PROJECT REPORT

STUDIES ON NON-PISCIAN RESOURCES SUCH AS CRABS & SNAILS AS FOOD BY THE PLAIN TRIBES OF ASSAM

(Sponsored by Assam Institute of Research for Tribals and Scheduled Caste, Govt. of Assam)

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* *Central Marine Fisheries Research Institute, Ernakulam.*
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CHAPTER I

INTRODUCTION

Non-piscian fishery resources including snails, crabs, prawns, shrimps, lobster, frog etc. are regarded as important resources alongwith both fresh and marine water fishes. The amount of fish produce in India could not meet the required demand corresponding to the number of population in our country. During this year of the celebration of the 50th anniversary of independence, it will be appropriate to ponder over and critically examine aspects pertaining to fish and fisheries along with the non-piscian resources that offer key to the production of less expensive protein diet which is valuable to the growing population and to increase or develop the economic situation of our country. The present requirement of fish in India is 3 million tonnes, whereas the current production is about 1.8 million tonnes (Prasad Rao, 1988). According to Marine products Export Development Authority reports, potential areas identified as suitable for aquaculture include 2.25 million hectares of ponds and tanks. 1.30 million hectares of lakes and 2.09 million hectares reservoirs. There is a vast scope for culturing and production of fish and other non-piscian species which could combat the requirement in the next century.

Varieties of snails, crabs, prawns, shrimps, lobsters etc. are available along with piscian fauna as non-piscian groups all over the world. Their habitat could be marine, freshwater or terrestrial. The size ranges from a few mm. to lucrative table size of commercial importance. In the present studies, the emphasis has been laid upon snails and crabs. Although there are varieties of snails and crabs in different habitat throughout the world, only certain selected varieties are recognize as edible species for human consumption.

The identification and its propagation of non-piscian fauna belonging to crabs and snails etc. is of paramount significance in India and North East India in particular. The Brahmaputra and the Barak river systems with its large number of perennial tributaries hill streams, swamps, beels (flood plains), man made ponds, reservoir etc. afford lucrative possibilities for its exploitation and propagation of the various such non-piscian fauna. However, there is scant information on its propagation of those resources. Further, it has been recognized that North Eastern Part is a hot spot concerning the occurrence of great biodiversity concerning different ecological riches.

Besides of their use as food there are example of lores that the consumption of these items in the day-to-day diet can cure various leisions relating to human health.

The Brahmaputra and the Barak river valleys along with the hilly regions of Assam are inhabited by various plains and hill tribes. It has been found that these people use various species of snails and crabs in their diet either by cooking or in raw conditions. Besides, some species have also been identified to be of commercial value as indicated by their high prices in different markets or trading centres. Although some tribes claim that molluscans or crustaceans are used in curing several health ailments, yet upto now no systematic studies have been made to evaluate their food value or the kind of edible species practiced by various tribes in different parts of the state.

The farming of snails and crabs have not been systematically developed. The various groups of tribals simply harvest them from the natural or wild water through traditional technique. Also, there is lack of well-organized market system for such products. In wild water or in ponds both groups grow to lucrative sizes in large numbers too. In certain areas the samples are either destroyed or thrown away without consumption or rearing. On the other way several tribal groups use these sample as duck-feed and recent report suggests that some fish farmers are using them as feed for cat fish farming. As a whole the exploitation of these resources is being carried out without any organized or systematic scientific planning. Now it is high time to consider their proper management and propagation for encouraging entrepreneurship development for the unemployed educated youth.

AIMS & OBJECTIVES

The aims and objectives of the present investigation are to explore the non-piscian resources such as snails and crabs of Assam with certain ideas of its taxonomic diversity, habit, habitat, ecology, propagation and food value. The detailed aspects are

i. Identification of various species of snails and crabs available in Assam.

ii. Habit, habitat and ecology pertaining to the dwelling environment.

iii. Reproductive features relating to reproduction.

iv. A brief aspects of growth and farming as well as their market potential.

v. Evaluation of food value viz. —

   (a) Snail eating habit :- Identification of edible snails.

   (b) Biochemical composition.

   (c) Biological value of the protein of snail and crabs.

   (d) Sanitation and hygiene during consumption. Health and hygiene of the consumers.

   (e) Eating of such food items and their link with certain health problem, if any.

CHAPTER - II

MATERIALS AND METHOD

The materials used and the methodology followed during the present study have been summarised as follows :

Collection of samples of snail and crabs :

Different samples of snails and crabs were collected from different regions of Assam either from (i) the rivers, swamps, beels, lakes, ponds etc. or (ii) directly from the fisherman's catch. Survey spots were visited periodically and the community fishing sites were also examined in different parts of the state in each year during December to March (1994-98). Fishing nets and traps were used while collecting the samples. Further, fishermen were employed directly in some sites for collection of crabs and snails.

The collected samples were packed in air tight polythene bags and taken to the laboratory for preservation. In certain cases, the preservation was made either in 7% formaline or in 70% alcohol immediately after catch.

Identification of the Samples :

The snails were identified following the procedure of Rao (189).

The crabs were identified following the taxonomic citation of Alcock (1910) and Chopra (1934).

The key for the identification of snails were followed as such :

The specimens collected were (i) preserved in formalin (5%) or (ii) shells were dried. The specimens were then brought to the laboratory and the identification were made following the key forwarded by Rao (1989).

KEY TO IDENTIFICATION OF MOLLUSCS :

1. Shell larger in size, inner lip and outer lip of the aperture strongly thickened and reflected, foot broad and not grooved. Aperture of the shell in life in closed by a circular or horny operculum.

   - *Cyclophotidae*

2. Shell small to large, globosly inflated, aperture large and ovate, operculum usually calcified, concentric; surface usually with bands or smooth.

   - *Pilidae.*

3. Shell of moderate size, smooth with or without bands, narrowly perforated or imperforate, aperture orbicular, found in stagnant waters.

   - *Viviparidae*

4. Shell elongated turreted, usually many whorled often with varied sculptures, spines or tubercles, sometimes rather smooth with roundish aperture ovate, usually angular below; usually found in streams.

   - *Thiaridae*

5. Shell thin, smooth, polished and ovate, spire elevated and pointed, body whorl large, columella twisted.

   - *Lymnidae*

6. Shell discoidally flattened, quite often disc shaped, spire very rarely raised.

   - *Planorbidae*

7. Shell thick and massive, trigonal and roundly ovate with course spiral striations. Umbones often eroded shell with two values.

   - *Corbiculidae*

8. Columellar fold not twisted, found on land or even trees.

   - *Succineidae*

9. Shell transversely elongated, ligament internal, outer surface without concentric shell, shell with two valves.

   - *Unionidae*

Limno-hydrobiological studies :

Water samples from the different habitat (places of different stations/habitat are shown in the respective chapter) of snails and crabs were collected and analysed. Studies on different parameters like dissolved oxygen (DO), hydrogen ion concentration (pH), carbon-dioxide, alkalinity, turbidity, productivity and water temperature etc. were followed after APHA (1985).

Dissolved oxygen (DO) was determined by Winkler's modified method. The hydrogen ion concentration was determined by using universal indicators in field and checked in the laboratory by pH meter (System X pH meter). Dissolved carbondioxide was determined using Sodium

hydroxide with phenophthalin as an indicator, and the alkalinity was determined by the double indicator method. Turbidity or transparency was determined by succi-disc and the water temperature by a 50°C Thermometer.

Identification of Plankton and other aquatic vegetation :

The aquatic vegetation viz. macrophytes, microphytes and zooplankton were identified from the references followed (Chutia *et al.*, 1991 ; Dutta *et al.*, 1990, 1993 ; Goswami, 1985 ; Naskar, 1989 ; Needham and Needham, 1980 ; Yadav *et al.*, 1984, 1987).

Biochemical analysis :

The different biochemical parameters were analysed following the procedures outlined below.

Moisture :

Moisture was estimated following the air oven drying method of Hart and Fisher (1971).

Total Nitrogen :

Total nitrogen content of the samples were determined by modified microkjeldel method described by Peace and Tray (1956). The methods involved sulphuric acid digestion, following by distillation and titration with N/28 HCl.

Protein nitrogen was determined first by precipitate to microkjeldal method as referred for estimation of total nitrogen.

Non-protein nitrogen was estimated by substracting the value of protein nitrogen from total nitrogen and was estimated as non-protein nitrogen.

Total protein :

Total protein values were obtained by multiplying the corresponding value of nitrogen by Kirk's conversion co-efficient i.e. 6.25 (Geigen and Borgstrom, 1962).

Amino acids :

Total amino acid content was determined by nin-hydrin methods described by Moore and stein (1948) using citric acid buffer and ninhydrin reagent along with diluent solution.

Thin layer chromatography (two dimensional) was followed as described by Plummer (1979).

Ash content :

Ash content was determined after ignition of the sample at 550°C in a muffle furnace for about 2 hours. Carbon-free white grey ash was weighted and expressed in percentage of wet weight of the sample.

Estimation of different minerals :

Different mineral content were estimated from the ash samples through 3120 Perkin Elmer atomic absorption spectroscopy using standard samples.

Estimation of carbohydrate :

Carbohydrate content was estimated using anthrone reagent described by Dubois *et al.*, 1951.

Estimation of glycogen :

The procedure is based on the released of glycogen by alkaline hydrolysis and measurement of intensity of colour producing reaction by anthrone as forwarded by Plummer, (1979).

Estimation of Fatty acids :

The methyl ester of extracted fat from the muscles were subjected to gaschromatography using standard fatty acids and finally estimation of the composition of different fatty acids. The alkaline hydrolysis were made during the preparation of methyl esters.

Calorific value :

Calorific value was determined from the muscles of crabs and snails after Saleem and Jafri (1978).

To find out the calorific values of isolated tissue, samples were dried in oven at 40°C until constant weight were obtained, the dried tissues were homogenised and the calorific values were determined using Advance Bomb Calorimety method. In this method amount of heat evolved was measured. Sample materials were burnt in a sealed chamber (Bomb) in presence of pure oxygen gas. In the sealed Bomb Calorimeter one gram of dried grinded sample making pellet was burnt. Initial temperature of the Bomb Calorimeter, jacket water and bucket water was recorded prior to the burning of sample. The change of temperature after firing to burn the sample was noted with the help of Beckman thermometer.

To find out calorific values of the samples, calculations were done according to standard methods of Advance Bomb Calorimeter. The water equivalent of the Calorimeter was determined following the formula.

$$W = \frac{HM + E_1 + E_2}{T}$$

Where,

W = Energy equivalent of calorimeter in calories per degree centigrade.

H = Heat of the combustion of standard benzoic acid in calories/g.

M = Mass of standard benzoic acid sample (g).

T = Corrected temperature rise in °C.

E_1 = Correction for heat formation of nitric acid in calories.

E_2 = Correction of heat Combustion of firing wire, in calories.

And, lastly energy content was calculated as :

$$\text{Energy of sample} = \frac{W \times T - (W + T)}{\text{Weight of the sample}} = \text{K cal/g}$$

Evaluation of protein value/Biological evaluation of protein :

For the digestibility test, the fresh samples of only a particular size group of a species and of only one season (November to December) was collected from their habitat. The sampling methods were same as adopted as described.

Reagents :

All the chemicals used were of 'Analytical grade' Pepsin (activity 1 : 3000) and trypsin (activity 1 : 250) were obtained from Loba-Chemic (Bombay). Double glass distilled water was used for preparation of the reagents. The solutions were prepared just before use from freshly opened bottles.

Pepsin Solution :

0.2 percent pepsin solution was prepared following the method of AOAC (1975). 2 gms. of fresh pepsin was added in 1000 ml. of dilute HCl (0.61% aqueous solution) pre-warmed at 42 - 45°C. The solution was stirred gently until dissolved.

Defatting of Sample :

4 gms. of the sample was homogenized with 30 ml. (1 : 20 w/v) of Chloroform-methanol mixture (2 : 1 v/v) following the method described by Overturf and Dryer (1969) for extraction of total lipids. The sample was suspended for 2 hours in the solvent mixture and then filtered through Whatman No.1 filter paper. The residue was resuspended for 1 hour and then filtered. The residue was collected and dried in an electric oven at 60°C. The defatted sample thus obtained was powdered and was ready for the digestibility experiment.

Pepsin and Trypsin Digestion :

1 gm. each of the finely ground defatted samples were taken in six 250 ml. conical flasks. To each flask, 150 ml. of freshly prepared standard pepsin solution was added and mixed thoroughly. The flasks were incubated at 42 ± 2°C for 2 hours. The suspension was thoroughly shaken from time to time. At the end of 2 hours, 3 conical flasks were taken out and the suspensions were filtered.

Simultaneously, at the end of 2 hours, the contents of the remaining 3 flasks were adjusted to pH 8.2 with 5N NaOH. To each flask, 0.3 gm. of trypsin was added. Then the solutions were incubated at 42 - 45°C for 22 hours and were shaken from time to time (Valanju and Sohonie, 1957). The suspensions were filtered. Enzyme blanks were run along with every experiment.

Determination of Digestible Nitrogen :

Total nitrogen values were estimated from the indigestible residue separately after the pepsin action and the combined pepsin and trypsin action. Values of digestible nitrogen were obtained by subtracting the values of nitrogen of the indigestible residues from those of the samples. Values of total nitrogen contents of the fishes and the fermented fish products are shown in Chapter III and IV respectively. The corresponding values of proteins were calculated by multiplying the values of nitrogen by 6.25. The results were expressed in percentage of wet weight of the samples using the following formula (modified from that of AOAC, 1975).

$$\text{Protein Digestible (\%)} = \frac{(\text{Protein in sample} - \text{Protein in residue}) \times 100}{\text{Protein in sample}}$$

CHAPTER III

TAXONOMIC STATUS OF THE COLLECTED SPECIMEN OF SNAILS AND CRABS

Snails :-

Throughout the study period altogether 40 species of gastropods were collected. Their systematic position and brief diagnostic characters have been presented.

Phylum : Mollusca
Class : Gastropoda
Order ; Basomatophora
Family : Lymnaeidae

Characters : Size varies from 5mm to 50 mm., spire pointed and of variable height, columellar axis typically twisted, the shell dextral and ovately oblong.

Distribution : India : Jammu & Kashmir, Assam, Andhra Pradesh; Burma.

Sample Species # 1. Species : *Lymnea luteola. f. impura* (Lamarck)
Sample Species # 2. Species : *L. acuminata f. refuscens* (Gray)
Sample Species # 3. Species : *L. acuminata f. gracilior* (Martens)
Sample Species # 4. Species ; *L. luteola f. ovalis* (Gray)
Sample Species # 5. Species : *L. luteola f. typica* (Lamarck)

Family : Planorbidae

Characters : Shells flattened discoidal with small aperture, apex do not project over the plan, foot simple, elongate and tapers to a point posteriorly, a broad and short-fleshy portion known as vellum situated above the foot in its anterior region, Vellum bears the head, tentacles and eyes.

