CHAPTER 5.

STUDY OF MOLLUSCS

INTRODUCTION

Molluscs are highly successful invertebrates in terms of ecology and adaptation and are found nearly in all habitats ranging from deepest ocean trenches to the intertidal zones, and freshwater to land occupying a wide range of habitats. During their evolution, they have adapted to live in nearly all available habitats. Of the recognized eight classes, all are represented in the sea with highest densities, followed by freshwater where only two groups [Gastropoda and Bivalvia (Pelecypoda)] are recorded and terrestrial habitats where only class (Gastropoda) occurs.

Of the two freshwater groups, Gastropods are divided further into two subclasses the prosobranchia, which possess a gill for respiration under water and the Pulmonata, which have a lung for obtaining air directly. Many pulmonates, however, are able to remain submerged in water for indefinite periods of time, perhaps for their entire existence, and have broad environmental tolerance. They tend to be more resistant to eutrophication, anoxia and brief exposure to air and have short generation times. Many of them are capable of self fertilization, and some are highly successful colonizers, as reflected in their ability to occupy newer ephemeral habitats (Okland, 1990). This renders many of them more resilient to human-mediated threats and less extinction prone than other freshwater forms (Michael, 1984). Bivalvia breathe by means of two gills suspended on each side of the body.

The estimated number of mollusca today varies from 80,000 species to 1,35,000 species (Abott, 1989) and the total diversity possibly as high as 2, 00,000. They are second only to arthropoda in species richness (Strong *et al*., 2008). 5070 species of Molluscs are reported from India. The diversity is contributed mainly by marine molluscs, whose knowledge is far from complete. The global freshwater gastropod fauna is estimated at approximately 4,000 described species, however, the total number is probably 8,000 (Strong *et al*., 2008) with 213 species reported from India (Subba Rao, 1989). Authentic data on the status of various species of molluscs is not readily available. Recent surveys have shown that species which were once abundant and easily available are hard to find now in their habitats (Subba Rao, 1989). As per world conservation Monitoring Centre about 170 species of molluscs have become extinct since 1800 AD, while the 1990 IUCN Red List recorded 425 species of molluscs under the threatened category.

Much of the molluscan diversity occurs in the tropical world. Despite this great diversity, very few studies on molluscs have been carried out in the tropical world. The rich land snail diversity from tropical rain-forest is mainly found in the leaf litter and the soil (Emberton, 1996). With their biomass this diversity is of great ecological significance. Most of these tropical molluscs remain to be described due to their minute sizes (Emberton, 1996; Cowie *et al*., 1995). Majority of the studies on land snails in India were during 19^{th} century by British naturalists like William Benson, Beddome, Blanfold, Godwin, Austin, Preston, Gude and Rao, whereas Ananndale and Rao have contributed to the biology and distribution of both freshwater and terrestrial molluscs during early and mid 20^{th} century. Recently a couple of compilation works on land snails have been published by the Zoological Survey of India. One publication has reviewed endemic land mollusc of India (Ramakrishna and Mitra, 2002). An attempt to address the diversity, endemism and geographical distribution patterns of land snail of western Ghats, has been made by Arvind *et al*. (2005). Till date 1487 species of land snails belonging to 32 families and 140 genera have been reported in India (Ramakrishna and Mitra, 2002). Recently the checklist of terrestrial gastropods of Karnataka (Mavinkurve *et al*., 2004) and land and freshwater mollusca of Maharashtra state have also been published (Patil and Talmale, 2005).

Wetland molluscs generally feed on algae and detritus (Ramchandra *et al*., 2002) and they in turn are eaten up by higher forms especially for their calcium requirements. Hence, they are involved in recycling and transport of nutrients from one trophic level to other trophic level forming an important link in the wetland food web (Ramchandra *et al*, 2002). Local environmental variables provide explanation of aquatic gastropod assemblage structure of an area (Perez Qunitero, 2007). The local environmental variables include productivity, temperature (Garg *et al*., 2009; Tarr *et al*., 2005), macrophyte (Antoine *et al*., 2004, Lewin and Smolinksi, 2006), bottom sediments (Lewin and Smolinksi, 2006), Calcium and pH (Briers, 2003), water chemistry and hydroperiod (Heino, 2000; Maltchik *et al*., 2010). The interaction between abiotic (pH, hardness, *etc*.) and biotic (plant-substrate and food resources and predators) factors have also been reported to be important environmental predictors for molluscan density and diversity (Dillon, 2000; Heino and Muotka, 2006; Horsak *et al*., 2007). The presence of predators, such as fish and crayfish (Lodge *et al*., 1987, Dillon, 2000), dragonfly larvae (Turner and Chislock, 2007) and birds (Stanczykowska *et al*., 1990) have strong control on local gastropod abundance across the habitat. Thus, molluscs gain special importance when ecology of wetland is studied (Ramchandra *et al*., 2002). In a wetland, the macroinvertebrate structure in general, has been associated with area and habitat heterogeneity (Oertli *et al*., 2002; Stenert *et al*., 2008).

Terrestrialism in molluscs is ancient. The earliest fossils of terrestrial forms date back to the mid Palaeozoic while their adaptive radiation into higher taxa that characterize extant faunas occurred in the lower Cretaceous (Solem and Yochelson, 1979). Land snails are regarded typically as generalist herbivores, frugivores and detritivores (Burch and Pearce, 1990) that exhibit weak levels of intraspecific competition (Barker and Mayhill, 1999). Their local-scale community patterns are less well known, especially in the tropical and sub-tropical environments where densities are often low, leading to acute sampling problems (Cameron and Pokryszko, 2005). Patterns are even more obscured because of sampling problems and differences. As many tropical and subtropical forests are oligotrophic and support very low densities of snails, it is often impossible in such circumstances to distinguish between genuine local heterogeneity and sampling effects. However, such heterogeneity could be significant both for speciation events and for co-existence of closely related species (Cameron *et al*., 2003).

Previous studies on land molluscs have shown that molluscs are influenced by various environmental factors. They have specific habitat preferences (Nekola, 2003) and are influenced by rainfall via primary productivity (Tattersfield *et al*., 2001). Their habitat preference is strongly associated with vegetation and leaf litter on the forest floor (Barker and Mayhill 1999; Baur *et al*., 2007). The diversity of snail species often increases along with the amount of calcium in the soil and the associated increase in pH (Emberton *et al*., 1997). Soil texture, moisture and temperature are the predictors of molluscs composition (Nekola, 2003). Moreover, predation pressure as well as habitat degradation due to human activities also affect molluscan diversity (Baur *et al*., 2007).

The molluscs directly as well as indirectly form economically very important group for human being. A list of edible mollusca is given by Subba Rao (1989) and of medicinal value by Mavinkurve *et al*. (2004). Freshwater mussels, pearl oysters, turban and top shells are sources of mother pearl. They also form basic raw material for shell Button Industries. Besides the direct values mentioned above, molluscs have an important role in ecosystem. They play an important role in food chain as well as in litter decomposition in the terrestrial ecosystem. They improve soil conditions and are easily collected and serve as indicators of leaf litter biodiversity (Seddon, 1998). However, some freshwater snails are vectors of disease, serving as the intermediate hosts for a number of infections for which humans or the livestock are definitive hosts (Ponder *et al*., 2006).

