Sex Ratio

Emerson (1994) and Lardies et al. (2004) while studying the sex ratio in *petrolisthes laevigatus* held that any deviation of sex ratio from 1:1 helps to internally regulate the population by affecting its reproductive potential. Tongdee (2001) determine the sex ratio of mud crabs (*Scylla* spp.) from three districts in Ranang viz. Laun, Muang and Kapoe and reported that the sex ratio of male to female varied at all the three districts as it was recorded to be 1:0.82, 1:0.76 and 1:0.90 respectively. Further in females the ratio of immature to mature female were recorded to be 1:0.51, 1:0.82 and 1:0.26 in respective districts. The sex ratio of blue swimmer crabs, *Portunus pelagicus* was analyzed by Xiao & Kumar (2004). They reported that the sex ratio of male increase with water depth from January to September but decreased when water depth also decreased. Litulo (2004) reported overall sex ratio of the fiddler crabs *Uca inversa* to be 1:0.84 with further indication of male biased population.

While working on mud crab, *Scylla serrata* of Sunderbans mangrove Ali et al., (2004) reported that in these crabs the overall sex ratio of male to female was found to be 1:0.94. Sex ratio was observed to fluctuate monthly, being highest in the month of May (1:1.89) & lowest in September (1:0.36). Further when the sex ratio of different class size
was determined it was observed to be highest in crabs of class size 71-80mm while lowest in 91-100mm size group. Litulo (2004) while studied the sex ratio of the fiddler crabs, *Uca inversa* and reported that in these crabs the overall sex ratio was recorded to be 1:0.84, thus was male biased population. Studies carried out on *Dotilla sulcata* by Sallam (2005) revealed that overall sex ratio was deviated from 1:1.1 and never remain constant but keep on fluctuating throughout the year. Within sex males surpass females in number except during August and November where reverse trend occurs i.e. female surpassed males. Litulo and Tudge (2005) while studying hermit crab *Diogenes brevirostris* observed that total of 622 crabs, 290 were males (46.6%), 170 were non-ovigerous females (27.3%) and 162 were ovigerous females. The overall sex ratio, therefore found to be 1:1.15 which was quite differed from the expected 1:1 ratio. Male recorded to attained larger size compare to females at any stage of development, thereby exhibiting well marked sexual dimorphism. They further stated that under studied crabs were continuous breeder thus breed throughout year with peak in March, August and December.

Seasonal changes in the population structure of the Chinese mitten crab, *Eriocheir sinensis* by studied by Czerniejewski and Wawrzyniak (2006) who advocated that sex ratio was different from the expected 1:1 ratio. Sex ratio further never remain to be constant but exhibit fluctuating trend throughout year. Overall males were numerically more than females in autumn months whereas in rest of months female surpassed males.

Lawal-Are (2010) determine the sex ratio in blue crab, *Callinectes amnicola* in Nigerian and reported that the overall sex ratio found to be 1:0.96 which, however, remain fluctuated as females were observe significantly more abundant than males in the dry months of March, May and August and early months of the rainy season in September. While investigating the population structure, fecundity and relative growth of crab, *Leurocyclus tuberculosus*, Stauffer et. al. (2011) reported that out of total 269 crabs, 168 were males and 101 were females (42 ovigerous). The sex ratio was therefore found to be 1:1.66 (M: F) that differed statistically from the expected 1:1 within population male attain larger size (12.81 to 71.67 mm with mean ±SD 48.77± 13.75 mm) from female (15.33 to 55.44 mm with mean ±SD, 36.19± 8.66mm). The size of maturity in both the sexes recorded to at 30 mm in females while at 55 mm in males. While
estimating sex ratio in *Paratelphusa masoniana*, Sharma and Gupta (2013) stated that out of total of 581 crabs, 283 (48.37%) were males and 302 (51.62%) were females. The overall sex ratio therefore was found to be 1:1.07 thereby indicating that females were numerically more as compared to males. However, sex ratio never remain constant but exhibited fluctuation pattern throughout year especially in the month of June-July and December-January when it was less than unity (1:0.40, 1, 1:0.6 and 1:0.55 respectively). The under studied crabs exhibited well marked sexual dimorphisms in morphology. They further held that male of this species attained greater size (5-6 CW) than females (4-5 cm CW). Devi and Smija (2013) while studying population structure and breeding periodicity in freshwater crab, *Travancoriana schirmerae* advocated that out of total of 3605 individuals, 2168 (60%) were males and 1437 (40%) females. Breeding period observed to extend from February-May and the highest frequency of ovigerous females was observed in March whereas females with juvenile underneath abdomen observed in the population from April-July, with the highest percentage in May. Recruitment of juveniles in the population was recorded at the onset of rainy season in June.

Mantellato et. al., (2002) studied the basic population structure of *Paguristes tortugae* in Ubatuba Brazil reported that our of total 306 crabs 138 males and 168 females therefore sex ratio found to be 0.86:1 i.e. slightly deviated from 1:1 ratio. Size distribution of the sampled population further observed to present a normal distribution pattern. Further size comparison analysis revealed that females attain significantly larger size (mean size 23.53 ± 4.8 mm CW) compare to males (22.32 ± 4.8 mm CW) counterpart.

**Size Frequency Distribution**

Jivoff (1997) while studying sexual competition among male blue crab, *Callinectes sapidus* advocated that in aquatic brachyuran, males attained maturity at bigger in size than females. Population structure and biology of crabs, *Dotilla sulcata* from Elgharqana was studied by Sallam (2005) who reported that in these crabs when size frequency histograms using 1mm class interval of carapace length were constructed it depicted that for both the sexes, the population consisted predominantly of adult individuals. Tongdee (2001) studied the size frequency distribution of mud crabs, *Scylla*
and reported that percentage of smaller crab (smaller than 7cm CW) increased in May, June and July and a gradual decrease from August to October and again increase during months of November. On the basis of these findings he held that in these crabs recruitment occurred twice in year, first in may to June and secondly in November.