Distribution : Throughout the plains of India, Pakistan, Srilanka, Burma, Thailand, Sumatra, Java and Bangladesh.

Sample Species # 6. Species : *Indopanorbis exustus* (Deshayes, 1834)

Order : Mesogastropoda
Family : Bithyniidae

Characters : Shells ovate to elongate-turreted, narrowly umbilicate to imperforate, moderately convex whorls, aperture ovate to round, sometimes expanded basally, operculum as long as aperture, calcareous and concentric with a small subcentral, spiral nucleus.

Distribution : Europe, India (Kashmir, Assam, West Bengal, Bihar, Punjab, Madhya Pradesh), Pakistan.

Sample Species # 7. Species : *Digoniostoma cerameopoma* (Benson)

Family : Viviparidae

Characters : Shells are generally olive brown or green, moderately large, whorls inflated, aperture ovate, shells of females are larger than that of males, operculum horny, concentric with a subcentral nucleus.

Distribution : Common throughout India and Burma.

Sample Species # 8. Species : *Angulyagra oxytropis*
Sample Species # 9. Species : *Bellamya bengalensis* (Lamarck,1882)
Sample Species # 10. Species : *B. bengalensis f. typica* (Lamarck)
Sample Species # 11. Species : *B. dissimilis* (Mueller)
Sample Species # 12. Species : *Cipangopaludina lecythis* (Benson)

Family : Pilidae

Characters : A large perforated or imperforate shells with an inflated body whorl and short spire, shells are generally green or olive brown in colour, operculum large, calcareous and concentric with a subcentral nucleus.

Distribution : India (Maharasthra, Madhya Pradesh, Uttar Pradesh, Bihar, West Bengal and Assam), Bangladesh.

Sample Species # 13. Species : *Pila globosa* (Swainson, 1822)
Sample Species # 14. Species : *P. theobaldi* (Henley)
Sample Species # 15. Species : *P. scutata* (Mousson)
Sample Species # 16. Species : *P. virens* (Lamarck)

Family : Thiaridae

Characters : The shell are elongated to ovate conical, whorls rounded with moderate or impressed structure, sculpture smooth to spiral or longitudinal ridges, aperture generally narrowly ovate, operculum smaller than aperture.

Distribution : India (Gangetic Plain, West Bengal, N. E. India), Burma, Malay, Archipelago, Indonesia, Sumatra, Java and Bangladesh.

Sample Species # 17. Species : *Brotia costula* (Rafinesque, 1833).
Sample Species # 18. Species : *Paludomus conica* (Gray)
Sample Species # 19. Species : *Thiara (Tarebia) lineata* (Gray)
Sample Species # 20. Species : *T. tuberculata* (Muller, 1774)
Sample Species # 21. Species : *T. scabra.*(Muller)
Sample Species # 22. Species : *Sulcospira hugeli* (Philippi)
Sample Species # 23. Species : *Paludomus f. conica*
Sample Species # 24. Species : *P. pustulosa*
Sample Species # 25. Species : *P. reticulata* (Blanford)
Sample Species # 26. Species : *T. granifera* (Lamarck, 1822)
Sample Species # 27. Species : *Digoniostoma cerameopoma* (Benson)

Family : Cyclophoridae

Characters : Shell is of moderate size, opercular opening is almost half of the size of the shell.

Distribution : North East India, Bangladesh, West Bengal and Orissa.

Sample Species # 28. Species : *Cyclophorus bensoni* (Pfeiffer)

Order : Stylomatophora
Family : Ariophanitidae

Characters : Shell is conical in shape. Foot is prominent and movement is quite active.

Distribution : Assam, Arunachal Pradesh, Meghalaya, Tripura, West Bengal and Orissa.

Sample Species # 29. Species : *Macrochlamys indica*

Family : *Achatinidae*

Characters : Land snails inhabiting the tropical regions. Shells are big in size attaining 10 to 15 cm. size. Prominent foot with long tentacles and secrat high amount of slime. Voracious plant eater (agricultural crop).

Distribution : Throughout India, Burma, Bangladesh, Pakistan, Sri Lanka, Thailand etc.

Sample Speices # 30. Species : *Achatina fulica fulica* (Bowdich)

Family : Ariophantidae

Characters : Shell is of moderate size with tappering the tip. Foot small in size, tentacles are small.

Distribution : North and North East India, Burma.

Sample Speices # 31. Species : *Macrochlamys indica*

Class : Bivalvia
Order : Unionida
Family : Amblemidae

Characters : Shells are medium size, generally thick tooth shaped, distinct radial zigzag ribs on beaks.

Distribution : India (N. E. India, West Bengal, Bihar, Andhra Pradesh, Karnataka, Maharashtra, Uttar Pradesh), Bangladesh, Burma, Indonesia and China.

Sample Speices # 32. Species : *Parreysia (p) favidens assamensis* (Preston)
Sample Speices # 33. Species : *Parreysia favidens*
Sample Speices # 34. Species : *P. (p) favidens plagiosoma* (Benson)
Sample Speices # 35. Species : *P. (p) (Radiatula) bonneaudi* (Eydoux)
Sample Speices # 36. Species : *P(p) (Radiatula) lima* (Simpson)
Sample Speices # 37. Species : *P(p) (Radiatula) occata* (Lea)

Family : Corbiculidae

Characters : Shells rounded-triangular to oval, strong fibrous periostracum, three cardinal teeth in each valve, ligament strong.

Distribution : South America, Africa, Australia, India (West Bengal, Bihar, Assam), Pakistan and Srilanka.

Sample Speices # 38. Species : *Corbiculus striatella*
Sample Speices # 39. Species : *C. assamensis* (Prasad)

Family : Unionidae

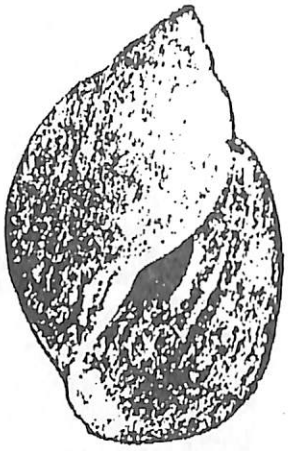
Characters : Shell equivalve, covered with a thick periostracum, umbonal cavity deep, ligament elongated and projecting, periostracum smooth and dark brown.

Distribution : Common throughout India, Bangladesh, Burma.

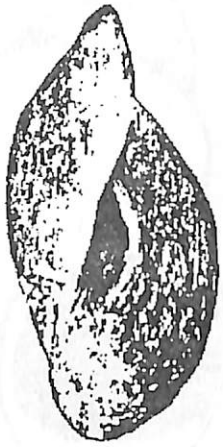
Sample Species # 40. Species : *Lamellidens corrianus* (Lea, 1834)

PLATE-I

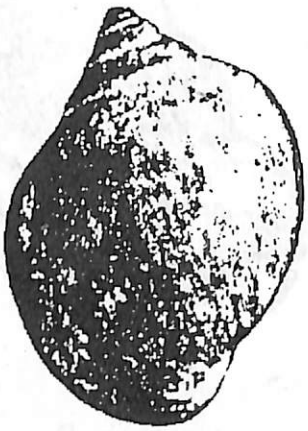
Lymnea luteola. f. impura



L. acuminata f. refuscens



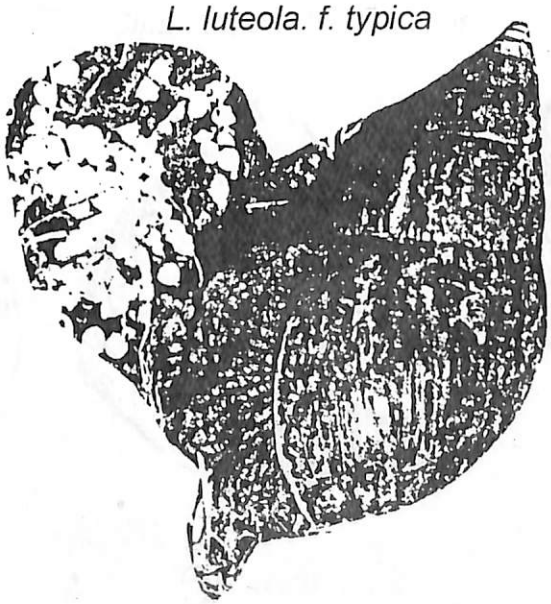
L. acuminata f. gracilior



L. luteola. f. ovalis

L. luteola. f. typica

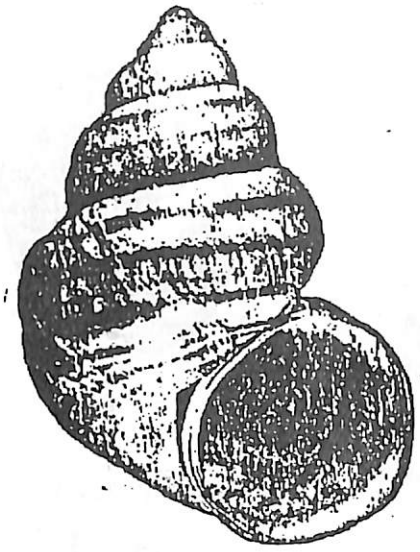
Indopianorbis exustus



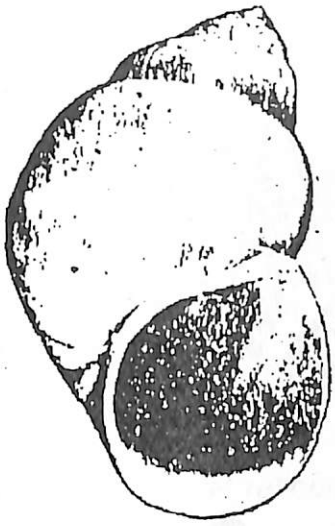
Achatina fulica fulica

PLATE-2

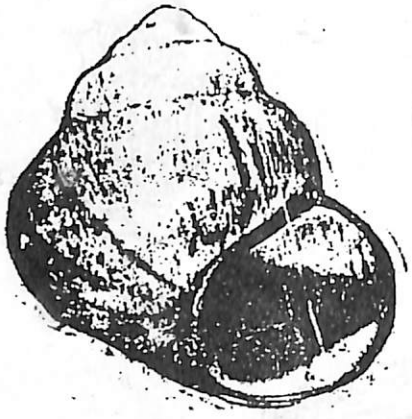
Angulyagra oxytropis



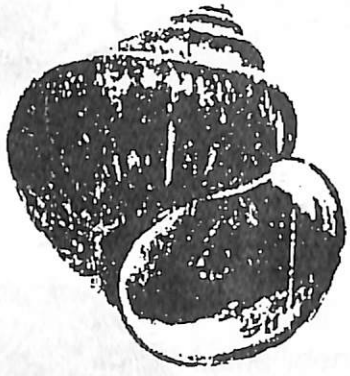
Bellamy bengalensis



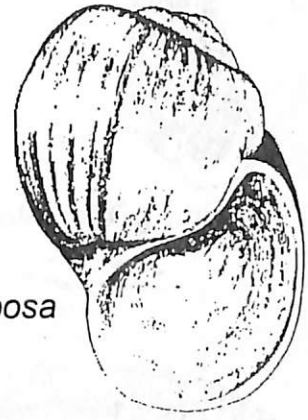
B. bengalensis f. typica



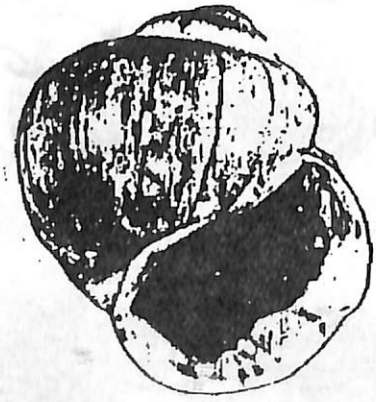
B. dissimilis



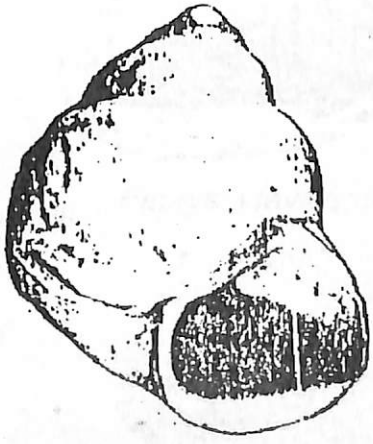
Cipangopaludina lecythis



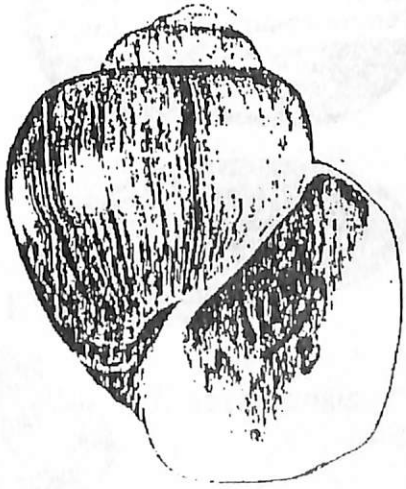
Pila globosa



P. theobaldi



P. scutata



P. virens

PLATE-3

Brotia costula

Paludomus conica

T. tuberculata

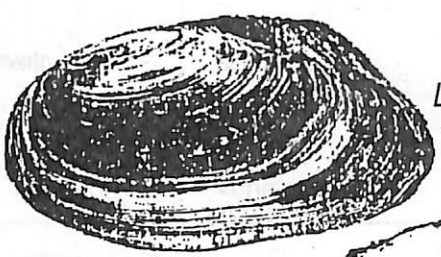
P. reticulata

T. scabra

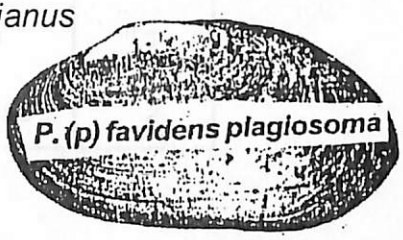
Paludomus conica. f.