Considering the role of molluscs in maintaining the overall environmental conditions, the conservation of this group is of urgent need. It requires multiple approaches including research (systematic, ecology *etc*.), inventories (distribution, population size), mitigation of human impact and active intervention to promote recovery (Lydeard *et al*., 2004; Seddon, 1998). Hence, while studying biodiversity and ecology of Lotus Lake an attempt is made to document density and diversity of mollusks - aquatic molluscs inhabiting Lotus Lake and the land mollusc present in the surrounding tropical forest at higher altitude Tornanmal Reserve Forest. Hence, the present chapter deals with both aquatic and land molluscs of the area.

MATERIAL AND METHODS

Study Area

A) Aquatic Molluscs: Lotus Lake

The molluscs of Lotus Lake were studied during two year period from December 2006 to November 2008. Three sampling sites selected on the Lotus Lake were as follows:

1) **LL-1**: Located on western side of the Lotus Lake. It is a shallow area with muddy bottom densely covered with macrophytes. The dominant vegetation here includes *Nymphaea pubescens* and *Polygonum barbatum.*

2) **LL-2**: Located on the eastern side of the Lotus Lake with least Macrophytes and sandy and rocky shore.

3) LL-3: Located on the northern side of the Lotus Lake, it is also a shallow area with moderate vegetation and muddy bottom.

Sampling Method

For collection of molluscs a unit corer with 10 cm height and 8 cm radius was inserted 5 to 6 spots at each field station. The soil collected was sieved and the molluscs were collected in a separate sample bottle as described by Michael (1984) and Tronstad *et al*., (2005). An average of this was considered as a unit for the site per visit. LL-1 and LL-3 where more macrophytes were present a net was directly dipped in the water and swept to collect mollusc with vegetation. The collected molluscs were preserved in 4% formalin and carried to the laboratory for quantitative and qualitative estimation. The collected molluscs were identified as per the key provided by Subba Rao (1989). The density of molluscs was calculated as No. /Cu.M.

B) Land Molluscs:

The land molluscs of Toranmal area were also studied during two year period from December 2006 to November 2008. Three sites (habitat) identified for sampling of land molluscs are as follows:

Study Area

1) Khadki area (Lmkh-1)

It is located at 21˚ 51’ 56” N and 74˚ 27’ 07” E and at 1003 mAMSL, extreme northwest of Toranmal plateau. It is plain area with degraded forest, very few tall trees such as *Phyllanthus emblica, Terminalia arjuna, T. bellirica, Butea monosperma, Acacia chundra, etc*. and many herbs, shrubs and grasses that start drying from post-monsoon. Cattle grazing were frequently recorded in this area. The soil was dry.

2) Kalapani area (Lmkp-2)

It is located at 21˚ 51’ 04” N and 74˚ 28 07” E and at 824 mAMSL. 10 Km before Toranmal. It is a forested and hilly area. Natural vegetation is of dry deciduous forest type mainly comprising *Tectona grandis* with many herbs, shrubs and grasses. The wild weeds *Achyranthus aspera, Cassia tora, Vernonia cinerea, Tridax procumbens* and *Andropogon spp* were abundant. The ground was moderately covered with leaf litter and cattle grazing was also observed in this area.

3) Yashwant Lake area (Lmyl-3)

The habitat is located on western side of Yashwant Lake at 21˚ 52’ 47” N and 74˚ 27’ 17” E and 980 mAMS with mix vegetation. Large trees present were *Madhuca longifolia, Phyllanthus emblica, T. arjuna, T. bellirica, Syzygium heyneanum* and *Mangifera indica*. Ground was covered with various herbs and shrubs. They include *Lantana camera*, *Tridax procumbens, Plectranthus mollis, Cassia obstusifolia, etc*. The soil was slightly damp due to dense vegetation cover. The area showed low level of cattle grazing and anthropogenic pressure.

Sampling Method

Quantitative and qualitative estimation of land molluscs were carried out by using quadrate method (Michael, 1984; Subba Rao, 1989). At least six quadrate (1 × 1m) were sampled from each of the habitat. The average of these was considered as density and species richness per m^2 for that habitat. The specimen not identified in the field were preserved in 4 % formalin and carried to the laboratory and identified by using standard keys and monographs. (Abbott, 1989; Blanford and Godwin, 1908; Gude, 1914; 1921).

Analysis

The data of the two year study (from December-2006 to November-2008) was pooled for three months and four seasons and analyzed for seasonal variations, with respect to winter (December, January, February), Summer (March, April, May), Monsoon (June, July, August) and Post-monsoon (September, October, November). Further, the Mean, Standard Error of Mean (SEM) were calculated for each season and One-Way ANOVA with No post test for various parameters for four seasons was performed using Graph Pad Prism version 3.00 for Windows (Graph Pad Software, San Diego California USA). The correlation between the abiotic factors and the molluscs was calculated. The Pearson correlation was calculated by keeping mollusc as dependent variable and other abiotic and biotic factors as independent variables with the help of SPSS 7.5 for Windows.

RESULTS

Aquatic Molluscs

Total nine species of aquatic molluscs were recorded belongs to seven genera and five families. These molluscs include seven species of Gastropods and two Bivalvia (Annexure-IV).

Density and species richness (Table 5.1, Fig. 5.1, 5.2)

LL-1: The density of molluscs showed significant seasonal variations at LL-1 ($F_{3\ 20}$ 75.26) with maximum density in post-monsoon (3376 ± 174 / m^3) and minimum in winter (1118 ± 67 / $m^{3)}$. Maximum species richness was also recorded in post-monsoon (7.83 ± 0.30) while minimum in winter (5.17 ± 0.30) with significant variations across the seasons ($P < 0.0001$ $F_{3\ 20}$ 13.9).

LL-2: The density and species richness of molluscs at LL-2 also showed significant seasonal variations ($P < .0001$ $F_{3\ 20}$ 113.00) for density and ($P < .0001$ $F_{3\ 20}$ 14.77) for species richness. Maximum density was observed in post-monsoon (2533 ± 69 / m^3) and minimum in winter (909 ± 47 / m^3) while maximum species richness was also recorded in post-monsoon (5.83 ± 0.30) and minimum in winter (3.33 ± 0.21).

LL-3: The trend in seasonal variations at LL-3 was not different than LL-1 and LL-2 with significant seasonal variations for density ($P < .0001$ $F_{3\ 20}$ 25.74) and species richness ($P < .0001$ $F_{3\ 20}$ 12.68). Maximum density was recorded in post-monsoon (3258 ± 330 / m^3) and minimum in winter (1047 ± 88 / m^3) with maximum species richness again in post-monsoon (7.66 ± 0.49) and minimum in winter (4.66 ± 0.21).

When density and species richness of three sites were compared, overall maximum density and species richness were recorded at site LL-1 and minimum at LL-2, while moderate at LL-3 over four seasons.