Sigana (2002) analyzed the abundance of crab, *Thalamita crebata* in Kenya and observed that in smaller size i.e. 40.5-55.44 mm females were recorded to be more numerous than males. However males dominate in larger size classes ranging from 55.4-80.44 mm. Studies on size frequency distribution was carried out by Ali *et. al.* (2004) on mud crabs, *Scylla serrata* of Bangladesh where they reported that in males the maximum size (130mm CW) was observed in the month of May while minimum size (47 mm CW) in month of August with the modal class size to be 81-90mm. In females the maximum size (100 mm CW) was recorded in month of June and minimum (32 mm CW) in July. Further the frequency of males were found to be more at class size 41-50 mm CW upto 81-90 mm CW and less thereafter, whereas in females the maximum frequency was recorded at 71-80mm CW.

Studies on size frequency distribution were carried out by Ali *et. al.*, (2004) on mud crabs, *Scylla serrata* of Bangladesh. Based on their studies they reported that in males the maximum size (130mm CW) was observed in the month of May and minimum (47 mm CW) in month of August with the modal class size to be 81-90mm. In females the maximum size (100 mm CW) was recorded in month of June and minimum (32 mm CW) in July. Further, the frequency of males was found by them to be more at class size 41-50 mm CW upto 81-90 mm CW and less thereafter, whereas in females the maximum frequency was recorded at 71-80 mm CW.

While studying the sex ratio of crab, *Trichodactylus borellianus*, Collin *et. al.* (2006) reported that in these crabs sex ratio showed seasonal variation as males were abundant only in late winter and spring while in rest of year females were more in number dominated males in number. When the correlation between crab abundance and water level was drawn it was also recorded that these crabs exhibited negative correlation with water level.
Distribution and abundance of crabs, spp. were determined by Dobson et al. (2007) who sampled the invertebrates from 21 sites on 19 rivers in Mt Kenya. The sites were divided into shaded site, agricultural site and forest site. They reported that crabs were though significantly more abundant in forest site than in either type of agricultural site, however as far as biomass was concerned it remained same in all the three sites. This they held was due to presence of large number of juveniles in forest site and absence of these in agricultural site where only adults were present. They further added that larval stage is absent in freshwater crabs, because from eggs miniature crabs emerges directly. Also in these crabs females were observed to carry their eggs and hatchling or juveniles in their brood pouch until the offspring are large enough to defend themselves.

Hartnoll et al. (2009) while studying the size distribution of land crabs, Johngarthia lagostoma observed that very few small size crabs were collected from the study period. Reasoning it, they suggested that the probably the juveniles occupied some unexamined habitat. Omolara (2009) carried out studies on the swim smooth crab, Portunus validus and reported that the carapace length of these crabs were found to ranged from 4.5 cm to 11.4 cm. The length frequency distribution was found to show a unimodal distribution and also that of the most crabs (80%) which belonged to medium size group happened of the same year class.

Sinha (2014) investigated the relationship between morphometric and allometric analysis of the freshwater crab Barytelphusa cunicularis. A total of 393 specimens were measured with the help of vernier calliper up to 0.01mm accuracy. Each sample were subjected to descriptive analysis that included computations of mean, standard error, median, mode, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum, sum and count. Regression and frequency was calculated for each group separately. The analysis was based on the biometric data, observing changes in the relative growth of some body parts related to other. The analysis suggests that the relative growth follows the allometric function (y=mx+c). Devi and Smija (2013) analyzed the population size frequency distribution and colour pattern in the freshwater crab, Travancoriana schirnerae for a period of two years (2009-2011). Results indicated that the size frequency distribution was bimodal in both the sexes. Juvenile crabs were present at higher proportion from June-November with peak in August, exhibited slight
decrement during winter and was low during summer. Adult frequency remained more or less the same irrespective of seasons. In *T. schirnerae*, adult male and female crabs exhibited identical colour patterns and three morphotypes were recognized: yellow, intermediate and purple. The population was dominated by intermediate morphs (60%) followed by yellow (28%) and purple (12%). There was no evidence of a size difference between morphs. The frequency of morphotypes showed significant difference in the total collection, among and between the sexes.

**Size at maturity**

Watson (1970) while studying morphological as well as physiological maturity in Spider Crab, *Chionoecetes opilio* stated that 50% maturity in these crabs occurred at about 57 and 50 mm carapace width for males and females respectively. Both sexes were mature at sizes considerably below the commercially acceptable size of 4 inches (102 mm) carapace width. Unlike females, male exhibited moulting even after attaining maturity. Field and laboratory observations suggest that more than one brood is commonly produced from one mating. The minimum size limit for commercial landings allows some mature males capable of mating to be left on the fishing grounds. Retention of this limit seems unlikely to affect the breeding potential of the population. Hartnoll (1974) while studying variations in growth pattern between some secondary sexual characters in crabs reported that in males chela exhibited a pronounced growth during adult phase. Such growth of chela according to him helps in reproductive, territorial and fight behaviour. However in females, the abdomen exhibited positive allometric growth in juveniles stage whereas isometric in adults. He also stated that the reduction in growth rate of abdomen in adult females helps them to protection the incubated eggs in pleopods, because otherwise continuous growth of abdomen would hamper the reproductive efficiency and also results difficulty in locomotion. Crane (1975) studied the relationship of chela shape with the food habits in fiddler crabs and advocated that crabs having chela with narrow gapes and serration tended to be associated with muddy habitats, whereas those having chela with wider gapes no serration were found to be associated with sandy habitat. Burrowing habit in fiddler crabs as stated by Christy (1982) revealed that held
that the female crabs prefer relatively deep burrows. These they added help them to provide stable thermal environment to the developing embryo.

