.75	7899	0.07	13.33	8623.75	0.15	4.64	11498.33	0.04
Dec	245	72732.50	0.34	11.15	8273	0.13	17.87	9091.56	0.20	3.50	12122.08	0.03
Aver-age	111.33	62572.30	0.18	3.15	6421.38	0.05	5.52	7858.00	0.07	1.86	10477.33	0.02

Note: TLF=Total Landing of Featherback; TLOF=Total Landing of other fishes; and PTL= Percentage with total landing; and the bold months indicate available landing.

Marketing Margin

The difference between the amount paid by the consumers and the amount received by the producers is referred to as 'gross margin' (Kohls, 1970). The term 'price spread' is often used synonymously with the term 'gross margin' (Sabur and Rahman, 1979). Gross margin includes all the cost of moving the commodity from the point of production to the point of consumption and of handling at all levels in the marketing channels. The gross margin usually consists of margins at several stages of distribution, and in each case, the margin is the differences between the buying and the selling prices of each distributor. Thus the gross margin consists of two component parts:

- a) Marketing costs (for performing various function); and
- b) Net margin (profit of the intermediaries)

a) Marketing costs

Mainly the price of a commodity varies due to marketing costs involved in different markets. The marketing cost includes packing materials, transportation, unloading, Aratders' commission, display cost for retailers, consumer service, incidental costs, market toll/taxes and miscellaneous. The average total cost of these items was found Tk. 12.63/kg (In season) and Tk. 12.81(Off season) during the study period (Appendix Table V_a). The highest marketing cost was recorded as Tk.13.50/kg both for in season and off season at Binodpur Bazar where it was lowest at Shalbagan Bazar as Tk.11.25/kg (in season) and Tk.11.50/kg (off season) shown in Appendix Table V_b. A comparative study of marketing cost among four markets was also done. It is observed that gradually the marketing cost of Beparies remains highest all over the study period and the lowest remains for Forias *i. e.* the general tend of cost involvement is obtained as Bepari > Retailer > Foria both in season and off season (Appendix Table V_c). The item wise in season and off season average percentage of marketing cost is shown in Fig. 5.3.

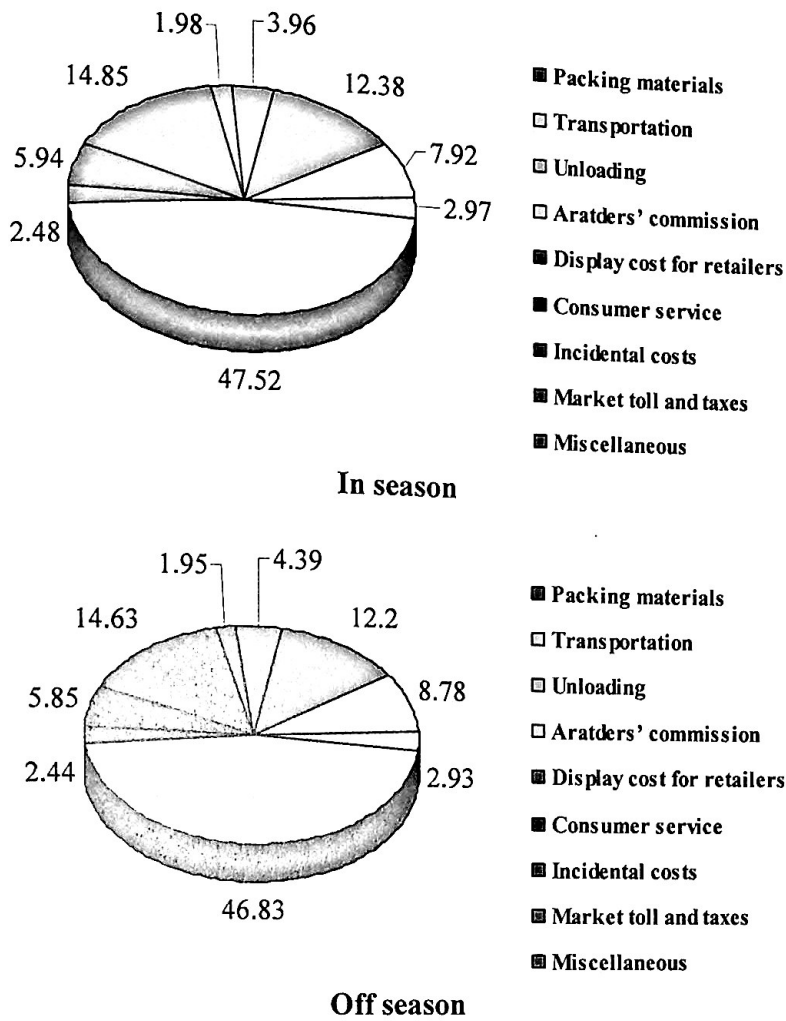


Fig.5.3: Percentage of average marketing cost involved during in season and off season marketing of *N. notopterus*

b) Net margin

The net margin earned by different intermediaries at four markets is found to vary among different markets. The average net margin of Faria, Bepari and Retailer was obtained as Tk. 4.69, 8.94 and 13.25 (in season); and Tk. 7.13, 11.56 and 18.50 (off season) respectively (Fig. 5.4 and Table 5.2). The average in season and off season percentage share of consumers pay received by growers and different intermediaries are also shown in Diagram 5.1 and Table 5.2.

The market price of the studied species had been found to vary among the four markets with seasonal price variation. The seasonal gross margins per kg of

species, with the margins of the intermediaries as found at the different markets are given in Appendix Table V_d, V_e, V_f, and V_g. The average total gross margins of *N. notopterus* were obtained as Tk. 39.51 and Tk. 50 per kg during in season and off season respectively (Fig. 5.4; Table 5.2)

The individual margins of different intermediaries were also studied in the present investigation. It is observed that the highest in season and off season net margin was found at Court Bazar as Tk. 31.75 and 41.75 per kg respectively; and in Shalbagan Bazaer it was lowest as Tk. 23.75 and 33.5 per kg respectively (Fig. 5.5).