Relative abundance of Aquatic Mollusc (Table 5.3)

The relative abundance of molluscs showed variations in three different habitats. At LL-1 *Lymnaea acuminate* appeared to be the most dominant species (19.2 %) while *Bellamya bengalensis* was least abundant (5.5%). At LL-2 *Thiara tuberculatus* appeared most dominant (19.7 %) while *Parreysia* (*Radiatula*) *caerulea* was least abundant (4.8 %) and at LL-3 again *L. acuminate* appeared most dominant (16.3 %) species, while *B. bengalensis* was least abundant (6.2 %).

The Pearson Correlation (Table 5.5) of different factors with density and species richness of aquatic molluscs revealed significant positive correlation at the level of .01 at all the three sites with humidity, NO_2^-, NO_3^- and PO_4^-, RF, TSS and WC while negatively with TH and Transparency at the same level. However, both were positively correlated at the level of .05 to AT (except DMLL1), and negatively with DO (except SPMLL3 and MLL3). Chlorides were correlated negatively significantly at .01 level with DM but at level of .05 and Sp at LL1 and LL3 only.

Land Molluscs

Total five species of land molluscs were recorded from Toranmal area over two year study (December 2006 to November 2008) belonging to five genera and three families (Annexure IV). These gastropods include two slugs and three snails.

Density and species richness (**Table 5.2, Fig 5.3, 5.4**)

When three sites are considered the density and species richness showed following trends.

1) Khadki area (LmKh): The density of molluscs showed significant seasonal variations at LmKh ($P < .0001$ $F_{3\ 20}$ 26.91). Maximum density of Land molluscs was recorded in monsoon (6.33 ± 0.89 / m^2) and minimum in summer (0.33 ± 0.16 / m^2). Maximum species richness was also recorded in monsoon 3 ± 0.26 and minimum in summer 0.17 ± 0.10 ($P < .0001$ $F_{3\ 20}$ 13.02).

2) Kalapani area (LmKp): With significant seasonal variations the density of molluscs at LmKp ($P < .001$ $F_{3\ 20}$ 16.37) was maximum in monsoon (6.58 ± 1.08 / m^2) and minimum in summer (0.66 ± 0.30 / m^2) with maximum species richness in monsoon 3.3 ± 0.2 and minimum in summer 0.58 ± 0.40 ($P < .001$ $F_{3\ 20}$ 16.46).

3) Yashwant Lake (LmYL): Maximum density of Land molluscs at LmYL were recorded in monsoon (8.91 ± 0.78 / m^2) and minimum in summer (0.91 ± 0.45 / m^2) ($P < .0001$ $F_{3\ 20}$ 52.75) with maximum 4.16 ± 0.30 species richness in monsoon and minimum 0.83 ± 0.54 in summer ($P < .0001$ $F_{3\ 20}$ 18.25).

Overall maximum density and species richness of Land molluscs were recorded at LmYL and minimum at LmKh, while moderate at LmKp.

Relative abundance of Land Mollusc (Table 5.4)

Among five species of Land molluscs the relative abundance of *M. indica* was maximum 30.8 % at LmKh followed by *A. laevipe* (25.8 %), *C. moussonianus* (19.3 %), *S. maculate* (12.5 %) and *L. alte* minimum 9.6 %. The trends were different at other two habitats with higher relative abundance of *C. moussonianus* (24.3 %), *A. laevipes* (23.2 %), *M. indica* (21.8 %) and lower of *S. maculate* (16.4 %) and *L. alte* (14.3 %) at LmKp. At LmYL relative abundance of *A. laevipes* (24.8 %) and *S. maculate* (23.2 %) were higher followed by *L. alte* (19.8 %) while that of *M. indica* (17.7 %) and *C. moussonianus* (14.5 %) were lower.

When **Pearson Correlation** was performed, the density and species richness of Land mollusc showed positive significant correlation (Table 5.6) with humidity and rainfall at the 0.01 level, while (density and richness) established non-significant (negative) correlation with atmospheric temperature and wind. Significant positive correlation is established between density and species richness of molluscs.

Table: 5.1 Seasonal Variations in density (no/m^3) and Species richness (No. of species) of Aquatic Molluscs at Lotus Lake (LL) during December 2006 to November 2008

Parameters	F value	Winter	Summer	Monsoon	Post-monsoon
Total density (LL-1)	$F_{3\ 20}$ 75.26	1118 ± 67	1684 ± 51	2338 ± 110	3376 ± 174
Species richness(LL-1)	$F_{3\ 20}$ 13.9	5.17 ± 0.3	6 ± 0.25	7 ± 0.36	7.83 ± 0.30
Total density (LL-2)	$F_{3\ 20}$ 113	909 ± 47	1386 ± 26	1806 ± 94	2533 ± 69
Species richness (LL-2)	$F_{3\ 20}$ 14.77	3.33 ± 0.21	4.16 ± 0.30	5.16 ± 0.30	5.83 ± 0.3
Total density (LL-3)	$F_{3\ 20}$ 25.74	1047 ± 88	1617 ± 85	2249 ± 123	3258 ± 330
Species richness (LL-3)	$F_{3\ 20}$ 12.68	4.66 ± 0.21	5.5 ± 0.42	6.8 ± 0.3	7.66 ± 0.4

Table: 5.2 Seasonal Variations in density (no/ m^2) and Species richness (No. of species) of Land Molluscs of Toranmal area at different habitat during December 2006 to November 2008

Parameters	F value	Winter	Summer	Monsoon	Post-monsoon
Total density (LmKh)	$F_{3\ 20}$ 26.91	3.41 ± 0.3	0.33 ± 0.16	6.33 ± 0.89	1.83 ± 0.33
Species richness(LmKh)	$F_{3\ 20}$ 13.02	1.66 ± 0.33	0.17 ± 0.10	3 ± 0.26	1.16 ± 0.30
Total density (LmKp)	$F_{3\ 20}$ 16.37	3.5 ± 0.34	0.66 ± 0.37	6.58 ± 1.08	2 ± 0.43
Species richness (LmKp)	$F_{3\ 20}$ 16.46	2.5 ± 0.22	0.58 ± 0.42	3.33 ± 0.21	1.67 ± 0.21
Total density (LmYL)	$F_{3\ 20}$ 52.75	4.25 ± 0.21	0.91 ± 0.45	8.91 ± 0.79	2.17 ± 0.25
Species richness (LmYL)	$F_{3\ 20}$ 18.25	3.16 ± 0.17	0.83 ± 0.54	4.17 ± 0.30	2.10 ± 0.17

Table: 5.3 Relative abundance (%) of Aquatic Molluscs at Lotus Lake during December 2006 to November 2008

Sr.No.	Name of the species	LL-1	LL-2	LL-3
1	*B. bengalensis* (*F. bengalensis*)	5.5	11.4	6.2
2	*B. bengalensis* (*F. annandalai*)	10.2	15.2	11.4
3	*T. tuberculatus*	7.5	19.7	8.2
4	*L. acuminate*	19.2	8.6	16.3
5	*L. luteola*	17.4	10.2	15.3
6	*I. Exustus*	10.7	17.4	9.4
7	*G. labiatus*	7.2	5.5	8.2
8	*L. marginalis*	12.5	7.2	14.3
9	*P.* (*Radiatula*) *caerulea*	8.7	4.8	9.7