The relative growth of chela in male and abdomen in female of crabs *Portunus (portunus) sanguinolentus* and *Portunus (portunus) pelagicus* was studied by Sukumaran and Neelakantan (1996). On the basis of morphological studies they stated that in these crabs transition in the cheliped dimension and abdominal width of these crabs were related to prepubertal and post pubertal changes associated with gonadal development and onset of sexual maturity. Study also indicated that in *P. (porunus.) sanguinolentus* and *P. (portunus) pelagicus* the pubertal moult occurred at a carapace width of 85-90mm in males and 80-90mm in females which is evident from sudden increase in morphological characteristics. Morphometric analysis and reproductive biology of crab, *Charbydis affinis* were carried out by Chu (1999). He stated that the crabs under studies were heterochelous with pronounced handedness in both sexes. Right cheliped was however more evident in males than females. Further the analysis of abdominal width at different maturation stages in both the sexes revealed that unlike males, female abdomen exhibited allometric type of growth. On the basis of gonadal development, 50% gonadal maturity (physiological maturity) was found to occur at 42 and 36mm CW for females and males respectively.

Lopez–Greco et. al. (2000) during their studies on the reproductive behavior of *Chasmagnathus granulatus* in nature as well as in laboratory conditions observed continuous that in these crabs males hold comparatively larger size than females. They held differentiated reproductive need of both the sexes as the main cause of variation in size of sexes and also added that females spent most of their energy for reproductive purpose such as spawning and incubation of eggs hence tends to mature at inferior size than males.

Morphometric, functional and sexual maturity of crab *Chaceon affinis* were studied by Fernández-Vergaz et al.(2000) and recorded that in males physiological maturity occurred prior to morphological maturity however in females morphological maturity follows physiological maturity. Thus both males and females follows different trend of maturity. Liu and Li et. al. (2000) conducted extensive studies on reproductive
behaviour of freshwater crab, *Candidiopotamon rathbuni* and stated that in these crabs the ovigerous females after mating prefer to stay on land in order to avoid injury by flash floods. It has also been observed that females use larger chela to defend the developing young juvenile against predators and thereby enhance their survival rate. Macia and Quincardete *et. al.* (2001) while studying the breeding behaviour of the fiddler crab *Uca annulipes* reported that in these crabs the ovigerous females spend prolonged period underground for incubation as well as protection of eggs.

Size at maturity in mud crab, *Scylla spp.* as studied by Tongdee (2001), was reported to witness two recruitments in a year which indicated that these crabs were seasonal breeder and breed twice in a year. Rosenberg (2002) studied claw shape variation in fiddler crab across genus *Uca* and reported that in these crabs the larger chela exhibited allometric growth which is characterized by increase in the length of the pollex relative to manus and the size of the propodus relative to carpus. The smaller chela however exhibited isometric type of growth. He further added that the regenerated larger chela shows higher allometric pattern than unregenerated one.

Studies on reproductive biology of the crabs *Munida subrugosa* in Argentina was carried out by Tapella *et. al.* (2002). He reported that in these crabs two types of maturity were observed viz. morphometric maturity and physiological maturity. Both females and males they stated attain physiological maturity at 9.9 and 8.0 mm CL. As far as fecundity is concerned it was found to be between 124 & 10750 eggs per female with the average diameter of recently extruded eggs to be 0.69mm.

Studies on reproductive biology and relative growth in the spider crab, *Maja crispate* was carried out by Carmona–Suarez (2002) on the basis of morphological characters and colour and consistency of gonads. Based on data they distinguished three postlarval stages in males viz. crabs with juveniles morphological character & immature gonads (between 1.69 and 5.03 cm c.l.), & crabs with juvenile morphological characters & mature gonads (between 4.98 and 7.16 cm c.l.). However, unlike males, in females only two postlarval stages were recorded viz. juveniles (between 1.87 and 4.62 cm c.l) and adults (between 3.56 and 6.11cm c.l.). He also observed that the breeding period extends from May to September and the mean number of eggs recorded were 11473 per
female. Litulo (2004) described the reproductive biology of fiddler crab in *Uca annulipes* and reported that in these crabs most of the females inhabited burrows at a depth of about 50cm which he earlier however, had reported to be of 30 cm in the same crab.

Dalabona *et. al.* (2005) analysed the morphometry and maturity of crab *Ucides cordatus* in both the sexes. They measured carapace length, chelipede propodus length & abdominal width and related them to carapace width to verify the sexual dimorphism & size at maturity of each sex. They observed that in males the propodus length exhibited allometric growth in adults in contrast to juveniles where it exhibited isometric growth. However in females the abdomen showed allometric growth in juveniles while isometric in adult. The size at maturity in males and females was found to attained at 44mm CW and 43 mm CW respectively. Golden crab, *Chaceon chilensis* were caught with trap from depth of 300 and 1000m by Guerrero and Arana (2009) for determining their size, structure & sexual maturity from Chile. They reported that out of 13,027 individuals 97.9% were males (12,754) and the rest were female (273). They also stated on the basis of comparison of linear regression between carapace length (CL) and chela length that males attain morphological maturity at 100mm CL whereas a numerical analysis showed the size at first sexual maturity to be 109 mm CL.

Size at maturity of the crabs *Portunus sanguinolentus* was determined by Rasheed and Mustaquim (2010) by examining the condition of gonads and growth of chelae and pleopods in males and females crabs respectively. They held that increase in relative growth of the male chela and female abdomen at the pubertal moult brings these structure to function fully and had been used to determine the size at maturity. Their results showed that in male crabs maturity was attained at a size of 64-70mm short carapace width and attain 50% maturity at 60.8 mm short carapace width. In females on the other hand size at maturity was recorded to be 63-71 mm CW and 50% maturity in females was attained at 63.5 mm CW. They further reported that berried females were found in all months except June. Minimum and maximum number of eggs were found to be 272, 2000 and 1,395,000 in crab having 63 and 120 mm CW, respectively.
Fecundity and gonadosomatic index

Pillai (1960) while working on marine crab, *Caridina laevis* held that female of this species produces 3,000 to 10,000,000 eggs which were quite higher in number compare to freshwater crabs (10 to 800 per female). Further he added that such differences in the number of eggs may be attributed to variation in their development and survival value of young ones.