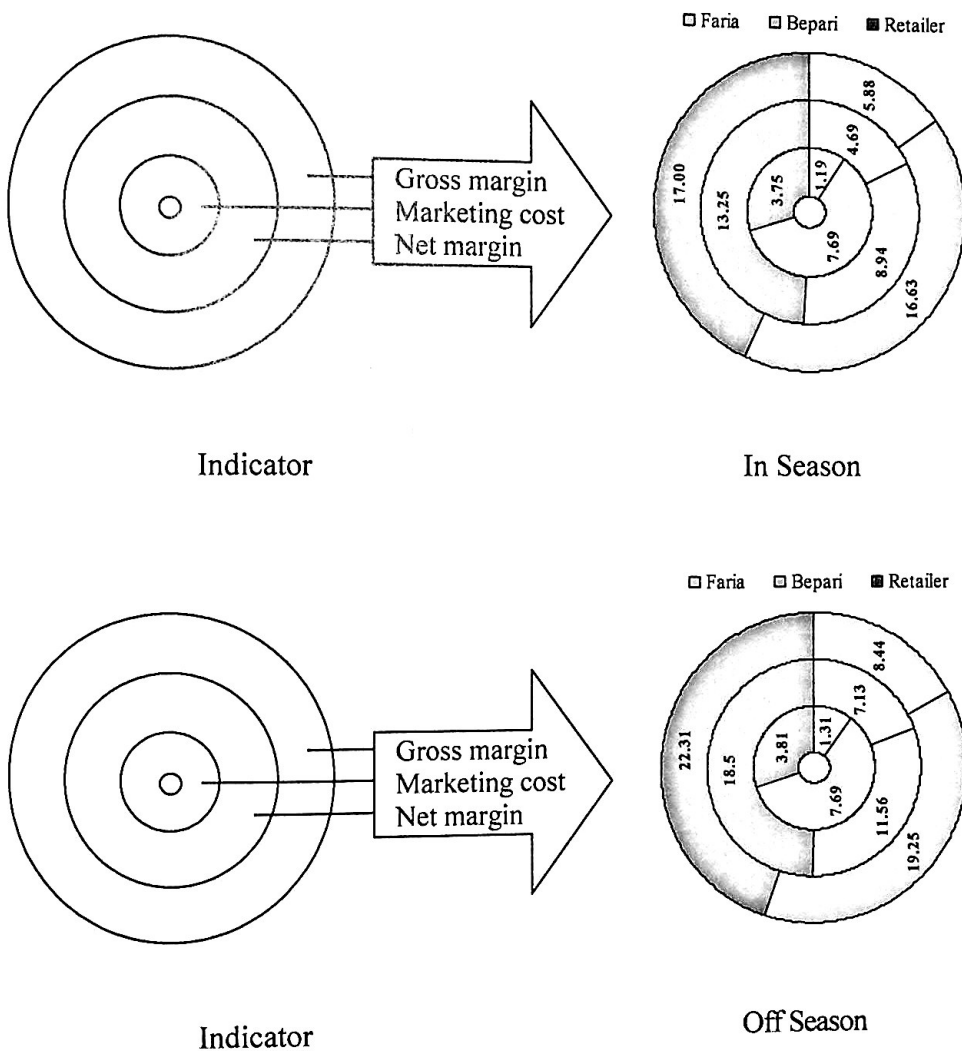


Fig. 5.4: The average in season and off season variation in marketing margin of different intermediaries in marketing channel of *N. notopterus* based on four fish markets of Rajshahi City Corporation

Table 5.2: Average price spread in *N. notopterus* marketing based on the data of four fish markets of Rajshahi City Corporation.

Intermediary	Items detail	In season		Off season	
		Taka/kg	Percentage with consumers price	Taka/kg	Percentage with consumers price
i = ith Intermediary (Faria)	Price Paid (PPi) Price Received by Fisherman (PRF)	107.5	73.12	127.5	71.83
	Marketing Cost (MCi)	1.19	0.81	1.31	0.74
	Gross Margin (GMi)	5.88	4.00	8.44	4.75
	Net Margin (NMi)	4.69	3.19	7.13	4.02
	Price Received (PRi)	113.38	77.12	135.94	76.59
i = ith Intermediary (Bepari)	Price Paid (PPi)	113.38	77.12	135.94	76.59
	Marketing Cost (MCi)	7.69	5.23	7.69	4.33
	Gross Margin (GMi)	16.63	11.31	19.25	10.85
	Net Margin (NMi)	8.94	6.08	11.56	6.51
	Price Received (PRi)	130.01	88.44	155.19	87.43
i = ith Intermediary (Retailer)	Price Paid (PPi)	130.01	88.44	155.19	87.43
	Marketing Cost (MCi)	3.75	2.55	3.81	2.15
	Gross Margin (GMi)	17	11.56	22.31	12.57
	Net Margin (NMi)	13.25	9.01	18.5	10.42
	Price Received (PRi)	147.01	100.00	177.5	100.00
Total Gross Margin (TGM)		39.51	26.88	50	28.17
Price Paid by Consumer (PPC)		147.01	100	177.5	100

Formulae Used:
Gross Margin (GMi) = PRi-PPi
Net Margin (NMi) = GMi-MCi
Price Paid by Consumer (PPC) = PRF+ TGM

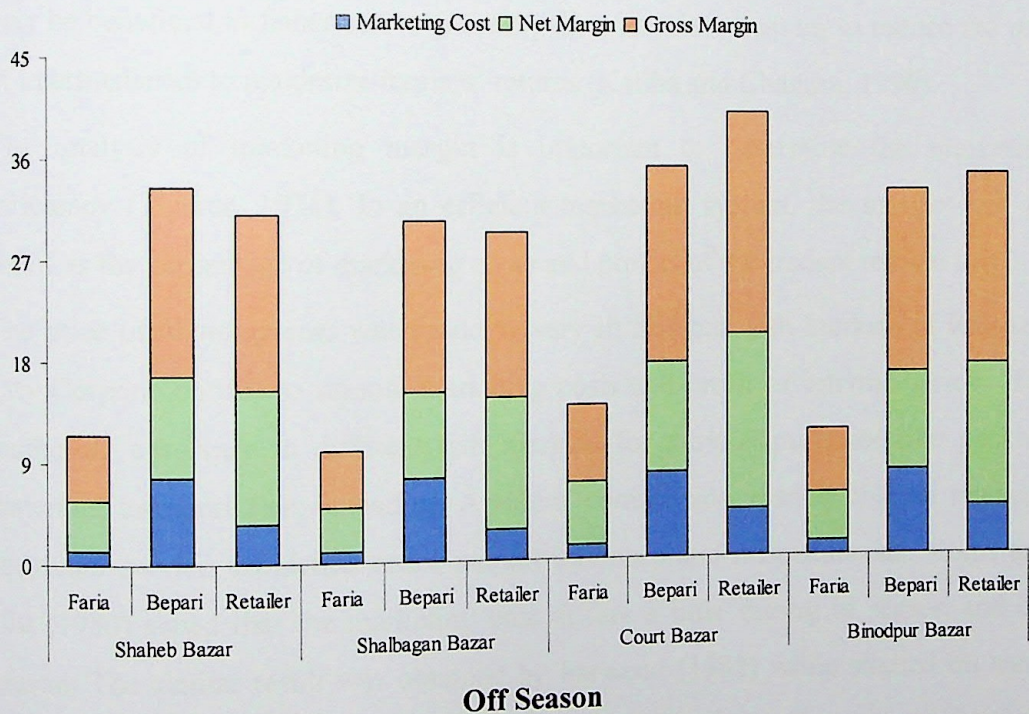
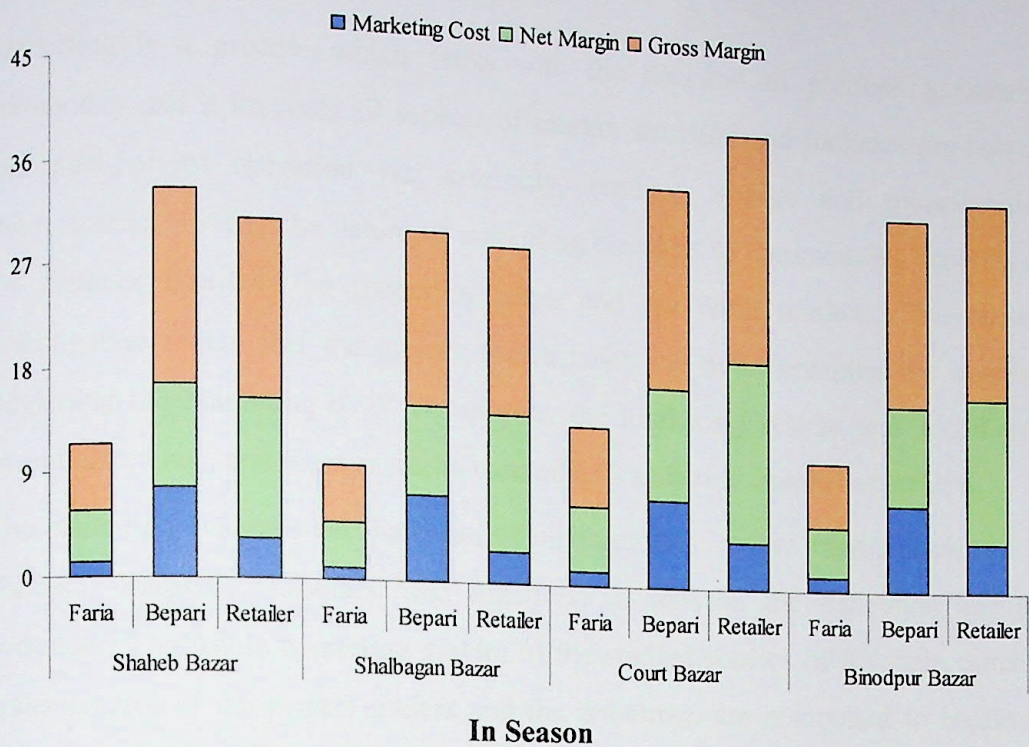