Table: 5.4 Relative abundance (%) of Land Molluscs of Toranmal area at different habitat during December 2006 to November 2008

Sr.No.	Name of the species	LmKh	LmKp	LmYL
1	*L. alte*	9.6	14.3	19.8
2	*S. maculata*	12.5	16.4	23.2
3	*C. moussonianus*	19.3	24.3	14.5
4	*A. laevipes*	25.8	23.2	24.8
5	*M. indica*	30.8	21.8	17.7

Table 5.5 Pearson Correlations: Aquatic Molluscs density and species richness with Abiotic parameter in Toranmal region during December 2006 to November 2008

Parameters	DMLL1	DMLL2	DMLL3	SPMLL1	SPMLL2	SPMLL3
AT	.276	.291*	.327*	.359*	.351*	.327*
WT	- .076	-.056	-.020	.031	.060	.039
WC	.591**	.580**	.553**	.495**	.483**	.471**
Trans	-.699**	-.662**	-.685**	-.706**	-.669**	-.749
TS	.060	.040	.104	.223	.168	.250
TSS	.660**	.637**	.649**	.664**	.619**	.734**
TDS	-.415**	-.423**	-.354*	-.219	-.255	-.239
HUMI	.639**	.600**	.623**	.647**	.766**	.535**
RF	.471**	.448**	.463**	.553**	.482**	.565**
DO	-.297*	-.355*	-.243	-.316*	-.334*	-.211
CO_2	.192	.203	.227	.261	.261	.263
Cl	.276	.291*	.327*	-.294*	-.269	-.314*
Ph	-.031	-.016	.003	,069	.065	.084
TH	-.516**	-.491**	-.484**	-.458**	-.433**	-.475**
NO_2	.783**	.773**	.751**	.766**	.695**	.771**
NO_3	.467**	.419**	.477**	.535**	.432**	.539**
PO_4	.384**	.390**	.406**	.438**	.484**	.495**

DMLL1, DMLL2,DMLL3: Density of Molluscs at LL1, LL2 and LL3, SPMLL1, SPMLL2, SPMLL3: Species Richness of Molluscs at LL1, LL2 and LL3

Table 5.6 Pearson Correlations: Land Molluscs density and species richness with Abiotic parameter in Toranmal region during December 2006 to November 2008

	AT	DLM1	DLM2	DLM3	HUMI	RF	SPR L1	SPR L2	SPR L3	WIND
AT	**1.000**									
DLM1	**-.152**	**1.000**								
DLM2	**-.142**	**.925****	**1.000**							
DLM3	**-.055**	**.920****	**.951****	**1.000**						
HUMI	**.240**	**.721****	**.725****	**.711****	**1.00**					
RF	**.279**	**.812****	**.825****	**.830****	**.952****	**1.000**				
SPRL1	**-.071**	**.805****	**.701****	**.772****	**.627****	**.662****	**1.000**			
SPRL2	**-.279**	**.827****	**.846****	**.857****	**.601****	**.630****	**.731****	**1.000**		
SPRL3	**-.317**	**.802****	**.736****	**.802****	**.557****	**.597****	**.812****	**.874****	**1.00**	**.060**
WIND	**.729****	**.260**	**.226**	**.346**	**.394**	**.518****	**.261**	**.069**	**.060**	**1.000**

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** Correlation is significant at the 0.01 level (2-tailed

* Correlation is significant at the 0.01 level (2-tailed).

DLM1, DLM2, DLM3 : Density of Land Molluscs at LL1, LL2 and LL3, SPRL 1, SPRL2, SPRL3: Species Richness of Land Molluscs at LL1, LL2 and LL3

Fig.: 5.1 Seasonal Variations in density (no/ m³) of Aquatic Molluscs at Lotus Lake (LL) during December 2006 to November 2008

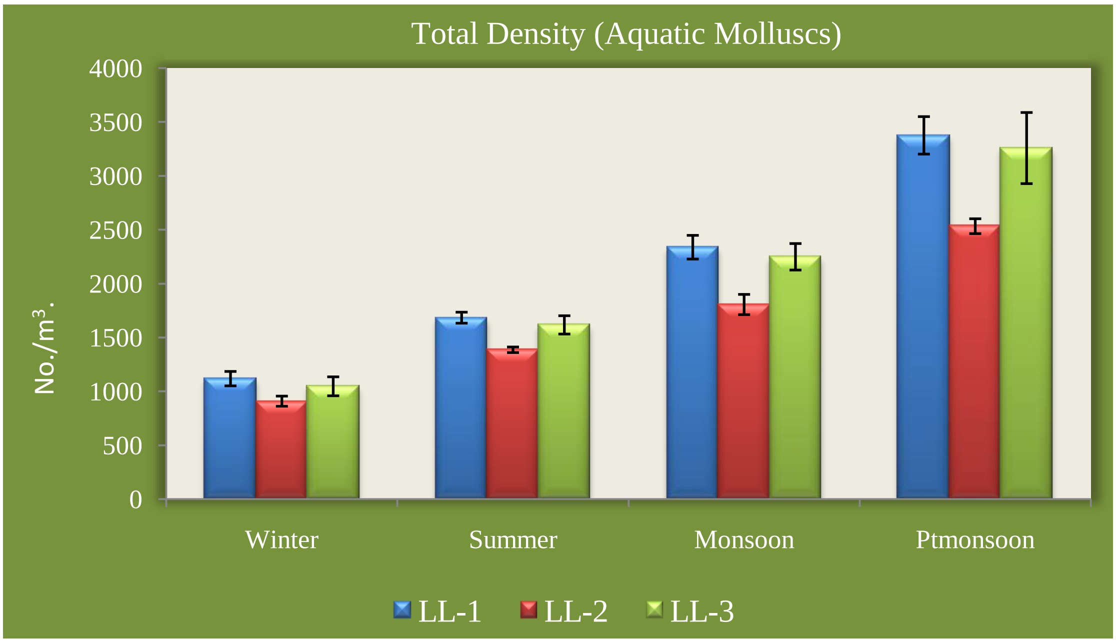


Fig.: 5.2 Seasonal Variations in Species richness (no. of species) of Aquatic Molluscs at Lotus Lake (LL) during December 2006 to November 2008

