Chapter: 6

Study of Molluscs

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Introduction

Molluscs are highly successful invertebrates in terms of ecology and adaptation and are found nearly in all habitats ranging from deepest ocean trances to the intertidal zone, and freshwater to moist land occupying a wide range of habitats (Dillon and Robert, 2004; Strong *et al*., 2008). The first molluscs appeared as early as Cambrian period, approximately 500 million years ago. Among the faunal diversity, mollusca are second largest group, which follows arthropods (1,113,000 numbers), and is followed by chordates (52,000) (Ruppert *et al*., 2004). Around 2,00,000 living species of molluscs are known to occur (Strong *et al*., 2008) with fossil species estimated to be around 70,000 (Brusca and Brusca, 2003). According to Venkataraman and Wafer (2005), in India about 5070 molluscan species have been recorded of which 3370 are Marine. This includes 1488 terrestrial species in 140 genera and 183 freshwater species in 53 genera. (Arvind et al., 2005).The later have received more attention because of their aesthetic and gastronomic appeals while less attention is received by freshwater molluscs probably due to their drab colours (SubbaRao, 1989). Globally, approximately 4,000 species of freshwater gastropod fauna have been described, however, the total number estimated to be is around 8,000 (Strong *et al*., 2008). Eighty percent of the freshwater molluscs are gastropods, whereas twenty persent are bivalves. Highest diversity of gastropods and bivalves are recorded from Palaearctic and Nearctic regions, respectively, however, the bivalve Unionidae family, of great economic importance, is most diverse in the Oriental region (Strong *et al*., 2008). SubbaRao, (1989) has recorded 213 freshwater species from India. However, Molluscs have been known to play significant role in the public and veterinary health and thus need to be more extensively explored.

Although preferences for the habitats are often linked with the morphology, feeding performances and dispersal ability of species, local environmental variables provide explanation for many species-specific assemblage structures of an area (Brown 1997). The local environmental variables include area and habitat heterogeneity (Aho, 1966; Oertli *et al*., 2002), productivity and hydro-period (Tarr *et al*., 2005), temperature (Hanson *et al*., 1988; Hall *et al*., 2004; Garg *et al*., 2009; Ekhande, 2010; Patil, 2011; Sharma *et al*., 2013) and dissolved oxygen (De Zwann, 1983; Hurley *et al*., 1995;

Habib, 1996; Brown, 2001). Other important environmental predictors for molluscan density and species richness are pH and CO_2 (Townsend *et al*., 1983; Okland, 1990; Emberton *et al*., 1997; Dillon and Robert, 2004; Garg *et al*., 2009). Calcium is prime nutrient to build the mollusc shell. Many workers have correlated this factor (Lodge and Kelly 1985; Briers, 2003; Ewald *et al*., 2009) that limits their dispersal to a defined habitat condition (Tokeshi *et al*., 2000). Nutrient contents of a wetland play significant role in shaping wetland community (Elser *et al*., 1988; Wetzel, 2006). In addition, bio-turbination due to the movements of snails on the sediments is believed to release nutrients for the uptake by the producers (Zheng *et al*., 2011; Pal *et al*, 2014). Apart from physicochemical factors substrate architecture (Lodge *et al.,* 1987; Lewin and Smolinski, 2006), availability of food, competition and prey-predator interactions also influence molluscan density and diversity (Lodge *et al*., 1987; Stanczykowska *et al*., 1990; Smith *et al*., 2003). Studies reported by Brown and Lydeard (2010) The large increase of constrained mollusks in permanent marsh and Great Lakes marsh habitats coincides with a prevalence of floating, emergent and submersed macrophyte growth that creates a complex three-dimensional habitat for gastropods, which primarily graze algae and biofilms from surfaces. Thus, a lack of such type of habitat is likely another constraint on mollusks.

