In the commercial culture of prawns, the huge problem is to control reproduction, which is highly complex in prawns. In order to regulate reproduction several environmental signals influence different hormonal effects. Each species peruse several environmental cues for its reproduction time. Van Herp *et al.* (1992) reported a precise knowledge which was needed in respect of mode and role of environmental factors for controlling reproduction and later it will help to provide strong basis for intensive aquaculture development. In the terrestrial, marine and freshwater environments, the crustaceans have a remarkable success in colonizing varied habitat. In their reproductive strategies and breeding pattern, crustaceans exhibit a great diversity. Paul (1942), Krishnaswami and Krishnan (1967) and Little (1968) state that in marine invertebrates the breeding variations correlated with salinity, availability of food and rainfall. Similarly there are several factors that affect the breeding variations of freshwater crustaceans.


Similar above studies have been done on decapod crustaceans by Lloyd and Yonge (1947), Menon (1952), Pike (1952), Rajyalakshmi (1961),
Agarwal and Kumar (1983), Chandran (1968), Joshi (1980), Jeol and Sanjeevaraj (1982), Rahaman (1967), Kulkarni (1972). Sastry (1983) states that breeding was not affected by one factor but with the coordination of several endogenous and exogenous factors which affect within the environment and the individual. From the point of fishery management and large seed production for aquaculture of prawns, Muthu (1982) reviewed the progress made in the field of development and culture of penaeid larvae.

Studies related with breeding pattern of freshwater prawns are very limited. A great emphasis by Raman (1967) and Rao (1967) was given on *Macrobrachium rosenburgii*. Few studies on *Macrobrachium malcolmsonii* are given by Ibrahim (1962) and Rajyalakshmi (1980). Similarly studies on *Palaemon* species are given by Rajyalakshmi (1961). Several studies on the breeding pattern of smaller species like *Macrobrachium kintenis* were done by Kulkarni (1972). The general biology of freshwater prawn *Macrobrachium lamarrei* in Biratnagar Nepal has been studied by Sharma and Subha (2005). Prasad and Kanaujia (2006) studied the availability and breeding behavior including spawning, incubation and hatching of *M. gangetium* (Bate) and *M. malcolmsonii* (H. Milne. Edwards) from the stretches of Ganga River around Patna. A study on reproductive biology of the freshwater shrimp *Atya scabra* (Leach, 1815) was done by Almeide et al. 2010) in Brazil. Bauer et al. 2008 studied the life history migration of Amphidromous River shrimps *Macrobrachium ohione* from a continental range of river system. Little information is available on *Macrobrachium lamarrei lamarrei* by Gyannath and Sarojini (1985).

In invertebrates, the gonadal development and maturation was an elaborated process known as active mobilization and synthesis of organic substances. The study of the physiology of gonadal rhythm with the seasonal changes was required to understand the breeding cycle. Some useful studies were made in decapods crustaceans by Binford (1913), Nath (1932) and
Baker and Rosof (1927) on testicular maturation similarly by King (1948) and Weitzman (1966) on oogenesis. Several interesting observations were made on vitellogenesis process by Bhatia and Nath (1931), Hinsch (1970) and Joshi and Khanna (1982 a). In the different crustaceans various remarkable differences are marked by Baker and Rosof (1927), Black (1966) and Diwan and Nagabhushanam (1974) for the patterns of seasonal cycle of ovary and testis. Goldstein and Lauria (1975), Joshi and Khanna (1982 b) and Agarwal (1985) are the few workers who traced the seasonal changes in gonads in crustaceans through histology. Rao et al. (1981) state that there was extremely less information available on histology of Indian freshwater prawns. Very little information available on the gonadal histology of freshwater by Rao et al. (1981), Mirajkar et al. (1983), Victor (1985) and Gyannath and Sarojini (1985).

Studies were conducted in order to elaborate more information on breeding pattern to develop a rational fishery of the species *Macrobrachium lamarrei lamarrei*.

**OBSERVATION**

**Habitat description**

The Baigul reservoir at Kicchha tehsil in the Tarai region of District Udham Singh Nagar was selected as the habitat for the present study on the prawn *Macrobrachium lamarrei lamarrei*. Baigul (Plate 6.1 & 6.2) is the small tributary of Ganga originating from foothills of Kumaun Himalayas. It lies in the south east of Tarai region. This reservoir is primarily confined for irrigation purpose. In the Baigul reservoir the water level is highly affected by heavy flood during the monsoon months and rivers discharge maximum water to the reservoir in the same season. Under the normal condition, the reservoir has algae and moderate bushy vegetation along its bank which mainly comprises of following species (Table 6.1).
1] Chadophora sps.  7] Hydrilla verticillata
3] Potamogetum eiripsus  9] Marsella minuta
4] Ipomoea fistulosa  10] Pozoulzia indica
6] Cryptococcus accresce

Table 6.1 Bimonthly variations in the relative density of vegetations of Baigul reservoir.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chadophora sps.</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Marsella minuta</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Hydrilla verticillata</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Ceratophyllum demersum</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Ipomoea fistulosa</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Polygonum glab</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Cryptococcus accresce</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Wolffia arrhiza</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Pozoulzia indica</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Polygonum hydropiper</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Potamogetum cripsus</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

+++ Abundantly presence
++ Moderate presence
+ Thin presence
- Not present
Sexual dimorphism

Like other decapods, a well marked sexual dimorphism was obtained in *Macrobrachium lamarrei lamarrei* (Plate 6.3). The male *M. lamarrei lamarrei* can easily be identified by their long and strong chelipeds with larger spines in comparison to females. Male animal contains appendix masculina on the endopod of the second pleopod whereas females do not possess such characteristics. Females possess a brood chamber forming first, second and third abdominal pleurae. Roughly comparison was made by their body structure which represent that males are larger than females.

Sex-ratio

Monthly estimation was done to calculate the sex ratio of *Macrobrachium lamarrei lamarrei* for one year (2009). In comparison to males, females found to be more in numbers except few months i.e. January, April, June, October and December. This difference found by statistics. No specific trend was found for this availability. In order to evaluate the level of significance the method of Chi-square was used. The values of Chi-square clearly indicates that the difference between two sexes availability. The difference observed was statistically significant at 5% levels by Chi-square method. The ratio of 1:1 was not found over the estimation of one year but in the present study the ratio obtained was 1: 2.29 (Table 6.2). Data estimated for whole year showed an apparent predominance of female animals. No specific trend between the ratio of males and females was observed during the study period. The relationship between sex ratio and% of berried animals is plotted in Figure 6.1.
Table 6.2: Monthly sex- ratio of male and female *Macrobrachium lamarrei lamarrei*.