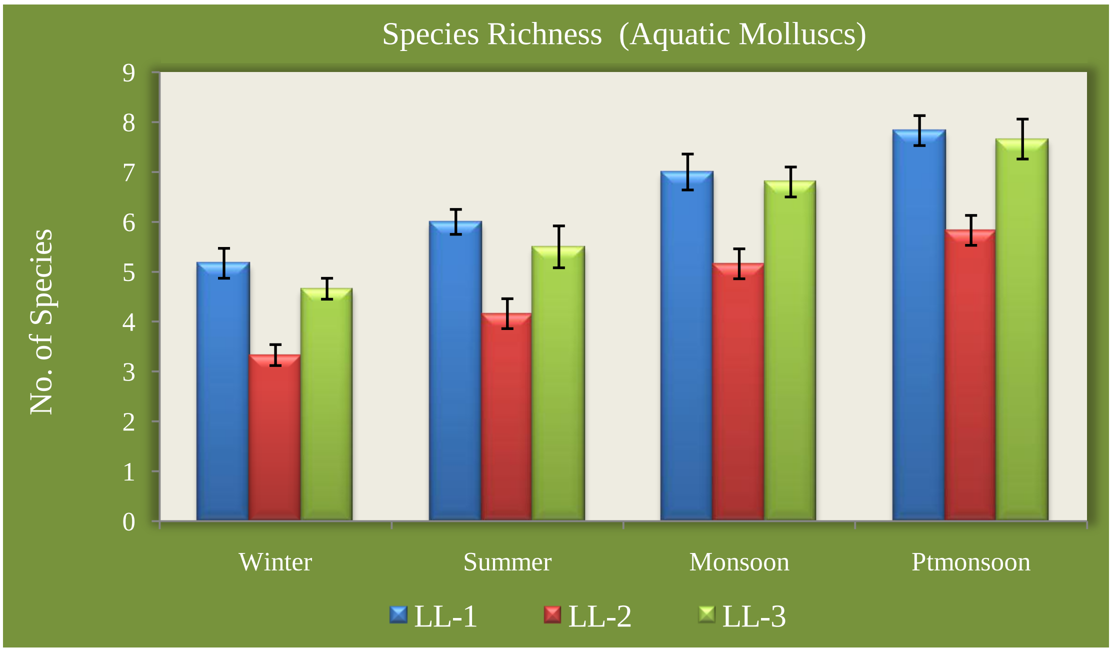


Fig.: 5.3 Seasonal Variations in density (no/m^2) of Land Molluscs of Toranmal area at different habitat during December 2006 to November 2008

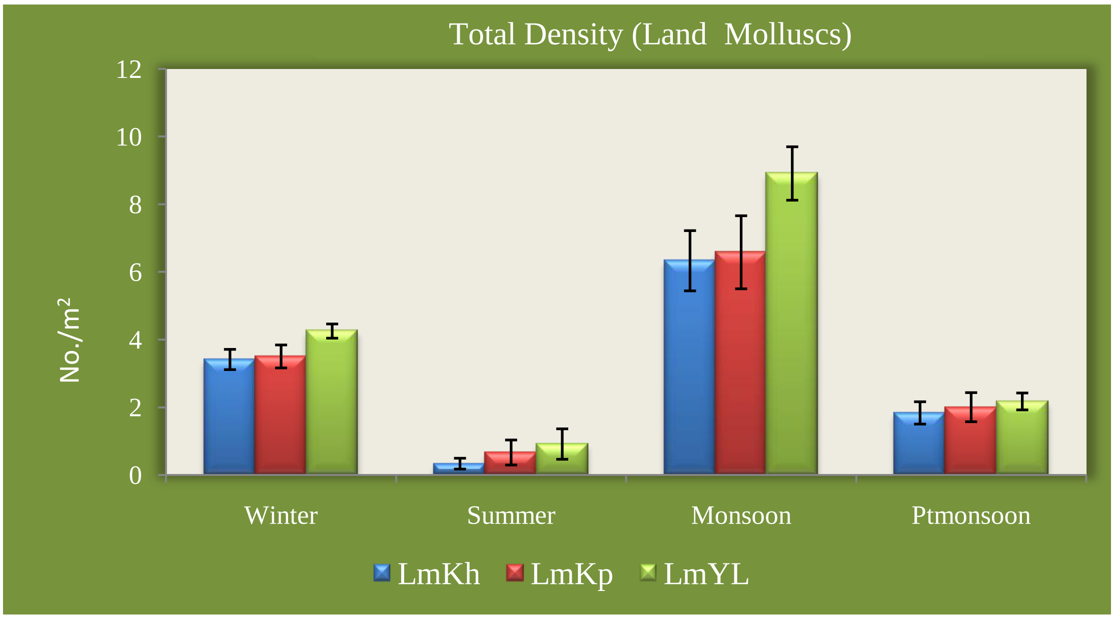


Fig: 5.4 Seasonal Variations in Species richness (no. of species) of Land Molluscs of Toranmal area at different habitat during December 2006 to November 2008

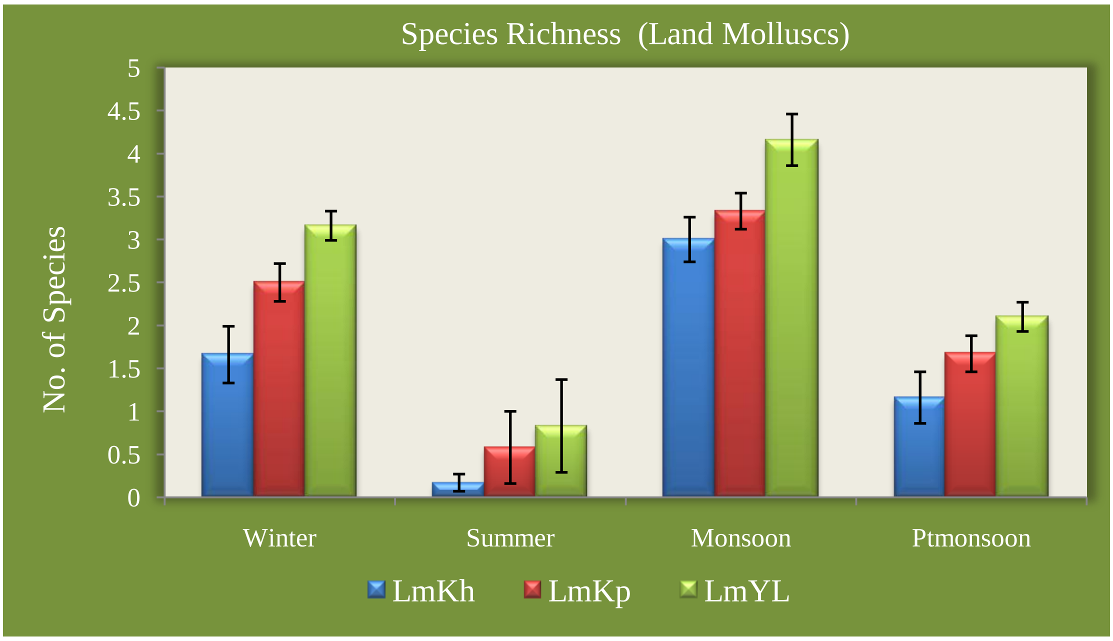


Fig.: 5.5 Relative abundance (%) of Aquatic Molluscs at Lotus Lake during December 2006 to November 2008