Fig. 5.5: In season and off season variation in marketing margin of *N. notopterus* in four fish markets of Rajshahi city Corporation

5.4 Discussion

Marketing is a process which starts with the decision to produce a saleable commodity and it involves all aspects of market structure and includes pre-harvest and post-harvest operation viz. assembly, grading, storage and transportation (Nuruzzaman, 1990). The nature of marketing channels of commodities depends on the distance between the producing areas and the retail markets. The present investigation reveals that the greater the distance the more complex the channel. Regarding the marketing of *N. notopterus*, the marketing system was found as a decentralized one, and there exists no methodical marketing channel anywhere.

The marketing channels that have been found comprise a few intermediaries (e. g. 'Farias', 'Beparis', 'Arotdars' and Retailers) in between the fisherman and the consumer. The whole marketing system of the studied species of Rajshahi remains under control of the private traders and the fishermen are compelled to handover their catches to these intermediaries at a price determined by them. Thus the intermediaries play a vital role in the marketing chain. A reduction of intermediaries may be beneficial to fishermen to get real price. So it is necessary to reduce the role of intermediaries to maximize farmers' returns (Katiha and Chandra, 1990).

The analysis of marketing margin is important to determine the marketing efficiency (Thakur, 1974). In an efficient marketing system, the margin will be small as the percentage of marketing costs and profits of the traders remain low.

The price of *N. notopterus* was found to vary in different fish markets of Rajshahi City Corporation due to season, marketing costs and profit of intermediaries. The marketing cost vary in different fish markets for various purposes like packing materials, transportation, unloading, Aratders' commission, display cost for retailers, consumer service, incidental costs, market toll/taxes and miscellaneous. Kohls and Uhl (1980) stated that the marketing cost differs a little during in season and off season. The similar result was obtained by Parween (1982) while studied on some aspects of fisheries of freshwater prawn, *Macrobrachium dyanum* of Rajshahi district. In the present study the aforementioned variation is again observed in the marketing of *N. notopterus*.

The variation in price of *N. notopterus* was observed in four fish markets. The average retail price was found as Tk.147.01/kg (in season) and Tk. 177.50/kg (off season). Generally in peak season the fish comes from open water and from culture system but in off season it comes more from open water than culture system. So, the price in off season remains high comparatively. Similar result was reported by Parween and Hossain in 1983. Another interesting cause of high price of *N. notopterus* is detected in the retail markets is that the retailers are able to keep the in fresh condition for long time for its low perishability and air breathing character. As a result they feel safe to bargain with the consumers for its high price at a low risk.

The price received by the fishermen was found highest in two markets throughout the year. The reason behind this the direct selling by fishermen which includes a good share of the consumers' price. Similar information was also reported by Ahmed (1977) from several fish markets of Pabna district.

Chapter Six

TRIAL OF NATURAL BREEDING

Chapter Six

TRIAL OF NATURAL BREEDING

6.1. Introduction

The fish culture trends in Bangladesh mainly directed to the three species of Indian major carps, few minor carps and some exotic carps. As a result large variety of our wild population is being neglected in farmers' level and even destroyed during preparation of carp culture ponds (Haniffa *et al.*, 2001). On the other hand the aquatic eco-systems are under increasing pressure due to various human stresses such as rapid urban development, population growth, over exploitation, pollution, disease etc. (Haniffa *et al.*, 2004). So, the feeding and breeding ground of these wild species are being reducing and the species are losing their shelter, finally causes extinction. Thus, along with the total wild varieties, the natural stock of featherback, *N. notopterus* is reducing day by day and treated as a threatened species in the Indian Sub-continent (CAMP, 1998) as well as in Bangladesh.

In India, many approaches have been used in the conservation of threatened species including captive breeding, cryopreservation of gametes, habitat restoration and stock transfer in both captivity and in the wild (Haniffa *et al.*, 2004) but in Bangladesh no approaches have not yet been taken except declaration of few sanctuary. But the species has a strong potentiality to play a vital role in the national economy for its market demand due to multipurpose use as described earlier in the Chapter one.

People involved in seed production generally prefer to use induced spawning techniques instead of natural breeding, and there is little doubt that the development of induced spawning techniques can contribute to the conservation of a species (Haniffa *et al.*, 2004).

In Bangladesh an attempt has been taken for conservation of *N. notopterus* through induced spawning techniques by Professor Dr. Md. Idris Mia of Bangladesh Agricultural University, but the technique is not yet been transferred to the field level (Source: The Daily Prothom Alo; 22 June, 2008). However, before attempting artificial propagation it is necessary to study the breeding and spawning behaviour of a species in captivity or natural condition.

As the literature says, the species is able to breed naturally in stagnant waters (Rahman, 2005; Haniffa *et al.*, 2004), a trial culture has been done in the present study aimed to determine the potentiality of natural breeding of the species in a carp polyculture system without extra care.

6.2 Materials and Methods

Collection and management of parent fish

The study was conducted over a period of two years from April, 2005 to March, 2006. A total of 20 adult featherback were collected from the “Gene Tank” of the Department of Zoology, University of Rajshahi and different fish landing centres of Rajshahi. The parents were sexed based on the secondary sexual characters (described in the Chapter 4) and acclimatized for 24 hours. Finally 12 parents considering 1:1 sex ratio were selected and released in a carp polyculture pond of the Department of Fisheries, University of Rajshahi. No extra care and feed had been provided for the parents. The culture system was allowed to run as usually in accordance of carp polyculture system. No shelter was provided to form breeding grounds and the fishes were allowed to breed in the environment of carp polyculture system.