<table>
<thead>
<tr>
<th>Month 2009</th>
<th>Total no. of specimens</th>
<th>Male prawn</th>
<th>Female prawn</th>
<th>Ratio Male : female</th>
<th>Chi-square</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JAN</td>
<td>61</td>
<td>20</td>
<td>41</td>
<td>67.21</td>
<td>1 : 2.05</td>
<td>1.204</td>
</tr>
<tr>
<td>FEB</td>
<td>80</td>
<td>36</td>
<td>44</td>
<td>55.00</td>
<td>1 : 1.22</td>
<td>2.110</td>
</tr>
<tr>
<td>MAR</td>
<td>80</td>
<td>31</td>
<td>49</td>
<td>61.25</td>
<td>1 : 1.58</td>
<td>5.394</td>
</tr>
<tr>
<td>APR</td>
<td>50</td>
<td>15</td>
<td>35</td>
<td>70.00</td>
<td>1 : 2.30</td>
<td>0.781</td>
</tr>
<tr>
<td>MAY</td>
<td>37</td>
<td>10</td>
<td>27</td>
<td>72.97</td>
<td>1 : 2.70</td>
<td>6.976</td>
</tr>
<tr>
<td>JUN</td>
<td>57</td>
<td>17</td>
<td>40</td>
<td>70.17</td>
<td>1 : 2.35</td>
<td>1.119</td>
</tr>
<tr>
<td>JUL</td>
<td>140</td>
<td>32</td>
<td>108</td>
<td>77.14</td>
<td>1 : 3.37</td>
<td>2.629</td>
</tr>
<tr>
<td>AUG</td>
<td>120</td>
<td>15</td>
<td>95</td>
<td>79.12</td>
<td>1 : 3.80</td>
<td>3.329</td>
</tr>
<tr>
<td>SEP</td>
<td>90</td>
<td>30</td>
<td>60</td>
<td>66.66</td>
<td>1 : 2.00</td>
<td>2.467</td>
</tr>
<tr>
<td>OCT</td>
<td>100</td>
<td>30</td>
<td>70</td>
<td>70.00</td>
<td>1 : 2.33</td>
<td>1.758</td>
</tr>
<tr>
<td>NOV</td>
<td>110</td>
<td>40</td>
<td>70</td>
<td>63.63</td>
<td>1 : 1.75</td>
<td>15.950</td>
</tr>
<tr>
<td>DEC</td>
<td>78</td>
<td>25</td>
<td>53</td>
<td>67.94</td>
<td>1 : 2.11</td>
<td>1.801</td>
</tr>
<tr>
<td>Annual</td>
<td>1003</td>
<td>301</td>
<td>692</td>
<td>-</td>
<td>1 : 2.29</td>
<td>-</td>
</tr>
</tbody>
</table>

NS = Non significant, significant at p ≤ 0.05 & 0.01
In gonads maturity related colour changes

In *Macrobrachium lamarrei lamarrei* ovaries undergo several colour changes during the annual cycle and are quite discernible through the carapace translucent in the live animal. A visual examination based on morphology and histology was done in order to correlate between ovaries colour changes and developmental stages in female animals at several sexual maturity stages (Table 6.3).

Table 6.3: Ovary colour changes in *M. lamarrei lamarrei* in various maturity stages.

<table>
<thead>
<tr>
<th>Maturity stages</th>
<th>Ovary colour</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immature</td>
<td>Off white</td>
<td>July/August-September</td>
</tr>
<tr>
<td>Maturity</td>
<td>Light green</td>
<td>October/November-March</td>
</tr>
<tr>
<td>Mature</td>
<td>Green</td>
<td>April/May-June</td>
</tr>
<tr>
<td>Spent</td>
<td>Transparent white</td>
<td>August/September</td>
</tr>
</tbody>
</table>

*Note*: In immature and spent stages the colour relations have been taken as one immature stage in the histological examination of seasonal variated ovary.

Size related sexual maturity

With gradual increase in size a large no of juvenile were collected and examined thoroughly for the development of gonads stage by the method given above. For the first time the minimum sexual maturity attained was 30-35 mm in total length found in both the sexes during the study. The incidence of spawning increased with increase in length of the prawn in the present study. The figure 6.2 has been plotted between occurrences of berried females (%) against different size groups of one year in order to know the gain of the size at which the majority of animals could be expected to spawn. Graph showed that at minimum total length of 51 mm, 50% of female prawns obtained a sexual maturity and undergo spawning. In size
with average increment of 4 mm an increased rate of spawning have been found including 100% ovigerous animal obtained at the total length range of 60 mm onwards (i.e. largest grown animals) (Fig. 6.2).

A graph has been plotted between maturity indices of both the sexes and berried females (Fig. 6.3). The parameters of various months are perfectly correlated with GSI and found minimum and maximum values for male in December and April and for female in December and April.

*Macrobrachium lamarrei lamarrei* is an annual breeder. It starts spawning somewhere from April/May and reaches to maximum by July/August where 80% berried animals were found. In the dark night period these animals copulate and oviposit eggs in laboratory observation. Moulting occurs before insemination of matured females. Due to potamonid habit of this prawn, they do not migrate during spawning but they choose a suitable place in the reservoir with good vegetation.

Moulting does not occur during the egg incubation period which last for 25-30 days. The berried female remains inactive generally (Fig. 6.3).

**Fecundity**

A revealing factor was observed by the estimation of fecundity that the numbers of eggs present in the brood (Plate 6.4) exhibit difference with total body weight and total body length. Similar observation was made for no. of eggs present in the ovary (Plate 6.5) with different variations in ovary weight. In *M. lamarrei lamarrei* the minimum and maximum brood fecundity counts was 80 and 264 (mean: 171±30.66) and for ovarian fecundity minimum and maximum count was 90 and 270 (mean: 191±41.50). Analysis was done to determine the regression equation between brood fecundity with total length and total weight and ovarian fecundity with ovary weight. Significant linear relationship was determined (Table 6.4) (Figs. 6.4, 6.5, 6.6, 6.7).
Table 6.4: Regression equations determine between fecundity and total length, total weight and ovarian weight.

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Equation determined</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brood fecundity/total length</td>
<td>$F = 7.4738x - 297.09L$</td>
<td>0.528 (P &lt; 0.05)</td>
</tr>
<tr>
<td>Brood fecundity/total weight</td>
<td>$F = 151.42x + 17.063W$</td>
<td>0.530 (P &lt; 0.05)</td>
</tr>
<tr>
<td>Ovarian fecundity/ovary weight</td>
<td>$F = 4.7367x + 170.13W$</td>
<td>0.500 (P &lt; 0.05)</td>
</tr>
</tbody>
</table>

The Gonadosomatic and Hepatosomatic indices

In *M. lamarrei lamarrei*, monthly changes in gonadosomatic and hepatosomatic indices were observed to determine the reproductive cycle.

During the year 2009, the mean monthly values of gastrosomatic and hepatosomatic indices of *M. lamarrei lamarrei* are plotted in the Fig. 6.8 and 6.9. The gonadal period and maturation period of both the sexes was somewhat in the same months. The GSI values were maximum in the month April (2.09±0.18) and minimum in the month of October (0.47±0.03) with forming a peak periods from March to June in males similarly in females, maximum in the month of April (3.07±0.11) and minimum in the month of September (0.62±0.02) with the peak period from March to May. During these months the testes and ovaries are found to be fully ripe. The values of GSI of both male and female start with consistent increase in the month and continued till the GSI value again reaches to its position.

When the hepatosomatic indices (HSI) of both the sexes were examined it was found to be inversely related to the gastrosomatic indices.
(GSI). The peak period found for male and female was from July to November and August to November. The highest and lowest value for male was 2.83±0.21 in the month of October and 0.76±0.04 in the month of June similarly for females was 6.5±0.76 in the month of October and 1.0±0.05 in the month of April (Fig. 6.8 & 6.9). The relationship between gonad weight and body weight are shown in figures 6.10 and 6.11.

HISTOLOGY OF TESTIS

In *M. lamarrei lamarrei*, the testis was paired and attached to each other intimately. The microscopical examination of serial sections of testis in *M. lamarrei lamarrei* shows that organ does not reveal any regional differentiation in its structure. Doubled layered seminiferous acini with narrow to wide lobules are found in which outer layer wall comprises thin connective tissue and inner layer wall comprises germinal epithelium. Quite thin germinal epithelium was observed but at different places prominent cellular aggregations lob was noticed and are known as “resting spermatogonia” or “sperm other cells” (Plate 6.6). In spent testis resting spermatogonia was more in number just before onset of another cycle. Not well defined boundaries with small rounded cells of resting spermatogonia were found with vesicular nucleus containing a few basophilic chromatin lumps. An eosinophilic cytoplasm which forms a thin layer around the nucleus was observed. Various stages were observed in the formation of sperms (spermatogonia) in the testis.

(a) **Primary spermatogonia:** The chromatin material of the daughter cells became perinucleus forming thin rim around the nucleus and vesicular remains the same, when the resting spermatogonia multiply their number by mitotic division. These newly formed cells are known as primary spermatogonia (Plate 6.7). The primary spermatogonia comprise of little
faintly staining cytoplasm. In comparison to resting spermatogonia, the primary spermatogonia were relatively larger in size.