Arshad (2006) advocated that fecundity in blue swimming crabs, *Protunus pelagicus* exhibit positive correlation with different morphometric parameters such as carapace length, carapace width and body weight.

Habashy and Hassan (2010) while working on *Macrobrachium rosenbergii* advocated that an optimum temperature i.e. 29°C has been recorded for increase in reproductive success of this species. Thus, any marked change from recorded value led to decline in reproductive rate.

Fecundity of Chinese mitten crab, *Eriocheir sinensis* was recorded to vary from 141100-686200 eggs by Przemyslaw and Marcello (2013) under laboratory conditions. The mean size of eggs found to varied from 361µ-375µ. Correlation between fecundity and different morophometric parameters was observed to positive. Swetha *et al.*, (2015) examined the natural reproductive cycle of freshwater crab, *Oziotrophusa senex senex* and stated that number of female bearing eggs or crablets were recorded highest during September-October compare to rest of months. The number of eggs varied from 130 to 120. Correlation between fecundity and body size recorded to be significantly positive, however, no correlation found between breeding cycle and different environmental factors such as temperature, photoperiod as well as rain fall.

While describing reproductive cycle of *P. pelagicus* off southern Australia, Kumar *et al.*(2000) observed that fecundity increases with carapace width and reported an increase of 83.9% from 105 mm to 125 mm carapace width. Sigan (2002) while studying the fecundity of brachyuran crab *Thalamita crenata* (Latreille) advocated fecundity of the crabs was obtained by counting the number of produced by female in a single spawn. He further added that regression analysis between fecundity and carapace
width revealed presence of significant positive correlation. Hadden (1994) while working on crab, *Ovalipes catharus* reported a significant increase in fecundity with body weight and thus exhibits positive correlation with high $r^2$ value. Sharma and Subba (2005) while analysing relationship between fecundity and body weight in freshwater prawn *Macrobrachium lamareii* reported an increase in fecundity with weight. They further held that though relationship between fecundity and weight recorded to be positive but had very low $r^2$ value.

The length-weight relationships, condition factor and fecundity of freshwater crab, *Sudanonautes africanus*, was analysed by Olusojil et al., (2009) from different freshwater bodies. Crabs were segregated into sex wise and the growth parameters $a$ and $b$ of the length-weight relationship, (LWR) $w = aL^b$, was studied on different sexes. The value of $a$ for *S. africanus* was 0.889, 5.029 and 0.713 for males, females and entire population, respectively. The values of $b$ however, recorded to be 2.475, 3.185 and 2.567 for males, females and whole population, respectively. The regression equation analysis for length-weight was recorded to be $W= - 0.046 + 2.475L$ in males, $W= 0.717+3.185L$ in females and $W= - 0.147 + 2.567L$ for the total crab population. The coefficient of determination in males, females and entire population were 0.716, 1.049 and 0.699, respectively, thereby indicating a strong correlation between these variables. Fecundity was found to vary from 120 to 449 eggs with a mean diameter of 1.66 mm ± 0.068 mm. correlation between egg size and carapace length recorded to be insignificant. Soundarapandian et al. (2013) while investigated the male and female reproductive system of *C. feriata*. The male reproductive system was observe to be consist of pair of testes, a pair of vas differentia and a pair of ejaculatory ducts. Based on morphology, the vas differentia was divided into three distinct regions viz., anterior, Median and Posterior vas deferens. The developmental stages of male gonads include immature, maturing and matured. The female reproductive system, however, on the other hand was mainly composed of a pair of ovaries, a pair of seminal receptacles and a pair of oviducts. GSI was observed to increased from immature crabs (0.48 & 1.95) to matured one (0.79 &3.97) in male and female respectively. They further reported that based on morphology of gonads three stages of development has been recorded in males (viz., immature, maturing and mature) whereas five in case of females viz., immature, early maturing, late
maturing, ripe and spent. The fecundity of the female was found to be from 2, 83,963 having carapace width 10.6 cm to 9, 67,293 with carapace width 14.1 cm.

Moulting

Based on their studies on crab, *Portunus pelagicus*, Hasma (1982) stated that these crabs undergo several moults during the process of development and attain marketable size of 140-145mm carapace width after undergoing twelve moults within a period of fourteen months.

Moulting of shore crabs (*Hemigrapsus sanguineus*) parasitized by Rhizocephalans (*Sacculina senta*) was observed by Takahashi And Matsuura (1994) in the laboratory, and the growth of the moulted crabs was compared with that of unparasitized animals. Moulting of the host was obstructed by the infestation, but was still possible. After the release of several broods of larvae, the externa (the external reproductive system of the parasite) detached from the host. Subsequent moulting occurred within 40 days in about 80% of the animals, but in the remainder, it was delayed for at most 4 months. Soon after moulting, a new externa protruded from the abdomen of every crab. Thus, the life-span of the externa and the moulting of the host would seem to be closely connected. In the female, the moult frequency was reduced, but the moult increment of the parasitized crabs was not different from that in the unparasitized ones. In the male, however, both the moult frequency and the moult increment were reduced. Thus, the annual growth of parasitized males and females was about half that of unparasitized crabs.