Physical features of the pond

The physical features of the pond, such as dike and bottom characters were recorded in the study. The soil type was determined by the soil textural triangle method (FAO, 1996). The aquatic vegetation was also recorded during the study period.

Measuring the water quality parameters

A number of water quality parameters such as temperature, transparency, dissolved oxygen, total hardness and p^H were monitored at weekly interval. The water temperature was recorded from at least 3 spots by using celsius thermometer. Water transparency was determined by a standard secchi disc. Dissolved oxygen was measured directly by using a digital DO meter (Model: Lutron DO-5509, Tiwan) and p^H was measured by direct reading of a digital p^H meter (Model: HI-98107, HANNA) in the field. The free CO_2 and total hardness were measured in the laboratory according to the standard titration method (APHA, 2005).

Monitoring food habit

The food and feeding habit of *N. notopterus* were observed in the chapter 3. Here, in the present trial the food items were again observed by the gut content analysis of some featherbacks to know the food and feeding habit in carp polyculture pond.

Harvesting of fish

Harvesting of fish has been run according to the need of carp polyculture system. Only at the end of the breeding season special harvesting was done by repeated netting with seine net (made of nylon thread having mesh size 5mm) to capture the existing population of *N. notoptrus* to observe the breeding performance.

6.3 Results and Observations

Physical feature of the pond

The pond was rectangular in shape having complete dyke. The total area of the pond was calculated as 1728 square meter (48m×36m) with an average effective water holding area of 1014 square meter (39m×26m); and having average depth of 1.4m (Plate 6.1). The pond was free from aquatic vegetation, completely independent and well exposed to sun light. But in rainy season some submerged weeds were observed just bellow the free board (Plate 6.1). The soil type of the pond was determined as sandy-loam (Fig. 6.1) and the bottom were less muddy.

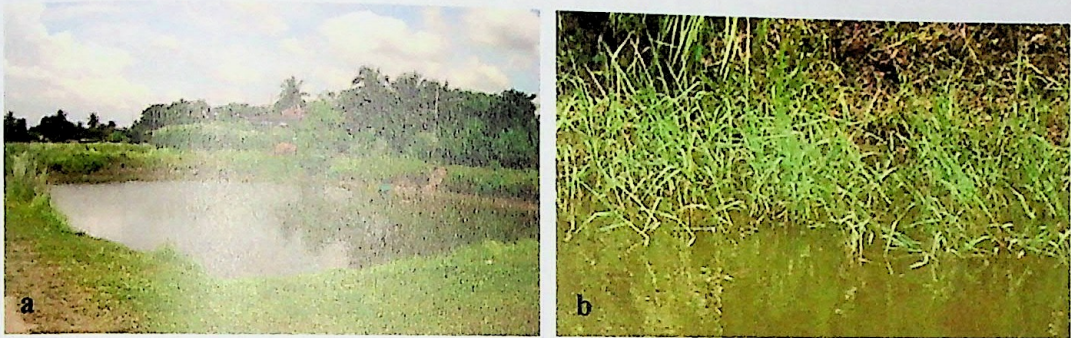


Plate 6.1: Displaying physical feature of the pond (a) showing submerged aquatic weeds (b).

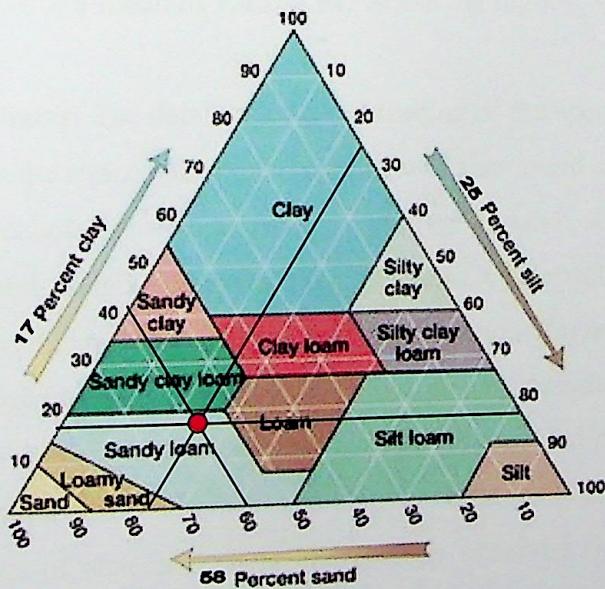


Fig. 6.1: The result of the soil type of the pond shown by the symbol “●” based on the soil textural triangle method (FAO, 1996)

Water quality parameters

The mean values and monthly variation in five water quality parameters obtained in the study are presented in the Table 6.1 as follows:

Temperature: Water temperature was ranged from 19.28 to 32.43°C with a mean of $27.78 \pm 1.30^\circ\text{C}$. The highest temperature was recorded in May and the lowest in December.

Transparency: Water transparency was found to vary from 15.5 to 27cm. The monthly variation was also observed during the study period. The mean value was obtained as $21.42 \pm 0.96\text{cm}$.

Dissolved oxygen: The highest value of dissolved oxygen was recorded in December (7.95mg/l) and the lowest was in May (4.15mg/l). The mean value of dissolved oxygen was obtained as $5.89 \pm 0.38\text{mg/l}$. The monthly variation was also observed for dissolved oxygen.

Free CO₂: The free CO₂ was observed highest (14.55mg/l) in October and lowest (3.62mg/l) in July with a mean of $8.07 \pm 0.94\text{mg/l}$ during the study period.

Total hardness: The total hardness of water was found to vary from 115 to 162mg/l. The highest was found in August and the lowest was in December. The mean value of total hardness was observed as $136.67 \pm 4.18\text{mg/l}$.

p^H: Variation in p^H values were found in suitable range. The p^H values were ranged from 6.73 to 8.23 with a mean of 7.45 ± 0.14 , where the highest was in July and the lowest in January.

Monitoring food habit: The detailed food and feeding of the species were described in the chapter 3. In the trial condition the species was also found carnivorous and the food items were recorded as fish and body parts (eg. *Puntius*, *Amblypharyngodon*, *Esomus*, *Chanda* and *Chela*), crustaceans (eg. *Daphnia*, *Cyclops*, *Cypris*, *Diaptomus*, Prawns and Larvae), aquatic insects (eg. *Belostoma*, *Regimbartia*, *Libellula*, *Notonecta*, *Epecordulea* and; Larvae, nymph and pupae), annelids (eg. *Aeolosoma* and *Branchiura*), molluscs (eg. *Anisus* and *Lymnea*), debris and mud, semi-digested matter, plant and plant parts and gravel and stones. These items are almost similar to that of the findings of chapter 3. It is interestingly observed that the fish do not compete for food with carp fishes, rather it helps to control weed fishes and crustaceans which causes harms in carp polyculture system.

Breeding performance

Breeding was occurred naturally in the pond under the water quality mentioned above. In the first year rearing the fries were first noticed in the pond at the end of the breeding period (October) during harvesting of carp fishes (Plate 6.2). The fries were allowed to rear usually together with carp fishes. After a five months rearing a total of 27 juvenile featherbacks together with 12 parents were captured from the pond. The survival rate of the fries was 1.69% which calculated based on the expected fecundity (Table 6.2). In the second year rearing observation was made on the same way and a total of 1638 juvenile featherbacks were captured together with the first year yield (Plate 6.2). This time the survival rate was found comparatively higher (17.08%) than that of first year performance (Table 6.2). The reason behind this may be the fishes are well adapted in the carp polyculture system.



