DISCUSSION

Morphometric growth of appendages

Structure and form of appendages depends on habitat and functions which is obviously confirmed in the present study. The appendages of freshwater prawn *Macrobrachium kistnensis* and freshwater crab *Barytelphusa cunicularis* showed variations in their morphology. Prawn bears nineteen appendages and crab has seventeen only. In the prawn *M. kistnensis* the antennules, a cephalic appendage, having flagellum and peduncle, these are absent in crab, *B. cunicularis*. The cephalic appendage antennae also differ—the prawn antennae are long sensory having flagellum, whereas crab has short and stumpy antennae. These two appendages, antennules and antennae are sensory in nature and are used in searching of food using chemoreceptors located on the flagellum. This difference in structure and function in these crustaceans is due their varied habitat; the prawn is aquatic and crab is semi terrestrial in habitat.

The mandibles (cephalic appendages) of prawn *M. kistnensis* consist of two—toothed incisor process and multidenticulate molar process with a palp, such type of structures are also present in Mystacocarida (Hessler and Sanders 1966). In freshwater crab *B. cunicularis* the mandibles has incisor and molar processes which are usually indistinct. Considerable variation occurs regarding the presence or absence of the palp. Mandibles are used for cutting the food into pieces. The morphological differences in shape and form in the mandibles are dependent upon the types of food and varied modes of feeding (McLaughlin 1982). Maxillulae and maxillae are relatively similar in morphological structure and function, primarily used as feeding appendages therefore treated as cephalic appendages. In freshwater prawn each maxillulae usually biramous is having a pair of well developed endites. The maxillulae have
endites and an endopodal palp as well each maxilla is biramous with bilobed endites in *B. cunicularis*. The exopod is developed as a scaphognathite which might be used in generation of respiratory currents in the gill chamber (McLaughlin 1982).

*M. kistnensis* and *B. cunicularis* have three thoracic appendages that are modified for feeding and/or food handling termed as maxillipedes. In crab, the third maxillipede is operculated effectively shielding the other mouth appendages. The third and second maxillipedes are provided with gills. The function of maxillipedes in both prawn and crab is same but the structure of third maxillipede differs in morphology. Pereiopod or walking legs, five pairs, observed in both crustaceans. In prawn first and second pereiopods are chelate and remaining three are nonchelate, while in crab first pereiopod is chelate and remaining four pereiopod are nonchelate. In the shrimp of family alpheidae first pair of chelate is very simple, specialized to provide a mechanism for sound production, territorial defense and prey capture (Johnsen et al 1947, MacGinite and MacGinitie 1949, Hazlett and Winn, 1962 and Goldberg 1971). In crab *B. cunicularis* first chelate leg (pereiopod) is asymmetric; right chelate is bigger than the left one. This asymmetry of chelate is common in number of other decapods viz lobsters of the genus *Homarus*, most hermit crabs, *Callianassids* and many brachyuran crabs. The pleopods are abdominal appendages; in prawn *M. kistnensis* five pairs of pleopods and an additional pair of uropod is present. These are provided with appendix internae but only in male the second pair of pleopod is little modified having appendix masculine which is used in copulation. In female pleopods are developed with profuse setae to provide attachment site for egg clusters. A pair of uropod, with telson forms a tail fan which is used rapid swimming to escape from predation. In *B. cunicularis* first two pairs of gonopod are modified pleopod,
particularly in male that are used during copulation. In female four pairs of pleopods are specialized (formation of setae) for attachment of eggs clusters. Uropod and telson are absent in crab.

Morphometric studies have been used in taxonomic purposes in decapods (Tesch 1915, Holthuis 1950, Koshy 1969, Jayachandran and Joseph, 1988, Chace and Bruce 1993, Suzuki and Kusamura 1997, Davidson and Marsden 1987, Clayton 1990, Abello et al 1990 and Aiken et al 1990). The morphological variations in appendages and their relative growth were studied to allometric level in *Macrobrachium kistnensis*. Relative growth of appendages and body dimensions (carapace width or length) showed a growth pattern in relation with sex and maturity in decapods (Teissier 1960, Hartnoll 1982). In this context, relative growth in *M. kistnensis* has been observed in maturing and matured phase of male and female.

The carapace width showed negative allometry in males and in maturing and matured phase females. Abdomen length showed positive allometric growth in male in maturing and matured phase, while in female it is isometric in maturing and positive allometric in matured females. Abdomen width showed negative allometric growth in male and female in maturing and matured phases. In prawn body grows linearly hence abdomen length shows higher growth then abdomen width. In freshwater prawn, *M. kistnensis* growth of abdomen length is higher in male than in female. Female attained larger size but their growth rate was slower than males, the reason is that female contributes energy in reproduction and nourishing the brooded embryos. So the reproduction inhibits growth of the body by reducing the molting and extending the intermolt period (Hartnoll 1985). Female body growth is decreased because large amount of energy is used for growing oocytes, while male does not have such type of investment (Wickins and Baerd 1974). Bauer (2004) stated
that the abdomen and the first three female abdominal segments undergo several morphological alterations to enhance eggs protection. These alterations occur during the molt that precede the first spawning, making the female sexually mature. Mossolin and Bueno (2003) and Fransozo et al., (2004) in their study on *M. olfersi* and *M. inhering* respectively, observed that males reached a greater total length than female as a function of the difference in growth rates and patterns of population structure between sexes.