(b) **Secondary spermatogonia:** The secondary spermatogonia are formed by further mitotic division in primary spermatogonia (Plate 6.8). Similar roughly dimensions occurred as earlier. One significant change seen in secondary spermatogonia was chromatin. Chromatin forms a perinuclear arrangement and into various reticular configurations chromatin well dispersed within the nucleus. Cytoplasm amount and its properties of staining remain unchanged.

(c) **Primary spermatocytes:** By the earlier stages, the primary spermatocytes were formed by the condensation way of the reticular chromatin into basophilic bodies which was large, rounded and strong within the nuclei. Within a hollow space the condensed chromatin was surrounded. Plasma membrane was not visible clearly. A negligible cytoplasm was contained by the primary spermatocytes (Plate 6.9).

(d) **Secondary spermatocytes:** A small secondary spermatocytes was formed by the meiotic division of primary spermatocytes. In the secondary spermatocytes the chromatin becomes more condensed and more basophilic (Plate 6.10). As in earlier stage the nuclear space around the chromatin was invariably hollow. The cytoplasm was acidophilic and stains faintly.

(e) **Spermatids:** Spermatids formation occurred by another division in secondary spermatocytes. Devoid of cytoplasm occurred in the spermatids. After the formation soon in the nucleus of each spermatids, during spermioteleosis, enlarges with crescentic in shape leaving a round vacuolar structure attach to it which vanishes further during the mean time. A moon like structure was formed by the newly formed spermatids along with its spherical vacuole (Plate 6.11).
(f) **Sperms:** In comparison to other freshwater prawns, *Macrobrachium lamarrei lamarrei* comprises a flagellated sperms. In appearance the sperm’s head was funnel shaped or crescentic shape with a small piece attaching to the tail or flagellum. With hematoxylin the head and tail was deeply stained (Plate 6.12). The sperms as they were generated and transferred in to vasa deferentia and further sparsely seen in matured testis acini.

**Seasonal changes in testis**

In order to make the convenient seasonal changes study, the testis development categorized in to three stages immature, maturing and mature.

(a) **Immature stages (August to October)**

In *Macrobrachium lamarrei lamarrei*, the normal spawning period was from August to October in which major spawning activity months was September/October. Around 75-80% female animals were studied in the month of August and found to be spawned and berried. Spawning was preceded by insemination therefore, the maximum testes examined during the months August to October are either contained exhausted acini lob with devoid of sperms filled with fluid medium in the testis or the testis shows the presence of the primary spermatogonia originates from resting spermatogonia when the sufficient spawning period elapsed. In the immature stage about 90% of total gonial cells of the testis contain resting spermatogonia and primary spermatogonia. A significant reduction was observed in the diameter of acini due to shrinkage. The average diameter obtained was 0.071 to 0.095 mm.

(b) **Maturing stage (November to April)**

In the early months November/December the male prawns were collected and found that in maximum testis about 50% or more than 50%
gonial cells consist of secondary spermatogonia and results that gonads gone to
next maturation cycle in addition to this, during these months November-
December GSI noticed was in falling trend in the earlier study. Histologically,
quite evident spermatogenic transformations have been seen in the following
months. Mass transformed stages were shown during the acini manifested
several stages of cell division. As the number of the spermatids increases, a
decrease in the number of secondary spermatocytes was observed in the
month of February. In the month of April the spermatids accounted for more
than 50% in all the stages. In the maturing stage the average diameter of
semeniferous tubules measured between 0.112 to 0.162 mm.

(c) Mature stage (May to July)

Matured testes were obtained and examined in the month of May
carrying 50% of sperms in them. Further the concentration of the sperms
increases in the following months and becomes 90% in the month of June/July.
Occasionally the stages of primary spermatocytes and other are seen. The
greatly dilated acini of matured testes were observed. The average diameter of
acini of matured testes measured was varied to 0.170 to 0.192 mm.

HISTOLOGY OF OVARY

In *Macrobrachium lamarrei lamarrei* the ovaries were placed very
close to cephalothorax and appear to be fused practically to the anterior and
posterior regions. The ovary was fully covered from all the sides by the
connective tissue sheath. A centre area “germinal zone” which contains
germinal epithelium was easily indentified in the maturing ovary. The new
crop of oocytes was produced from germinal zone (Plate 6.13). In between
the oocytes or in loose manner the branching strands of follicular cells were
recognized. A few groups of cells known as “oogonial nests were found in
germinall zone. Due to mitotic division in the oogonial nests of the oogonia,
the new oocytes were produced. After entering the ovarian stroma the growing oocytes move towards the ovary periphery. By the small amount of cytoplasm, the oogonium forms an indistinguishable cell boundary which contains a strong basophilic nucleus with a chromatin material to present various configurations in relation to different stages of cell division. During the oogenic cycle in the ovary different type of oocytes were found as below:

(a) **Very young oocytes:** The very first oocyte formed after mitotic division of oogonium was the very young oocytes (Plate 6.14). In the germinal zone these oocytes were seen in the close proximity. When they were newly formed they were very naked but when grows with the time surrounds around the follicular epithelium. The nucleus of very young oocytes was larger than earlier stage and was evenly distributed by chromatin. The one nucleolus was found with eccentric position which was strained deep black in hematoxylin-eosin and shining red with Mallory’s triple strain. Occurrence of more than one nucleolus was uncommon. With basophilic cytoplasm the nucleus was surrounded. The diameter of very young oocytes was measured as 0.110 to 0.130 mm.

(b) **Previtellogenic oocytes:** Due to the accumulation of more number of basophilic cytoplasm, the previtellogenic oocytes are formed from very young oocytes (Plate 6.15). Due to the course of time the previtellogenic oocytes was enveloped with the squamous follicular epithelium from all sides. Very young oocytes are converted in to previtellogenic oocytes. If the very young oocytes were not covered by follicular epithelium then they were eventually resorbed and do not enter into vitellogenesis. Same nucleus as in earlier stage was formed. The mean diameter of previtellogenic oocytes was 0.170 mm.
(c) **Vitellogenesis:** when the oocytes attain the average diameter value of 0.190 mm then the vitellogenesis starts generally. For the commencement of vitellogenesis, size was not a precondition. During this process the yolkly substance consist of lipids, protein and carbohydrate was accumulated in the oocytes. Vitellogenesis complied in three stages.

(d) **Primary vitellogenic oocytes:** The primary vitellogenic oocytes diameter range was from 0.200 to 0.261 mm. In the primary oocytes the follicular epithelium surrounds and becomes rectangular or cubiodal from its squamous shape (Plate 6.15). The cytoplasm which was uniform earlier now gets divided into two regions. There was a narrow region of finely granulated cytoplasm which encircled the nucleus (Plate 6.16). A wider peripheral area of homogenous cytoplasm was found outside the granular region. Presence of vitellogenesis stage was marked by the appearance of vacuoles in the peripheral ooplasm. The vacuoles were confined as loci of lipid droplets and known as yolk vacuoles. In the staining reaction of ooplasm, no change has been observed.

(e) **Secondary vitellogenic oocytes:** The diameter range of secondary vitellogenic oocytes ranged from 0.240 to 0.290 mm. Secondary vitellogenic oocytes was slightly larger than primary oocytes. All the details of cellular things are same as in earlier stage except the greater deposition of yolkly substances to the centre by spreading of yolk vacuoles. In the surrounding of these oocytes the follicular epithelium appears to have proliferated and forms various layers around it (Plate 6.16 & 6.17).

(f) **Tertiary vitellogenic oocytes:** The diameter of tertiary vitellogenic oocytes was measured as 0.270 to 0.45 mm. With the deposition of yolk
globules due to which glycoproteins were probably transported into the oocytes then the secondary oocytes were changed into tertiary oocytes. Firstly the yolk globules appear at the periphery then spread at the centre of the cytoplasm like yolk vacuoles and get fully mixed with the yolk vacuoles (Plate 6.18). The uniform basophilic ooplasm was changed into acidophilic in staining reaction with the decomposition of yolk globules. No change in nucleus and its content was observed.