The moulting of crab, *Carcinus maenas*, was study by Vineusa (2007) who held that the most important physiological events taking place during the annual cycle of the adult population were as follows: (1) male moult occurred mainly in November and female moult between January and the beginning of March; (2) the reproductive season started in January, after a courtship in which the male, larger in size, holds the female until the moult, and spermatophores are ejaculated once the old exoskeleton is cast off; (3) females left the intertidal zone early and moved to lower littoral levels during fall and winter; (4) larvae appeared in September.
Xue et al., (2010) studied the developmental changes that take place inside the eggs of the semi-terrestrial freshwater crab, *Sinopotamon yangtsekiense*, and reported that the egg consists of two layers, a thick outer membrane and a thin inner membrane that encloses the fluid filled embryonic sac. Development in this species took up to 77 days, after which the free-living juvenile hatchling crab emerged from the egg. During development the embryo underwent a series of morphological changes that corresponded to the free-living larval stages of marine crabs, and the yolk mass decreased in size and changed colour (from creamy pale yellow, to orange, and finally grey). The eggs remained attached to the pleopods in the female’s abdominal brood pouch during development and showed a great deal of independence from water. Embryos developed normally whether they were immersed in water or in air. The implications of this adaptation for freshwater crab evolution are discussed.

Przemysław and Marcello (2013) while studying the Chinese mitten investigated some reproduction aspects in laboratory. The results showed that the fecundity of *Eriocheir sinensis* range from 141100 to 686200 eggs (mean 461100 eggs per female) with first brood, and mean eggs size were 371.4 μm (range 361 - 375μm). All the morphometric characteristics studied showed positive correlation with fecundity and the degree of relationship varied considerably. Among these, the carapace width was found to be the best morphometric character for predicting the fecundity of Chinese mitten crab.

Moulting cycle of spider crab, *Maja squinado*, was assessed and used as methods to identify the intermoult stage in each individual by Corgos et al. (2007) This inter moult staging was later verified by means of the microscopic observation of the maxilla. They further held that such staging technique help for the identification of the principal intermoult stages, postmoult, intermoult and premoult. In 90% of the cases analysed, there was a correlation between the presence of an underlying carapace and a pink colour of the abdominal vein in crabs in advanced premoult stages. The seasonality of the moult was studied based on the number of specimens in the postmoult stage. There were two main moulting periods –the first occurring in April, and the second, longer period was between July and November. A hypothetical growth model was established and growth rates were determined by length frequency distribution analyses. Three groups of
juveniles and one group of adults were identified. The adults were only found among the population between July and October. In both males and females, the moult increment rate was lower in terminal mouls (mean=22%) than in juvenile or prepubertal mouls (mean=27%).

Morphometric parameters

Information about individual body weight, length/width relationships in population is important for estimating the population size of a stock, specifically such information regarding the distinguishing characters and size relationships in sexually mature individuals is of significant importance in commercially valuable crustaceans. Such knowledge help establishing Taxonomy of a species, its life history patterns and also serve important tool in fishery resource management and culture.

According to Huxley (1932), the allometric equation is the most utilized method for analysis of growth during the ontogeny. To estimate the coefficients of allometric equation, the data are usually logarithmized and subjected to linear regression (Teissier, 1960). According to Lagler (1968), the carapace and the length weight relationship can be used to estimate the recovery of edible meat from crabs of various sizes.

Decapod crustaceans generally show sexual dimorphism in their external morphology. Sexual difference observed in the growth of several body parts relative to carapace size have often been used to examine the relationship between morphometrics and sexual activity in addition to morphometric difference among population or species (Kanno, 1972). In decapods, Hartnoll (1974) reported the importance of chelar dimensions to characterize sexual dimorphism or to estimate size at sexual maturity. Decapod species develop these chelipeds for combat, display and courtship.

The mathematical length weight relationship yields information on the general well being of individuals, variation in growth according to sex, size at first maturity, gonadal development and breeding season. Study of length-weight relationship in aquatic animals has wide application in delineating the growth patterns during their developmental pathways (Bagenal, and Tesch, 1978). Schmidt-Nielsen (1997) described
allometric regression changes in soft tissue content or total animal weight for crustaceans relative to carapace width/length.

Shine (1988) proposed a pattern regarding the difference in the size at morphological sexual maturity between females and males, according to which the morphological difference between the sexes being the requirement for reproduction. When females allocate their energy for reproductive purpose, they tend to mature at smaller sizes than males, who invest their resources in somatic growth and reach maturity at greater sizes. The length width/weight relationships are regarded as more suitable for evaluating crustacean populations (Prasad and Neelakantan, 1989). The transitional phase in Brachyura involves morphological changes that can be detected by inflections or discontinuities in a series of linear or curvilinear relationships using a bivariate analysis (Haefner Jr., 1990).

Positive allometric growth is an indication of a crabs heaviness with the implication that the crabs are heavier than their lengths. The change in growth coefficient (b) value depends primarily on the shape and fatness of the species, seasons or time of the year, temperature, salinity food (quantity, quality and size), sex and stage of maturity (Sparre, 1992). Studies of relative growth in crustaceans allow to define the type of allometry in the growth of different body parts such as chelae, locomotor appendages, abdomen and pleopods and to relate them to their specific functions. One responsible factor for these changes in allometric growth is the sexual maturity (Gonzalez et al., 1995).

Allometric analysis contributes to a better understanding of many biological events that occur in life cycle of animals (Gould, 1996). Body weight, total length and carapace length are the most frequently used dimensions in the study of Crustaceans (Sukumaran and Neelakantan, 1997a). Chu (1999), analyzed morphometric character and organ indices in Charybdia affinis collected from Zhuyiang estuary, China. There was marked sexual difference in relative growth of the cheliped. The female abdomen increased in size at puberty, accompanied by a reduced allometric growth rate. Analysis of gonad development gave the estimate of 50% gonadal maturity at 42 and 36mm carapace width for females and males, respectively.
In a study of the crab Chaceon affinis, by Fernandez-vergaz *et. al.*, (2000), it was suggested that although the functional capacity of mating is related with the morphological maturity, this is attained before the individual becomes physiologically mature and is therefore able to reproduce. Rosenberg (2002) used modern methods of describing shape and size, geometric morphometry to study claw variation across the genus Uca. Within the species, major claws showed allometric trends in both shape and size being isometric with respect to size, but allometric with respect to shape.