The first chelate leg showed positive allometric growth in male during maturing and matured phase whereas in female positive allometric growth in matured phase and isometric growth in maturing phase. Growth is higher in male than female and it is greater in matured stage than maturing one. The functional significant growth in sex difference may be required for territorial defense, combat, display and courtship which is characteristic of decapods (Hartnoll 1982, Lynne et al 1997). The use of chelae for carrying female during courtship in male *Corystes* (Hartnoll 1968) and in non brachyuran species like amphipoda, *Caprella gorgonian* (Lewbel 1978) in prawn *Macrobrachium rosenbergii* (Barki 1991), *M. australiense* (Lee and Fielder 1983), for burrow protection, in snapping shrimp *Alpheus heterochaelis* (Conover and Miller 1978), holding the female during copulation in crayfish *Orconectes propinquus* (Stein, 1976) and protecting the defenseless female after premating molt in prawn *M. nobilli* (Balasundaram 1980) have been well reported. The second chelate leg also showed positive allometric growth in male and female in both maturing and matured stage, growth is higher in male than female. Female used chelate leg only for feeding and for defense and in signaling display in Male *Uca* (Crane 1975), and for carrying of female during courtship and mating (Hartnoll 1968).
Pereiopods- 3rd, 4th and 5th show positive allometric growth in male during maturing and matured phase. Female showed isometric growth in 3rd and 4th pereiopod during maturing and positive allometric growth in matured phase, while 5th pereiopod showed positive allometric growth in both maturing and matured female. Growth is greater in male than female. All pleopods (1st, 2nd, 3rd, 4th and 5th) and uropod showed negative allometric growth in male and female in both phases of maturity in prawn. Relative growth is greater in male in thoracic appendages (1st chelate, 2nd chelate and walking legs) than in females. The fact that males are morphologically more specialized for an aggressive interaction implies that conflicts are more recurrent in males (Knowlton and Keller 1982) than female. In comparative situations as observed in previous works (Collins 1997, Williner and Collins 1997) fights between individual of the same sex, in both males and females are very frequent wherein large individuals win with longer chelate legs. If the opponents are of the similar size have the fierce fights (Volpato and Hoshino 1984, Karplus et al 1989, Karplus et al 1991, Casas-Sanchez et al 1995, Hughes 1996 and Sneddon et al 1997). The measurements of body and its appendages have provided an informative data for taxonomic classifications with new sight to solve the problem of species categorization, sexual maturity and ontogenetic polymorphism in freshwater prawns.

The morphometric growth of swimming appendages (pleopods, uropod and abdomen) show negative allometric growth statistically very significant in *Macrobrachium kistnensis*. The reason is reduction in overall swimming ability with increasing size. The pereiopods (walking legs) are related to walking ability and cropping behavior in feeding activities. Positive allometric growth or isometric growth was observed in pereiopods and the rapid locomotion decreases with big
size of pereiopods. The prawn *M. kistnensis* is fully aquatic animal and walking ability is of not much use as they are good swimmers; walking legs have been used in balancing the body during feeding and grooming behaviors. Large pereiopod was required not for fast walking but for balancing the body in different activities in crustaceans (Ivanor and Krylov 1980, Menz and Bowers 1980, Rodrigues 1987 and Demestre 1990).

In prawn *M. kistnensis* the relationship between total length and carapace length was negative allometric growth during maturing and isometric while matured phase in both sexes. Larger growth in matured phase indicates gonad development (Collins 2001). In matured phase the gonad develops and process of reproduction starts and for that large size of abdomen required. Males are morphologically more specialized for an aggressive interaction with other males than females (Knowlton and Keller 1982). Collins (1997) observed that in prawn fights between individuals of the same sex, in both male and female, are very frequent. According to Collins (2001) Maynard and Price (1973), and Caldwell and Dingle (1978) the chelae size plays a small function of body size in males, though it could be used to assess body size in early interaction, before engaging in more risky behaviors. The fear of cannibalism is common to injured animals that are hurt in the fights or even in molted animals (Kurihara et al., 1989, Dick 1995).

The relative growth using morphometric data has been widely studied in brachyuran species or true crabs by the researcher Hartnoll (1982). In the present study on *B. cunucularis*, CW and CL show negative allometric growth in males and females. The Carapace width has been considered an independent variable used in the morphometric study. The reasons for that is carapace width shows phylogenic change through ontogeny of crab (Barens 1968,
The rate of carapace length growth is similar in males and females. Carapace length shows same growth in immature, maturing and matured phases in males and females. Sexual maturity or functional maturity is not indicated by carapace length as well as carapace width relationship also not used for size in marine crabs (Pinheiro and Hattori 2006, Pinheiro and Fransozo 1998, Somerton and Maclntosh 1983, Dalabona et al 2005).