(g) **Mature ova:** The diameter of mature ova measured ranged from 0.420 to 0.760 mm. Among all the oocytes the mature ova or ripe ova was the largest one (Plate 6.19). In the ovary the mature ova occupies the peripheral position. Various sizes of yolk globules are densely packed in matured ova. Nucleus was not visible. Very thin or absent follicular epithelium were observed in mature ova. In reaction the ooplasm of matured ovum are acidophilic entirely. In the ovarian material an interesting anomalies were observed. Atretic oocytes are limited in number but found in all the stages.

**SEASONAL CHANGES IN OVARIES**

In order to make the convenient seasonal changes study, the ovary development categorized in to three stages immature, maturing and mature.

(a) **Immature stages (July to September):** After the spawning the immature animals were observed from the months July to September. Very young and previtellogenic oocytes were found in this stage which together amounted to 70% including ripe ova and atretic oocytes. Due to the completion of this stage there was a reduction of very young oocytes number and increment in the no. of previtellogenic oocytes. During July to September the average diameter of ova was 0.119 to 0.196 mm.
(b) **Maturing stages (November to April):** This phase lasts for six months and in the ovarian cycle this was the longest phase. Active vitellogenesis was marked. Majority of population contained more than 60% primary vitellogenic oocytes from the month of November. During November to April, the secondary vitellogenic oocyte was accomplished from January to March and the tertiary vitellogenesis occurs thereafter in March to May. Due to gain in weight in the oocytes by the vitellogenesis, a consistent rise in GSI was observed at this stage. The average ova diameter range from March to July was in between 0.21 to 0.390 mm.

(c) **Mature stage (May to June):** In the ovaries significant presence of proportion of ripe ova are the characteristic of this stage. Maturation of ovaries was delayed in comparison to testis. Transformation of tertiary oocytes occurs during this phase. The average ova diameter during May to June was in between 0.450 to 0.520 mm.

**Life history**

Under the laboratory condition, the duration between brooding and hatching at 26±3 °C was for 25 to 30 days. Hatching could not occur at the temperature below 20 °C because at this temperature the brood gradually disintegrated. If the brood was already separated from the animal’s body then it was not possible to hatch those eggs. The life history of *M. lamarrei lamarrei* comprises three advanced zoeal forms i.e. first zoea, second zoea and third zoea and postlarva. The period of metamorphosis was 5-6 days. During their larval rearing green algae and artificial feed was given to them with continuous aeration under the water.

Hatching took place between 2-3 days for all the eggs of brood to hatch. White transparent eggs were hatched with two black spots of eye externally visible before hatching. Slightly elliptical mature eggs were
obtained measured as 0.52 to 0.63 at their long axis. Eggs hatch after 5-6 hrs after laying. The female move vigorously their pleopods so that eggs evenly dispersed in to water.

Accomplishment of hatching was done with the increased internal pressure due to increased size of larva and by the movement of appendages. During the hatching the mother prawn moves the pleopods rapidly to disperse new hatchling. Then they rested just below its brim against the beaker’s wall. After they left the mother’s body, the larvae were kept in mesh covered beakers within the common aquarium. Active feeding was started from post larvae stage. Post larvae crawled at the bottom of the beaker and became benthotropic.

(1) First Zoea (Fig. 6.12: 1-18)

The first Zoea measured was 4.3±0.06 mm in length. Rostrum was straight, extending beyond to sessile eyes slightly or equal. Abdomen was smooth and five segmented (Fig. 6.12:1). The carapace was observed with a small pterygostomial spine. Antennule was with unsegmented peduncle (Fig.6.12.2). Mouth parts possess poorly setose and setae were represented by minute denticles. Plumose setae was represented in inner ramus whereas in the outer one with one short plumose seta, one long seta and three aesthetascs. In antenna, the peduncle was with a small spine having 2-unsegmented endopod which was shorter than scale terminating in a pointed papillar tip with 2 minute setae. Scales with 1 incomplete and 3 complete distal segment are obtained including 11 plumose setae on inner sides and small distal seta on outer sides (Fig. 6.12.3). Mandibles were represented with 2 unequal teeth where incisor and molar were not differentiated (Fig. 6.12.4). In the first maxilla, the palp was not bifid with a small denticles and coxal and basal endites with 3 denticles each (Fig. 6.12.5). The second maxilla was having bilobed coxal endite with 2+2 and small basal endite with 1 denticles.
Scaphognathite was broad with about 20 setae in which most posterior one was being large and stout. Endopod was being with a terminal plumose seta and small basal lobe carrying 2 small unequal plain setae (Fig. 6.12.6). First maxillipede possess broad basis with 2 small delicate setae and 2 denticles on inner margin. Epipod was broad and elongated whereas endopod was unsegmented, small bearing 3 terminal and 1 subterminal setae. Exopod was long with 3 faint annulations and 4 natatory setae (Fig. 6.12.7). Second maxillipede possess basis with small seta. 5 segmented endopod bearing 0, 0, 2 and 3 setae distallywards. Exopod found with about 17 faint annulations and 4 nataory setae (Fig. 6.12.8). In the third maxillipede, the basis was found with 2 small setae with 5 segmented endopod setation distallywards being 1,0,2,3 and 4. Endopods of second and third maxillipede terminates into a long, bristle like seta. Exopod was bearing 20 faint annulations and 4 natatory setae (Fig.6.12.9). All the pereiopods (Fig. 6.12.10 to 14) were well developed possessing segmented buds whereas first three pairs are biramous and last 2 are uniramous. Well developed pleurobranches were observed in each pereiopod. Five pairs of biramous pleopod buds were seen (Fig. 6.12.15, 6.12.16, 6.12.17). Orange red chromatophores on bluish black ground were distributed as follows, dorsally on carapace behind the eyes, on oral region, distally on antennular peduncle, dorsolaterally on carapace, third abdominal segment, base of all pereiopods and fourth abdominal segment and dorsally on 1st abdominal segment and telson. In the further stages no change in chromatophores observed. Broadly triangular telson was seen with process formula 7+7. Uropods buds were seen through cuticle. 7 to 10 fine hairs were fringed in posterior margin between the processes except the 3 (Fig. 6.12.18).

(2) Second Zoea (Fig. 6.13, 1-18)

The second zoea measured was 4.6 mm in length. Rostral formula observed was 1/0. To the first antennular segment the rostrum almost reached. The carapace was seen with a prominent supraorbital spine. Eyes
are stalked. Antennular peduncle was 3 segmented with long basal segment having a future stylocerite and anteriorly directed ventral spines. Inner ramus was unsegmented with a long terminal plain seta whereas outer with 2 segmented bearing 3 aestetascas+1seta. Antennal peduncle was 3-segmented in which 2nd segment was with a small distal spine and scale with terminal spine and setae along its entire inner margin possessing long and flagellar endopod with about 10 segments. In mandibles, the incisor and molar parts were separated with 3 denticles. In second maxilla, scaphognathite was with about 25 setae. In first maxilliped, basis seta was reduced to one whereas endopod terminal seta was reduced in second and third. Clearly segmented 5 pairs of pereiopods were observed in which first with two chelate, third to fifth with sharp terminating endopod bearing spine like seta with minute hair. Exopod were present with first 3 pairs having 6, 6 and 4 natatory setae respectively. From the sixth abdominal segment telson was separated. Pleopods were segmented. Process formula for telson was 8+8, second process plumose on both the margins are seen. Through in the telson cuticle the uropod are seen as elongated buds.