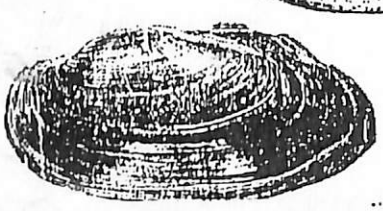
Sulcospira hugeli

T. granifera



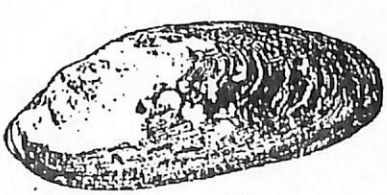
Lamellidens corrianus



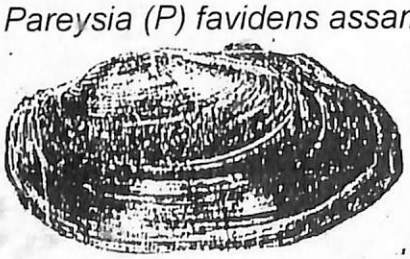


Pareysia (P) favidens assamensis

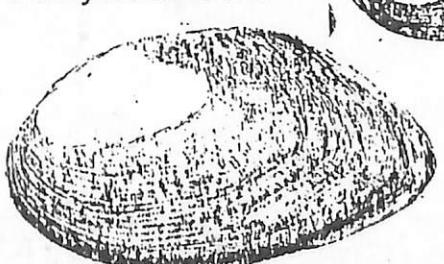
Pareysia favidens



C.assamensis



P. (p) (Radiatula) bonneaudi



P. (p) (Radiatula) occata

Summary of the No. of species of snails under different orders, family etc.

Class	Order	Family	Nos. of Species
Gastropoda	Mesogastropoda	1. Bithyniidae	2
		2. Viviparidae	5
		3. Pilidae	4
		4. Thiariadae	10
		5. Cyclophoridae	1
	Basomatophora	1. Lymnaeidae	5
		2. Planorbidae	1
	Stylomatophora	1. Ariophantidae	2
		2. Achatinidae	1
Bivalivia	Unionida	1. Amblemidae	7
		2. Unionidae	1
	Veneroida	1. Corbiculidae	2

Crabs :

The taxonomy of the fresh water crabs (*Paratelphusa* and *Potamon*) have been confusing due to the great morphological plasticity of this groups showing considerable intra-specific variations over shadowing the genetic affinities between related species. In the present collection following species were collected and identified (Alcock, 1910; Chopra, 1931; Dutta, 1984).

Phylum : Arthropoda
Class : Crustacea
Order : Decapoda
Family : Paratelphusidae

Sample Species # 1. Species : *Serteriana spinigera,* Woodmason.

The Caraface is broad and convex and its length is about 2/3rd its greatest breadth, its depth is about 1/2 its length. The well arched antero-lateral boarders are sharp and indistinctly crenulate. The chelipeds are unequal in both sexes.

Family : Potamonidae

Sample Species # 2. Species : *Lebethelphusa woodmasoni,* Rathbun.

The carapace is fairly broad, convex with an uneven surface. The antero-lateral boarders of carapace cut into four clow like spines. In the adult female the chelipeds are almost equal and are rather slender and shorter than the legs.

Distribution : Potamons are founds for Afganistan, India, Bhutan, Bangladesh, South-East Asian including China. In North East, it is found in both Brahmaputra/Barak Valley and extended its distribution in the entire region.

Dutta (1984) reported the occurrence of following species with their characteristics. However, in the present collection only two species could be identified as *P. spinigera* and *P. woodmansoni.* The species described by Dutta (1984) are :

Sample Species # 1. Species : *Paratelphusa (Barytelphusa) eduntula, Alcock*

The cervical groove is board and deep running to the lateral epibranchial tooth. The epigastric is broad and blunt. The outer half of the post orbital portion of the epigastric crest is sharp and inner portion is blunt. The legs are strong and shorter than smaller cheliped.

Sample Species # 2. Species : *P. (Brarytelphusa) guerini,* A.M. Edw.

The cervical groove is broad and deep, running towards, but not reaching the site of the lateral-epibranchial tooth. The epigastric and post orbital crests form a bold ridge on either side of the mesogastric furrow. In the chelate leg, the pits are linearly arranged on the fingers and there are some squami-form tubercles on the upper surface of the palm.

Sample Species # 3. Species : *P. (Brarytelphusa) harpax.* A.I. Cock.

The cervical groove is deep and so the region appears more convex. In the orbital border of the carapace, 3-4 distinct teeth are present and the rest of the area in the form of a serrated structure. The sixth segment of the abdomen is longer and its sides are more concave.

Sample Species # 4. Species : *P. (Paratelphusa) sinensis*

The cervical groove is just visible but is very supervicial and indistinctly represented by a line of irregular pits. The post-frontal mesogastric groove is indistinct. The epigastric crests are slightly overlapping. The post orbital crests distinct and sharp at their inner edge and blunt behind the orbit.

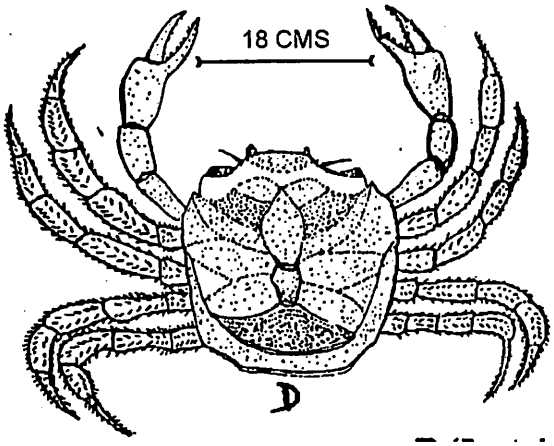
Sample Species # 5. Species : *P. (Paratelphusa) spinigera*

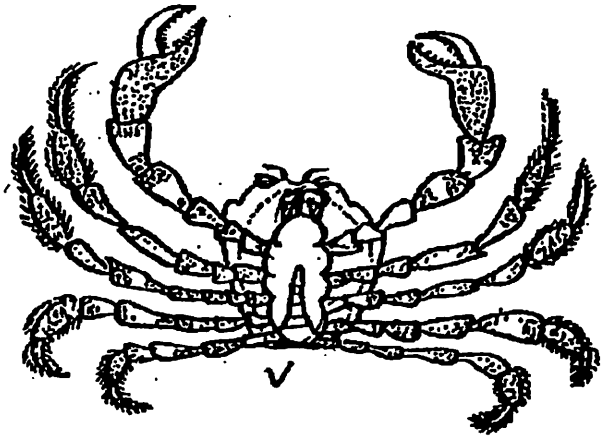
The deep cervical groove runs towards the outer end of the post-orbital crests, but becomes quite indistinct behind them. The epigastric crest is prominent but becomes indistinct beyond the point where the cervical groove approaches them.

Sample Species # 6. Species : *Potamon (Acanthotelphusa) woodmasoni*

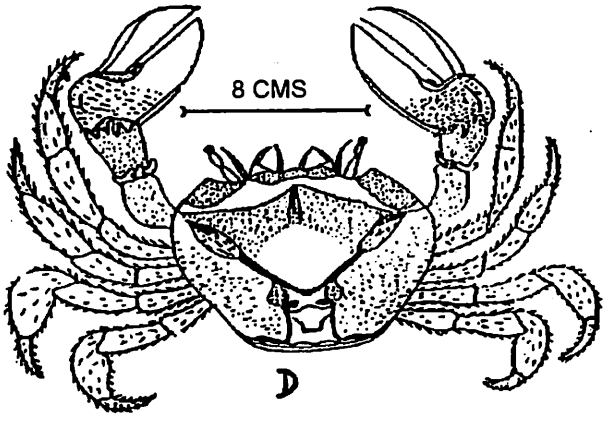
The cervical groove is deep, broad and superficial. The epigastric crests are regulose and become indistinct beyond the points where they are met by the cervical groove.