CW and AL shows negative allometric growth in males and females in all three phases of life. The abdomen shape show a sexual dimorphism in crab, there is a ‘U’ shaped abdomen in female body wherein eggs are incubated during embryonic growth period up to hatching. The AW and CW relationship shows negative allometric growth in immature, maturing and matured phases of male crab. In female immature, maturing phase show negative allometric growth, while matured phase (adult) female crab show isometric growth. Abdomen is the region used for reproductive purposes. The abdomen width is increased after puberty molt, which brings female into a functional size. The growth of abdomen can operate together with the sternum. In the segments of the abdomen of brachyuran there is no marked gradient in male, but in females there is a distinct gradient with a growth centre in the penultimate or final segment. In Jaera albifrons, growth centre lies in the fourth segment, and in Carcinus maenas, the carapace has one at the level of maximum width (Teissier 1960).

In matured female abdomen and abdominal appendages prepare an incubating chamber as brood for the eggs, developing embryos and hatched young ones till they are released successfully in the water stream. In freshwater crab Barytelphusa cunicularis egg development is direct; in a sense no floating larva was seen. Hatching of eggs takes
place within abdomen chamber (Hartnoll 1974, Vogt 2013 and Silva et al 2014). In contrast to females, in males rate of growth of abdomen is not much obvious. Male crab use abdomen only for protecting the gonopod, as it acts as an intromittent organ during copulation (Daniels 2001, Castiglioni and Franzoso, 2004). Such results of abdomen growth were similar to the results published by Silva et al (2014) and Lima et al (2012).

In Decapods major chelate leg is very important organ due its use in inter and intra species interactions. In freshwater crab *Barytelphusa cunicularis*, growth of chelate leg is isometric in immature stage male and female, and positive allometric in maturing and matured phase. The morphometric growth is higher in male crab than female. Male used chelate leg in courtship, agonistic behaviors, for defense of their territory protecting female during mating (Mariappan et al 2000 and Daniels 2001), also used for feeding and predatory interaction (Levinten et al 1995 and Daniels 2001). Porter (1960) studied that the males of *M. mercenaria* used their chelifeds for the protection of entrance of holes occupied by premolt females, prior to copulation. In *Eriphia smithi*, the powerful chela is related to the conquest and defense of suitable burrows (Vaninni 1987 and Vaninni & Gherardi 1988). In females the chelate leg is used for feeding, protecting and to carry the young ones. Jivoft (1997a, b) observed the reproductive behavior of *Callinectes sapidus*, and stated that large sized male with large chela had an advantage in partner selection, and also in making signals. The male chelate has isometric growth in immature stage (juvenile) it moves to positive allometric growth at the puberty molt. The combination of these factors brings the chelae to fully functional size at sexual maturity. After the puberty molt the relative growth becomes yet higher in the level of allometry ie, positive allometry. This is because the chelae are basically independent effectors and not
functionally restricted by the size of other body parts. In essence the larger chelae are more advantageous to male. Comparatively in female the growth of chelae is less than that male crab. The chelae grow with only slight positive allometry. The enlarged chelae of larger females will equip them for their more prominent role in both intra and inter specific contacts. The sexual dimorphism of the chelae can be correlated with behavior pattern. In grapsid crab *Goniopis cruenta*, there is little sexual dimorphism and both sexes play essentially equal roles in inter specific display and combat, whereas Mangrove crab *Aratus pisoni* highly dimorphic chelae in female is notably subservient (Warner, 1970).

Propodus is the important part of chelate leg, a second last segment in chelate leg. Propodus grows more vigorously in males than females that to it is more in adult male and female crabs. In crab *Barytelphusa cunicularis*, the CW and PDL relationship shows positive allometric growth in matured (adult) stage in males ($b= 1.56$), and negative allometric growth in immature and maturing stages. Maturing phase is much closer to isometric growth and growth constant ($b=0.88$). While in females the growth is negative in all the three stages except matured phase where it is isometric growth ($b=0.84$). The growth centre lies in propodus of chelate leg (Huxley 1932). The propodus is the largest segment of chelate and higher growth was observed in propodus of *Barytelpusa cunicularis*. Actually the growth centre lies in the propodus. Huxely (1932) observed a growth centre in propodus with maximum allometry in that segment and reducing levels towards the dactylus and coxa. In the chelate of *Alpheus dentipes*, the growth centre was observed in propodus (Dawes, 1934) and in thoracic limbs of *Asellus aquaticus* in the carpus or propodus (Needham 1943). According to Huxley (1932) the form of the growth gradient within an appendage can change during ontogeny. He observed in *Pagurus bernhardus*, the growth centre in
right chelae of male lies in the merus during early growth and in later phase of strong allometric growth shifted to propodus (Huxley, 1932).