(3) Third Zoea (Fig. 6.14, 1-18)

The third zoea was measured 5.0±0.10 mm in length. Rostral formula observed was 6/5 and the rostrum reaching across the antenna length. With the antennal spine carapace was observed. 3 segmented antennule of inner ramus was seen. Antennal peduncle was 3-segmented having basal segment with a minute spine. Flagellum with 18 segments was seen. Completely smooth endites and palp of second maxilla were observed. Distinctly bilobed epipod of first maxilliped was observed having endopod with 2 small hairs and the exopod with slightly expanded basal part showing beginning of ‘Caridean lobe’ carrying 3 setae. In the second and third maxilliped the exopod bears with 5 natatory setae, first 2 pairs of pereiopods are fully chelate and exopods of first 3 pairs are with 5 natatory setae. With
a pair of small posteriolateral spines the sixth abdominal segment was seen. Pleopods are elongated, clearly segmented with future setae representing 1 to 6 protuberances. Second to fifth pleopods are with appendix interna buds. Telson process by formula 8+8 in which first process reduced to a small slightly lateral spines. Uropods were with setose exopods but endopods were still narrow elongated buds.

(4) Post larvae (Fig. 6.15, 1-18)

The postlarva was measured as 5.4±.012 mm in length. Rostrum bends upwards towards the tip and reaching almost to the doubled of antenna length. Rostral formula was 7/6. Carapace was without supraorbital spines. The basal segment of antennular peduncle was with pointed stylocerite and an anterolateral tooth. Inner flagellum was 5-segmented. After the 2nd segment the outer was bifid and upper branch was shorter, unsegmented with 2 terminal and 1 subterminal aesthetascos and lower 2-segmented. Antenna was adult like. Mandibles are well developed. Incisior are with 3 sharp subequal teeth having molar with 4 to 6 grinding projections. Palp was not well developed. Maxillae and maxillipedes are as in adult but with less setose. On the first 3 pair of pereiopods the exopods are much reduced. Pleopods are fully setose. Appendix interna of 2nd to 5th are with 2 hooks. Exopods are with 8 to 11 and endopods are with 5 to 7 setae. Over the new zoeal larva a new orange-red chromatophore was added, on 2 pairs of carapace dorsally and one on 2nd abdominal segment on mid-dorsal side and on junction of thorax and abdomen ventrally including all the abdominal segments. Rectangular telson was with shallow and median notch on concave posterior margin. Out of 5+5 process, the first 3 process are lateral and spine-like whereas the outer one was largest and spine-like and non-plumose. The outer margin of exopod ending in an apical tooth without any accessory subapical spine were seen in both rami of uropods as a characteristics of adult.
DISCUSSION

In the decapods crustaceans, variety of breeding pattern was exhibited with the various variable factors. In comparison to the tropical and subtropical environments the animals living in temperate areas have a shorter breeding period (Sastry, 1983). Exceptions are available in this pattern. Several species inhabiting the temperate waters of Monterey bay, U.S.A while Continuous breeders are Pugettia producta and Petrolisthes cinctipes whereas restricted breeding are observed in Pachygrapsus crassipes, Hemigrapsus nudus and Emerita analoga (Boolootian et al., 1959). Similarly in the tropical waters of Karachi, Pakistan, species like Pachycheles natalensis and Pachycheles tomentosus are continuous breeder whereas Petrolisthes boscii and Petrolisthes rufescens are annual breeders (Ahmed and Mustaquim, 1974).

Sex-ratio

Nikolshii (1963) reported that in fishes, the sex ratios varies from species to species at different population and closely lie to the ratio of 1:1. From the point of breeding biology the variations in the sex ratio is the important aspect of any particular species but in only few crustaceans the male female sex ratio was studied during its breeding period. Thomas (1974) conducted a study on sex ratio of male female Penaeus semisulcatus for two years found a ratio of 1:1. Menon (1957) reported the same observation on the species Penaeus indicus. George and Rao (1967) found significant variations in the sex ratio of some Penaeids i.e. P. indicus, Parapenaeopsis stylifera, Metapenaeus affinis and M. dobsoni collected from the trawl catches off the coast of Cochin. Hong and Oh (1989) reported a season related variation in the shrimp Crangon affinis in the sex ratio. Agarwal (1985) reported a sex ratio in freshwater brachyuran Paratelphusa masoniana in which there was significant reduction in the population of
female crab during distinct cycle and gonadal maturation period (Nov-Feb). In the freshwater prawn *M. hendersodayanum*, Kaur (1993) reported the predominance of female animals over the year with the maximum male female sex ratio of 1:9. A significant sex ratio of 1.2 M: F in the species *A. margaritacea* in Mexico was observed. Galvao and Bueno (2000) observed a higher population of females of *A. scabra* in Brazil i.e. 1 male for 2.23 females. In Mexico, Palacios *et al.*, 2008 reported the sex ratio of Male and female *A. margaritacea* as 1.96 M: F and found that males are more frequent than females. In the present study on *Macrobrachium lamarrei lamarrei* a predominance of female animals were found over the male animal. Greater abundance of females was seen on monthly as well as yearly basis. The ratio of 1:1 was not found over the study of one period but the maximum male female sex ratio was found to be 1:2.29 (Table 6.2) and (Fig. 6.1).

**Size-related sexual maturity**

In the fishery biology, one of the important aspects of breeding was the size-related sexual maturity. This aspect was examined in very few prawns. Thomas (1974) reported that in large prawn *Penaeus semisulcatus*, the males attain maturity earlier than females. In this species on first sexual maturity the carapace length was 17-18 mm in males while in the female it was about 23.0 mm. Bauer (2004) found there was strong relationship in between sexual dimorphism and mating in carideans and in *Macrobrachium* sps. the body of male was larger than females. *Macrobrachium lamarrei lamarrei* is a small prawn where male and female attains the sexual maturity at the minimum total length of 30-34 mm in the present study. In both the sexes 50% maturity was found at the total length of 51 mm (Fig. 6.2). From the point of fishery, important and useful information had come up from the point of its culture.
In *M. lamarrei lamarrei*, the monthly values of maturity indices are found to be significantly correlated with GSI variations and incidence of berried females (Fig. 6.3). The value of maturity index shows a sharp decline soon after the major spell of spawning and reached below the 10 index value. In the following months the animals of both the sexes could not show the total disappearance of the population until the number start increases in the beginning month of the peak period. If the environmental conditions remain favorable then in the present study the animal shows the potential of continuous breeding. In the present study the species shows breeding for nine months (except Jan, Feb and Dec). Rao et al. (1981) reported for the allied species *M. lanchesteri* for having a tendency for repetitive breeding from the Itaparica Island shows the breeding period of nine months whereas male exist throughout the year.

**Fecundity**

In the present study of the species *M. lamarrei lamarrei*, the minimum and maximum individual brood fecundity counts were recorded as 80 and 264 (mean: 191±41.50) and for ovarian fecundity minimum and maximum count was 90 and 270 (mean: 171±30.66). For a species fecundity is considered as characteristic feature. Particularly for the prawns of Macrobrachium genus several inter-specific and intra-specific variations are observed earlier. Larger prawns have larger fecundity. Piva and Costa (1962) estimated that the mean fecundity of *M. acanthurus* was 4,528 eggs at Fortaleza whereas Carvalho (1973) at Sao Sebastiao having 2000 to 5000 eggs similarly at Florida, 18000 eggs observe by Dugan et al. (1975). Valenti et al. (1989) reported 8,292 eggs from the species inhabiting river Ribeira de Iguape in southern Brazil. Labao et al. (1985) observed 6,350 to 1,94,350 eggs in *M. carcinus* similarly Ibrahim (1962) estimated the fecundity range of 3,465 to 63,080 eggs for *M. malcolmsonii*. Rajyalakshmi
(1961), Raman (1967) and Ling (1969) estimated the fecundity for *M. rosenbergii* from 7,000 to 1,39,600. Palacoius et al. (2008) estimated the fecundity of *A. margaritacea* ranged from 1860-22,400 eggs of females of total length 43-59 mm. Almeida et al. (2010) estimated the fecundity for freshwater shrimp *Atya scabra* is 114,349 eggs. These are few larger species with larger fecundity.