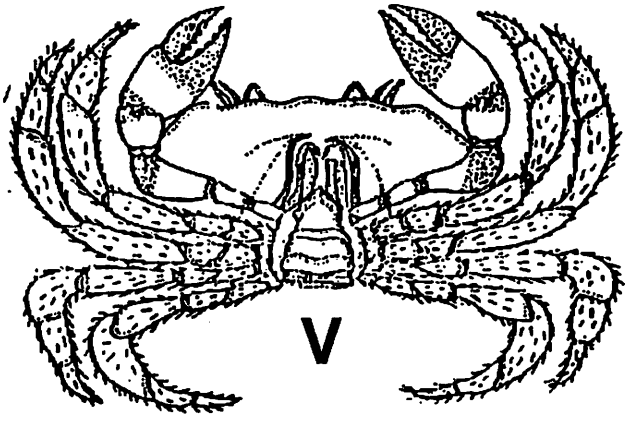
PLATE-4



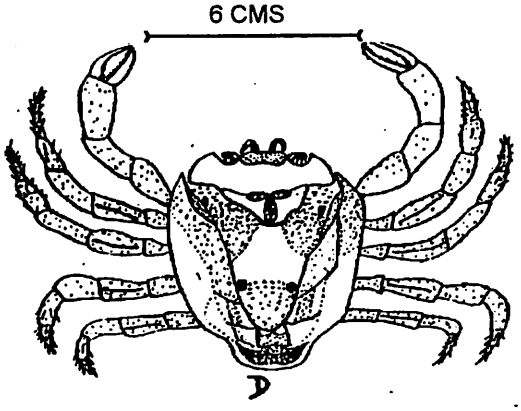


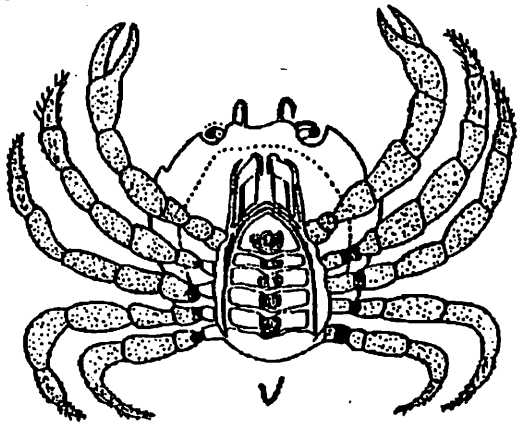
Paratelphusa (Barytelphusa) eduntula





P. (Barytelphusa) guerini

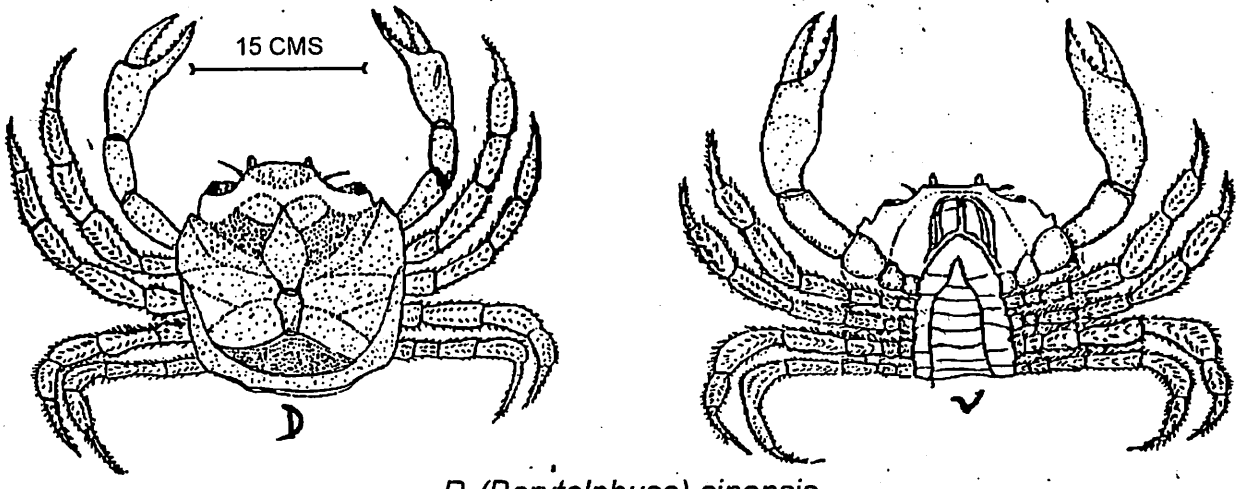




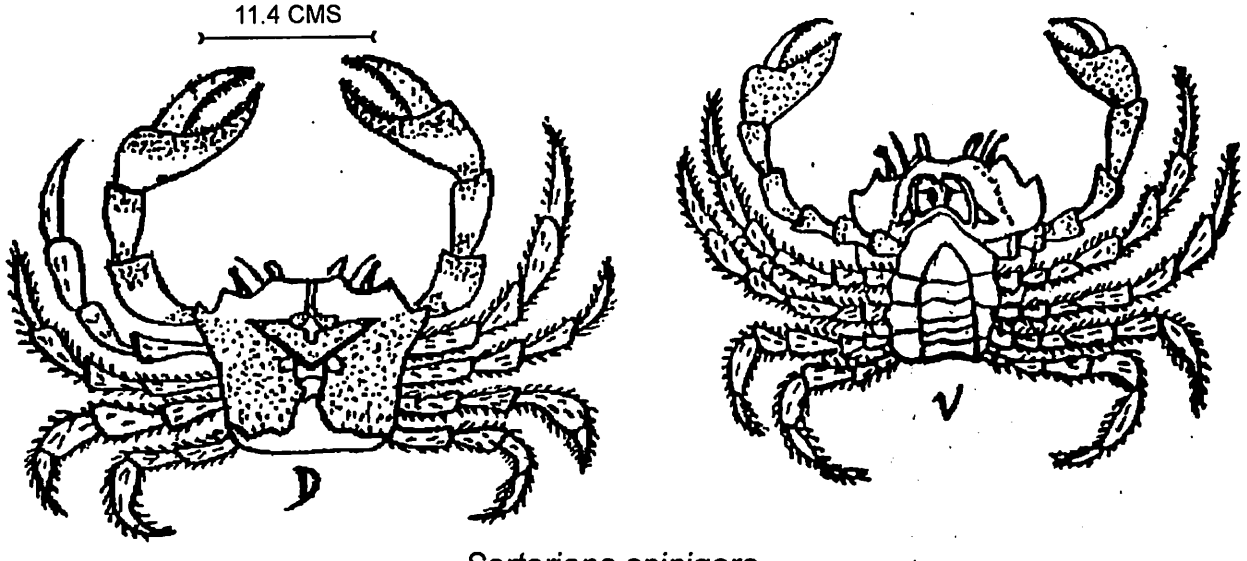
P. (Barytelphusa) harpax

D = Dorsal **V = Ventral**

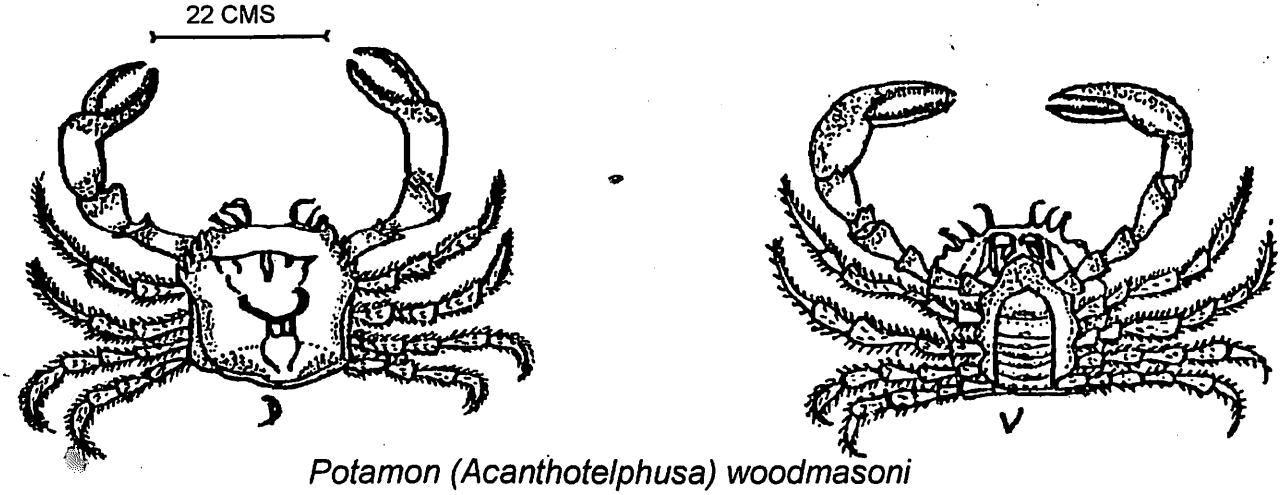
PLATE-5



P. (Barytelphusa) sinensis



Serteriana spinigera



Potamon (Acanthotelphusa) woodmasoni

D = Dorsal **V = Ventral**

CHAPTER IV

HABIT AND HABITAT OF SNAILS AND CRABS

The Brahmaputra river system with its large number of tributaries, beels, lakes, swamps etc. are lucrative in response to the habit of various species of crabs and snails. North East India and Assam in particular, a myriad of swampy water bodies or beels, lakes are the most natural habitat in which acquatic snails and crabs as well as the land snails live. Besides the low-lying inundated areas (flood plain) and pond, certain small tributaries with a series of vegetation areas are suitable environment for the propagation of the species. Although a series of studies with reference to limnological and hydrobiological aspects of the habit of the Brahmaputra river system is available (Kohli, 1984; Sarma, 1995), yet a few parameters regarding the habitat has been critically analysed as shown in Table 1.

The acidic condition of the entire habitat, which showed the pH variation for 4.45 to 7.5, dissolved oxygen 1.8 - 15.33 mg/litre, free carbondioxide 1.0 - 9.0 mg/litre total alkalinity 12 - 86 mg/litre and the phosphate between 0.24 - 13.6 mg/litre. The net primary production values ranged for 0 - 98.21 mg^C/m^3/hour and 0 - 12 mg^C/m^3/hour respectively. The methods of estimation and analysis of these parameters were discussed in earlier chapter (Materials and Methods).

It may be mentioned that some of the hydrobiological and limnological parameters were common for both snails and crabs. A comprehensive analysis comprising the vegetation and hydrobiological condition are summarised in Table 1 and in vegetation list.

ECOLOGY

Snails :

The ecology of great majority of the India an freshwater molluscs is not known. Biological studies are limited only to a few species. Biologically known species are Viviparids, Thiarids (melanids) and Pilids (Annandale,1921 ; Annandale and Sewell,1921 ; Ramamoorthi,1950 ; 1955 ; Jacob, 1958 ; Prasad, 1925 ;1928 ; Muley, 1977 ; Rao, 1989 ; Nevill, 1877 ; Kotpal, 1988). There is no report or attempt to study the eco-biology of different species of snails in general the edible snails in particular.

Freshwater molluscs are common in quiet water pool, ponds, lakes and in flowing water like perennial rivers, irrigation canals etc.(Anand and Prasad,1919 ; Bhattacharjee,1980 ; Blandford *et al.*, 1980 ; Kapoor and Khanna,1979). The malacofauna of stagnant waters may be somewhat different from that of the streams (Rao, 1989). The streams in the hills and at a slightly higher elevations have different fauna than those in the plains. In this respect the streams in the Western Ghats and Nilgiri are remarkable for their characteristics malacofauna. Snails belonging to the families Neritidae, Thiariadae, Ancylidae and Littorinidae inhabit streams and small rivers, whereas members of Viviparidae, Pilidae, Lymnaeidae and Planorbidae live in stagnant waters. Gastropods are generally found attached to submerged vegetation, rocks, sticks etc. But bivalves live partly buried in the sand or mud. Similar to the gastropods, the bivalves exhibit variations in shell depending upon the ecology of the species and may produce ecophenotypes.

Under the tropical conditions the freshwater molluscs are usually faced with an annual dry season. Gastropods and bivalves show varying capacity to survive desiccation. Many snails can overcome this by aestivating either under dead vegetation or debris or by actively burrowing at least the aperture of the shell in the mud. Some of the snails are capable of anaerobic respiration. With the advent of favourable conditions the molluscs resume their normal activities. The discontinuous and transient nature of freshwater bodies led to isolation of snails or bivalves into small local population.

Land Snails : The ecology and behaviour of land snail, *Achatina fulica fulica* requires a thorough study. It may be mentioned that the species has not yet been fully utilized and its biology and culture require special attention as it can be utilized as farm feed for fish, duck and in poultry feed. In the present study it has been recorded as the largest sample among all the collection upto 20 cm shell length and body length upto 30 cm.

The land snail found its way to India from its native place in Kenya (East Africa) through Mauritus as early as 1847 when a few specimens were introduce to Botanical Gardens, Calcutta by W.H. Benson (Vinci *et al.*, 1990). Later, the snails proliferated, spread throughout India and people realize as menace to agrihorticultural economy especially of the Eastern, North Eastern part of India. Attention has been made to utilize this resource as a farm feed. It is a serious pest to the crops.

The prominent behavioural features of almost all land snails including the giant snail is the dormancy during unfavourable climatic condition and an enranged activity during favourable season, mostly confined to monsoon months.

The activity of the land snails depend on the following factors :

Humidity : It maintain a constant balance between the fluid content of its tissues and the relative humidity of the environment. During dry weather, it dehydrates itself to ensure its fluid level remains constant during humid weather.

Temperature : Temperature plays a very vital role in the behaviour of snails. Below 6°C their activities slow down and the snails go for hibernation. Temperature above 40°C is intolerable for the snails and they prefer to withdraw themselves from all activities and go for aestivation.

Light : Very little information on the role of light has been known. However in the present studies it has been shown that light has affected the growth and overall metabolic activities of the snails.

Hibernation period : By nature these snails are moisture-loving and the length of the active period depends on the length of rainy season prevailing in the area. It has been found that in the Brahmaputra valley snails come out of their hibernation during early April and the availability extends right upto the end of October. There can be a brief period of summer aestivation during May-June followed by the peak period of availability in July-September.

At the period of hibernation or aestivation, the snail retracts its foot upto the shell, seals it with an epiphragm (mucous) secretion except for a small hope left for exchange of gases. In this state, they bury themselves in the soil or underneath the heap of dried and decaying leaves or twigs. The factors that induce dormancy in the snail have been identified as low and high temperatures, low humidity, amount of body water and starvation. The period of dormancy may extend upto 8 months depending on the climate of the zone. Burrows in the wood/stems are also its favourite places for hibernation. Crevices in the walls, bricks, heaps of logs and dried grasses, etc. also form its preferred places for hiding. Some sort of schooling behaviour is seen during this period. As much as sixty snails were found hiding in a 3 feet long hollow stem of a papaya tree.

Once the season sets in, with a heavy downpour, large number of snails wake up from their long slunder, shed their mucous seal and set out to attack a variety of plants at night. They devour economic plants with a preference for leafy or fleshy vegetables. Their dislike is restricted only to a few items like bitter grourd, onion or chilli. No wonder, they cause enough distress to the farmers. Rout & Ghose (1984) also have given an account of the habitat and behaviour of these snails. Some of their observations are as follows :

"The snails always prefer damp and shady places and avoid direct sunlight. They occur mostly in an around villages, though quite a few are often found in open woodlands, parks, gardens, cemetries, hedgerows, borders of marshes and similar habitats. Being nocturnal in habit they hide themselves in daytime in a retracted and quiescent state, under bricks, rocks, fallen logs, plant mats, holes in trees, decaying leaves and the like or partially burried in loose soil. *A. fulica* climbs walls and tree trunks to a height of 400 cm and spend the day there. Interestingly, a some sort of advance signalling system in response to change in weather is present in *A. fulica fulica,* since in the vast majority of the cases they move to protected sites prior to outbreak of a storm, and climb up for some support quite ahead of heavy shower" (Hora and Rao, 1927 ; Hyman, 1967).

Crabs :

Crabs are decapod crustaceans, belonging to the sub order Brachyura. Their important characteristics are well-developed carapace and greatly reduced abdomen that is flexed under the body. The brachyurans or the true crabs, though differ from species to species in shape size and structure, resemble closely among themselves in general external morphology and biology (Warner, 1977 ; Woodmanson, 1871).

The regular activities of life in crabs alternate with periods of inactivity or rest. The rhythmicity of the activities is geared up with the environmental condition relating to temperature and rainfall. The rainfall or during the monsoon period the growth as well as reproduction of crabs, or as a whole propagation takes place. In case of estuarine environment the activities has got direct influence with the tidal waves as well as the lunar cycle. Estuarine species showed a wonderful synchronization with tides, temperature and lunar cycle showing as the existence of a 'biological clock'.

Activities such as movement of the body or appendages is essential for all crabs irrespective of their habitat and habit. The movement is achieved by muscle through the articulation of the appendages by means of lever system. The main moving parts of a crabs are the long legs with one used for running, swimming, jumping, clubbing or burrowing. The mouth parts are used for manipulation of food and the chelipeds for catching preys, impressing rivals and attracting mates.

Almost all crabs are able to swim (Hartroll, 1971) owing to the strongly built exoskeleton and slip legs, and in some case the last two podometers of the last pair of legs and flattened to act as paddles, which provide the efficient swimming activities of different species of crabs. Virtually all legs are modified for swimming which help them to swim with easy and speed. The basal muscle of the leg help in beating of the paddle forwards and backwards. This produces of

sculling action. (Spirito, 1972) which gives both propulsion and lift. Most of the terrestrial crabs construct burrows. The aquatic species including portunid, calappid, paratelphusa etc. sometimes resort to burrowing chiefly for concealment during their inactive periods. The habit of burrowing is particularly pronounced in *S. serrata, S. spinigera, L. woodmansoni* at the time of moulting. The crabs in general, may be categorised as back-burrowers and side-burrowers. The back burrowers are usually found underwater or sandy substrata. The make temporary burrows by tilting backwards and digging down into the sand with their walking legs (Warner, 1977). Side-burrowing crabs usually dig genuine burrows which may serve as shelters for several days or weeks/months. Many side-burrowers dig complex burrows with several openings. The burrows are simple tunnels which descend downwards either straight or slightly slanted and are always devoid of any superstructure. The depth of a burrow is about one and half times more than the length of the crab inhabiting the burrow. The width of the burrow is nearly twice the depth (thickness) of the crab (Kapoor and Khanna, 1979 ; Nandi and Devroy, 1991 ; Tonapi, 1980).

In Figure - I, the structure of burrows, one with single external opening and the other with two external openings are shown. In the present studies the habitat of crabs with reference to their burrowing habits was examined in 80 different places and almost similar habitats have been recorded. Further, the burrow becomes dry in the opening surface during October to March and among the 80 burrows 7 burrows were associated with *N. natrix*. In most cases some species of *channidae* and small *cyprinids* were found in the burrows along with the crabs during the periods of inactive state.

Crabs are opportunistic omnivorous eating on a variety of foods, with a preference for animal food, in general. The freshwater species like *Paratelphusa spinigera* is omnivorous feeding detritus, crustaceans molluscs and polychaetes. As a whole small gastropods, copepods and polychaete worms, algae decayed plant matter of higher plant etc. form an appreciable part of the food several species of crabs (Menon, 1952).

Social behaviour of crabs tends to be competitive rather than co-operative. Besides the sexual activities, social behaviour is mainly agnostic and unfriendly. Hence they usually avoid meeting each other. If they do meet they threatened each other and fight.

Crabs inhabit freshwater ponds, beels, lake, half burried in mud as well as in estuaries and in marine environment as the examples of marine species. In polluted environment, the species cannot survive.

The freshwater habitat has been analysed with reference to snails and crabs and tabulated in Table - 1 and in vegetation list.

Table 1 : Physico-chemical parameters of certain wetlands habitat of crabs and snail (Survey reports for 1995-1997 covering all seasons)

Parameters	Dighali		Dora		Ghorajan		Deepar		Thekaraguri	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Water temperature (°C)	17.6	31.0	20.5	30.0	21.5	30.5	21.5	35.0	17.5	31.0
Transparency(cm)	51.6	96.0	45.0	118.0	62.0	110.0	--	--	45.0	110.0
Dissolved Oxygen(mgl^{-1})	5.2	9.0	5.1	10.2	3.7	5.6	3.2	10.1	5.0	10.0
pH	6.3	7.3	6.1	7.5	6.3	6.8	5.5	8.3	6.5	7.2
Free CO_2(mgl^{-1})	2.6	15.4	3.5	14.2	23.1	33.8	2.7	6.7	15.0	29.2
Total alkalinity (mgl^{-1})	24.9	37.6	27.6	36.5	31.3	38.4	78.3	174.3	24.0	37.0
Specific conductance (mhos)	52.3	81.3	61.4	78.2	60.4	69.5	58.0	90.0	60.0	75.0
Total dissolved solid (mgl^{-1})	24.6	41.1	30.2	37.6	28.2	39.8	--	--	25.0	36.0
Total hardness (mgl^{-1})	24.0	35.0	27.6	36.3	27.6	38.0	99.6	176.0	25.5	33.1
Nitrate (mgl^{-1})	0.15	0.41	0.19	0.75	0.18	0.32	0.14	0.41	0.15	0.6
Phosphate (mgl^{-1})	0.04	0.15	0.19	0.28	0.03	0.05	0.3	0.51	0.03	0.26
Silicate (mgl^{-1})	2.7	6.9	3.8	7.4	4.5	12.8	4.5	18.5	2.0	7.6
Inorganic matter (mgl^{-1})	0.03	0.19	0.12	0.24	0.09	0.22	0.09	0.31	0.03	0.25
Dissolved organic matter (mgl^{-1})	26	3.4	1.9	4.1	1.5	2.9	1.1	3.5	2.0	4.0

Table 2 : Physico-chemical parameters of some water bodies inhabiting crabs and snails

River/Beel/Pond	Parameters							
	Water Temp °C	pH mg/L^{-1}	Free CO_2 mg/L^{-1}	Total alkalinity	Dissolved 0_2mg/L^{-1}	Nitrate (NO_3) mg/L^{-1}	Phosphate mg/L^{-1}	Area (ha.)
1. The Brahmaputra river (Singh *et al*, 1982)	18.0-31.0	7.4-8.1	2.5-3.5	56.0-97.0	7.0-10.45	0.033-0.71	0.052-0.003	N.R.
2. Dipar Beel (Kakati and Bhattacharya, 1989)	N.R.	7.26-7.89	N.R.	110-135	1.8-3.0	0.6-1.1	4.70-6.75	1.01
3. Sone Beel (Kar, 1984)	18.7-32.3	6.0-7.9	N.R.	25.0-74.4	2.4-6.4	N.R.	N.R.	3458.0
4. Dhir Beel (Yadava, 1987)	19.0-31.2	6.4-7.4	N.R.	21.0-58.0	7.6-10.6	0.01-0.31	0.05-0.37	689.0
5. Dighali Beel (Yadava *et al*, 1987)	18.0-30,0	6.5-7.5	3.3-23.4	25.0-43.0	2.6-10.9	0.15-0.63	Tr.-0.23	250
6. Chandubi Beel (Goswami, 1985)	19.0-35.5	5.9-7.6	0.5-9.0	17.0-61.0	6.0-19.0	0.01-0.8	0.64-9.2	712.0
7. Tezpur Pond (1) (Chutia *et al*, 1991)	23.0-31.7	6.2-7.1	8.2-12.2	N.R.	4.6-7.2	N.R.	N.R.	--

Contd.....