The relative growth in length of pereiopod (2nd and 5th) and carapace width shows negative allometric growth in male and females in immature and maturing stages of life, while isometric growth was observed in matured phase. A relationship between Length of 3rd pereiopod and carapace width was negative allometrical in immature phase however; positive allometric growth in maturing and matured phases in males and females. The length of 4th pereiopod and carapace width male crab shows isometric growth in immature phase, while positive allometric growth in maturing and matured phase. In female the length of 4th pereiopod shows negative allometric growth in immature stage, isometric growth in maturing stage and positive allometric growth in matured stage. The pereiopods- second to fifth, are walking legs used for locomotion. Walking legs are also used in balancing the body during capturing the prey, for agnostic interaction, hence appropriate growth in pereiopods is observed in *Barytelphusa cunicularis*. In growing *Asellus aquaticus*, the level of allometry increases from anterior thorax to the posterior limbs (Needham, 1943). It is true that high allometric growth in a particular organ has induced changes in the allometry of adjacent structures (Hartnoll 1982). In *Macropodia rostrata*, the high allometry of male chelae influences the growth of all the walking legs (Guillaume et al, 1963) and same applies Uca (Huxley and Callow 1933) and *Pagurus* (Huxley 1932), specifically heterochely in in walking legs. In female *Uca*, abdomen allometry is associated with faster growth in the last two pairs of walking legs (Tazelaar 1933). The associated growth along with the growth one effective organ might have evolved as functionally necessity for optimal mechanical efficiency of the organism, or could be a reflection of merely inescapable mechanism controlling allometric growth.
According to Hartnoll (1974) there is correlation between the size of the pleopod and genital opening located on third pleopod in female. In freshwater crab *Barytelphusa cunicularis* mating or pairing is often between small female with a large male; or as per the suitable size of gonopore that matches with the size of male pleopod. This could be the proper reason of absence of a positive allometric growth in the male pleopods. The 2nd pleopod is very small than 1st and soft in texture, not calcareous like 1st pleopod so the reason is it may not be used in copulation.

The relative growth of female pleopod is not discussed so far in literature; very few authors have observed and studied the brachyuran species. In *Barytelphusa cunicularis*, the growth of female pleopod is negative in relation with carapace width in all the three stages, immature, maturing and matured. Female pleopods show isometric growth with carapace length, positive allometric growth with abdomen length and abdomen width and pleopods grow more in size in adult condition. The exopodite of pleopod protect the eggs and brood, preventing them from desiccation for a long period, as in *B. cunicularis* development is direct. So in this species protection of eggs, developing embryos and young ones is very important to avoid the loss in drastic environmental conditions; hence young ones are maintained and nourished till their successful release in favorable habitat. Similar results are observed by Gherardi and Vannini (1990) in freshwater crab *Potamen fluviatile*. According to Huxley and Richards (1931), in brachyuran, abdomen growth is only used to estimate the proper size of females at puberty, because abdomen growth is related with certain somites that has shown showed striking modifications in growth and morphology during ontogeny.
The correlation of gonad maturation and appendages growth

In freshwater prawn *Macrobrachium kistnensis* gonad maturation has correlated with body growth, (abdomen length, appendage length, total length). Gonad starts maturing in male at size 3mm and in female 5mm carapace length. In males two stages of testis was observed in maturing stage. Stage 1st at size 3mm to 5mm and stage 2nd at size 5mm to 7mm. Third stage was observed in matured stage at size 7mm to 9mm carapace length. In male abdomen length, appendages (length of pereiopods) shows positive allometric growth in maturing and matured stage, while other parts like carapace width, abdomen width, and total length shows negative allometric growth. In female the onset of maturing ovary was observed in maturing stage. Female also has 1st and 2nd stage of development of ovary in maturing phase. 1st stage of ovary was observed at size 3mm to 7mm carapace length, 2nd stage observed at size 7mm to 9 mm. Third stages was observed in matured stage at size 9mm to 12mm. In maturing stage female prawn shows positive allometric growth in abdomen length, all pereiopod except 3rd pereiopod, isometric growth was observed in total length, and negative allometric growth was found in carapace length, abdomen width, length of all five pleopod, uropod length. Whereas matured phase shows positive allometric growth only in second chelate leg and fifth pereiopod, isometric growth was observed in abdomen length, first chelate leg, third and fourth pereiopod, , negative allometric growth was found in carapace length, abdomen width, total length, length of all five pleopod and uropod length. The morphometric growth was higher in maturing stage then matured stage. During maturation appendage growth was fast at maturing phase and reduced in matured phase. The sexual maturity was occurs prior to morphometric maturity. As the animal morphometrical
matured it is capable of reproducing young ones. According to Bauer, (2004) the abdomen segments undergoes several morphological alterations for protection of eggs. These alterations occurs during the moult that precedes the first spawning, making the female sexually mature. Collins and Petriella, (1990) observed that puberty molt were occurs in cephalothorax of *Macrobrachium borellii*, and in the second pereiopod of *C. merley*, (Botello and Alvarez, (2006), and in the abdominal pleura of *P. northropi*, (Pralon and Negreiros-Fransozo, (2006). Wenner et al., (1985) and Bauer and Abdalla, (2000) reported that the presence and extrusion of eggs in female pleopod is an indicator of sexual maturity in females, which is determined by length of the smallest capture ovigerous female. Wenner et al., (1985) and Oh et al., (1999) concluded that the variations in maturity sizes are common in crustacean, and caused by variations in growth rate and several degree of variability which occurs on a seasonal basis in a single habitat or in different locations. Paschoal, et al., (2013) founded that there was synchrony between physiological and morphological maturity.