Among the smaller species of *Macrobrachium* genus, in the smaller prawns lesser number of eggs was found. Thus less than 200 eggs are estimated in smaller species like *M. jelskii* (Paiva and Barreto, 1960), *M. iheringi* (Bueno, 1981), *M. borellii* and *M. potiuna* (Bond and Buckup, 1982) including some marins shrimp *Lucifer faxoni* (Lee et al., 1992). In the present study the species *M. lamarrei lamarrei* show a brood fecundity of 171 eggs related to the smaller size of the prawn.

Labao et al. (1985) observed the relationship in *M. carcinus* between fecundity and total length, fecundity and total weight similarly Valenti (1984) also examined the above relationship in *M. carcinus*. In the present study on the prawn *M. lamarrei lamarrei* a strong relationship between brood fecundity with total weight, brood fecundity with total length and ovarian fecundity with ovary weight and fecundity with months has been observed with the linear model of regression ($r= 0.530$ and $p< 0.01$). Similarly in the species *M. hendersodayanum*, *M. amazonicum* (Labao et al. 1985), *M. acanthurus* (Valenti et al., 1989), *M. dayanum* (Bhattacharjee and Das Gupta, 1989) and the shrimp *Crangon affinis* (Hong and Oh, 1989) a direct relationship between the fecundity with total length and fecundity with total weight have been observed using the linear equation. The equation used for establishing the relationship was $Y = a X^b$. The species which used this equation are *M. rosenbergii* (Rajyalakshmi, 1961) and lobster *Panulirus intereuptus* (Barrera et al., 1981).
The GSI estimation was done to measure a numeric value to its gonads or to the individual in the aquatic animals. According to the Giese (1989), Rodrigues et al. (1978) and Vazzoler (1982) during the reproductive cycle the GSI estimation was done to measure the average state of the population in the particular time. Santos (1972) said that GSI is the simple concept of prerequisite in which the body weight and gonad weight possess a linear relationship. In *M. lamarrei lamarrei* a linear relationship has been observed in gonad weight and total body weight in both the sexes.

A protracted breeding season was seen in the marine decapods of Indian tropical waters that’s why their spawning period differs from species to species. Kulkarni and Nagabhushanam (1982) reported that the Penaeid prawn *Parapenaeopsis Hardwickii* from the Bombay coast and exhibits a rise in GSI from October to June. According to Thomas (1974) another Penaeid prawn *Penaeus semisulcatus* inhabiting from the water of Palk Bay and Gulf of Mannar possess the annual variation in the GSI from 2.2 to 13.2 and breeds continuously. In freshwater prawns *M. hendersodayanum* inhabiting from Tarai River Parveen at Katima shows a short period of breeding from February to May with one rise in GSI from January to March in male and female (Kaur, 1993). Chandran (1968) reported that in crab *Charybdis variegata* from the east coast of India is a biannual breeder with two peak periods of GSI and spawning in March and September. These crabs are provided good water temperature with no changes throughout the year. Magalhaes et al. (2012) determine the participation of hepatopancreas in the availability of reserves to the gonadal development and to the molting process.

In the present study in *M. lamarrei lamarrei* nine months breeding was observed because less or more numbers of berried animals are found throughout the year except Jan, Feb and Dec. Therefore they can be considered as annual breeder with rise in GSI period from March to June in
males with highest month recorded in April whereas in female the rise in GSI from March to May with the highest month April. According to Gyananath and Sarojini (1986) in the freshwater prawn *M. lamarrei* from the Marathwada region breed continuously with two peak period of GSI over the year but the *M. lamarrei lamarrei* collected from the Baigul reservoir dist. Udham Singh Nagar possess a tropical environment with several changes in temperature, water velocity during different period and availability of food etc are responsible for single peak period of GSI in both the sexes with annual breeding of nine months. The Proliferation of next crop of gonial cells are observed in histological preparations of gonads.

Pillay and Nair (1973), Giese and Pearse (1974) reported that in crustaceans, the hepatopancreas functions as a storage of nutrient and fluctuations in hepatosomatic index (HSI) during the gonadal maturation which results as nutrient transfer from hepatopancreas to gonads. In *M. lamarrei lamarrei* such transfer have been seen and a well define inverse relationship have been observe during gonadal development and maturation between GSI and HSI.

Giese (1959), Cano (1980), Chandran et al. (1982) and Victor (1984) state that in the decapods crustaceans including shrimp and prawns the inter and intra-specific variations are observed in breeding periods which may or may not correlate with changes in environmental and geographical conditions. In the Indian seas the marine prawns living in the same environmental and geographical conditions exhibits seasonal breeding activity (Kulkarni and Nagabhushanam, 1982) as well as continuous breeding activity (Thomas, 1974). Hong and Oh (1989) reported that the sand shrimp *Crangon affinis* from Nakdong River Estuary, Korea was a continuous breeder whereas Lloyd and Yonge (1974) reported that the common shrimp *C. crangon* from the Bristol Channel and
Severn Estuary, U.K. was a seasonal breeder. In the freshwater prawns *Caridina weberi* (Chinnayya, 1968 and Jyoti, 1974) and *C. rajadhari* (Victor, 1984) from the Marathwada region was continuous breeder with variable frequency in the berried animal availability at different times. Among the freshwater prawns similar breeding pattern exhibit in the Marathwada region due to the geographical influenced phenomenon with water conditions (Peninsular India). Cano (1980) observed a continuous breeding in *M. acanthurus* in Mexico but a discontinuous breeding was observed by Ingle and Eldred (1960) in Antilles and West Indies.

During a fixed period a whole year reproduction was obtained in the genus *Macrobrachium* with the greater intensity having species like *M. mirabilis* from India (Rajyalakshmi, 1961), *M. holthuisi* from Sao Paulo, Brazil (Labao et al., 1978), *M. tenellum* from Mexico (Cabrere-Jimenez et al., 1979) and *M. amazonicum* from Venezuela (Romero, 1982). Thus the species *M. lamarrei lamarrei* living in the tarai region of Kumaun Himalayas was the annual breeder for except three months.

According to the Carvalho (1978) and Valenti et al. (1986) the temperature both low and high stimulates the breeding pattern in *Macrobrachium acanthurus* at two different locations. Raman (1967) observed that the peak breeding in *M. rosenbergii* was in March and May in river Hoogly following the north east monsoon and in October/November following the south east monsoon in south India. Rajyalakshmi (1980) observed that the species *M. malcolmsonii* inhabiting at Godavari river system, the breeding is related with the high concentration of DO with fall in temperature and rainfall. Lewis et al. (1966) and Silva et al. (1981) on species *M. carnicus*, Arroio et al. (1982) on species *M. tenellum* and Romero (1982) on the species *M. amazonicum* reported the monsoon related intense breeding.
In the north Indian waters, there are several species of genus *Macrobrachium* present but in spite of that, very less information is available in relation with breeding pattern and their governing factors. The prawn *M. lamarrei lamarrei* inhabiting the tarai region in Baigul reservoir of dist. Udham Singh Nagar mainly breeds from March to November with the fluctuations in numbers of berried animals during the period. During the study period several fluctuations are seen in temperature of Baigul reservoir. So the stimulations of spawning period were clearly observed but a higher temperature stimulates the spawning period. The period before the monsoon i.e. February to April months attributes the development of gonads. Baigul is the small tributary of Ganga originating from the foothills of Kumaun Himalayas gets affected by the heavy floods and becomes extremely turbid during the monsoon period (May to September) due to heavy discharge of waste from the rivers, massive bank erosion and fast flow of water which bring the vegetation and plankton (Table 6.1) which mainly constitute the main food of growing prawns from the other rivers. Some part of breeding accomplished in this season. The juveniles and prawns survive under the protective macro vegetation with planktonic food. The juveniles of *M. lamarrei lamarrei* grow faster too large enough to survive with the adverse condition. During the monsoon months the prawns are found deep in the bottom of the reservoir in order to protect themselves from the heavy flow of water and to make the use of microorganisms as main source of nourishment from the bottom mud and sand.