Table 2 (Contd.) : Physico-chemical parameters of some water bodies inhabiting crabs and snails

River/Beel/Pond	Parameters							
	Water Temp °C	pH mg/L^{-1}	Free CO_2 mg/L^{-1}	Total alkalinity	Dissolved 0_2mg/L^{-1}	Nitrate (NO_3) mg/L^{-1}	Phosphate mg/L^{-1}	Area (ha.)
8. Dora Beel (Dey and Lahon, 1979)	18.0-30.0	6.0-7.2	N.R.	14.0-54.4	3.1-10.6	0.0-1.4	0.27-1.04	463
9. Tezpur Pond (2) (Chutia *et al*, 1991)	23.0-31.7	6.5-7.0	8.5-11.2	N.R.	5.0-3.2	N.R.	N.R.	3.0(Pond)
10. Dighali Pukhuri (Hazarika & Dutta,1994)	21.0	7.5	4.0	5.2	4.07	N.R.	N.R.	N.R.
11. Dipar Beel (Dey, 1994)	19.8-33.0	4.5-7.5	N.R.	12.0-80.0	2.4-10.2	0.0-1.2	0.46-0.96	146.3
12. Ulubari Fish Pond (Hazarika & Dutta, 1994)	19.0	8.1	6.0	9.2	6.3	N.R.	N.R.	N.R.
13. Jalukbari Pond (1) (Dutta *et al*, 1990)	22-32	6.2-7.5	Nil-15.0	42-57	5.0-8.0	N.R.	N.R.	N.R.
14. Jalubari Pond (2) (Dutta *et al*, 1990)	22-32	6.5-8.0	Nil-8.0	44.0-59.0	5.4-8.0	N.R.	N.R.	0.6
15. University Pond (Dutta *et al*, 1993)	18.9-23.5	7.7-8.6	1.1-4.9	60.0-85.0	10.6-12.9	N.R.	N.R.	1.5

Vegetation of the habitat of *Snails and Crabs* :

The following macrophytes, microphytes and zooplankton have identified from the references cited in the list. In the following list only the names of the species have been given ; no taxonomic criteria such as families, order are shown alongwith their names.

A. Macrophytes :

(a) Free Floating hydrophytes :

Azolla spp.	*Eichhornia crassipes*
Pistia stratiotes	*Salvinia nature*
Spirodella polyrrhiza	*Trapa bispinosa*
Wolffia arrhiza	

(b) Rooted submerged hydrophytes :

Ceratophyllum demersum	*Hydrilla verticillata*
Myriophyllum indicum	*Naja graminia*
Nechamandra alternifolia	*Ottelia alesmodes*
Urticularia inlfexa	

(c) Rooted hydrophytes with floating leaves :

Aponogeton natans	*Neptunia oleracca*
Nelubium spp.	*Nymphoides* spp.
Potamogeton spp.	*Sagittaria* spp.

(d) Rooted and immerged hydrophytes or amphibious plants :

Aeschynomene indica	*Amischophacellus axillaris*
Aeschynomene aspera	*Alocasia fornicata*
Alternanthera spp.	*Colocasia esculanta*
Ammania spp.	*Colocasia nymphaefolia*
Alisma spp.	

B. Microphytes (Phytoplankton) :

Arthrodesmus spp.	*Chalmydomonas* spp.
Cymbella spp.	*Diatomo* spp.
Eudorina spp.	*Euglena* spp.
Fragillaria spp.	*Microcystis* spp.
Meridion spp.	*Mongeota* spp.
Micrasterias	*Naviculla* spp.
Nostoc spp.	*Oscillatoria* spp.
Spriogyra spp.	*Synendra* spp.
Tabellaria spp.	*Ulothrix* spp.
Volvox spp.	

C. Zooplankton :

Brachionus spp.	*Bosmina* spp.
Cyclop spp.	*Ceratinum* spp.
Diaptomus spp.	*Daphnia* spp.
Filinia spp.	*Keratella* spp.
Moina spp.	*Nauplius* spp.
Polyathra spp.	

D. Macrobenthos :

Amnicola spp.	*Anodonta* spp.
Brachirua spp.	*Bythinia* spp.
Chironomus spp.	*Culicodes* spp.
Centrocypris spp.	*Caenis* spp.
Cyzicus spp.	*Carinifex* spp.
Camphyloma spp.	*Dero digitata*

Donacia spp.	*Dromogomphus* spp.
Gyraulus spp.	*Hydrocanthus* spp.
Hagenius spp.	*Helisom* spp.
Laccophilus spp.	*Lynceus* spp.
Ligumina spp.	*Musculium* spp.
Nais simplex	*Pisdium* spp.
Plea spp.	*Planorbulla* spp.
Promenetus spp.	*Placobdella* spp.
Stenocypris spp.	*Sphaerium* spp.
Syncaris spp.	*Tubifex* spp.
Tarnetrumm spp.	*Viviparus* spp.

* Chutia *et al.* 1991 ; Dutta *et al.* 1990, 1993 ; Goswami, 1985 ; Hazarika *et al.* 1994 ; Naskar, 1989 and Yadava *et al.* 1984, 1987.

Note : Microphytes (phytoplanton), Zooplanton, Macrobenthos, etc. were identified upto genus level.

CHAPTER V

REPRODUCTION IN SNAILS AND CRABS

The observation as reproduction of snails and crabs are illustrated separately in two parts.

PART - I

REPRODUCTION OF SNAILS OBSERVED IN DIFFERENT STATIONS

Reproduction in snails is significantly different from other vertebrates. In the present collection comprising 40 Nos. of Vivalvin species sample shown in Chapter III, it has been found that in the majority, sexes, are separated, dioecious or gonochoristic. Hermaphrodism or monocious condition is known in pulmonates and in bivalvata among the prosobranchs. Natural parthenogenetic reproduction was observed in *Thiara* (*Melanoids*) *tuberculatus*, *T.* (*Terebia*) *lineatus* and *T (Thiara) scraba*. In dioecious prosobranchs sexual dimorphism is hardly visible. Generally female has a larger shell than the male. Sex is normally ascertained by the presence or absence of penis. Males are either absent or rarely found in certain Thiarids such as *T(M) tuberculatus*, *T(T) lineatus* and *T(T) scrabra*. In viviparids the males can be distinguished by their short, thick and curved right tentacle.

Breeding time :

Breeding is confined generally to monsoon season. There are instances of their breeding in late winter and early summer months also specially where there are rains during these periods. In Table 3 the time of breeding that has been observed in different species and the minimum length at which they breed has been illustrated.

Table 3 : The breeding biology has been observed in 14 different stations St-1 (Dhubri), St-2 (Kokrajhar), St-3 (Bijni), St-4 (Sorbhog), St-5 (Nalbari), St-5 (Deepar Beel), St-6 (Ghorajan), St-7 (Kukurmara), St-8 (Dighali), St-9 (Thekeraguri), St-10 (Jakhalabandha), St-11 (Sibsagar), St-12 (Dibrugarh), St-13 (Tezpur), St-14 (Lakhimpur) from 1995-1998 (Total duration 4 years). The time of breeding as shown with the first alphabet of each moths (only for May = Ma) along with the attainment of minimum length (mm) for breeding has been shown against each species.

Species	Breeding time	Minimum length (mm)
L. L.f. impura	J.J.A.S.	20
L. L.f. ovalis	J.J.A.S.	20
L. L.f. typica	J.J.A.S.	20
I. exustug	Ma J.J.A.S.O.	18
D. ceremeopoma	Ma.J.J.A.	30
B. bengalensis	A. Ma.J.J.A.S.O.	30
B. bengalensis f. typica	A.M.J.J.A.S.O	30
P. globosa	M.A.Ma.J.J.A.S.O.	50
P. theobaldi	M.A.Ma.J.J.A.S.O.	40
P. vireus	M.J.Ma. J.J.A.S.O.	45
B. costula	J.J.A.S.	40
T(T) lineatu	J.J.A.S.	35
A. fulica fulica	M.A. Ma. J.J.A.S.O.	55
P. favidens plagiosoma	Ma.J.J.A.S.	35
P. (Radiatula) bonneaudi	Ma.J.J.A.S.	35
L. corrianus	A.Ma.J.J.A.S.	35

The observations have been carried out simultaneously in all 14 different stations. No differences in breeding time and minimum length for attaining sexual maturity have been observed.

Note : The above observations/findings will help any breeder to form a comprehensive idea about the breeding time and attainment of minimum size for sexual maturity.

Environmental conditions for land snails for land snails :

Following environmental conditions are conducive conditions for breeding snails in their natural environment

Temperature – 22-37°C

Humidity – > 86%

Rainfall – Drizzling in cloudy days

Breeding Months – As shown for different species in Table 3 from March to October.

Reproductive Strategies :

1. Mating starts from March onwards (vide Table 3) or after first shower of monsoon.

2. Copulation extends : The extends of copulation in different species are shown as follows :-

Species	Time(hours)
L. luteola f. imura	3 - 4
B. bengalensis	1 - 3
P. globosa	2 - 3
A. fulica fulica	2 - 5
B. costula	2 - 3
T. tuberculata	2 - 5
L. corrianus	2 - 4
P. favidens assamensis	1 - 3

Fertilization, Egg laying/hatching :

In gastropods the sperm received after copulation are stored in the seminal receptacle or in oviduct. The number of eggs laid after mating are variable depending upon the species. Species of gastropods observed were usually breed throughout the year and the peak is reached soon after monsoon.

Pulmonates are hermaphrodites with synchronous ripening of male and female gametes and practice copulation. Certain species are functionally protandrous and pair when the male organ ripe. [Elsewhere self fertilization has been reported in Lymnaeidae, Planorbidae and Ancylidae, Rao, 1989].

All pulmonates and some prosobranchs eggs are laid in capsules embedded in a jelly-like gelatinous substance which stick to the aquatic vegetation. The number of eggs in each capsule varies species to species. In the present observation.

Following No. of eggs of different species were recorded from the observations made in different station (Stations were describe in Table 3).

Table 4 : No. of eggs observed in different stations in *P. globossa* and *A. fulica fulica* , B. Costula, *P. favidens assamensis.*

Species	Stations	Number of eggs
P. globosa	St.1, 4, 5, 6, 7, 8, 9, 10, 11	200-325
A. fulica fulica	St.1, 4, 5, 6, 7, 8, 9, 10	75-350
B. costula	St. 5, 6, 7, 9	60-150
P. favidens assamasis	St. 5, 6, 7, 8	30-90

In viviparids and thiarids the eggs are retained in a special brood pounch or chamber. In some the pallial oviduct is modified to act as the uterus. The egg complete their development within the mother and the young ones hatch out in a form resembling that of adult.

In land snail *A. fulica fulica* sperms are collected in the spermtheca. Sperms are viable for long time (6 months observed in our present observation, however, there are reports that sperms remain viable upto 1 year, Rao, 1989). The genital glands does not produce any eggs immediately and after sperm collection the male part of the animal is reabsorbed and the female part develops. The sperm then leave the copulative pocket and travel to the top of the genital tract to fertilize the eggs supplied by the hermaphrodite gland.

In bivalvia fertilization takes place in the bronchial cavity and the fertilized ova pass into the spaces of gill lamellae. The development takes place in the puch provided by the gills which may be either interlamellar occuring between inner and outer demibranch or either the inner or outer demibranch only.

Hatching :

After mating hatching will take 15 - 30 days in both gastropods and bivalvia. It has been found that within same species in same area the hatching time differs from sample to sample. It is difficult to ascertain a specific time that is required for hatching.

In case of land snail the most conducive condition is high moisture content for which the mother snail provides a mucous covering to the egg mass. The ideal condition is 78 - 95% humidity and 22 - 35°C in the Brahmaputra valley.

Larvae :

Freshwater gastropods have no planktonic larval stage. The embryo hatch as young snails resembling the adult. There are few species of genus Thiara such as - *T. lineata*, *T. tuberculata*, *T. scraba* found in the Brahmaputra river system; but species *T. (Melanoids) crenulata* is the only freshwater snail where free swimming veligers larvae occur as an intermediate phase between the fertilized and adult stage.

In unionid bivalves the embryo develop into a larvae known as glochidium.

Growth :

It has been found that the larval stages are completed within eggs and the miniature of an adult snail is hatched out from the egg. The growth can be divided into the following phases in both gastropods and bivalvia.

Infantile phase : It is a fast growing phase and restricted to 20-40 days among different species.

Juvenile phase : It is almost adult, the shape and pigmentation of the shell nearly like those of an adult. The reticulation on the foot and visceral stalk is almost like that of an adult. 55-75 days are enough after infantile stage. The rate of growth will be uninterrupted with the animal reaches its adult phase.

Adult stage : After 60-75 days the gastropods and bivalves attain adult stage.

PART - II

REPRODUCTION OF CRABS IN DIFFERENT STATIONS OBSERVED IN THE BRAHMAPUTRA VALLEY

In the earlier chapters we have described the occurrence of crabs species, hydrobiological features and ecology of freshwater crabs available in the Brahmaputra valley.