In brachyuran’s body growths includes growth of carapace, abdomen and appendages and have a correlation to gonad maturation. Carapace and abdomen growth is needed for acquiring space for growing gonads, as well as abdomen for development of a brood. The appendages growth, particularly the male chelae, is meaningful for attracting the female for copulation or mating. The female pleopods are used for preparing an incubation chamber for fertilized eggs till their hatching quite for a long duration. The same observations are noted in freshwater crab *Barytelphusa cunicularis*.

At carapace width 15-17mm, the sexes are undifferentiated. The advancement of pleopod (2 pairs’ in male and 4 pairs’ female) growth in *Barytelphusa cunicularis* as a demarcation of sexual dimorphism is
distinct from carapace width 18mm onwards. Thereafter male and female show varied growth of abdomen. The immature *Barytelphusa cunicularis* of both sexes show growth of carapace (CWxCL) as negative allometric; only slight increase was observed in maturing and matured phase. Even the abdomen width also shows negative allometric growth in immature phase. In immature stage, female gonad is white translucent in color, with developing oocytes and with progressive oocyte maturation (in II stage) the ovary becomes yellow in colour however, at this phase abdomen shows negative allometric growth. In completely matured ovary oocytes attain the maximum growth such stage of abdomen show isometric growth. Later ovary achieve dark orange colour and histologically the oocytes show completion of vitellogenesis and get ready to spawn. The similar observations are reported in other brachyuran species (Chenet et al 1994, Leme 2005, Castilho et al 2008, Rostant et al 2008, Keunecke et al 2009, Souza and Sliva, 2009 and Sliva et al 2001).

The growth in appendages is somewhat different then the carapace and abdomen on both sexes. In male *B. cunicularis* growth of appendage is isometric in the maturing phase and then turns to positive allometric in matured phase but it is always negative allometric in immature stage. The attainment of functional maturity in both the sexes is essentially a final step before mating; at this point of time the sizes of male and female carapace reach a maximum growth (refer Table 8). Simultaneously the chelae of male show positive allometric growth and get ready for mating activities like, attracting females, mating, protecting females. It is mentioned in the literature large chelae are required for successful mating. Sexual maturity in *B. cunicularis* was observed in the crabs that fall in the carapace size 85-94 and mm and 87-97mm in male and female respectively. After reaching the sexual maturity, male and female abdomen change its shape- as V alphabet structure in male and U in
female and it's an external identification characteristic of the animal. The final changes specific to male and female in morphology including allometric changes in carapace, abdomen and appendages is a functional maturity of a crab that enables them to mate (Corgos and Freire, 2006). In some brachyurans, gonad maturity does not coincide with above definition of functional maturity (Conan and Comeau 1986). Our results coincide with other brachyurans species like *Maja brachydactyla, Chionecetes opilio* (Conan and Comeau 1986, Sainte-Marie et al 1995) *C. Bairdi* and *Paralithodes camtschatica* (Paul 1992, Corgos and Freire 2006). Hartnoll (1965) explained the spermatophores formation in testes could not be sign of the morphological maturity in males. The presence of spermatophores is only circumstantial evidence of gonad maturity and it requires the experimental data of actual mating took place or not. Paul and Paul (1990) and Paul (1992) studied morphometry of immature males *Chionoecetes* and *Parathodes* that were capable of mating. Powell et al (1972) observed in majids male mating in wild was usually morphometrically mature and larger in size than female (Brosham 1981, Conan and Comeau 1986, Enries et al 1988 and Paul 1992). In several male brachyuran species mating is initiated after agonistic interaction (Stevens et al 1993, Van Der Meer en 1994, Elner and Beninger 1995, Jivoff 1997, Wada et al 1997, Sante-Marie et al 1997, 1999, Rondeau and Sante-Marie 2001, Correa et al 2003, Corgos and Freire 2006). Goshima et al (2000) state that smaller males are rejected by females, because the allometric increase of chelae size is related to the role they play in supporting the female during courtship and mating (Brusnan 1981, Rodhouse 1984, Jivoff 1997). According to Corgos and Freire (2006) mature crabs of larger size compete advantageously over smaller ones and have chance to mate with large size female. Therefore, male crabs that have attained gonad maturity and have attained functionally maturity have good chance for successful mating.
Nervous system and nerves ramification, as morphometric variation of a species

The freshwater prawn *Macrobrachium kistnensis* consist of three parts, 1) brain or suprareosophageal ganglion, optic ganglion and a set of nerves emerging from respective ganglions 2) a pair of commissural ganglion and circumoesophageal commissure and Thoracic ganglion (a group of five ganglion) with its nerves 3) abdominal ganglion and nerve cord and nerve supplied to pleopods and telson. From the brain or suprareosophageal ganglion following nerves arising from it are, optic nerve to the eyestalks, ophthalmic nerve to muscles of eyes, antennulary nerve to statocyst, muscles of the antennules and three feelers of the antennules, antennary nerve to squama and feeler of the antenna, nerve to circumoesophageal ganglion. From the thoracic ganglia eleven nerves are arising on each side. The first pairs of nerve to the mandibles, the second and third pairs of nerves to the maxilla and maxillulae, fourth, fifth and sixth pairs of nerves to the first, second and third maxillipedes as well as five pairs nerves supply to the five walking legs. There are six paired abdominal ganglia situated segmental in abdominal segment lying above the muscles. Each pair of first five abdominal ganglia gives off nerves to the appendage and extensor muscle to the own segment and flexor muscle to the succeeding segment and pleopods. Two pairs of nerves give rise to flexor muscle of sixth segment, and to the uropod and muscles of telson, single nerve to the rectum and the hind gut.