**Histology**

Ryan (1967), Mauchline and Fisher (1969) state that in crustaceans a great deal of similarity in the histology of testis with regard to spermatogenesis have been observed and with the minor variations in the duration of various stages and in the degree of synchrony is obtained in different seminiferous tubules. The present study of histological
examination of testis shows the presence of uniformly distributed germinal epithelium in the testis without any regional differentiation. Joshi and Khanna (1982) reported the absence of germinal epithelium from the posterior part of the testis in potamonid crab, Potamon koolooense.

In decapods a general observation was made that until the end of testicular cycle the spermatogonial cells do not exhibit any differentiations. The same cells at the start of new cycle undergo rapid proliferation and produce new crop of spermatogonia. Later these cells are known as “Primary spermatogonia” in the crab *Menippe mercenaria* (Binford, 1913) similarly in freshwater crab *Potamon koolooense* (Joshi and Khanna, 1982 b) they are called as “resting spermatogonia” and in prawn *Pandalus kessleri* (Aoto, 1952) they are named as “residual spermatogonia”. Prawns exhibit very less information on their histological variations in testicular activity in comparison to crab. The histological examination of present prawn *M. lamarrei lamarrei* shows the pattern of new crop development of gonial cells from the pre-existing stock cells known as “resting spermatogonia” or “sperm mother cells”. Resting spermatogonia under the microscopic study reveals that they are different from the structure of the other stages and becomes the prominent group under the seminiferous tubule of fully matured testes or spent testes. Proliferation occurs and forms primary spermatogonia after insemination.

Black (1966), Chiba and Honma (1972) and Weiglus (1976) observed the continuous or discontinuous spermatogenic activity in the testes. Generally seasonality in the testicular activity of decapods was observed in the species having limited breeding period although exceptions are always there. Kon and Honma (1970) reported that the testis of *Chionoecetes opilio* shows a continuous breeding activity although it was a seasonal breeder. Pillay and Nair (1971) observed that the testicular cycle manifests peak in
their activity but with not a definite breeding pattern in *Uca lactea annulipes*, *Portunus pelagicus* and the marine prawn *Metapenaeus affinis*. Ryan (1967) reported that sperm population is not related with the breeding cycle in the tropical crab *Portunus sanguinolentus*. Mauchline and Fisher (1969) reported that some species the testicular peaks were observed prior to mating regardless of whether the species possess a seasonal or continuous breeding. In the present prawn a definite correlation between the histological changes in testis with the breeding season has been observed. In both the sexes of *M. lamarrei lamarrei* highest percentage of mature gametes were obtained in the month of May for female and June for males when the animal starts with effective breeding and possesses highest GSI values.

Agarwal (1985) reported that in the seminiferous tubules at the particular, a synchronous mass transformation takes place from primary spermatocytes to secondary spermatocytes followed by spermatid then to the sperms in the species *Paratelphusa masoniana*. Iyer (1933), Spalding (1942) and Ryan (1967) observed that in some crab, during the early stage of testicular maturation or later stage closer to the testicular cycle, the presence of spermatogenetic cells of one or same stage of development at a time in the seminiferous tubules are seen. In the present prawn *M. lamarrei lamarrei* during the immature phase the occurrence of resting spermatogonia with primary spermatogonia and during maturing stage both types of spermatocytes mixed with spermatids and resting spermatogonia in the same tubules are observed. These observations concur with the species *Menippe mercenaria* and it was observed by Binford (1913) and in *Scylla serrata* by Sen Gupta and Chatterji (1976). Due to species variations these differences are observed. In the prawn *M. lamarrei lamarrei* the various transformation of spermatogenetic cells were observed at slow pace. In the seminiferous tubules the synchronous appearance of similar stages was rarely found but
the relative abundance of different types of gonial cells at different times are seen through the temporal staging of testicular activity.

Sastry (1983) reported that in decapods crustaceans, quantitative data based on histological observations are rarely found on the relative abundance of different types of gonial cells. High rate of spermioteleosis in the prawn *M. lamarrei lamarrei* occurred during April and May in which testes contains 50% of sperms in the month of May. In the present study the absence of any period of gonadal quiescence in the testicular activity was observed as an interesting feature after the histological examination.

The process of oogenesis seems to be more variable with regard to period and frequency of oogenic cycle in comparison to the spermatogenesis. Sastry (1983) reported that in some lobster period was long for two years and in copepods for few days. Within the ovarian tissue the ovarian germinal zone manifests the variations in their arrangement and position. King (1948) reported that they are initially present on the periphery but later are restricted to one side in the shrimp *Penaeus setiferus*. Binford (1913) observed in *Menippe mercenaria* that it forms inner lining of the ovarian wall whereas Weitzman (1966) observe that it may be present throughout in ovary as “germinal nests” in *Gecarcinus lateralis*. Agarwal (1985) describe that the germinal epithelium mixed with the strands of the follicular cells in *Paratelphusa masoniana* and Joshi and Khanna (1982) describes the similarity to its position in *Potamon koolooense*. In the prawn *M. lamarrei lamarrei* the germinal epithelium in the ovary was located in middle as a central staff containing “oogonal cells”. From there due to mitotic division new crop of oocytes originates. After the spawning from the oogonal nests there was a rapid proliferation of very young oocytes in the month of July. Aoto (1952) reported the same mode of production of new
oocytes in *Pandalus Kessleri* whereas a continuous proliferation activity was shown by the germinal epithelium of ovary in crab *Pachygrapsus marmoratus*.

Towards the formation of matured ova, the process of vitellogenesis was important during which yolky substances are deposited in the oocytes. Varadarajan and Subramonian (1982 b) reported that during vitellogenesis the yolk spheres represent the lipoprotein, yolk granules reflect the deposition of neutral phospholipids into the oocyte and the yolk globules represent glycolipoproteins in the hermit crab *Clibanarius clibanarius*. Bhatia and Nath (1931) reported that the yolk vesicles and yolk globules of the oocyte represent the fatty yolk and protein yolk in *Paratelphusa spinigera*. In the freshwater prawn during the vitellogenesis the presence of yolk globules was observed by Rao (1968) in *Macrobrachium lanchesteri* similarly the presence of yolk granules are seen in *Palaemon paucidens* by Kamiguchi (1971). Tan-Fermin and Pudedera (1989) reported that with the addition of elliptical bodies known as cortical rod from the periphery towards the nucleus of the oocytes the process of vitellogenesis was completed in Penaeid prawn *P. monodon*. During the vitellogenesis, the appearance of yolk vesicles, yolk granules and yolk globules represents the yolk deposition in the oocyte. During the histological examination of the ovaries of *M. lamarrei lamarrei* it has been observed that there was a change from basophilic to acidophilic in the ooplasmic staining reactions during tertiary vitellogenesis which indicates a change during yolk deposition in the biochemical composition of ooplasm. Bomirski and Klek (1976) and Tan-Fermin and Pudadera (1989) observed a complete or differential change in shrimp and prawns during the transformation of the previtellogenesis into vitellogenesis oocyte from basophilic to acidophilic staining and this observation confirms the observation on present prawn.
Kessel (1968), Lui and O’Conner (1976) observed that during the vitellogenesis the appearance of yolk was attributed to intraoocytic synthesis of yolk substances whereas Wolin et al. (1973) observed that during the vitellogenesis it also appeared through follicular cells transport from haemolymph. In the yolk accumulations the follicular cells played an important role within the oocytes either by synthesis of yolk or by transporting its precursors into ooplasm from haemolymph and this was demonstrated by Varadarajan and Subramonian (1982 a, c). Prawn *M. lamarrei lamarrei* shows a presence of yolk vacuoles in the ooplasm which underwent a differentiation into a peripheral homogenous zone and narrow perinuclear granular zone. The yolk material synthesizes within the oocyte and it was represented in perinuclear granules whereas within the oocytes the appearance of peripheral yolk vacuoles and yolk granules and their centripetal movement are the indication for the yolk transport and transportation of extra oocytic origin of yolk precursors through follicular cells. Zerbib (1973) by electronic microscopic examination noticed the intimate attachment of follicular cells to the surface of the oocyte in *Orchestia gammarella*. In the oocyte of *M. lamarrei lamarrei* a significant involvement of transportation of yolk material was observed during vitellogenesis due to the change in the follicular cell shape from inactive squamous to active cuboidal and rectangular with their presence in more than one layer around the oocyte.