As Molluscs play multiple functional roles in freshwater bodies, for the conservation and restoration of wetlands the study of molluscs in essential (Gutierrez *et al*., 2003; Ormerod *et al*., 2010). The restoration of the degraded habitats as well as the maintenance of the community composition is facilitated with the documentation of the abundance of various species. In present study an attempt is made to document the same within the community of the three wetlands that i.e. Malpur dam, Baldane dam and Krishna Park reservoir in Dhule district of North Maharashtra, India.

Results

Total fifteen species of molluscs recorded belong to ten genera and six families (Table.1). When temporal variations are considered, maximum densities as well as species richness were recorded in monsoon and minimum in winter (Fig.1).

1) Molluscs of Malpur Dam

Total 14 species of molluscs were recorded at Malpur Dam. On the basis of percentage relative abundance, the *Melanoid tuberculata* appeared most dominant species (16.7%) while the *Parreysia corugata* least abundant (0.6%). Abundance of

Bellamaya bengalensis (F.) *bengalensis*, *Bellamaya bengalensis* (F.) *annandali*, *Lymnea luteola*, and *Indoplanorbis exustus* were also high (Table 1).

In monsoon density of molluscs at Malpur dam was 1870±75.25no/m^3, in winter it was 981.6±41.91no/m^3 while in summer it was 1304±64.9no/m^3. The differences were significant at $P < 0.001$ $F_{2\ 21}$ 52.16. Similarly, maximum species richness 6.3 ± 0.38 was noted during monsoon and minimum 3.2±0.25 sp. during winter with 4.5 ±0.33 sp. in summer with significant differences at $P< .0001$ $F_{2\ 21}$ 23.92 (Table 2).

Density of molluscs and species richness administered positive significant Correlation with humidity, NO_3, PO_4, rainfall, TS, TSS and WT while significant negative correlation with density of total phytoplankton, pH, TH and transparency (Table 3) .

2) Molluscs of Baldane reservoir

At Baldane reservoir also minimum density of Molluscs was recorded in winter (670.8±47.18 no./m^3), it increased to 1072±61.72no/m^3in summer and reached highest 1453±46.59no./m^3 in monsoon (Table.2, Fig.1) with significant seasonal variations at $P < 0.0001$$F_{2\ 21}$ 55.8 Similarly, the minimum species richness was recorded in winter 3.25±0.25 no. of species, increasing in summer to 4.13± 0.23 and reaching highest at 6.13±0.29 in monsoon ($P < 0.000$ $F_{2\ 21}$ 32.43).

Total 13 species of molluscs were recorded at Baldane reservoir (Table.1) with highest percentage relative abundance for *Lymnaea accuminata* with 20.2%, followed by *Lymnea luteola* at 15.5% and *Lamellidens marginalis* at 14.6%.

Density of molluscs showed significant positive correlation with AT, CO_2, humidity, PO_4, TS, TSS, WT and species richness, while it showed negative significant correlation with DO, pH, transparency and density of total phytoplankton. Species richness of molluscs showed significant positive correlation with AT, humidity, PO_4, TS, TSS, WC and density of molluscs, while showed significantly negatively correlation with Cl^-, pH, transparency and density of total phytoplankton.

3. Molluscs of Krishna Park Reservoir

Here also maximum density of molluscs were recorded in monsoon 1145±39.95no./m^3, moderate in summer 648.8±62.4no/$m^3$and minimum in winter 480.8±59.39 no/m^3 (Table.2, Fig.1). With significant seasonal variations at $P<0.0001$ $F_{2\ 21}$ 40.83 respectively. Similarly, maximum species richness of molluscs was recorded in monsoon with 5.38±0.26 numbers, moderate numbers in summer with 3.88±0.3 numbers, while minimum in winter with 2.63±0.26 numbers at $P<0.0001$ $F_{2\ 21}$ 25.23. Total eleven species were recorded at Krishna Park. *Lymnea accuminata*

(17.2%) and Lamelidens marginalis (16.7%) were the dominant species closely followed by *Lymnea luteolla* at 14.5% and *Bellamya bengalensis annandalai* at 12.5%.