According to Atar and Secer (2003), the relationships between carapace length and weight of the crabs have many uses. They are often used to calculate the standing stock biomass, condition indices, analysis of ontogenic changes and several other aspects of crustacean population dynamics including management of population. Carapace width is the body dimension most used as the independent variable in the analysis of relative growth of crabs, because it fully represents the physiological changes that occur throughout their life history (Castiglioni and Negreires-Fransozo, 2004).

In crustaceans, the allometric relationship between body size and various organs are used to estimate the sexual maturity, assuming that the secondary sexual characteristics appear and grow at different rates in mature and immature stages Sukumaran and Neelakantan, (2007b). Ashkenazi *et. al.*, (2005) proposed for the first time a series of 22 easily measurable morphometric parameters that permit assessment of the pincer size of fossil fresh water crabs from measurable fragmented pincers. The pincer length represented the crab body size in *Potamon potamios*. Regression line equations were given as an implicative tool for future assessment of the pincer size of fragmentary fossil crabs from the northern Jordan Valley.

The allometric relationships are powerful tools used by taxonomists and ecologists in the analysis of intraspecific and interspecific variation among different populations and to estimate the average size at sexual maturity related to environmental conditions (Costa and Soares-Gomes, 2009). Olusoji *et. al.*, (2009) studied length weight relationships of the West-African freshwater crab, *Sudanonautes africanus*. Growth parameters a and b of the length weight relationship was 0.889, 5.029 and 0713 for males, females and entire population respectively. There was strong relationship (r2
=0.81) between length and weight of males and females and the entire crab population. The length weight relationship (LWR) was allometric for all crabs.

Branco and Masunari (2000) while analysing condition factor in crabs Callinectes danae held that male had higher conditional factor compare to female that may attributed to difference in diet of sex resulting variation in size, changes in cheliped strength, foraging behaviour as well as metabolic rate of species. Josileen (2011) studied the interrelationships between various morphometric characters viz., carapace width and length and chelar propodus length and height in males, as well as carapace width and length and abdominal width and length in females were estimated using a total of 980 crabs, Portunus pelagicus. The allometric relationships suggested that most relationships are positive and highly significant. The „b” values for carapace width-weight in males and females were 3.607 and 3.293, respectively and for carapace length-weight they were 3.049 and 2.774, respectively. The result showed a significant deviation from an isometric growth pattern, indicating a significant difference between sexes with respect to the carapace width-weight relationship. Length-weight relationship in Barytelphusa gurini has been determined by Patil and Patil (2012) who state that crab exhibited negative allometric growth with high coefficient of correlation for male as well as female.

Pathre and Bhutekar (2013) carried out studies on morphometery of freshwater crab, Barytelphusa cunicularis. In males all the segments in major and minor chela showed positive allometric growth while in female, merus and propodus only showed positive allometric growth. Analysis of covariance of growth indicated there was a significant difference in growth pattern whereas in females the growth constants did not differ significantly with respect to chela segments in both the sexes. Pathre and Meena (2010) studied size at sexual maturity and the allometric growth of the semi-terrestrial crab Barytelphusa cunicularis. A total of 492 crabs, being 262 males and 230 females were obtained. The specimens were measured at carapace width (CW), the left and right propodus length and height (RPL, RPH, LPL and LPH), and abdomen width (AW) of females. In males, based on the relationship between CW and length of right propodus (LRP), the morphological size at the onset of maturity was 27.14mm. In females, the size at sexual maturity was 22.97 mm, based on the relationship CW and AW. Herrera et. al.,
(2013) determined the size at sexual maturity in the freshwater crab *Dilocarcinus pagei*. The dimensions measured were carapace width (CW), carapace length (CL) propodus length (PL), and abdomen width (AW). The morphological maturity was estimated based on the analysis of relative growth based on the allometric equations $Y=ax^b$. Based on the relationships, the estimated value to morphological sexual maturity was 21.5 mm (CW) in males and 19.7 mm (CW) in females. The minimum size for capture in *D. pagei* was reported to be 40mm (CW) based on the data obtained for sexual maturity.

Mady-Goma *et al.*, (2014) carried out morphometric study to describe freshwater crab *Sudanonautes aubryi*. 186 specimens were identified and measured with sex ratio equal to 1.62, and the average weight to be 6.3g. The average weight of females (8.13g) is higher than that of males (5.03g). The average width of the carapace is 25.73mm; the carapace of the female being larger (30.18mm) than males (22.99mm). Okon and Sikoki (2014) studied length weight relationship and condition factor of the West African fiddler crab (*Ucatangeri*). *Ucatangeri* exhibited sexual dimorphism with sex ratio of 1.2:1.0 which was significantly biased in favour of males. The length-weight relationship showed negative allometric growth, $b=1.6431$.

Sinha (2014) investigated the relationship between morphometric and allometric analysis of the freshwater crab *Barytelphusa cunicularis*. A total of 393 specimens were measured with the help of vernier calliper up to 0.01mm accuracy and each sample was subjected to descriptive analysis that included computations of mean, standard error, median, mode, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum, sum and count. Regression and frequency was calculated for each group separately. The analysis was based on the biometric data, observing changes in the relative growth of some body parts related to other. The analysis suggests that the relative growth follows the allometric function ($y=mx+c$).

**Physico-chemical**

Rukke (2002) while studying the effect of low calcium concentration on two common freshwater crustacean, *Gammarus lacustris* and *Astacus astacus* stated that in
soft water bodies the calcium concentration check the distribution and success of calcium demanding crustacean.