As reported by Kamiguchi (1971), Tan-Fermin and Pudadera (1989) that the atretic (resorbing) oocytes were found less in number similarly in *M. lamarrei lamarrei* these oocytes were noticed in less numbers but during previtellogenic or vitellogenic stages in the ovaries a cyclic changes never exhibited a resting phase. The histological examination of the ovaries of freshly spawned prawns collected in the month of July/August exhibits a
large number of very young oocytes and previtellogenesis oocytes with their transformation towards the maturity months represent the next crop of oocytes.

**Life history**

There are several species in which studies on their life cycle has been made in the Indian freshwater prawns. Species like *M. malcolmsonii* (Kewalramani *et al.*, 1971), *M. kistenensis* (Jahilal *et al.*, 1979) and Nagabhushanam and Kulkarni, 1981) in which larval studies were made. Sollaud (1923) reported in caridean shrimp that it possesses three types of larval development. Type I: Common or typical type- in this particular type a large number of small eggs are found with extended life history possessing several free swimming larval stages. This type exemplified by the species *M. acanthurus* (Chaudhary, 1970), *M. malcolmsonii* (Kewalramani *et al.*, 1971), *M. carcinus* (Chaudhary, 1971), *M. intermedium* (Williamson, 1972), *M. rosenbergii* (Ling, 1969) and *Palaemon ortmanni* (Tsou *et al.*, 1989). Type II: abbreviated type- this includes large sized animals with lesser number of eggs and possessing free swimming larval stages. This type exemplified *M. potiuna* (Sollaud, 1923) and *M. lamarrei* (Rajyalakshmi, 1961). Type III: Totally abbreviated type- it possesses lesser number of eggs than type II with minimum number of larval stages. Larva was non-free swimming.

In the present study on *M. lamarrei lamarrei*, the animal was found with larger sizes having lesser number of eggs and the larva on hatching was free swimming. So considering the above fact *M. lamarrei lamarrei* belongs to type II. The abbreviated life cycle in the present material under the study was exhibited by possessing well developed organs as antennule, antenna, first maxilla, second maxilla, maxillipeds as well as five pairs of well developed pereiopods in which first three pairs are biramous and last two are
unimargous. Broadly triangular telson was present. Orange red chromatophores are seen. The newly hatched larvae swim actively close to the surface of the water. *M. lamarrei lamarrei* comprises three zoeal stage i.e. 1\(^{\text{st}}\) zoea, 2\(^{\text{nd}}\) zoea and 3\(^{\text{rd}}\) zoea then a post larval stage. The post larval stage was characterized by the presence of adult-like antenna, mandibles, maxillae, maxillipedes, modifications in rostrum and by the presence of rectangular telson with shallow median notch on concave and new chromatophores are added over the zoeal stages. Shokita (1973) indentified 2 zoeal and 1 megalopa stages before the juvenile stage in the species *M. shokitai*. In the *M. shokitai*, biramous uropod was not observed before the juvenile stage so the juvenile stage of the species was considered as post larval stage. Hence it possesses three zoeal stages. The few species like *Palaemonetes sinensis* (Shen, 1939), *M. shokitai* (Shokita, 1973), *M. kistnensis* (Jahilal et al., 1979) and *Palaemon ortmanni* (Tsou et al., 1989) possess a unique feature of *Macrobrachium* larva i.e. the presence of rounded fan-shaped telson with certain number of marginal processes.

The prawn *M. lamarrei lamarrei* possesses a broad triangular telson with process formula 7+7 at first larval stage whereas in the post larval stage a rectangular telson with shallow median notch in which first three processes are lateral and spine-like was found which resembled with the telson describe by Jahilal *et al.* (1979).
Fig. 6.1: Seasonal relationship between male female sex-ratio and the berried females.

Fig. 6.2: Size frequency distribution of the berried females of *M. lamarrei*. 

Estelar
Fig. 6.3: Seasonal variations in the maturity indices of male and female with percentage of berried animals of *M. lamarrei lamarrei*.

Fig. 6.4: Relationship between brood fecundity and total weight in *M. lamarrei lamarrei*. 

\[
y = 151.42x + 17.063
\]

\[
R^2 = 0.5308
\]
Fig. 6.5: Relationship between brood fecundity and total length in *M. lamarrei lamarrei*.

\[ y = 7.4738x - 297.09 \]
\[ R^2 = 0.528 \]

Fig 6.6: Relationship between brood fecundity and months in *M. lamarrei lamarrei*.
Fig. 6.7: Relationship between ovarian fecundity and ovary weight in *M. lamarrei lamarrei.*
Fig. 6.8: Seasonal variations in male *M. lamarrei lamarrei* with relation of gonadosomatic indices (GSI) and hepatosomatic indices (HSI).

Fig. 6.9: Seasonal variations in female *M. lamarrei lamarrei* with relation of gonadosomatic indices (GSI) and hepatosomatic indices (HSI).
Fig. 6.10: Relationship between gonad wt and body weight in male *M. lamarrei lamarrei*.

![Graph showing the relationship between gonad weight and body weight in male *M. lamarrei lamarrei*. The equation is \( y = 0.0232x - 0.0109 \) and the coefficient of determination is \( R^2 = 0.6668 \).]

Fig. 6.11: Relationship between gonad wt and body weight in female *M. lamarrei lamarrei*.

![Graph showing the relationship between gonad weight and body weight in female *M. lamarrei lamarrei*. The equation is \( y = 0.0179x + 0.0006 \) and the coefficient of determination is \( R^2 = 0.5397 \).]
Fig. 6.12: Morphological characteristics of zoea larva I of *Macrobrachium lamarrei lamarrei*.

Fig. 6.13: Morphological characteristics of zoea larva II of *Macrobrachium lamarrei lamarrei*.

Fig. 6.14: Morphological characteristics of zoea larva III of *Macrobrachium lamarrei lamarrei*.

Fig. 6.15: Morphological characteristics of zoea larva IV of *Macrobrachium lamarrei lamarrei*.

Plate 6.1: Baigul reservoir at Dist. Udham Singh Nagar showing its bushy bank vegetation.

Plate 6.2: A far view of Baigul reservoir showing its typical vegetation.
Plate 6.3: Secondary sexual characters of male and female *Macrobrachium lamarrei lamarrei*
Plate 6.4: Berried animals of *M. lamarrei lamarrei*.

Plate 6.5: Animals carrying eggs in their ovary.
Plate 6.6: T.S. of testis showing resting spermatogonia within the seminiferous tubule. H & E ×300.

Plate 6.7: Testis showing large no. of primary spermatogonia. H & E ×300.
Plate 6.8: Testis showing secondary spermatogonia with few primary spermatocytes. H & E ×200.

Plate 6.9: T.S. testis showing primary spermatocytes. H&E×400.
Plate 6.10: Testis showing secondary spermatocytes. H & E×200.

Plate 6.11 T.S. testis showing spermatids. H & E × 300.

Plate 6.13: A part of ovary showing germinal epithelium with very young oocytes H & E ×300.
Plate 6.14: A part of germinal zone showing the newly formed very young oocytes and nucleolus. H & E × 400.

Plate 6.15: T.S. of ovary showing previtellogenic oocytes enveloped with follicular epithelium and primary vitellogenic oocytes surrounds with rectangular follicular epithelium. H & E × 400.
Plate 6.16: A part of ovary showing primary vitellogenic oocytes and secondary vitellogenic oocytes. H & E × 400.

Plate 6.18: A part of ovary showing tertiary vitellogenic oocytes with deposition of yolk globules. H & E × 400.