In freshwater crab *Barytelphusa cunicularis* the nervous system comprises cerebral ganglion, commissural ganglion, and thoracic ganglia. The cerebral ganglion supplies different nerves to the optic nerve to the eyestalks, antennulary nerve to the antennules,
antennary nerve to the antennae, occulomotor nerve to the muscles of eye, tegumentary nerve to integument and large nerve to the commissural ganglia. Commissural ganglia supplies nerves to the stomatogastric system supplies branches of nerves to the complete foregut. The thoracic ganglionic mass lies between the two branchial chambers below the heart. The thoracic ganglionic mass is formed by many smaller ganglia. Five pairs of ganglias supplies nine nerves to the thoracic appendages from mandibles to fifth pereiopod.

The abdominal ganglia are reduced. Five abdominal nerves arise from the ventral mass, and each nerve given off many small branches of nerves that are supplied to the segments of the abdomen. In crayfish, cerebral ganglia give off an anterior median nerve going to the muscles which control the fused medial joint of the eyestalk. Many researchers had worked on cerebral ganglion and its nerves viz on anterior median nerve (Steinackers1975), optic nerve, occulomotor nerves (Sandeman 1964, Mellon 1977), antennulary nerve (Sandeman and Okajinan 1973), antennary nerve (Taylor 1975), tegumentary nerve (sandeman 1967a). Thoracic ganglia are five in number which have main and minor roots. In crayfish there are five abdominal ganglia (Hughes and Wiersnia 1960, Davis 1968, 1969). There is variation in the number of nerve branches in the caudal ganglia of decapods.

The abdominal structural system of decapods crustacean has been investigated in Astacidae (Wine et al 1974, Thampson and Page 1982) the morphology of abdomen of the shrimp Cragon cragon (Caridea) show a high degree of similarity with that of Astacidea. In spite of the varied behavioral patterns of crayfish, lobsters, shrimp there no essential difference was detected in the morphological arrangement of abdomen. The thoracic ganglia in crab Barytelphusa cunicularis are fused and the lobes of this single ganglionic mass correspond with
the segmental appendages. The abdomen and abdominal ganglia are much reduced. The ganglionic arrangement and the anatomy in *M. quadrispina* are much more similar in crabs, which have undergone a similar fusion of thoracic and first abdominal ganglia than to those in lobsters and crayfish (Harzsch and Dawirs 1995, Antonsen and Paul 2001).

In prawn *Macrobrachium kistnensis* the abdomen is straight and slender whereas in crab *Barytelphusa cunicularis* it is short compactly packed at the posterior to thorax. Such type of variation in arrangement of body is caused by aquatic adaptation in prawn and semi terrestrial adaptation in crab. According to posture of body nervous system was developed. The main difference was founded in arrangement of abdomen ganglia in both decapods, in prawn six abdominal ganglia are segmental but in crab the ganglia is much reduced in size and number. These are the major characters which classified these two decapods in sub order natantia and brachyuran respectively.
Role of appendages in grooming, feeding, and predatory behavior

Grooming Behavior

Grooming activities were prominently observed in freshwater prawn *Macrobrachium kistnensis*. First pereiopod, and fifth pereiopod play a very significant role in cleaning the body. These appendages are also known as grooming appendages. First pereiopod cleans antennules, antennae, eyes, dorsal and ventral surface of carapace, rostrum, telson, embryos, brood pouch and uropod. Antennular preening is done by first pereiopod (chelate) in some shrimp species of group carideans, penaeidean, stenopodidean and palaemonets. In freshwater prawn *Pandalus danae*, and *Palaemon ritteri*, third maxillipede was maximally used in antennular grooming (Bauer 1981). *M. kistnensis* uses antennules and not third maxillipedes in antennuale grooming. For this purpose, first pereiopod bear serrate setae by which antennules flagella are cleaned. Such type of cleaning was observed in Penaeidean species. American Penaeids use propodus brush for cleaning of antennules (Anderson and Linder, 1943) and similar observations by Hansen (1919) in Sergistid (*Sergestes orientalis*). Judkins (1978) also observed carpal and propodal brushes of first pereiopod has role in cleaning of antennules in *Sergestes geminus*, and presence of this character is used in the diagnosis of the *S. edwardsii* species group. Bauer (1981) reported Natantian species show antennular grooming by first pereiopod, and reptantia species by third maxilliped.

The antennules bear olfactory esthetases that are groomed by first pereiopod. The antennules are important chemosensory appendages mediating the information of dissolved food, water and pheromones, (Reeder and Ache 1980, Dunhan 1978). Grooming of antennules has rather evolved to maintain esthetases free of fouling so that can help
in searching the location of food and a potential mate for mating in decapods.