Influence of calcium concentration on freshwater crustacean was studied by Ryhamen (1962). He held that in freshwater bodies calcium concentration has marked affect on gastropods as well as crustacean. He also advocated that the deficiency of calcium cause delayed recovery in both gastropods & crustacean and result in prolonged period of soft exoskeleton and subsequently make freshwater crustaceans more vulnerable to predation.

Adiyodi and Adiyodi (1970) analysed the endocrine control of reproduction in decapoda crustacean stated that in crustacean and temperature plays an important role by acting as a catalytic agent to accelerate the physiological mechanism associated with development of gonadal tissue.

Wild (1980) studied the effect of temperature on spawning in crabs, *Cancer magister* and recorded that in these crabs the time required for eggs to develop from spawning to hatch at 16.7°C was comparatively less (64 days) than at 9.4°C where it was recorded to be occurred in 123 days. He also held that in warmer water eggs developed at faster rate than in colder. However, he however he further added that the hatching success was lower in warmer water compare to colder due to deterioration and mortalities of egg masses during the brooding period.

Larval development of Chinese mitten crabs were studied by Anger (1991) to determine the effect of temperature. He reported that in these crabs the development from hatching to metamorphosis occurred only at a temperature above 12°C. Further rise in temperature he added though result in overall increase in survival as well as range of salinity tolerance but development decrease exponentially.

Neufield and Cameron (1994) conducted an experiment on blue crab, *Callinectes sapidus* to determine the effect of calcium concentration of water body on the post moult and observed that the crabs acclimated to 2% sea water with a calcium concentration of 1.4 mmoll\(^{-1}\) was dependent on the magnitude and direction of the electrochemical gradient for calcium. They further reported that rate of calcium uptake increased by 50% when crabs were transferred to water having high concentration of calcium (6mmol l\(^{-1}\))
but decrease when transferred to water with a low calcium concentration (0.10mmol l$^{-1}$). Flores and Nigreos (1998) conducted studies on graspid crab *Goniopsis cruentata* to determine the effect of environmental factors on breeding behaviour of these crabs. Based on studies they held that any variation in environmental factors especially temperature and photoperiod results to exhibits well define seasonal pattern and continuous breeding. Fisher (1999) while investigating the effect of salinity and temperature on size at maturity of crab *Callinectes sapidus* from nine Texas Bay system stated in these crabs the size at maturity varied with the variations in temperature and salinity of water along coast. He further added that crabs become mature at smaller size in summer and early fall but at larger size in winter and spring thus compared to salinity temperature has marked effect on size at maturity.

The effect of human trampling on the population parameters of the soldier crab *Dotilla fenestrata* was studied by Pereira *et. al.* (2000) in two area of different level of human disturbance viz. one having low disturbance area and second with high disturbance area was studied by collecting sample before and after a day of disturbance. He reported that there was no significant difference before and after the day of disturbance thus, human disturbances had an insignificant effect on crab and suggested that probably behavioural and habitat structure played an important role on the ecology of the soldier crabs.

Cheng *et al.* (2003) studied the effect of dissolved oxygen on Abalone *Haliotis diversicolor supertaxa* and reported that dissolved oxygen not only effect haemolymph osmolality, sodium concentration in these Abalone but also acid base balance, glucose and lactose level. Further according to him the concentration at 3.08mg/l and lower than these causes disturbance resulted in acid base balance and cause short acidosis.

The influence of water and air temperature as well as photoperiod on the breeding season of red mangrove crab *Goniopsis cruentata* was evaluated by Cobo and Fransozo (2002). He observed reported that both air and water temperature showed highest correlation coefficient with the frequency of ovigerous females depicting $r^2= 0.73$ and 0.68 respectively. However, further analysis of the set of environmental variables, revealed that photoperiod was the factor of highest association with ovigerous frequency
Migration of the freshwater *Potamonautes unispinus* in a seasonal stream, Zimbabwe was studied by Gratwicke (2003). He stated that these crabs exhibit seasonal migration as they show upstream movement after first rain. He further added that most of the upstream migrated crabs were females carrying either eggs or juveniles under their flexed abdomens. Some crabs observed to show downstream migration when river gets dried and assumed further upward migration when rain occurred and this time females were without young males and juveniles.

Chatterji *et. al.* (2004) studied the effect of salinity on larval growth of horse shoe crab, *Tachypleus gigas* (Muller) and reported that in these crabs growth rate was observed to be higher at 40% salinity and moulting was observed to occur on 35th day of experimental period whereas in other salinities (10, 20 and 30%) moulting was recorded on 42nd day.

Influence of environmental on age and size at maturity of soil mite *Sancassania berlesei* was studied by Plaistow *et. al.* (2004). They held that those mites that were reared in poor growth conditions (characterized by less availability of food) attained maturity at smaller size compared to mites that were reared in good growth conditions (having sufficient food availability). Based on the observations they held that size as well as age of maturity of these mites depend on the kind of environment where they are reared.

The influence of temperature and rainfall on the reproductive activity of hairy crab *Pilumnus vespertillo* were investigated by Litulo (2005) who stated that both temperature and rainfall were positively associated with frequency of ovigerous females. However, when multiple regression modal was applied it was observed that the temperature was the main factor controlling the reproductive activities of these crabs in the study area.

The effect of different levels of hypercapnia, induced acidification (pH=7.96, 7.31, 6.74 and 6.05) on the extracellular acid base balance of a shallow water crustacean, the velvet swimming crab *Necora pubes*, studied by Spice *et al* (2007) for over a period of 16 days. They reported that in these crabs the occurrence of extracellular acidosis was completely compensated by an increase in bicarbonate that was partially supplied by
dissolution of the exoskeleton. They also held that this compensation was sustained for 16 days under all experimental treatment.

Yamanaka et al. (2007) while determining the relationship between water temperature and catch fluctuation on snow crab, *Chinoecetes opilo* held that catch per unit values represent crab abundance and any change in values indicate the fluctuation in crab abundance. Correlation between water temperature and crab abundance was found by them to show positive correlation at depth of 50, 100 and 200m.