Plate 6.2: Monitoring natural breeding of featherback (a. netting; b. first observation of fry; c. fries of different length groups; d. juveniles observed after five months rearing; e. sample of total yield).

Table 6.1: The monthly variation in physicochemical parameters of the pond water based on two years average data.

Year	Month	Temperature (°C)	Transparency (cm)	Dissolved Oxygen mg/l	Free CO ₂ mg/l	Total Hardness mg/l	pH
2005-2006	Jan	20.35	23.5	7.23	8.44	130	6.73*
	Feb	24.33	25.5	7.36	5.23	145	7.11
	Mar	27.84	23	4.74	9.88	134	7.58
	Apr	30.21	19	6.55	7.56	150	7.25
	May	32.43**	18.5	4.15*	10.15	156	8.12
	Jun	32.24	27**	4.45	6.74	128	7.55
	Jul	31.85	20.5	4.24	3.62*	137	8.23**
	Aug	31.15	18	5.78	9.88	162**	7.66
	Sep	29.84	15.5*	5.13	3.78	139	7.35
	Oct	27.62	21	6.47	14.55**	124	7.88
	Nov	26.23	22.5	6.58	11.28	120	7.10
	Dec	19.28*	23	7.95**	5.74	115*	6.85
Mean±SE		27.78±1.30	21.42±0.96	5.89±0.38	8.07±0.94	136.67±4.18	7.45±0.14

Note: * means the minimum value; and ** means the maximum value

Table 6.2: Breeding performance of *N. notopterus* in a carp polyculture system in natural condition

Trial year	At stocking (In April, 2005)				At harvesting (In March, 2006)				
	Number of fish	Sex ratio (Male: Female)	Number of ripe females	Initial weight (kg)	Expected fecundity @1598	Number of fries obtained	Total number of fish	Survival rate of fry (%)	Final weight after six months rearing (kg)
2005	12	1:1	1	1.755	1598*	27	39	1.69	3.65
2006	39	1:1.2	6	2.687	9588*	1638	1687	17.08	119.70

* means the expected fecundity, obtained from the result of the chapter 4

6.4 Discussion

Water quality parameters

Suitable water quality is a prerequisite for maintenance of a healthy aquatic ecosystem. The water quality parameters of the trialled pond were found to be within the acceptable ranges for the breeding of *N. notopterus* and there was no abrupt change in any parameter was observed.

Temperature: Water temperature is one of the most important factor that plays significant role in aquatic production that influence all physicochemical, biochemical and biological factors of a water body. The observed range of water temperature (19.28 to 32.43°C) with a mean value of $27.78 \pm 1.30^\circ\text{C}$ are found suitable for aquaculture which is more or less similar to Mollah and Haque (1978) who reported the acceptable range of water temperature form 26.00 to 32.44°C. The statement is also supported by Jhingran, 1991.

Transparency: Water transparency is the turbidity of water caused by plankton that expresses the productivity of a water body. Boyd (1998) suggested water transparency between 15 to 40cm is good for fish culture. In the present study the water transparency is found to vary from 15.5 to 27cm with a mean value of $21.42 \pm 0.96\text{cm}$ which is under the suitable range of Boyd (1998).

Dissolved oxygen (DO): Dissolved oxygen is the most important chemical factor for all aquatic organisms except anaerobic bacteria. The general trend of changes in dissolved oxygen concentration in different months is directly or indirectly governs by fluctuation of temperature and BOD (Palharya, *et al.*, 1993). During the study period comparatively higher values of DO was observed in winter months. Similar observation is reported by Khondker and Parveen (1992). Sharma, *et al.* (1978) stated that DO content may vary with in different period of a day. Banerjee (1967) considered 5.6 to 7.0 mg/l dissolved oxygen content of water to be fair or good in respect of productivity and water having dissolved oxygen bellow 5mg/l to be unproductive. In the present study the DO content of water ranged from 4.15 to 7.95mg/l with a mean of $5.89 \pm 0.38\text{mg/l}$ which is fair for fish culture as well as for *N. notopterus*.

Free CO₂: CO₂ plays a vital role in the aquatic primary production. It is essential for photosynthesis for the aquatic plants. In an aquatic ecosystem CO₂ is always present in the form of bicarbonate and carbonate. The low concentration of CO₂, HCO₃ and CO₃ increase the p^H of water that indicate the higher growth of phytoplankton and macrophytes as well as the suitability of pond water for fish culture. In the present study the free CO₂ was found to vary from 3.62 to 14.55mg/l with a mean value of 8.07±0.94mg/l. The result is similar to that of Kern (1960) and Wetzel (1985).

Total hardness: Swingle (1967) has suggested a total hardness of 50mg/l as CaCO₃ equivalent to the dividing line between soft and hard water. According to him pond waters having a hardness of 15mg/l or above are satisfactory for the growth of fish and do not require addition of lime, where as waters having hardness less than 12mg/l require liming for higher production of fish. In the present study the total hardness level of the pond water was ranged from 115mg/l to 162mg/l with a mean of 136.67±4.18mg/l which may concluded that the pond was suitable for fish culture. The result is more or less similar to Azim *et al.* (1995) and Wahab *et al.* (1995).

p^H: p^H is considered as an important factor in fish culture. An acidic p^H of water reduces the growth rate, metabolic rate and other physiological activities of fishes (Swingle, 1967). The two years observed average of p^H values were ranged from 6.73 to 8.23 with a mean of 7.45±0.14 which indicate that the pond is suitable for fish culture according to Swingle (1967) who reported that p^H range from 6.5 to 9.0 is suitable for pond fish culture. The p^H range of the study is more or less similar to the findings of Mollah and Haque (1978), Ali *et al.*, (1982), Hossain *et al.* (1997a) and Kohinoor *et al.* (1998).

Breeding performance: The two years trial of Natural breeding reveals that the *N. notopterus* is able to breed naturally in stagnant water of carp polyculture system. But the number of harvested juveniles was found lesser than expected. The reason behind this may be the unavailability of good breeding ground and hampering in parental care due to random operation of carp polyculture system. As a result huge

number of eggs may be damaged due to oxygen deficiency; and bacterial, protozoan and fungal infestations. The doubt is similar to the findings of Potts (1984). So, low but acceptable survival rate of fries were obtained at the end of second year trial. To achieve this result all together some positive factors like sandy-loam soil of the pond, submerged vegetation, suitable water quality and well adaptation of the fish act as key factor. The observation revealed that natural breeding of *N. notopterus* is possible in carp polyculture system. Research for conservation of this threatened species in natural condition is very scanty. Haniffa *et al.* (2004) made an attempt to conserve the species through natural breeding in captivity and Professor Dr. Md. Idris Mia of Bangladesh Agricultural University also took same attempt for conservation of *N. notopterus* through induced spawning techniques that not yet been transferred to the field level (Source: The Daily Prothom Alo; 22 June, 2008). But the findings of two years trial conclude for strong potentiality of natural breeding of *N. notopterus* which may play an important role in production and conservation of the species.