Gills are enclosed in branchial chamber playing an important role in respiration. Water current, when passes over gill filament, gill lamellae, and ramie filters, it carries fine sediment particles along with the current. These fine particles get settled on gill lamellae or filament due to absence of very fine filtering of the water current. To overcome this problem, gill, cleaning mechanism has evolved in decapods. In prawn *M. kistnensis* gill is cleaned by setae on the first pereiopod (Chelate). Same behavior was observed by Bauer in caridean shrimp and Vuillemin (1967) Bauer (1981) surveyed several species of caridean shrimps who keep the gills clean by one or two pair of chelate legs. Stenopodid shrimp used the setae of first and second pair of cheliped to clean the gills; Anomurans used the last thoracic leg as a grooming appendage. Gill cleaning in decapods is the result of selection of pressure for maintaining gill surface clean, which is good for exchange of respiration gases.

In *M. kistnensis* first chelate also grooms dorsal and ventral surface of carapace, eyes, area between the body and appendages, uropod, telson, which can be categorized as general grooming. Fifth pereiopod cleans upper and lower dorsum of abdomen, pleopods, brood pouch, and embryos. Baure (1981) observed in the nantantian species, setae and chelae are the important in general grooming of the limbs ; whereas the penaeids use all the three pairs, Atyids, both pairs of chelipedes for cleaning and Carideans primarily clean with either the first or the second pair of chelipedes.

Grooming in brachyuran species is absent in true freshwater species and little present in false crab like Anomuran species such as galatheid (*Pleuroncodes planipes*), porcellanid (*Petrolisthes cabrillas*),
and lithodidae (except for the Axiid thalassinids if included in Anomura) and some marine species (Bauer 1981, Martin and Felgenhauer 1986, Bauer 1989 and Fleisher et al 1992). Active body grooming is absent in freshwater crab *Barytelphusa cunicularis*. Freshwater crabs are semiterrestrial hence they lived in water as well as on land as per the season and needs. On land they lived in burrows excavated in mud; only for feeding they go to water bodies. This crab avoids its continuous exposure in aquatic medium hence fouling was rarely or never found on its’ body surface. Appendages of crab are not modified for grooming activities. The maxillipede is short in length and does not reach to body surface; also first and fifth pereiopod is not smooth and flexible for cleaning. One more thing has been noted that in freshwater crab the larval development is direct so no embryo cleaning was needed, because incubation or development of embryo take place within ventral region of abdomen. For such reasons, grooming behavior is not developed in freshwater crab *Barytelphusa cunicularis*.

The reduction of body grooming within the decapoda may have accompanied the groups’ major evolutionary trend, the body can change from the shrimp like caridoid form to crab like brachyuran form. The caridoid species has a set of adaptations for swimming by contrast both forward and backward (escape) movement of swimming in shrimps and prawns is replaced by efficient walking and running in brachyurans. The whole morphological modified body structures have made possible the crab in transforming the locomotion and life style too. Dorso-ventrally flattened and lateral expansion of the cephalothorax, reduction in the overall abdomen size, well developed musculature in thoracic region, and folding of the abdomen beneath the cephalothorax as well altered pleopod function from swimming to reproduction are few noted distinct adaptive changes in the crab.
The loss of uropod and retrograde escape swimming by rapid abdominal flexion, and loss of the long rostrum and rudder like antennal scales (Calman 1909 and Glaessner 1960) are other additional changes observed. Anomuran decapoda show several intermediate morphological and locomotory states between the Macruran and Brachyuran species (Bauer 1981).

Burrowing behavior in many crab species resulted in abrasion of exoskeleton in grooming and smoothening of sediment would deter epizoic fouling; for example the shame faced crab burrows themselves in sand or mud (Kastner 1974). Terrestrial, semi terrestrial or amphibious crab shows reduction in any type of fouling. Because the settlement of epizoites are low or absent and if any fouling organisms managing to settle on these crab it would have serious desiccation and feeding problem. Crane (1975) reported that fiddler crab (Uca species) live in muddy habitat dig a rind around themselves by plunging into the standing water of their burrows. Fouling pressure is varied in different habitat brachyurans. Wolf (1958) reported that Oxyrhyynchous crab reduces fouling by inhabiting in rocky reef that is kept clean by strong water currents. Norse and Estevez (1977) explained that euryhaline portunid crab, Calinectes spp shows epibiontic fouling. The epibiontic fouling was higher in marine than in estuarine or freshwater habitats. Stenohaline, marine portunid show little fouling. There is paucity of study of grooming behavior in freshwater Macruran and Brachyuran species in decapods.

**Feeding behavior**

Freshwater prawn *Macrobrachium kistnensis* are more herbivores then carnivorous, while crab *Barytelphusa cunicularis* are omnivorous and carnivorous. The appendages like cephalic and thoracic collectively play a vital in feeding behavior. Prawn is fully
aquatic feeding on algae and aquatic plat leaves. Sometimes also feed on sand particles, along with food particles. Many times they are found to feed on dead and decaying part of prawns. Prawn first searches the food by antennules and antennae by their olfactory setae. After finding the location of food prawn moves toward the food and picked up by chelate legs and third maxillipede. Then the food particles are handled properly with chelate and third maxillipede conveyed to the mouth for eating. Freshwater crab *Barytelphusa cunicularis* is carnivores and omnivorous feeding on small crustacean, snail, insects, and crabs. Crab first searches the food by walking. As the food is found subsequently it is collected and picked up by the chelate leg. The food particles are conveyed to the mouth by chelate and third maxillipedes. In mouth first food is cut into pieces or grinded by mandible.