Nayan et al. (2008) investigated the relationship between populations of crabs *Paratelphus (Sarloriana) spinigera* in relation to its ecological characteristics in Kawar lake, India. They reported that these crabs were abundantly found in the rainy season and that their population exhibited positive correlation to water temperature (*r*=0.121), conductivity (*r*=0.491); total hardness (*r*=0.202) and calcium hardness (*r*=0.163), while negative correlation was exhibited with pH (*r*=-0.1242) and chloride (*r*=-0.3612).

Saskia et al. (2008) carried out the studies on ecology and conservation status of freshwater crabs and reported that there was patchy distribution of crabs which were locally abundant (0-28 individuals m$^{-2}$). The crab densities recorded to decrease with depth and dry mass of crab assemblage ranged from 0.0 to 117.7gm$^{-2}$. Further studies also revealed that crab sedimentation had no influence alteration of crab densities and species richness.

The effect of salinity and pH on the survival and growth of *callinectes amnicola* was monitored for 22 weeks in laboratory conditions by Lawal-Are et al. (2010). They found that reported that the crabs were euryhaline as they tolerated a salinity range of 5%$\text{o}$ to 25%$\text{o}$. They also held that maximum (90%) survival of crabs was recorded at 15 and 20%$\text{o}$ salinity. Further when growth were also taken into account they observed that the highest gain in weight and carapace width occurred at salinity of 15%$\text{o}$ and the complete moulting took place at same salinity within 12 weeks of experiment.

Blumenshine et al. (2011) on the basis of long term life term data studied the relative importance of reproductive potential and environmental factors in regulating the mitten crabs population dynamics. They stated that both analysis bivarate data and exploratory regression tree supports that the density of planktonic zoae larva is influenced
not only by the interaction between number of breeding female crabs but by the timing of reproduction and water temperature.

**Feeding ecology**

Valilela *et al.* (1974) while studying the feeding behaviour of fiddler crab *Uca pugnax* held that in crabs the smaller chela is used for feeding purpose while larger one played role in reproductive activities. Since, in these crabs, heterochely is the characteristic feature of males only and have only one smaller chela used for feeding purpose, so, at a particular point of time males cannot eat as much food as female counterpart. He added that males in order to overcome this drawback possess high feeding efficiency and feed at faster rate and for longer duration compared to females.

Caine (1975) while working on different Anomura crustaceans held that both juveniles as well as adult crabs of this species exhibited difference in their diet composition. In this context, he further added that variation in diet mainly related to degree of calcification of the gastric mill and feeding appendages which is more pronounced in larger crabs than smaller crabs.

Comparatively higher proportion of empty stomachs were in advance moulting stage of crabs, *Carcinus maenas* and in ovigerous females by Reid *et al.*, (1977). In this context they held that at the time of moulting crabs lost their exoskeleton and thus become less active and therefore, can easily subjected to predation. Thus feeding during such conditions could attract predator resulting increase in vulnerability to predation.

Collins (1999) while studying feeding ecology of *Palaemonetes argentinus*, reported that larger size prawn comparatively consumed larger quantity of plant remains than smaller ones. Reasoning out, he held that plant matter may have higher energy value and can be easily masticated by larger size crabs due to well calcification of their grinding mill compare to smaller size crab.

Baeta *et al.*, (2004) while studying feeding ecology of mangrove crab, *Carcinus maenas* by occurrence method held that out of 837 stomachs so far examined, 25 different food items were identified of which *Crangon crangon, Hediste diversicolor*, and
Teleostei were recorded to be the most important food items. When compare to sex, no significant difference were observed with respect to prey preference. Comparison of feeding ecology at different developmental stages revealed that feed intensity of crabs get lower at considerable extend at the time of moulting. Cannibalism was more prevalent than reported in literature and the crab based on feeding habit considered to be a top predator in the food web.

The diet composition and feeding activity of crab, *Trichodactylus borellianus*, was studied by Collins et al. (2006) who stated that these crabs consumed several plant as well as animal items and therefore were omnivorous. The crabs were further observed to exhibit predatory habits that varied with season and time of day. While working on Habitat as well as food and feeding ecology of herring bow crab, *Varuna litterata*, Devi *et al.*, (2013) held that the stomach contents of these crabs mainly consist of crustacean remains, plants, sand and debris, fishes, miscellaneous group and unidentified matter. Crustaceans form dominant food in adults as well as sub adults, whereas, in juveniles, sand & debris formed dominant group.

Difference in the feeding habits among four species of crabs viz., *Sesarma brockii*, *S. Plicatum*, *Neoepisesarma medari* and *Nanosesarma minutum* has been investigated by Sylvester *et al.*, (2013) and held that calorific value of food contents were high in *N. minutum* while lowest in *N. mederi*. Assimilation efficiency on the other hand was recorded to be high in *S. brockii* whereas lowest in *S. plicatum*. Based on degree of emptiness and identification of stomach contents, the diet composition and the feeding activity of *T. borellianus* were evaluated by Williner and Collins (2013) and reported that the species consumed several plant as well as different animals such as *amoeba*, rotifers, oligochaetes, copepods, cladocerans, and insect larvae. They further stated that stomach contents of under studied species species also have shown presence of unicellular algae, diatoms, fungi, and macrophytic remains. The predatory habit was quite prevalent and observes to vary with the season and time of day. Based on the diversity of food item, they suggested that crab of this species is basically omnivore as well as an opportunistic predator thereby act as a connection among several trophic levels from both aquatic and terrestrial communities.
Vishwanathan and Raffi (2015) while studying feeding ecology of crab, *S. Olivacea* stated that no significant difference was observed in the quantity of food consumed by males as well as females. He further added that similarity in the feeding of habit of both the sexes might be based on fact that they were inhabiting the same water body as well as locality.