CONCLUSION AND RECOMMENDATIONS

CONCLUSION AND RECOMMENDATIONS

Climate change- one of the burning issues of the twenty first century seriously affects the life of both terrestrial and aquatic organisms. To assess this impact the research is carried out on the present status and basic requirements of life of *N. notopterus* for its successful management. The result provided some new and updated information on the morphometric structure, feeding behaviour, reproductive biology and gonadal structure of the fish which will be helpful to the fisheries scientists all over the world. Though *N. notopterus* is a small fish, it has very good consumer demand with relatively high price. It is a good diet for patients due to its nutritional value. The fish grows well in seasonal ponds and has no risk of over population and do not harm the culturable species rather helps to control the unwanted small fishes, insects, zooplanktons etc. On the basis of the culture experience the fish is regarded as a natural breeder and self recruiting species (SRS) that may be a turning point of poor farmers to use their derelict water bodies as a source of income generation including scope of employment. On the other hand the farmers themselves will be able to produce a good amount of fish for their own consumption which will increase their protein intake and ultimately to protect the protein energy malnutrition (PEM). It is also observed that the fish has a strong potentiality to breed in carp polyculture system and thus the findings of the present work may play an important role in the production and conservation of the species.

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APPENDICES

APPENDICES

Appendix Table II_a: Percentage distribution of male and female *N. notopterus* in relation to their size during the study period.

Length groups	No. of Male	No. of Female	Total specimens	Percentage of male considering size group	Percentage of female considering size group	Percentage of male considering total male	Percentage of female considering total female
07-09	45	39	84	53.57	46.43	6.39	5.30
09-11	38	45	83	45.78	54.22	5.40	6.11
11-13	37	40	77	48.05	51.95	5.26	5.43
13-15	52	44	96	54.17	45.83	7.39	5.98
15-17	47	59	106	44.34	55.66	6.68	8.02
17-19	53	71	124	42.74	57.26	7.53	9.65
19-21	63	71	134	47.01	52.99	8.95	9.65
21-23	67	76	143	46.85	53.15	9.52	10.33
23-25	81	87	168	48.21	51.79	11.51	11.82
25-27	66	73	139	47.48	52.52	9.38	9.92
27-29	80	74	154	51.95	48.05	11.36	10.05
29-31	61	48	109	55.96	44.04	8.66	6.52
31-33	14	9	23	60.87	39.13	1.99	1.22
Total	704	736	1440	48.89	51.11		

Appendix Table II_b: Seasonal variation in Fulton's, allometric and relative condition factor of *N. notopterus*.

Season	n	Mean±SE		
		Fulton's condition factor (K)	Allometric condition factor (K _a)	Relative condition factor (K _n)
Summer	503	0.889±0.015	0.779±0.013	1.011±0.017
Rainy	375	0.869±0.016	0.443±0.006	1.005±0.013
Winter	562	0.886±0.015	0.886±0.015	1.002±0.017

Note: n, sample size; SE, Standard Error

Appendix Table II_c: Sex-dependant variation in Fulton's, allometric and relative condition factor of *N. notopterus*.

Sex	n	Mean±SE		
		Fulton's condition factor (K)	Allometric condition factor (K _a)	Relative condition factor (K _n)
Male	704	0.862±0.003	0.784±0.003	1.004±0.004
Female	736	0.904±0.002	0.847±0.002	1.003±0.003
Combined	1440	0.884±0.002	0.816±0.002	1.003±0.002

Note: n, sample size; SE, Standard Error

Appendix Table II_d: Sex based percentage distribution of *N. notopterus* among different fin ray groups.

Name of Fin	Group Name of Rays	Male		Female		Combined Sex	
		No. of Fish Studied	Percentage	No. of Fish Studied	Percentage	No. of Fish Studied	Percentage
Dorsal	DRF-7	154	21.88*	183	24.86*	337	23.40*
	DRF-8	302	42.90**	325	44.16**	627	43.54**
	DRF-9	248	35.23	228	30.98	476	33.06
Pectoral	PFR-15	179	25.43*	207	28.13*	386	26.81*
	PFR-16	241	34.23	253	34.38	494	34.31
	PFR-17	284	40.34**	276	37.50**	560	38.89**
Pelvic	PvFR-5	321	45.60	353	47.96	674	46.81
	PvFR-6	383	54.40	383	52.04	766	53.19
Anal + Caudal	ACFR-99	38	5.40*	36	4.89	74	5.14*
	ACFR-100	70	9.94	68	9.24	138	9.58
	ACFR-101	53	7.53	40	5.43	93	6.46
	ACFR-102	68	9.66	72	9.78	140	9.72
	ACFR-103	49	6.96	72	9.78	121	8.40
	ACFR-104	55	7.81	82	11.14	137	9.51
	ACFR-105	106	15.06**	109	14.81**	215	14.93**
	ACFR-106	55	7.81	76	10.33	131	9.10
	ACFR-107	48	6.82	60	8.15	108	7.50
	ACFR-108	63	8.95	66	8.97	129	8.96
	ACFR-109	44	6.25	35	4.76	79	5.49
	ACFR-110	55	7.81	20	2.72*	75	5.21

Note: DFR, Dorsal fin rays; PFR, Pectoral fin rays; PvFR, Pelvic fin rays; ACFR, Anal and caudal fin rays; the symbol * means lowest value and ** means highest value.

Appendix Table IV_a: Monthly summary of the collection and observation of adult *N. notopterus* and status of female fish including sex-ratio.

Year	Months	Total no. of specimens	Total male	Total female	Percentage of male	Percentage of female	Sex-ratio (Male : Female)
2005	January	35	16	19	45.71	54.29	1:1.19
	February	55	29	26	52.73	47.27	1:0.90
	March	40	17	23	42.50	57.50	1:1.35
	April	47	21	26	44.68	55.32	1:1.24
	May	60	32	28	53.33	46.67	1:0.88
	June	59	30	29	50.85	49.15	1:0.97
	July	57	30	27	52.63	47.37	1:0.90
	August	57	26	31	45.61	54.39	1:1.19
	September	55	29	26	52.73	47.27	1:0.90
	October	53	25	28	47.17	52.83	1:1.12
	November	59	27	32	45.76	54.24	1:1.19
	December	50	28	22	56.00	44.00	1:0.79
2006	January	47	26	21	55.32	44.68	1:0.81
	February	48	25	23	52.08	47.92	1:0.92
	March	42	23	19	54.76	45.24	1:0.83
	April	50	25	25	50.00	50.00	1:1.00
	May	52	27	25	51.92	48.08	1:0.93
	June	50	24	26	48.00	52.00	1:1.08
	July	53	28	25	52.83	47.17	1:0.89
	August	54	29	25	53.70	46.30	1:0.86
	September	52	28	24	53.85	46.15	1:0.86
	October	51	26	25	50.98	49.02	1:0.96
	November	50	23	27	46.00	54.00	1:1.17
	December	49	24	25	48.98	51.02	1:1.04
Total		1225	618	607	50.45	49.55	1:0.98

Appendix Table IV_b: Calculated value of total χ^2 , overall χ^2 including χ^2 heterogeneity.