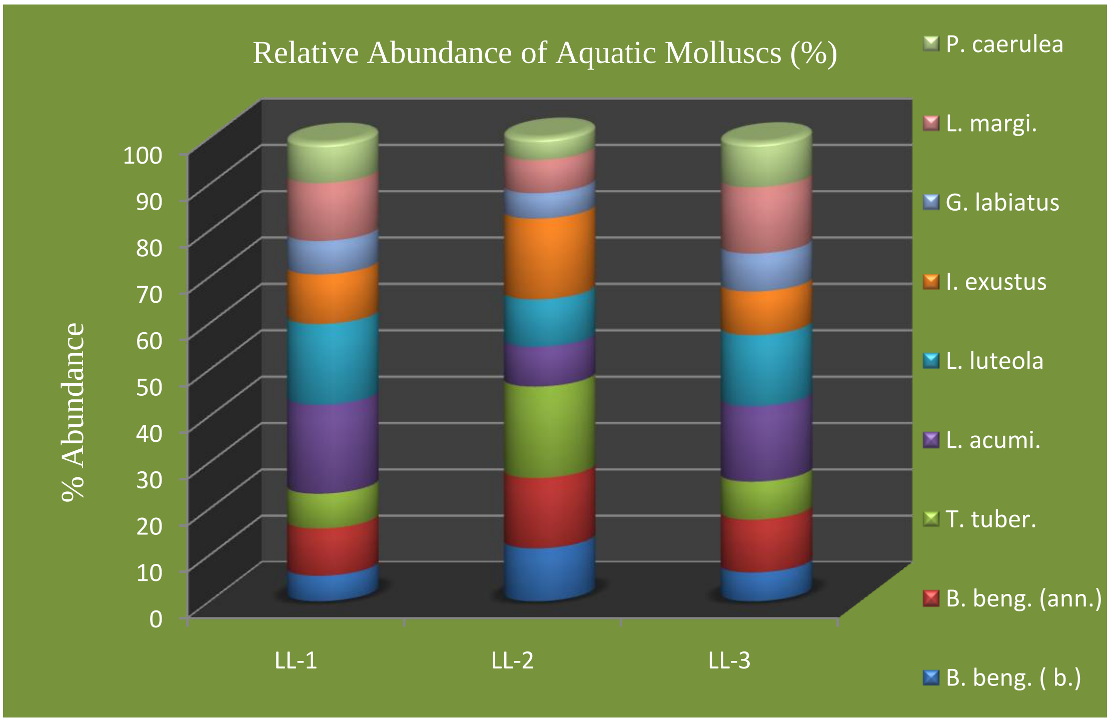
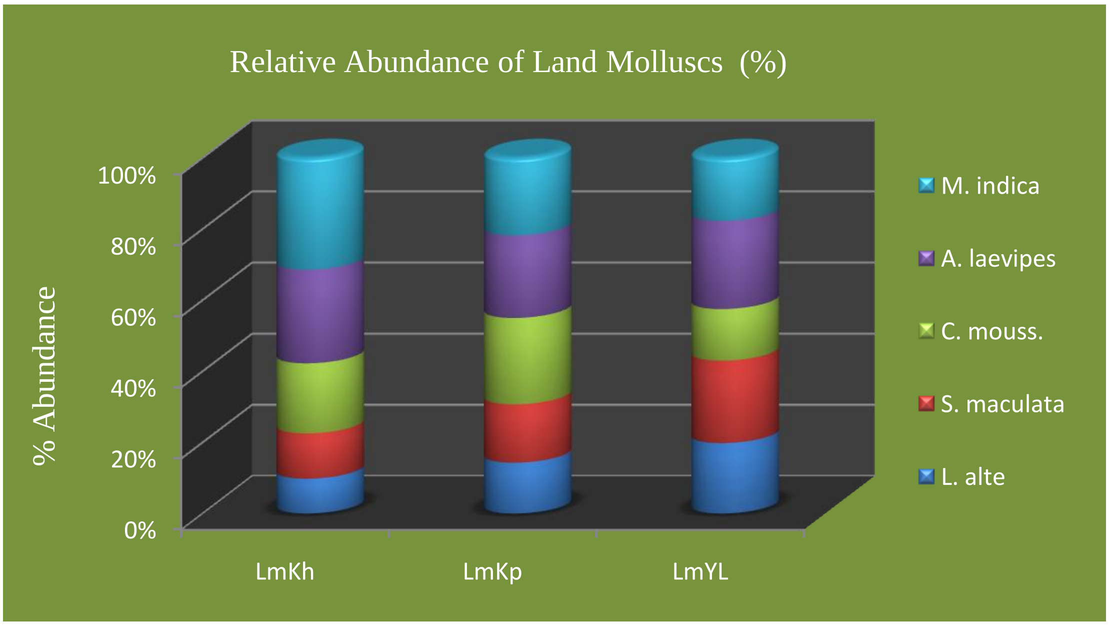


Fig.: 5.6 Relative abundance (%) of Land Molluscs of Toranmal area at different habitat during December 2006 to November 2008



DISCUSSION

Aquatic Molluscs

The pond communities appear to be the product of a number of abiotic and biotic variables, whose relative importance differ among species as well as ponds (Pip, 1986). Human activities have adverse effects on both the physical and the chemical characteristics of ponds especially on near shore habitats. These activities include agricultural practices, municipal waste treatment and recreational development. With more distant human activities in watershed these activities ultimately influence the end receiving waters like lakes, ponds and rivers. These factors may in turn affect species composition and abundance of gastropod and freshwater mussel communities (Heino and Muotka, 2006; Pip, 2006; Garg *et al*., 2009).

In the present study of molluscs significant seasonal variations were recorded in density and species richness at Lotus Lake and surrounding area. The seasonality of molluscs may be correlated with temporal variations of biotic and abiotic parameters. Maximum density and species richness of aquatic molluscs were recorded in post-monsoon, when weather is moderate.

When various physicochemical parameter of Lotus Lake are considered with respect to overall molluscan density and species richness both were significantly positively correlated with rainfall at Lotus Lake. Magare (2007) also reported higher density of mollusc during same season from the neighbouring area. Monsoon is one of the determinant factor in regulating density and distribution of plants (the macrophytes) as it influences the physical and chemical characteristics of the Lake. One of the parameters influenced by rainfall is water cover which was also significantly positively correlated with the density and species richness of the molluscs. The increased water cover (spread) may provide more microhabitat to the mollusc and better opportunity for colonization leading to increased density and species richness not only in monsoon but also in following post-monsoon. Opposite effects, may be apparent in summer, when the water cover of Lotus Lake decreased (upto 40%) and affecting pond area. Darby *et al*., (2002) correlated molluscan density with pond area. According to these authors, if the pond area decreases due to drying, the molluscs (*e.g*. Apple snail) move towards the water. As the water cover declines, several dead empty shells accumulate at receding water margin. In addition, during summer, due to lower water cover the macrophyte community of the drying zone is affected, thus the opportunity for colonizing the area decreases lowering the density and species richness. The fundamental biogeographic principle proposes that the larger lakes support more gastropod species (Carlson, 2001). Positive correlation between gastropod species richness and pond surface area were also reported by the Oertli *et al*., (2002). In several other studies also it has been reported that the hydroperiod influences structure of wetland macroinvertebrate communities including molluscs (Wellborn *et al*., 1996; Zimmer *et al*., 2000).