The first and second pereiopods and the mouth parts are the appendages directly involved in the feeding behavior of laomadiid shrimp *Axianassa australis* (Coelho and Rodrigues 2001). Nickell and Atkinson (1995), observed in *Jaxea nocturna*, second pereiopods to resuspend the sediment, the third pair of maxillipedes collects the particles in suspensions and transfer them to the second pair of maxillipede. The main function of the appendages have been described for some species of thalassinidean shrimp through direct observation or inferred from morphological differences (Nickell et al 1998, Stamhuis et al 1998, Coelho et al 2000b, Coelho and Rodrigues 2001). The mechanisms of particle selection have been observed in many crustaceans (Nicol 1932, Thomas 1970, Kunze and Anderson 1979, Schembri 1982, Alexander and Hindley 1985, Coelho et al. 2000b, Coelho and Rodrigues 2001). Nickell et al (1998) analyzed the setaeal morphology of three thalassinidean species, and concluded that dense amount of pappose, plumose and
plumodenticulate setae are adaptations to filter feeding. More number of denticulate setae and cuspidate setae are specialized for filter and deposit feeding and high count of serrate and cuspidate setae are related to deposit feeding.

Feeding behavior in decapods crustaceans is activated by sensing the differing chemical stimuli (Zimmer-Faust and Case 1982, Zimmer-Faust 1989), which are detected by chemosensory organs (Derby and Atema, 1982). Stimuli are probably integrated from different receptors to activate particular behavior (Derby and Atema 1982), with final consumption of prey possibly determined by relative stimuli from chelae and pereopods receptors (Jubb et al 1983). The presence of shell and gravel pieces gives diverse stimuli, creating an abundance of chemical and mechanical stimuli, and necessitates more time for prey detection.

The *Ovalipes guadulpensis* (Caine 1977) is nocturnal organism and the detection of food or prey achieved with the dactylus of the walking legs. The chemosensory properties of the dactylus of brachyuran, *Carcinus meanas* have been observed by Case and Gouillians (1961) and Case (1964). The oral appendages are articulated in such a way so the mandibles move ventrolaterally and are capable of both medio-lateral and dorso-ventral movement (Borradaily 1922).

**Predatory behavior**

Predatory behavior is not well developed in prawn *Macrobrachium kistnensis*, while it is more seen in crab, *Barytelphusa cunicularis*. Appendages play important role during predation. Appendages of prawn are thin and delicate, not good for predation purposes so prawn does not show any predatory activity. In prawn canabalism was observed or they can feed on dead animals or decaying matter. Freshwater crab *Barytelphusa cunicularis* shows predatory behavior.
Crab attack on animals (snails, prawn, and insects) by chelate leg, break the shell and remove the animal into the shell by chelate and then eat with the help of mandibles. For predation powerful appendages are required, and chelate is most strong and powerful appendage amongst other walking legs. The other walking legs of crab are also strong and used for balancing the body during predation.

Predation is a complex behavior, which includes an array of steps such as prey detection, capture, breaking of shell (in case of prey item is bivalve or snail). Predatory activities involve the synchronous movements of cephalic, (chemosensory) and thoracic (mechanosensory) appendages. Sensory setae are present in the cephalic and thoracic appendages in decapods. In freshwater crab, *Barytelphusa cunicularis*, predatory behavior is well developed because it’s semiterrestrial living style. Crab body-built is strong with tough chitinous shell and power full appendages, which are well adapted for predation. For searching the prey, stalked eyes, antennae and antennules are in execution and chelate leg and walking legs are used for capturing the prey. After searching the prey, chelae is used to capture the prey by an attack, then grip on the prey come in force using dactylus and propodus and later it is break into pieces for eating. In case prey is having cover like shell, then crab first opens the shell and then feed on it in above manner. According to Ache (1982), Bush and Laverack (1982), prey detection and capture involve a combination of chemo- and mechanoreceptors.

Shell crushing is one of the important activities during preying on snails of different size and shape of shells. Zipser and Vermeij (1978) observed the method of crushing of shell successfully of a snail by crabs that are relatively similar to the size of crab. Shoup (1968) and Vermeij (1976) described another method of peeling out the animal
out of shell in larger shell snails. The method of shell breaking have
been observed by many authors in other tropical and subtropical
 crab species (Shoup 1968, Rossi and Parisi 1973, Vermeij 1976,
1978, Zipser and Vermeiji 1978) and also gives suggestion that the
size affect the adaptation of these breaking techniques in Guamanian
crabs. Hermit crab used their walking legs for moving the shell
forward and then grasps it with the minor chelae, which transports
the shell to the mouth parts. In the predatory behavior of crab *Eriphio*
and *Ozius*, the larger chelae with large dactylus molar are used for
breaking shells either by crushing or peeling. The molariform teeth
are located on the inner proximal edge of the dactylus, and they
maximize mechanical advantage.