Year	Month	Sex	O	E	(O-E)	(O-E) ²	$\chi^2 = \frac{(O-E)^2}{E}$	Total χ^2	χ^2 Heterogeneity
2005	Jan	Male	16	17.50	-1.5	2.25	0.13	6.50	6.40
		Female	19	17.50					
	Feb	Male	29	27.50	1.5	2.25	0.13		
		Female	26	27.50					
	Mar	Male	17	20	1.5	2.25	0.08		
		Female	23	20					
	Apr	Male	21	23.50	-1.5	2.25	0.08		
		Female	26	23.50					
	May	Male	32	30	-3	9	0.45		
		Female	28	30					
	Jun	Male	30	29.50	3	9	0.45		
		Female	29	29.50					
Jul	Male	30	28.50	-2.5	6.25	0.27			
	Female	27	28.50						
Aug	Male	26	28.50	2.5	6.25	0.27			
	Female	31	28.50						
Sep	Male	29	27.50	2	4	0.13			
	Female	26	27.50						
Oct	Male	25	26.50	-2	4	0.13			
	Female	28	26.50						
Nov	Male	27	29.50	0.5	0.25	0.01			
	Female	32	29.50						
Dec	Male	28	25	-0.5	0.25	0.01			
	Female	22	25						
2006	Jan	Male	26	23.50	1.5	2.25	0.08		
		Female	21	23.50					
	Feb	Male	25	24	-1.5	2.25	0.08		
		Female	23	24					
	Mar	Male	23	21	-2.5	6.25	0.22		
		Female	19	21					
	Apr	Male	25	25	2.5	6.25	0.22		
		Female	25	25					
	May	Male	27	26	1.5	2.25	0.08		
		Female	25	26					
	Jun	Male	24	25	-1.5	2.25	0.08		
		Female	26	25					
	Jul	Male	28	26.50	-1.5	2.25	0.08		
		Female	25	26.50					
	Aug	Male	29	27	1.5	2.25	0.08		
		Female	25	27					
	Sep	Male	28	26	-2.5	6.25	0.21		
		Female	24	26					
	Oct	Male	26	25.50	2.5	6.25	0.21		
		Female	25	25.50					
	Nov	Male	23	25	3	9	0.36		
		Female	27	25					
	Dec	Male	24	24.50	-3	9	0.36		
		Female	25	24.50					
Overall χ^2		Male	618	612.5	5.5	30.25	0.05	0.10	
		Female	607	612.5	-5.5	30.25	0.05		

Appendix Table IV_c: Range and mean $\pm$ SE of length and weight of ovary in different stages of maturity of *N. notopterus*.

Stages of maturation	Length (cm)		Weight (g)	
	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE
I. Immature	1.65-2.85	2.28 $\pm$ 0.05	0.41-1.90	1.07 $\pm$ 0.06
II. Maturing	1.60-4.30	3.16 $\pm$ 0.04	0.75-17.87	5.84 $\pm$ 0.30
III. Mature	3.20-4.95	4.13 $\pm$ 0.07	6.00-22.90	12.51 $\pm$ 0.66
IV. Ripe	3.20-5.25	4.37 $\pm$ 0.05	6.20-26.60	16.37 $\pm$ 0.56

Appendix Table V_a: Average marketing costs involved during marketing of *N. notopterus* (Tk/kg) in four fish markets of Rajshahi City Corporation.

Items detail	In season		Off season	
	Average Cost	Percentage with total cost	Average Cost	Percentage with total cost
1. Packing materials (container, polythene, rope, jute bag etc.)	1.56	12.38	1.56	12.20
2. Transportation (trolley, rickshaw, van, motor van etc.)	1.00	7.92	1.13	8.78
3. Unloading (labour charge)	0.38	2.97	0.38	2.93
4. Aratders' commission @ Tk. 3-4%	6.00	47.52	6.00	46.83
5. Display cost for retailers (polythene, tray, water etc.)	0.31	2.48	0.31	2.44
6. Consumer service (polythene bags for handover the fish)	0.75	5.94	0.75	5.85
7. Incidental costs	1.88	14.85	1.88	14.63
8. Market toll and taxes	0.25	1.98	0.25	1.95
9. Miscellaneous (telephone, entertainment etc.)	0.50	3.96	0.56	4.39
Average Total Cost	12.63	100	12.81	100

Appendix Table V_b: Marketing costs involved during marketing of *N. notopterus* (Tk/kg) among four fish markets of Rajshahi City Corporation.

Items detail	In season cost (Tk/kg)								Off season cost (Tk/kg)							
	Shaheb Bazar		Shalbagan Bazar		Court Bazar		Binodpur Bazar		Shaheb Bazar		Shalbagan Bazar		Court Bazar		Binodpur Bazar	
	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
1. Packing materials (container, polythene, rope, jute bag etc.)	1.5	12	1.25	11.11	1.75	13.21	1.75	12.96	1.5	11.54	1.25	10.87	1.75	13.21	1.75	1.5
2. Transportation (trolley, rickshaw, van, motor van etc.)	0.75	6	0.5	4.44	1.25	9.43	1.5	11.11	1	7.69	0.75	6.52	1.25	9.43	1.5	0.75
3. Unloading (labour charge)	0.25	2	0.25	2.22	0.5	3.77	0.5	3.70	0.25	1.92	0.25	2.17	0.5	3.77	0.5	0.25
4. Aratders' commission @ Tk. 3-4%	6	48	6	53.33	6	45.28	6	44.44	6	46.15	6	52.17	6	45.28	6	6
5. Display cost for retailers (polythene, tray, water etc.)	0.5	4	0.25	2.22	0.25	1.89	0.25	1.85	0.5	3.85	0.25	2.17	0.25	1.89	0.25	0.5
6. Consumer service (polythene bags for handover the fish)	0.75	6	0.75	6.67	0.75	5.66	0.75	5.56	0.75	5.77	0.75	6.52	0.75	5.66	0.75	0.75
7. Incidental costs	2	16	1.5	13.33	2	15.09	2	14.81	2	15.38	1.5	13.04	2	15.09	2	2
8. Market toll and taxes	0.25	2	0.25	2.22	0.25	1.89	0.25	1.85	0.25	1.92	0.25	2.17	0.25	1.89	0.25	0.25
9. Miscellaneous (telephone, entertainment etc.)	0.5	4	0.5	4.44	0.5	3.77	0.5	3.70	0.75	5.77	0.5	4.35	0.5	3.77	0.5	0.5
Total cost	12.5	100	11.25	100	13.25	100	13.5	100	13	100	11.5	100	13.25	100	13.5	12.5

Appendix Table V_c: Marketing costs of different intermediaries during marketing of *N. notopterus* (Tk/kg) among four fish markets of Rajshahi City Corporation.