Relationship of Aquatic Mollusc with abiotic parameters

The density and species richness of molluscs in the Lotus Lake was non-significantly correlated with water temperature but significantly correlated with atmospheric temperature. These may be attributed to the fact that water cools as well as warms up slowly compared to the air. The minimum AT may have adverse effect on the molluscs forcing them to hibernate or move to deeper soil resulting in lowering their density and species richness in winter and similarly forcing them to aestivate at higher temperature of summer. The aestivation process in molluscs has been reported by Teles and Marques (1989) in subtropical climatic conditions.

Moderate hardness (see chapt-3) of Lotus Lake water probably supports molluscan density. More gastropod species occur in moderately hard waters compared to hard waters. Many authors have considered the relationship between gastropoda distribution and calcium concentration in waters (Briers, 2003; Dussart 1976; Mackie and Filipance, 1983). Calcium is an essential requirement for the successful growth and development of gastropod (Wareborn, 1970). In the present study, seven species of gastropods recorded with higher densities indicate that available calcium range may be sufficient for the gastropods in the Lotus Lake. However, at Lotus lake TH is negatively significantly correlated with density and species richness of aquatic mollusc at all the three sites.

Molluscs were found to be independent of fluctuations with respect to pH, since a very weak and insignificant correlation was obtained between them. However, the pH of Lotus Lake remained alkaline throughout the study period. Pennak (1989) has reported greater molluscan population in alkaline lakes as compared to acidic lakes. TSS probably provides protection from predators hence is positively correlated.

Similarly increased WC also provides moisture and increased area for breeding leading to higher density.

The nutrients (NO_2^-, NO_3^- and PO_4^{-3}) were positively significantly correlated with molluscan density and species richness at Lotus Lake. The algal flora (the periphyton), the base of the molluscan food chain is dependent on biogenic elements in water which in turn depend on nitrate concentration. The positive correlation between the gastropod densities and nitrate concentration in water may explain alimentation relationships (Iga and Adam, 2006).

Further, the Dissolved oxygen of Lotus Lake established inverse correlation at different levels and different sites with molluscn density and species richness. Previous studies have shown that DO is an important factor effecting the distributions of snails both positively (Van Someren, 1946) and negatively (Hurley *et al*., 1995). Some molluscs can survive in very low oxygen conditions and have an inverse relationship (Sharma, 1986). Dissolved oxygen has been found to be important in the distribution of bivalves too (Biswas and Raut, 1999).

Similarities are observed in the seasonal pattern of density and species richness of molluscs. However, variations in community composition at different biotopes of the Lotus Lake (LL-1, LL-2 and LL-3) (Table 5.1, 5.2, 5.3, Fig. 5.1, 5.2) indicates effect of weather on one hand and habitat preferences by different species on the other. These variations in the domination of particular species in selected biotope may be attributed to the specific available microhabitat which may favour particular species. Among the three biotopes, maximum density and richness were recorded at LL-1 while minimum at LL-2 all throughout the year in all seasons. The highest density and diversity in post-monsoon was high due to water cover, moderate photoperiod and temperature favouring the growth of macrophytes. These factors influence snails directly by providing different architecture and periphyton substrate, but other local factors such as hydroperiod or water chemistry also influences the density and species richness (Zealand and Jetfries, 2009). The macrophytes (emergent, submerge and free floating in the littoral zone of the Lake) such as *Nymphaea pubescens, Polygonum barbatum, Ipomoea carnea, Ipomoea aquatic, Typha domingensis, Hydrophila schulli, Sesbania bispinosa, Ceratophyllum demersum, etc*. and other grasses and sedges were present in maximum number at LL-1 followed by LL-3. These diverse macrophytes may provide better hiding places to the molluscs in these biotope (LL-1 and LL-3) and lead to their higher density and richness. Snail diversity generally increases with increasing macrophyte density and some snails shows specific associations with particular plants (Lodge and Kelly, 1985; Zealand and Jeffries, 2009). Macrophytes have an important influence on snail communities providing both physical habitat to live and varied surface for them to graze the periphyton. In the Lotus Lake *Lymnea acuminate* and *L. luteola* were found attached on the underside of broad leaves of *Nymphaea pubescens* with high population at LL-1 and LL-3. (*L. acuminata* 19.2 % and *L. luteola* 17.4 % at LL-1 and *L. acuminata* 16.3 % and *L. luteola* 15.3 % at LL-3, Table 5.3). Gastropods have preferences for macrophyte species with broader leaves (Brown, 1997) hence were concentrated in shallow areas with presence of macrophyte. Macrophytes stabilize bottom sediment, provide shelter from predators, act as physical substrate for resting and egg laying and also provide food. Food is also an important determinant of gastropod distribution and abundance (Lodge *et al*., 1987).

The two species of mussels recorded from LL-1 and LL-3 were *Lamellidens marginalis* and *Perreysia* (Radiatula) *aeralea*. The occurrence of these species may be correlated to shallowness of the site. Biswas and Raut (1999) found that depth is important in explaining bivalve distribution as juveniles prefer the shallow waters while older individuals occur in deeper waters. Weatherhead and James (2001) found that substrate type, macrophyte biomass and the amount of detritus were important in bivalve distribution. The higher density of macrophyte at muddy soil with detritus and shallowness at LL-1 and LL-3 may support the bivalvia in the Lotus Lake and contribute in the higher density and richness of molluscs at these biotopes.

Since adult mussels are very limited in their mobility on the bottom sediments, they cannot seek other areas when conditions in their microhabitats become unsuitable. From conservation point of view of the mussel, it is very important to develop connections between water bodies to allow active dispersal. Though the upstream Yashwant Lake is connected with Lotus Lake the Bivalve *Parreysia* (*Radiatula*) *caerulea* was not recorded in Yashwant Lake (Ekhande, 2010). Hence, considering this species the habitat should be conserved.

Variations were recorded in the dominance of molluscs at LL-2 as well. Here the same nine species occurred but their relative abundance was different as compared to LL-1 and LL-3. Here, *Thiara tuberculata* and *Indoplanorbis exustus* appeared to be dominant gastropod, while the two members of bivalvia were present with lower percentage as compared to LL-1 and LL-3. The habitat at LL-2 is characterized by rocky shore with few macrophytes. As stated above the two species of *Lymnea* are associated with *Nymphaea pubescens* and thus its density was lower at LL-2 compared to LL-1 and LL-3. According to Iga and Adam (2006) significant correlation exist between gastropods and sand and clay sediments perhaps due to the film of algae on this kind of substratum. Present study confirms this association at LL-1 and LL-3 where the muddy bottom with clay was maximum, while the bottom characteristic of LL-2 was rocky with less clay supporting lower macrophytes density. This characteristic may be attributed to lowered total density and richness of molluscs as well as habitat not favouring *Lymnea luteola*. However, *Thiara tuberculata* and *Indoplanorbis exustus* thrive better at this habitat with rocky substratum. This habitat is also exposed to higher anthropogenic activities. The lower density and richness of molluscs may be again influenced by various human activities such as cleaning and washing. According to Williams *et al*. (2004) lowest density of the molluscs occur in the area with higher anthropogenic pressure.