The study on the reproductive biology and development of crabs mostly centres around economic species. Chacko and Thyagarajan (1952) studied the fecundity, early development and parental care of *Paratelphusa jacquemontii.* Prasad and Tampi (1953) reported on the breeding season and early larval stages of *Portunus pelagieus.* Naidu (1955) describes the early development of *Scylla serrata* and *Portunus sanguinolentus.* Chhapgar (1956) reported the breeding period and larval stages of some portunid and calappid crabs from Bombay waters. George and Nayak (1961) indicated the breeding and maturity of *Portunus* species from Mangalore. Pillai and Nair (1973) made valuable contribution to the breeding biology of some crabs from the South-Western part of India. Shanmugam and Bensam (1980), Lalitha Devi (1985) and Sukumaran (1986) have dealt with the breeding biology relating to size and maturity, sex-ratio, breeding season and fecundity of some commercial crabs.The freshwater crabs belonging to the family Potamonidae have been studied by Wood-Mason (1871), Alcock (1910) Kemp (1924), Chopra (1939), Chopra and Tiwari (1947), Ramakrishna (1950), Chacko and Thygarajan (1952), Ali (1955), Adijyoti (1968). For significant contribution on taxonomy and biology of freshwater crabs in India mention may be made by Bott (1970), Diwan and Nagabhushanam (1974), Joshi and Khanna (1982, a,b) and Manna and Sen (1984).

Sexes are separate, bisexual crustaceans. It is available in the swamps, ponds, rivers and in rainy seasons it can be seen in any pond paddy field, swamps or low lying area, half burried in the mud. In dry season it digs deep burrows to get down to the ground water. Gonodial maturation starts from February onwards and breeding seasons continue till October (Menon, 1952 ; Nandi and Pramanik, 1991).

Abdomen of the species showed the sexual dimorphic characters. Abdomen is remarkably reduced and tucked away under the body. It consists of six segments. It is a jointed flap like structure which differs in both sexes. In fact the abdomen is specialized for reproductive structures

and functions. The female has a fairly broad abdomen with four pairs of biramous pleopods, used for holding eggs. The male has relatively narrower abdomen than in female and bears only first two pairs of pleopods. The second pair of pleopods act as pistons inside channel of the first pair to pump sperm into the female at the time of copulation. The anus is terminal and located at the end of the abdomen.

Breeding behaviour and Courtship :

It is essential for bringing sexually receptive females and sexually capable males together for successful reproduction. Sexual dimorphism of cheliped and abdominal structure allow easy recognition of the opposite sex and facilitates courtship behaviour. The receptive females react either by not retreating or by approaching the adult male. The olfactory signals or phenomones released by the receptive females in the urine specially enable the adult male to recognize the receptiveness in aquatic crabs. The release of pheromones in the urine of crabs was demonstrated by Rayan (1966). The sex pheromones as the moulting hormone crustecdysone is common in some crabs in which soft female mating is accomplished.

The breeding habit of crabs are interestingly associated with moulting. The male crab is attracted to the female a few days before the moult. It holds her beneath his sternum until moulting. The mating pair of *S. spinigera* stays in this position for about 2 - 5 days in burrows and in aquatic habitant.

The female remains passive in this state while the male actively drive away any intruder. Copulation takes place just after moult. The male often guards the female even after copulation until her exoskeleton is partially hardened.

During copulation, the male turns the female so that the ventral surfaces of both the sexes are opposed to each other. The abdomens become unfolded with the males's on the inside and ultimately the second pair of abdominal appendages of the male are inserted inside the first, and both together acting as penis are thrust into the female genital openings.

The mating activities starts from the end of March to October. It may be mentioned that locating the species in mating conditions and taking photographs is a difficult observation. However, in our present studies, we could able to observe 8 pairs of *S. spinigera* and 3 pairs of *L. woodmansoni* in the following stations (Table 4).

Table 5 : Courtship observation different species of crabs in different stations (The stations are defined in Table 3 of this Chapter).

Species	Stations	Duration of Courtship
S. spinigera	St. 4 (n =2)	Sample 1 (2d), Sample 2 (4)
	St. 6 (n =1)	5d
	St. 7 (n =2)	Sample 1 (3d)*, Sample 2 (5d)
	St. 8 (n =2)	Sample 1 (2d), Sample 2 (4d)
	St.10 (n =1)	4d
L. woodmasoni	St. 4 (n =1)	5d
	St. 7 (n =1)	4d*
	St. 9 (n =1)	4d

* Observed in burrows, other are outside of burrow

Reproduction and development :

P.spinigera and *P. woodmansoni* attain sexual maturity with 6 - 8 months. The maturing female copulate immediately after moulting and retain sperms in the spermathecae for a longer time. The eggs, in such cases are fertilized as they pass through the spermatheca on their way out. They are carried in a mass under the cephalatherax and are held in the position by the flexed broad abdomen of the female. These females are known as ovigerous or berried species.

When the eggs of the crabs hatch, the larvae are released in the form beneath the abdomen of the female and lead a planktonic life and pass through free swimming larval stage *viz.* zoea, megalopa. There are few structural changes of zoea and megalopa before attaining the adult shape.

CHAPTER - VI

GROWTH, FARMING AND MARKETING OF SNAILS AND CRABS

Growth and farming of snails and crabs were examined through experimental conditions in ponds, paddy fields and by preparing earthen pits. Field trials were also conducted in paddy fields. In the case of land snail, moist snail enclosures were used for the examination of their growth and rearing.

The experimental conditions in various systems were standardised as follows. The detailed growth, survivability have been described in separate part for snails and crabs.

In Pond :

Experimental Pond (using nursery pond) :

Experimental ponds used were (n = 10, 5m X 3.5 m, water level 0.7 m) like the nursery ponds used in rearing fries of major India carps. The ponds were manured (with N.P.K., Cowdung) and limed as per standard recommendations (Jhingaran, 1982) and rearing of snails and crabs were monitored for 3 or 6 months. Prior to stocking the ponds were netted out in order to remove all snails and crabs available in the pond.

Earthen pit :

Earthen pit (2 m X 1.5 m, 0.4 m depth water level, surrounded by fine bamboo fencing - which will prevent escape of any snails or crabs from the pits on the bank of the pits) were prepared by digging the earth. Snails and crabs were reared in the pit and their growth were monitored.

Moist Snail Chamber :

A protected moist chamber 4 m X 4 m was used (n = 4) for brood stock management as well as rearing small snails under control conditions. The moist chamber is made up from brick

materials (base) with 4-side cover with wooden frame. Dry leaves in moist conditions were placed before introducing the snails.

Paddy fields :

Small plot of paddy fields (10 m X 10 m ; paddy with 0.2 m water level, n = 3) were selected. The plots were protected with raising its divisions and boundaries. Care was taken to avoid any earlier samples of snails or crabs. Wholes were stopped with earth packing and constant monitoring was made after placing the specimen.

Precautions were taken to stop the entry of any birds such as stork, heron, kingfisher etc. by erecting some paper flags. No extra feed or plant materials were introduced in those paddy plots. The vegetation and other hydrobiological condition are same as described in earlier chapter (Chapter - IV).

The details of rearing or farming of snails and crabs were illustrated in the following parts.

PART - I

Snails :

Brood Stock Management :

Matured Snails (*P. globosa*, *A. fulica fulica*, *B. costula*, *B. bengalensis*, *L. corrianis* and *P. favidens assamensis*) were collected from the swamps of different region and were maintained in a pond (5 m X 3.5 m size, with 0.5 - 0.7 m water level, fish nursery pond, n =4) and care was taken for supplying the necessary food matter concerning their food habit. Larvae of different samples were procured and reared in subsequent nursery ponds as well as in moist chamber (*A. fulica fulica*).

Feed of Snails :

Snails are almost omnivorous, they eat plant matter, animal matter along with detritus. The food spectrum of the water-snails are (as per after examination of their alimentary tract, *viz.*. stomach content) :

Phytoplankton group : Myxophyceab, Chlorophyceae, Desmidiacene, Bacillariophyceae, and Dinophyceae.

Zooplankton groups : Rotifers, Coperpods, Protozoans, Cladocerans.

Others : Aquatic Higher plants and detritus - mud materials.

Care was taken to introduce clusters of green and blue-green algae, and aquatic plants (as described in earlier, Chapter - IV).

Feed for land snail (*A. fulica fulica*) :

In the experiments conducted, land snails were feed with different plant and vegetable matter and were supplied in fresh conditions in the moist chamber.

The young snails prefer tender or fleshy leaves and fleshy vegetables. Ash gourd or bottle gourd can prove to be a good choice at this stage. At this voraciously eating stage, the feed can be given @ 20% of the body weight of the snails. Food spectrum can slowly be enlarged to a variety of plant materials, kitchen refuses, and leafy left-outs that are collected from the vegetable markets. Some of the feed items that are generally preferred by *Achatina* were worked out in the present investigations as well by earlier workers. The following list will give a broad idea about the feed preferences of this species.

Amarananth (*Amaranthus gangeticus, A. viridis*)	leaves, twigs and stem body and seedlings.
Antigonon (*Antigonon leptopus*)	only leaves
Ballabhianga (*Allangana lamarcana*)	leaves and twigs
Balsam (*Impatiens balsamina*)	leaves and flowers (fallen leaves and flowers are preferred).
Banana (*Musa sapiendurn*)	only fruit
Basella rubra	whole plant
Beans (*Dolichos* spp., *glycine* spp.)	leaves, twigs and fruits
Boerhaavia (*Boerhaavia diffusa*)	leaves, twigs, flowers and fruits
Bougain villea (*Bougainvillea spectabilis*)	leaves
Cabbage (*Brassica oleracea* var. *capitata*)	whole plant
Carum carvi (*Momordica cochinchienensis*)	whole plant
Castor (*Ricinus communis*)	Leaves and seelings
Cauliflower (*Brassica oleracea* var. *botrytis*)	whole plant

Table 6. : Growth of snails after rearing for 30 days in different rearing conditions

Rearing Condition	Species	Intial weight	Final Weight	Survivality
In Nursery Fish Pond (n=10)	*P. globosa*	1.5	30	90
	B. costula	1	25	85
	B. bengalensi	1.2	21	80
	L. corrianis	0.5	18	80
	P. favidus assamesis	0.8	19	80
In Earthen Pit (n=15)	*P. globosa*	1.5	29	95
	B. Costula	1	25	90
	B. bengalensis	1	21	90
	L. corrianis	0.5	15	85
	P. favidens assamensis	0.8	17	85
In Moist Chamber	*A. fulica fulica*	2	45	95
In paddy fields (n=3)	*P. globosa*	1.5	33	90
	B. costula	1	28	75
	B. bengalensis	1.2	23	85
	L. corrianis	0.5	19	85
	P. favidens assamensis	0.8	21	88

It has been found that growth of the snails were better in paddy fields than in nursery ponds and earthen pits.

PART - II

Crabs :

Feeding :

Crabs are opportunistic omnivorous, feeding on a variety of foods, with preference for animal feed in general. Generally they eat detritus materials present in mud, algae, zooplankton etc. In the case of crabs experiments upon fed and unfed specimens (as shown in Table 7) pursued and the growth were compared.

Crab-feed were prepared by mining thrash fish, snail meet or sometimes with slaughter-house waste. All these feed in fine minced condition were used at the rate 10 g./m²/day pelleted feed using rice bran: fish meal: mustard oil cake (1:1:1) was tried, but in the present experiment both species of crab (*S. spinigera*; *L. woodmansoni*) did not accept the fine pelleted feed.

Several other feed items such as (a) prawn meal, ground nut oil cake, and rice bran (1:1:1); (b) fish powder and wheat flour (2:1) were also tried after taking from different markets, but like the other feed rice bran: fish meal and mustard oil cake pellets, both species rejected the above two meals.

The details of the growth feeding and survivality in the different conditions have been described in the following Table (Table 7).

Brood-stock management :

To obtain mature and berried females for breeding and getting the seed for rearing, adult crabs of both sexes were stocked in nursery fish pond. The size of the adult specimen stocked were 80-175 mm in size and 90-200 g in weight for the both sexes and the male: female ratio was 2:3. No attempt has been made with eyestalk ablation. The same female developed egg 2-3 times in a breeding seasons. (March - October).

Mating has been observed in the nursery ponds and both sexes were found continuously for 2-5 days. After breeding the crab seeds were procured and reared in different conditions as shown in Table 7 with feeding or without feeding.

Availability of wild seed :

In the Brahmaputra river system there is the occurrence of a large number of matured and berried male and female and with careful management, there is ample scope of obtaining a large number of wild seed of crab for farming.

Table 7 : The growth of different species of crabs after rearing in different conditions.

Rearing	Species	Initial Average		After 120 days		% of
		Size (mm)	Weight (g.)	Size (mm)	Weight (g.)	Survivality
In fish Nursery pond without feeding	*S. spinigera*	40	20	131	252	90
	L. woodmansoni	38	18	125	239	90
in Fish Nursery pond with feeding	*S. spinigera*	40	20	135	262	95
	L. woodmansoni	38	18	130	242	95
In earthen pit without feeding	*S. spinigera*	40	20	120	242	90
	L. woodmansoni	38	18	119	220	85
In earthen pit with feeding	*S. spinigera*	40	20	132	250	95
	L. woodmansoni	38	18	130	240	95
In paddy field	*S. spinigera*	40	20	133	250	95
	L. woodmansoni	38	18	135	245	95

The stoking rate was maintained 185 No/m^2 in all experiments.

It has been found that both species of crabs require supplemental feeding which enhanced the growth and survivality.

Fattening of crabs :

The female of both speices of crabs were tried to fatten for attracting the consumers. It has been found that there is high price in South East Asian and western countries in fattened crabs.

Experiments were conducted to fatten the gravid female, where the same condition crabs were isolated and kept for selling instead of breeding them. Gravid female crabs with their internal visceral organs and orange-red/yellowish eggs masses, which filled up the carapace are much in demand.

The isolated females were maintained for 2 months and later on reabsorption of eggs takes place. However, as the species developed egg more than one time, so fattening can be processed in any time of the year. 6-8 cm size fattening crabs has high market value.

CHAPTER - VII

FOOD VALUE OF SNAILS AND CRABS

Man's interest from primitive times in crabs and snails as an important item of food has occupied an important position in the lives of the Indian people and more so with different tribes in particular. It is needless to emphasize the utilization of snails and crabs in different ways as a regular dietary feature of certain tribes. The identification of these as special food item in certain seasons, times and in the context of certain diseases is a long tradition. There are several beliefs on the use of these food items in curing certain diseases or leisions such as malaria, nightblindness, cardiovascular problems and other such day-to-day health affairs. The most important part of these facts are that there are no systematic studies on the food value of such food items.

In the present studies, the attempt has been made to analyse the food value or the nutrient status of these non-piscian resources with reference to their protein, carbohydrate, fat, glycogen, calorific values and the fatty acid composition of the samples besides that the quality of the protein has been exclusively studies through *in vitro* reaction for establishing the snail and crab meat as high quality meat.