Items detail	In season cost (Tk/kg)								Off season cost (Tk/kg)							
	Shaheb Bazar		Shalbagan Bazar		Court Bazar		Binodpur Bazar		Shaheb Bazar		Shalbagan Bazar		Court Bazar		Binodpur Bazar	
	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
Faria	1.25	10	1	8.89	1.25	9.43	1.25	9.26	1.5	11.54	1	8.70	1.25	9.43	1.5	11.11
Bepari	7.75	62	7.5	66.67	7.75	58.49	7.75	57.41	7.75	59.62	7.5	65.22	7.5	56.60	8	59.26
Retailer	3.5	28	2.75	24.44	4.25	32.08	4.5	33.33	3.75	28.85	3	26.09	4.5	33.96	4	29.63
Total cost	12.5	100	11.25	100	13.25	100	13.5	100	13	100	11.5	100	13.25	100	13.5	100

Appendix Table V_d: Marketing margin for *N. notopterus* in Shaheb Bazar.

Intermediary	Items detail	In season		Off season	
		Taka/kg	Percentage with consumers price	Taka/kg	Percentage with consumers price
$i = 1^{th}$ Intermediary (Faria)	Price Paid (PPi) Price Received by Fisherman (PRF)	110	74.32	130	72.22
	Marketing Cost (MCi)	1.25	0.84	1.5	0.83
	Gross Margin (GMi)	5.75	3.89	8.5	4.72
	Net Margin (NMi)	4.5	3.04	7	3.89
	Price Received (PRi)	115.75	78.21	138.5	76.94
$i = i^{th}$ Intermediary (Bepari)	Price Paid (PPi)	115.75	78.21	138.5	76.94
	Marketing Cost (MCi)	7.75	5.24	7.75	4.31
	Gross Margin (GMi)	16.75	11.32	19.75	10.97
	Net Margin (NMi)	9	6.08	12	6.67
	Price Received (PRi)	132.5	89.53	158.25	87.92
$i = i^{th}$ Intermediary (Retailer)	Price Paid (PPi)	132.5	89.53	158.25	87.92
	Marketing Cost (MCi)	3.5	2.36	3.75	2.08
	Gross Margin (GMi)	15.5	10.47	21.75	12.08
	Net Margin (NMi)	12	8.11	18	10.00
	Price Received (PRi)	148	100	180	100.00
Total Gross Margin (TGM)		38	25.68	50	27.78
Price Paid by Consumer (PPC)		148	100	180	100

Formulae Used:

Gross Margin (GMi) = $PR_i - PP_i$ Net Margin (NMi) = $GM_i - MC_i$ Price Paid by Consumer (PPC) = $PRF + TGM$

Appendix Table V_c: Marketing margin for *N. notopterus* in Shalbagan Bazar.

Intermediary	Items detail	In season		Off season	
		Taka/kg	Percentage with consumers price	Taka/kg	Percentage with consumers price
i = 1th Intermediary (Faria)	Price Paid (PPi) Price Received by Fisherman (PRF)	105	75.00	125	73.53
	Marketing Cost (MCi)	1	0.71	1	0.59
	Gross Margin (GMi)	5	3.57	7	4.12
	Net Margin (NMi)	4	2.86	6	3.53
	Price Received (PRi)	110	78.57	132	77.65
i = 1th Intermediary (Bepari)	Price Paid (PPi)	110	78.57	132	77.65
	Marketing Cost (MCi)	7.5	5.36	7.5	4.41
	Gross Margin (GMi)	15.25	10.89	18	10.59
	Net Margin (NMi)	7.75	5.54	10.5	6.18
	Price Received (PRi)	125.25	89.46	150	88.24
i = 1th Intermediary (Retailer)	Price Paid (PPi)	125.25	89.46	150	88.24
	Marketing Cost (MCi)	2.75	1.96	3	1.76
	Gross Margin (GMi)	14.75	10.54	20	11.76
	Net Margin (NMi)	12	8.57	17	10.00
	Price Received (PRi)	140	100.00	170	100.00
Total Gross Margin (TGM)		35	25.00	45	26.47
Price Paid by Consumer (PPC)		140	100	170	100

Formulae Used:

Gross Margin (GMi) = PRi-PPi

Net Margin (NMi) = GMi-MCi

Price Paid by Consumer (PPC) = PRF+ TGM

Appendix Table V_f: Marketing margin for *N. notopterus* in Court Bazar.

Intermediary	Items detail	In season		Off season	
		Taka/kg	Percentage with consumers price	Taka/kg	Percentage with consumers price
$i = i^{\text{th}}$ Intermediary (Faria)	Price Paid (PPi) Price Received by Fisherman (PRF)	110	70.97	130	70.27
	Marketing Cost (MCi)	1.25	0.81	1.25	0.68
	Gross Margin (GMi)	7	4.52	9.75	5.27
	Net Margin (NMi)	5.75	3.71	8.5	4.59
	Price Received (PRi)	117	75.48	139.75	75.54
$i = i^{\text{th}}$ Intermediary (Bepari)	Price Paid (PPi)	117	75.48	139.75	75.54
	Marketing Cost (MCi)	7.75	5.00	7.5	4.05
	Gross Margin (GMi)	17.75	11.45	19.75	10.68
	Net Margin (NMi)	10	6.45	12.25	6.62
	Price Received (PRi)	134.75	86.94	159.5	86.22
$i = i^{\text{th}}$ Intermediary (Retailer)	Price Paid (PPi)	134.75	86.94	159.5	86.22
	Marketing Cost (MCi)	4.25	2.74	4.5	2.43
	Gross Margin (GMi)	20.25	13.06	25.5	13.78
	Net Margin (NMi)	16	10.32	21	11.35
	Price Received (PRi)	155	100.00	185	100.00
Total Gross Margin (TGM)		45	29.03	55	29.73
Price Paid by Consumer (PPC)		155	100	185	100

Formulae Used:

Gross Margin (GMi) = PRi-PPi

Net Margin (NMi) = GMi-MCi

Price Paid by Consumer (PPC) = PRF+ TGM

Appendix Table V_g: Marketing margin for *N. notopterus* in Binodpur Bazar.

Intermediary	Items detail	In season		Off season	
		Taka/kg	Percentage with consumers price	Taka/kg	Percentage with consumers price
i = ith Intermediary (Faria)	Price Paid (PPi) Price Received by Fisherman (PRF)	105	72.41	125	71.43
	Marketing Cost (MCi)	1.25	0.86	1.5	0.86
	Gross Margin (GMi)	5.75	3.97	8.5	4.86
	Net Margin (NMi)	4.5	3.10	7	4.00
	Price Received (PRi)	110.75	76.38	133.5	76.29
i = ith Intermediary (Bepari)	Price Paid (PPi)	110.75	76.38	133.5	76.29
	Marketing Cost (MCi)	7.75	5.34	8	4.57
	Gross Margin (GMi)	16.75	11.55	19.5	11.14
	Net Margin (NMi)	9	6.21	11.5	6.57
	Price Received (PRi)	127.5	87.93	153	87.43
i = ith Intermediary (Retailer)	Price Paid (PPi)	127.5	87.93	153	87.43
	Marketing Cost (MCi)	4.5	3.10	4	2.29
	Gross Margin (GMi)	17.5	12.07	22	12.57
	Net Margin (NMi)	13	8.97	18	10.29
	Price Received (PRi)	145	100.00	175	100.00
Total Gross Margin (TGM)		40	27.59	50	28.57
Price Paid by Consumer (PPC)		145	100	175	100

Formulae Used:

Gross Margin (GMi) = PRi-PPi

Net Margin (NMi) = GMi-MCi

Price Paid by Consumer (PPC) = PRF+ TGM