Such patchiness of individuals within a pond has consequences for intra-specific and inter-specific interactions. If only mean densities are considered one might greatly underestimate the potential for competition, predation or parasitism (or any other density dependent factors) to be important (Smith *et al*., 2003). However, the lower density and richness in winter may be correlated with the water fowl population. Waterfowl form one of the major groups of predators of molluscs for their calcium needs. Stanczykowska et al., (1990) have discussed distribution of waterfowl in relation to mollusc populations in Lake Zegrzynskie. As Lotus Lake is also visited by several waterfowls during winter, effect of predation on molluscan density cannot be ruled out that may additionally decrease the density of molluscs at Lotus Lake. Further, dragonfly nymphs are also known to feed on pulmonate snails in marshes and ponds. (Turner and Chislock, 2007). However, the effect of this group on molluscan density needs to be evaluated. Among the molluscan community, particular species may be more affected by predation pressure. To summarize the discussion, the molluscan community of Lotus Lake is influenced by various biotic and abiotic factors. The water chemistry as well as physical factors such as temperature, rainfall and water cover plays a vital role in the structuring of molluscan community. Mollusc communities occur primarily in shallow near shore areas in the lake, and are particularly vulnerable to human disturbance. Any changes in this microhabitat can influence the density and diversity of molluscs. Molluscan community of the lake is also influenced by consumers at higher trophic levels, such as fish, waterfowl and dragonfly nymphs. Both pulmonate snails and their predators - dragonfly nymphs are present at Lotus Lake and hence molluscs are likely to be regulated by odonate predation.

LAND MOLLUSCS

In the present study of land molluscs, the density and richness (pooled together for the three habitat studied) were significantly correlated positively with the rainfall. The probable explanation lies in the energy present in the ecosystem. The "more individuals hypothesis" (also called as 'energy richness hypothesis') of Srivastava and Lawton (1998) postulates that more productive areas have more individuals. Further Wright (1983) argued that at the base of global web plant richness is limited 'primarily by solar energy and water availability (*i.e.* water energy dynamics) indicating that productivity depends on water. The main driving component in the primary productivity around Lotus Lake is mainly governed by the southwest monsoon in the Toranmal area. Hence, the monsoon is one of the determinant factor in the density and distribution of vegetation which in turn influences the higher taxa as is also reported by Mason (1970) and Tattersfield *et al*. (2001). In monsoon, rainfall also favours the decomposition of leaf litter favouring detritivorous species and hence leads to higher density and richness of land mollusc in monsoon. Further, rainfall and moderate temperature maintain higher humidity supporting vegetation, shelter and food supply to mollusc. Food and shelter are required for successful breeding of any organism. Hence, availability of food and shelter in monsoon may increase breeding performance of molluscs. Significant positive correlation is established between density as well as species richness of the molluscs with humidity. Atmospheric temperature showed non-significant negative correlation indicating that moderate temperature of monsoon is preferred by molluscan community on land.

Habitat of molluscs

Land molluscs were surveyed only at limited ecological (only three habitat sub types) and geographical (within 10 Km radius) scale around Lotus Lake in Toranmal areas.

However, few significant correlations were established in the study. The three different habitats showed variation in richness, density and relative abundance of species. In monsoon, maximum density and richness of land molluscs were recorded which were again highest around Yashwant Lake area (LmYL) and lowest in Khadki area (LmKh). Mollusc species diversity and abundance increases with the floristic diversity (Barker and Mayhill, 1999). The higher density and richness of molluscs at LmYL may be attributed to floristic diversity present in the area. Nikolic and Stamol (1990) and Stamol (1993) have reported that mollusc communities can differ between vegetation community types. Further, Molluscs species diversity and abundance may also be regulated by niche availability and thus species richness may be correlated with increasing floral richness via site succession development. Sites of high floristic diversity can be presumed to have higher fractional complexity and more varied inhabitable substrate (microhabitat differentiated) than sites of low floristic diversity. It is observed that although the floristic diversity of Kalapani area was high the density and richness of mollusc were moderate. Kalapani area is hilly with slope and dry soil and low litter depth compared to LmYL. Snail communities are influenced primarily by the diversity of plant species making up the forest floor litter (Getz and Uetz, 1994). These factors may be correlated to the variations in relative abundance of species. At both LmKP and LmYL *A. laevipes* was one of the dominant species, however, at LmKP *C. moussonianus* and *M. indica* shared dominance almost at equal level while at LmYL the dominance was shared by only one species *S. maculate*. Further, though *A. laevipes* was dominant at LmKp, *M. indica* had higher relative abundance at the site (Table 5.4). This indicates that species composition and relative abundance of different species differs in the three microhabitats studied. It is reported that the *A. laevipes* and *C. moussonianus* prefer wet rock having algae or lichens and shady places (Magare, 2007) which were abundant at LmKP and LMYL in monsoon favouring these species. *S. maculate* and *L. alte* are abundant near the horticultural crops in the field particularly associated with cucurbitaceae (Magare, 2007). Khadki habitat is characterized by very few trees and open ground covered with grasses and herbs. According to Suryawanshi (2008) the soil at Khadki is silt clay and loam type with 7.5 pH and 68.4 % exchangeable Calcium, probably not suitable for vegetation and hence supporting less vegetation. As the molluscs are associated with vegetation, its lowest density and richness were noted at Khadki area. Sparse and low vegetation also lowers humidity and leaf litter layers. According to Nekola (2003) soil moisture and sunlight levels influence land snail community composition with the driest and sunniest habitats (Upland grasslands) being most different in land snail composition from wet shaded lowland forests. Hence, at Khadki the shelled protected molluscs (*M. indica*, *A. laevipes* and *C. moussonianus*) appeared dominant over slugs (*L. alte* and *S. maculate*). At Khadki the layer of leaf litter was low. The leaf litter is a highly complex three dimensional, horizontally stratified habitat. It may be subdivided (with the molluscan viewpoint) into many subunits like, fragmented leaves, twigs and decomposed litter further down; and wet litter and particulate humus above ground level. Thus, the reduced habitat structure in this area may be attributed to overall lowest density and richness of the molluscs at Khadki. In addition, the influence of anthropogenic pressure and land use pattern cannot be ruled out. According to Tasser and Tappeiner (2002) the general trend of grassland abandonment in remote areas is increasingly intensified in easily accessible mountain areas. At Khadki, cattle grazing activity was seen frequently. Grazing may influence molluscs indirectly by altering the amount and quality of the food supply and by changing the microclimate, or directly by trampling the snail shells (Baur, 1986; Boschi and Baur, 2007).

To conclude, we can say that land mollusc density and richness were associated with abiotic factors such as rainfall and humidity as well as characteristic of soil leaf litter distribution on ground and biotic factors such as vegetation cover and various anthropogenic pressure such as land use, cattle grazing *etc*. So from conservation point of view proper management of vegetation and land use pattern should be considered.

When both the groups of molluscs are considered post-monsoon is favourable for aquatic mollusc while monsoon for land molluscs.