The different methods for the analysis of these items have been described in the chapter (Chapter II) entitled Materials and Methods.

A thorough survey has been made in the tribal dominated areas of Assam and edible varieties of snail and crabs were identified with the help of the tribes consuming the same. The abundance of each sample was also noted in Table 8 along with the tribes, which consume such varieties.

In case of snail species only few varieties are preferred, where as all varieties of freshwater crabs are used in their food items. No such tabular representation (as shown in edible snails in Table 8) were made for crabs separately.

Besides the evaluation of food value, the history of snail eating habit has been evaluated in order to focus more attention as well as popularization as snail meat. It is no doubt that crab eating habit has a long history and in every corner of the world crab meat is used as delicacy by all communities, whereas still there are some feeling or hesitation on the practice of snail eating. Hence in the present chapter a review has been made on the history of snail eating.

The popularity on crabs meat is quite evident from its association with the Zodiac, namely Cancer which is a genus of edible brachyuran crabs

History of Snail Eating Habit :

Snails are considered index fossils. Their distribution characterizes the eating habits of the primitive living forms and helps paint past events. Found in North Africa were 90 mounds of fossilized snail shells ranging in diameter from 30 - 60 feet and upto six feet high (Encyclopedia Americana, 1988). These findings would lead on to suppose that the people who formed these deposits lived principally upon these molluscs. Similar accounts in the Philippines were described by Fox (1971) in his description of the archaeological excavations of the Guri Cave in Lipuon Point in Palawan, which was said to be frequented by man from about 8,000 to 4,000 years ago. Excavation studies yielded substantial data about the behaviour of the hunter - gatherers that inhabited the cave. Their life was certainly linked intimately with food quest. Based on fossil bones retrieved, they hunted and trapped pigs and deer, and less frequently birds and small mammals. Also recovered were over 20,000 pieces of marine shells and land snails which showed that they ate edible molluscs as well. Unsuccessful hunters might also have gathered land snails in the forest, specifically during the rainy season. Land snails were perhaps collected daily with large folded leaves or bark of trees during the periods of low tide. The meat of the tasty marine snails like the cowries and trochus were obtained by breaking the dorsal surface of the shell in the same fashion as is done by local people today. Molluscs could had been boiled in bark or leaf vessels or could had been eaten raw.

One interesting point in Fox's findings was the analysis of the molluscs excavated in Guri cave. He cited that 88% of the edible land snails excavated were of the genus *Camaena* spp., a rainforest land snail commonly called "bayuku" as identified by Mr. Jaime Cabrera, conchologist of the Philippine National Museum (Fox, 1971). Based on anatomical differences in shell apertures, the forest land snail found in Luzon island is a distant relative of the Palawan variety and belongs to another family of medium-- large land snails under Zonitidae (Faustino, 1930) and it was identified by the Institute of Biological Sciences, UPLB, College, Laguna (pers comm., 1991) as *Rysotta ovum.*

As cited earlier in the text, the Romans relished *Helix pomatia.* Thus, in 54 B.C., before the civil war with Pompey, Fuvius Lippinus established the first snail farm. Snails which were caught from the wild were then raised in special gardens called "cochlearia" (Encyclopedia Brittanica, 1971). During regular voyages to colonies, ships were stocked with snails for food -- thus spreading the practice of eating snails throughout the Roman Empire.

Adjunct to the spread to Christianity in Europe, snails became standard table fare during the Lenten season. Convents and monsteries thus had put up snail paddocks and likewise farmed the famous Roman snail.

French POW's of the second World War avoided starvation in the German camps because they dug and ate snails. Upon their return to civilian life, they eased painful was memories by relishing the snails that saved them from death. Also during that war, the Japanese stocked their ships with African snails as food for their troops which eventually led to the spread and boom of *Achanna fulica* in Southeast Asian countries.

Snail Eating Today :

Aside from the famous Roman land snail - *Helix pomania* which is served as "Escargotde Bourgogue" an first-class French restaurants, there are other smaller species of land snails of *Helix* that are eaten and these are *H. aspersa, H. rigata and H. lucorum, H. cincta* and *H. aperia.* These species are also consumed in quantities in some areas and are considered good substitutes for the less common and high priced *H. pomatia* (Fausboell, 1989). Likewise, *Otala* spp. and *Eobania* spp. from Morocco are exported to the USA as food (Ency. Brittanica, 1971).

The edible marine species considered to be a part of the diet of the affluents are the abalone - *Halious* spp. in which the large foot of this snail is tenderized and served as a steak in USA, Australia, Japan and other South East Asian countries. Total Philippines abalone exports to these countries in 1989 was worth $446, 583 (NCSO, 1989). Abalone is often canned and marketed worldwide. In France, one small tin can of escargot cost $7.00 (Ang. 1984). Other marine species commonly eaten by the poorer classes are the periwinkle - *Littorina littorea* in Europe; the top shell *Livona pica* and the conch - *Strombus gigas* in West Indies. The flesh of the conch is used to make a delicious chowder. The eggs of the indigenous species of large sea hare - *Dollabella* spp. is popularly consumed as food in Southern Philippines as cited by Licuanan *1987).

The giant African snail *Archachatina marginata* (about 8 inches long) and the common *African snail Archatina fulica* are the main species eaten and traded along the coastal areas of

West Africa as cited by Elmstie (1984). Likewise, in Southeast Asia - *Achauna fulica* is abundant and considered as an agricultural pest. It is used as a cheap source of protein for animal feeds (Khacharoen, 1985; Bayuga, 1987). *Achauna* meat, though barely consumed in these countries, turned out to be an exportable commodity. It now contributes much to the supply of edible snails in Western European markets. Its meat is used as a substitute for *Helix pomatia* in some restaurants.

The other land snail of export potential common to montane ecosystems in the country is the "bayuku". Based on L.A. Faustino's list of Philippine Land Snails, the "bayuku" referred to by forest dwellers is represented by two genera - *Camaena* spp. and *Rysotta* spp. The difference between the two species is the presence of labral folds in the aperture opening and the colour of the shell lips. They are both described as medium to large in size (Sprinsteen and Leobrera, 1986). The former is eaten in large quantities and considered as "famine food" by the Palawenos and Tagbanuas as cited by Fox (1971). Dr. V. Calilung of the Institute of Biological Sciences of the University of the Philippines at Los Banos stated that the Luzon island "bayuku" -- *Rysotta ovum* is not as common today as it was in 1960 (pers. com. 1991). She further added that the snail used to abound in Mt. Makiling National Park, especially during the rainy months of July through December. Likewise, according to Atty. W. Natividad, Chief Science Research Specialist of the DENR-ERDB Los Banos Experiment Station based at Mud Spring, the snail has been a regular part of the diet of forest dwellers, particularly in Mt. Makiling (pers. comm. 1991).

In the Philippines, the several species of native freshwater snails or "kuhol" -- *Pilaiuzonica* and *Vivipara angularis* which have been part of the diet of rural families for so long are now fast becoming endangered and displaced by the golden apple snail" -- *Pomacea canticulata* given the acronym "GAS" as discussed by Guerrero (1989). The GAS, which is a serious rice pest of South America, eventually spread to Hawaii in 1945, then to Taiwan in 1982, then to Japan in 1985. Actually there are other two species of GAS introduced and these are *P. cuprina* and *P. gigas* (Guevarra, 1987). They were introduced commercially in the country in the early 80's by the now abolished livelihood project Kilusang Kabuhayan sa Kaunlaran (KKK) because of its export potential as human food, but evidently the snail escaped from the demonstration farms, multiplied fast in the country and invaded fishponds and ricefields and fed voraciously on azolla, duck weed, water hyacinth, other succulent leafy plants and vegetables and mostly on young rice seedlings (FAO-UNDP, 1989).

Edible snails are eating by various tribal communities of Assam. In the present experiments edible snails were identified and their food values were determined.

In Table 8, the edible snails of Assam were shown, which are being consumed by different tirbal communities of Assam.

Table - 8 : Showing the edible snails of Assam was shown, which are being consumed by different tribal communities of Assam.
(Abbreviation used ++++ = high, +++ = medium, ++ = poor, + = insignificant)

Sl. No.	District	Plain Tribes	Edible fresh water species of snails consumeed by different tribes		Status of availability
			Family	Species	
(1)	(2)	(3)	(4)	(5)	(6)
1.	Kamrup	Rava Boro Kachari	Pilidae " " Viviparidae Thiaridae	*Pila globosa* *Pila theobaldi* *Pila virens* *Bettamya bengalensis* *Brotia costula*	++++ ++ + ++++ +++
2.	Nalbari	Boro Kachari	Pilidae " Viviparidae	*Pila globosa* *Pila theobaldi* *Pila virens* *Bellemya bengalensis*	+++ + + ++++
3.	Barpeta	Boro Kachari	Pilidae " " Viviparidae	*Pila Globosa* *Pila theobaldi* *Pila Virens* *Bellemya bengalensis*	++++ + + ++++
4.	Dibrugarh	Deori Kachari Sonowal	Pilidae " " Viviparidae Unioxidae	*Pila globosa* *Pila theobeldi* *Pila virens* *Bellemya bengalensis* *Lamellidens corrianus*	+++ + + ++++ +++
5.	Sibsagar	Mishing, Boro- Kachari Kachari- Sonowal, Deori	Pilidae	*Pila globosa*	+++
6.	Jorhat	Mishing Boro- Kachari Kachari- Sonowal, Deori	Pilidae	*Pila globosa*	+++

Contd.....

Table 8 : (Contd.....)

(1)	(2)	(3)	(4)	(5)	(6)
7.	Majuli	Mishing	Pilidae Thiaridae	*Pila globosa* *Brotia costula*	+ + + + + + +
8.	Lakhimpur	Kachari-Sonowal, Mishing, Boro-Kachari	Pilidae " "	*Pila globosa* *Pila theobaldi* *Pila virens*	+ + + + + + +
9.	Dhemaji-Jonai. "	Kachari-Sonwal Mishing Deori, Boro-Kachari, Hajong, Lalung.	Pilidae " " Viviparidae Thiaridae	*Pila globosa* *Pila theobaldi* *Pila virens* *Ballemya bengalensis* *Brotia contula*	+ + + + + + + + + + + + +
9.	Bongaigaon.	Garo, Rabha, Boro-Kachari	Pilidae " " Viviparidae Thiaridae	*Pila globosa* *Pila theobaldi* *Pila virens* *Bellemya bengalensis* *Brotia costula*	+ + + + + + + + + + + +
10.	Kokrajhar	Boro-Kachari Rava, Garo,	Pilidae " " Viviparidae Thiaridae	*Pila globosa* *Pila theobaldi* *Pila virens* *Bellemya bengalensis* *Brotia contula* *Lameledonus corrianis*	+ + + + + + + + + + + + + + +

Biochemical composition of snails and crabs :

The biochemical composition such as proximate composition, mineral contents, fatty acid profiles were analysed through the procedure as described earlier (Chapter Materials and Methods) as shown in Table 9 to 14.

Table 9 : Proximate composition of edible snails (The results are the mean value of 10 different estimations)

Bio-chemical parameters (gm%)	*Pila globosa* (gm%)	*Bellamya bengalensis* (gm%)	*Brotia costula* (gm%)	*L. corrionus* (gm%)
1. Protein	47.50	38.06	28.25	35.37
2. Corbohydrate	6.13	17.25	8.48	15.37
3. Fat	0.84	1.30	1.25	2.80
4. Ash.	23.69	28.04	45.70	26.64
5. Moisture	16.48	11.35	11.82	16.32
6. Glycogen	15.2	7.5	10.2	10.5

Table 10 : Mineral content in different species of snails (The results are the mean value of 10 different estimations)

Minerals	*Pila globosa* (gm%)	*Bellamya bengalensis* (gm%)	*Brotia costula* (gm%)	*L. corrionus* (gm%)
1. Sodium	0.235	0.194	0.177	0.083
2. Potassium	0.105	0.055	0.041	0.0193
3. Calcium	5.389	13.391	5.546	0.096
4. Phosphorus	0.576	0.629	0.396	1.183
5. Iron	0.71	0.68	0.75	0.62

Table 11 : Fatty acids composition of edible snails*

Fatty acids	*P. globosa*	*B. bengalensis*	*B. costula*	*L. corrionus*
Saturated				
12:0	1.0	1.2	1.0	1.5
13:0	0.0	0.3	0.2	0.15
14:0	5.1	4.2	3.1	6.2
15:0	0.7	1.0	1.2	0.8
16:0	8.5	9.2	10.0	8.3
17:0	5.0	4.8	5.5	5.7
18:0	8.3	6.7	10.9	13.1
19:0	0.2	0.5	0.6	1.0
Mono unsaturated				
16:1	8.2	10.2	7.1	7.7
17:1	2.0	1.0	1.5	0.5
18:1	5.4	9.2	8.8	7.6
20:1	8.2	7.2	0.5	7.5
22:1	2.0	0.2	3.2	4.2
Poly unsaturated				
18:2	8.6	5.7	3.9	5.2
18:3	10.3	12.2	14.2	12.5
18:4	5.3	5.2	4.5	3.5
20:2	4.5	5.0	3.2	3.0
20:3	1.0	0.5	1.5	1.6
20:4	0.8	0.2	4.2	3.2
20:5	3.7	4.2	5.0	2.2
22:4	1.2	2.1	2.5	1.2
22:5	0.7	0.2	0.1	0.1
22:6	9.5	8.2	10.1	8.0

* Results are the mean value of 10 different estimations

Table 12 : Proximate composition of edible crabs
(mean value of 10 different estimations from each species)

Bio-chemical parameters (gm%)	*L. woodmansoni* (gm%)	*S. spinigera* (gm%)
1. Protein	17.5	19
2. Corbohydrate	3.2	3.5
3. Fat	0.22	0.25
4. Ash.	1.2	1.25
5. Moisture	79	76
6. Glycogen		
7. Calorefic valu		

Table 13 : Mineral content in different species of crabs
(mean value of 10 different estimations from each species)

Minerals (mg%)	*L. woodmansoni* (gm%)	*S. spinigera* (gm%)
1. Sodium	165	180
2. Potassium	350	375
3. Calcium	68	72
4. Phosphorus	165	178
5. Iron	15	22

Table 14 : Fatty acids composition of edible crabs*

Fatty acids	*S. spinigera*	*L. woodmansoni*
Saturated		
12:0	1.7	1.1
13:0	0.3	0.2
14:0	6.8	7.3
15:0	1.3	1.5
16:0	10.2	7.5
17:0	6.3	6.2
18:0	14.3	14.2
19:0	1.3	1.8
Mono unsaturated		
16:1	12.2	12.5
17:1	2.2	2.7
18:1	10.2	11.0
20:1	8.9	7.0
22:1	8.0	8.6
Poly unsaturated		
18:2	9.2	9.0
18:3	18.2	17.5
18:4	5.8	6.0
20:2	6.9	6.7
20:3	3.8	5.2
20:4	7.3	10.3
20:5	4.2	2.2
22:4	5.1	8.0
22:5	2.2	0.2
22:6	10.2	12.0

* The results are the mean value of 10 different estimations of each species

Biological evaluation of the proteins of snail crab meat :

In order to measure the biological evaluation of protein of the snails and crabs, it is necessary to know the background for understanding the need of this experiment to know more about the importance of these types of protein.

The foods are the raw materials that supply energy for construction and repair to the living machine. Various life processes in all the faculties of living system including growth, reproduction, repair, maintenance, resistance to disease etc. are correlated with the intake and utilization of foods. The digestion of dietary proteins in gastro-intestinal tract furnishes amino acids, possibly polypeptides too, which are the raw materials needed to build the body proteins in animals. These body proteins form the matrix of the living system; They are the catalysts, the centres around which the dynamic equilibria of live develop; they are the protein stores of the body (Allison, 1949). It is also reported that one type of tissue protein contributes to the construction of others and food nitrogen entering into the system loses its identity and becomes part of body nitrogen. The 'biological value' of proteins may be defined as the amount of nitrogen retained in the body of an animal.

It is generally accepted that consumption of protein that fail to provide the essential amino acids are the most significant factors in human malnutrition and that the supply of suitable protein is the chief limiting factor of good nutrition in all continents. Rose (1938) demonstrated that a mixture of amino acid, viz. valine, methionine, threonine, leucine, isoleucine, tryptophan, lysine, histidine and arginine must be included in the normal growth of rat. These are essential for growth and other physiological activities of the living system, which could not be synthesized by the animals in sufficient quantities to meet the needs of the animals. However, an amino acid, essential for growth may not be essential for all the faculties of the living system. It is clear that the pattern of essential amino acids varies with the physiological state of the animal and with the species. Thus the retention of nitrogen in the animal is a function of this pattern (Allison, 1949). The amino acid composition of a protein is directly correlated to its nutritive value. Thus essential amino acid is a chief limiting factor for animal nutrition. Consideration must also be given to the correlation between the amino acid composition of a protein and its nutritive value.

However, the purposes of protein nutrition are filled only if all the raw materials are present in optimum amounts. If carbohydrates and fat are absent, amino acids in the diet are utilized to supply energy so that the construction and repair of the living system are reduced or interrupted entirely. Some proteins are active protein catalysts of intermediary metabolism, whose absence

interrupts the information of catalysis and the system cannot function. Thus, the biological evaluation of any food such as proteins must be done in presence of all other foods, with the full realization of their interdependence (Allison, 1949).

Determination of digestible protein is very important from nutritional point of view, since protein are not nutritionally available. Values of proteins can be evaluated through (i) nitrogen balance (ii) growth (iii) tissue regeneration and (iv) amino acid analysis.

The simplest method to evaluate nitrogen retention in an animal is to determine the difference between nitrogen intake and nitrogen excreted. This difference called nitrogen balance shows whether an animal is maintaining, losing or gaining nitrogen. Growth has in it the most of the phases of metabolism which contribute towards the retention of nitrogen by the animal. Evaluation of protein or amino acids through growth is, therefore, one of the most rigorous of all methods, integrating most of the functions of proteins into one measurement. The nitrogen retained in growing animals is the sum of the fractions of nitrogen retained for growth and for maintenance. Barnes et al. (1946) have shown that the relative proportion of dietary nitrogen entering into growth and maintenance varied markedly depending upon the amount and the nutritive quality of dietary proteins. It was reported that there was an increase to consumption of dietary proteins by the young rats as the amount of protein source in the diet was raised. The increased consumption of protein increased the rate of growth until a maximum was obtained.

Cannon (1947, 1948) has reported on the need of the presence of essential amino acids to the animal in proper proportions and in proper amounts. The obvious relationship between the presence of the essential amino acids in the protein with the retention of nitrogen of a dietary protein have given impetus to correlations between amino acid composition and nitrogen retention. Harte and Travers (1947) pointed out that the nutritive values of proteins are determined largely by the essential amino acid fraction. Mitchell and Block (1946) and Block and Mitchell (1946-47) also showed that the amino acid composition of the protein reveals much concerning the nutritive value of a protein.

Adachi *et al.*, (1958) proposed the invitro digestibility experiments. The values obtained in vitro and in vivo digestibility experiments were found parallel.

The quality of the proteins of snails and crabs were determined after calculating the value of digestible protein in pepsin and combined samples of samples of snails (*p. globosa* and *a. fulica fulica*) and one species of crab (*P. spinigera*). In table X the % of crude protein, indigestible and digestible protein in (i) pepsin and (ii) pepsin trypsin digestion are shown.

Considering the different biochemical compositions and nature of the protein, which contain all the essential aminoacids, it can be concluded that both snails and crabs are excellent sources of protein. They contain a high amount of unsaturated fatty acids which an important for human nutrition in connection with anticarcinogenic properties, preventing cardiovascular problems, such as reducing cholesterol etc.

Besides all these, the *in vitro* reaction concerning the pepsin and pepsin trypsin digestion showed a substantial amount of digestible protein along with the liberation of all the essential amino acids. These experiments have been designed in such a way, so that a comprehensive idea on the nature and quality of protein could be understood. Further the background of the experiments where the detailed review has been elucidated in order to understand the importance of such experiments, thus throwing light on the quality of such proteins in establishing a Class I protein for human nutrition.

The realisation of the importance of such proteins i.e. snail and crab meat by people of early times is really a strange phenomenon, where tribal people have been adopting such food items in their day-to-day diet. There is no doubt the high food value of these food items can easily combat the protein malnutrition or general anaemia and other diseases, which they solely believe that snail meat or crab meat is the key factor in subsiding or controlling the diseases.

The reaction involving the pepsin, pepsin-trypsin reactions are described in details in Table 15.

Table 15 : Digestibility of protein in vitro after pepsin and pepsin-trypsin digestion from 1 g. defeated samples of snails and crab

Species	% of Crude protein	Pepsin Digestion		Pepsion-Trypsin Digestion	
		% of indigestable protein	% of digestable protein	% of indigestable protein	% of Digestable protein
P. globosa	17.65	8	60	2.5	92
A. fulica fulica	17.52	9.5	58	3	88
P. spinigera	18.6	6	65	1.5	95

Table 16 : Amino acids liberated by enzyme actions from Snails and Crab meat.

Amino acids	*P. globosa*		*A. fulica fulica*		*P. Spinigera*	
	Pepsin	Pepsin+ Trypsin	Pepsin	Pepsin+ Trypsin	Pepsin	Pepsin+ Trypsin
L- Leucine	+	+	+	+	+	+
DL-Phenylalanine	+	+	+	+	+	+
DL-Valine	+	+	+	+	+	+
DL-Methionine	+	+	+	+	+	+
DL-Butyric acid	+	+	-	-	-	+
DL-Alanine	-	-	+	+	-	-
DL-Threonine	-	+	-	-	+	+
L-Tyrosine	+	+	-	+	-	-
L-Glutamic acid	+	+	+	+	+	+
Glycine	-	-	-	+	+	-
L-Arginine	-	+	-	+	+	+
DL-Serine	+	+	+	+	-	-
DL-Aspertic acid	-	-	-	+	-	-
L-Histidine	-	+	-	+	-	-
L-Lysine	+	+	+	+	+	+
L-Cystic acid	-	-	+	+	-	-

Snail and Crab Meat and sanitation/maintaining hygienic condition :

A. In our present studies it has been found that all snail species act as a secondary host of a large number of helminths or worms. These parasites take snails as the secondary host in order to complete their life cycle either in man or in livestock. In the present studies, it has been found that 80% snails are infested with parasitic worms/flukes and other larvae. The parasitic infestations are quite high immediately after the monsoon. Further most parasitic infestation are found to occur in all species of snails. Some of the common helminthes are :

- *Fasciola paramphistomum*, *Schistosoma mansoni*, A. *magna*, A. *perfoliata*, *Ancylostomata*, *Halmonchus*, *Ostertagia*, *Strongyloides*, *Ascaries* etc. which are quite common in all species of snails.

A large part of the their life history takes places in aquatic habitats like stagnant water, swamps, beels, rivers etc,

Maintenance of Hygienic Snail meat :

A. As described above the occurrence of such parasites is quite common. Considering the parasitic infestation, the meat should be cooked properly, so that there will not be a problem from parasitic infection in snail meat. Crab meats are not infected with some parasitic infestation.

B. Application of 0.2% $KMNO_4$ in the snail meat provides ample scope for cleaning or removing parasites from within the meat. It has been found that fluke and worms usually came out within 5 minutes after reacting with $KMNO_4$ treatment.

C. The processed or de-shelled snail meat should be immediately washed with 0.9% NaCl solution, which will kill or remove the inner parasite from the meat.

D. Proper cooking (100% for 10 - 15 minutes) removes all the non-hygienic materials and becomes clean for consumption in the proper way.

E. Application of weekly antibiotic solution of tetracycline, oxytetracycline (5%) in the meat could restore the quality and other organoleptic conditions of the meat.

Establishment of any relationship if at all, with the curing of some diseases after eating snail meat :

Although there are some lores or beliefs with respect to certain diseases and remedial measure after eating the snail meat in the interior parts of the tribal regions, but we could not establish any relationship with particular snails or crabs with particular disease.

The high food value of the species such as presence of high quality protein, unsaturated fatty acid etc. are the main criteria, which cure any health problems among different tribes.

SUMMARY

Taxonomic status :

(i) The present survey on the occurrence of various species of snails under taxonomic criteria show that altogether 40 species belong to 12 families.

(ii) The survey of crabs shows the presence of two species (*P. spinigera* and *P. woodmansoni*) under family paratelphusidae. Although there are earlier reports on the occurrence of 7 species of crabs, but the present taxonomic status of those were reviewed and only 2 species of crabs were identified from the Brahmaputra and Barak valley.

Habit, Habitat & Ecology :

(i) The freshwater system of the Brahmaputra river comprising different perennial tributaries, hill streams, swamps, beels lakes (flood plains) and man made ponds and reservoir are suitable habitats for both snails and crabs.

(ii) The suitable hydrobiological parameters, such as pH with 4.45 - 7.5, dissolve oxygen 2 - 15.3 mg/lt., free CO_2 1.0 - 9.00 mg/lt. and total alkalinity 12 - 86 mg/lt. are some of the conditions that prevailed in the habitat of crabs and snails.

(iii) A survey on the aquatic vegetation and different hydrobiological parameters pertaining to the physiological condition of the habitat has been reviewed from earlier works and present analysis from certain aquatic systems.

Reproduction :

(i) In the majority of snails, sexes are separate, dioecious or gonochoristic, hermaphrodism or monecious conditions and natural parthenogenetic reproduction has been encountered.

(ii) Breeding time of snails, continues immediately after the first shower of rains, usually from March till October, which varies from species to species as well as on the habitat conditions of the species.

(iii) For land snail, *A. fulica fulica*, condusive environmental conditions are temperature 20 - 37°C, humidity > 86%, drizzling condition etc.

(iv) Copulation of snails extends 2 - 5 hours which has been observed in the edible varieties of snails from different working stations of the Brahmaputra valley.

(v) In gastropods the sperms received after copulation are stored in the seminal receptacle or the oviduct. The eggs developed in the ovary are later fertilized with the eggs.

(vi) Pulmonates and some prosobrachs, lay their eggs in capsules embeded in a jelly-like gelatinous substance which sticks to the vegetation.

No. of eggs observed in different species are : *P. globosa* = 85 - 250 ; *A. fulica fulica* = 75 - 350 ; *B. costula* = 60 - 150 ; *P. favidens assamensis* = 30 - 90, were recorded from different swamps.

In bivalvia fertilization takes place in the branchieal cavity and fertilized ova remain in the spaces of gill lamellae.

Hatching of eggs takes 15 - 30 days after laying.

No planktonic larval forms exist in gastropods species belonging to genus *Thiara* produce veliger larvae. Unionid bivalve produce glychodium.

Molluscan growth follow infantile upto 20 - 40 and later juvenile phase continue from 50 - 75 days which metamorphosed into adult with sexual maturation.

In crabs sexes are separate, bisexual. Abdomen of crabs shows sexual dimorphism. In females the abdomen is broad with 4 pairs of biramous pleopods used for holding the eggs.

Growth, Farming and Marketing :

(i) Experiments on growth/rearing or farming were conducted in experimental nursery ponds (10.5 m x 3.5 m.), earthen pit (2m. x 1.5 m) and in paddy field (10 m. x 10 m.), while in case of land snail the same experiments were performed in moist snail chamber.

(ii) Feeding strategies is very simple. Introduction of clusters of algae and other food items showed its acceptance in rearing condition.

(iii) Snails attain lucrative growth after rearing for 30 days in different experimental condition as shown in Table 6.

(iv) Crab-feed prepared after mincing the thrash fish, snail meat are suitable feed during rearing conditions. Pelleted feed were rejected.

(v) Rearing crabs in fish nursery pond, earthen pit and in paddy field with the supplementation of feed or without supplementation showed excellent growth after rearing the same for 120 days. However, feed supplemented groups showed better growth than the non-supplemented groups.

(vi) There is no specific market or price in such non-piscian groups. A systematic organization of market is lacking in guiding the growers/farmers. However, in some markets snails are selling at the price of Rs. 8 to Rs.10 per Kg. Similar prices are also found for crabs.

Food value of crabs and snails :

(i) All specimens of crabs are edible and consumed by all tribes.

(ii) There are 7 edible varieties of snails available in the markets that are being consumed by different tribes.

(iii) Proximate composition shows that edible varieties of snails has got high nutrient value. Considering the protein, carbohydrate and lipids, the high amount of polyunsaturated fat showed the high quality of snail and crab meat for nutrition.

(iv) Protein from snail and crabs is 1st grade in nature showing its easy digestibility after confirming the pepsin and pepsin-trypsin digestion reaction. Liberation of essential amino acid showed that the protein is of high quality.

(v) There are no specific criteria involved in curing any health problem with the use of snail and crab meat in the day-to-day diet. Specific links with certain health problems have no substantial relationship. However, the high quality of its protein and the presence of polyunsaturated fatty acid is the clear indication, where the meat may act in multifereous ways with health problems such as protein malnutrition, anaemia, cardiovascular problem etc.

(vi) All snails are the carrier of most of the human diseases carrying parasites and act as secondary host for the completion of their life cycle.

(vii) Hygienic condition of the snail and crab meat can be created after treating with $KMNO_4$ treatment (0.2%) or with saline solution treatment (0.9 g/lt. NaCl). Further, proper cooking is essential in order to avoid the metacerceria, cerceria or any cyst.

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