Density of molluscs showed significant positive Correlation with AT, humidity, PO_4, rainfall, TS, TSS, WT and species richness, while significant negative correlation with pH, transparency and density of total phytoplankton. Species richness of molluscs showed significant positive correlation with density of molluscs, humidity, PO_4, rainfall, TS, TSS, WT and species richness. It significantly negatively correlated with pH, transparency and density of total phytoplankton (Table.3).

Table: 6.1. Molluscs Species and their relative abundance recorded in the wetlands (Malpur Dam, Baldane Reservoir and Krishna Park) during Study period October 2011 – September 2013.

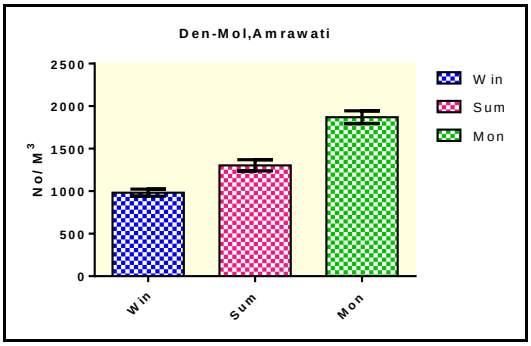
Sr.No.	Name of Species	Malpur	Baldane	Krishna
1	*Lymnaea accuminata*	9.2	20.2	17.2
2	*Lymnaea accuminata* (F.) *ovalis*	1	0	0
3	*Lymnaea luteola*	11.8	15.5	14.5
4	*Bellamya bengalensis* (F.) *bengalensis*	13.4	7.5	8.1
5	*Bellamya bengalensis* (F.) *annandalai*	11.5	10.7	12.5
6	*Thiara linneata*	0.9	2.3	0
7	*Melanoid tuberculata*	16.7	8.2	10.7
8	*Indoplanorbis exustus*	14.7	11.2	10.4
9	*Lamellidens savidens*	0	0.6	0
10	*Lamelliden marginalis*	8.4	14.6	16.7
11	*Gyraululla biatus*	0.7	0.8	0.9
12	*Parreysia (Radiatula) caerulea*	2.1	0	1.6
13	*Parreysia corugata*	0.6	0.7	0
14	*Gabbia orcula*	0.8	0.6	0.7
15	*Tarebia granifera*	8.2	7.1	6.7
	Total species	14	13	11

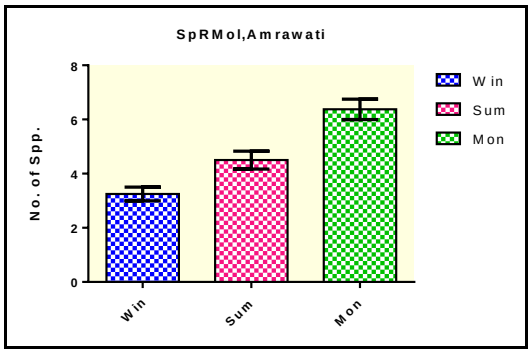
Table 6.2: Seasonal Variations of Molluscs, density and Species Richness at three wetlands during October 2011 – September 2013.

Malpur Dam	**F Value**	**Win**	**Sum**	**Mon**
Density of Molluscs	$F_{2\ 21}$ 52.16	981.6 ± 41.91	1304 ± 64.9	1870 ± 75.25
Sp. Richness	$F_{2\ 21}$ 23.92	3.25 ± 0.25	4.5 ± 0.33	6.375 ± 0.38
Baldane Reservoir		Win	Sum	Mon
Density of Molluscs	$F_{2\ 21}$ 55.87	670.8 ± 47.18	1072 ± 61.72	1453 ± 46.59
Sp. Richness	$F_{2\ 21}$ 32.43	3.25 ± 0.25	4.13 ± 0.23	6.13 ± 0.29
Krishna Park		Win	Sum	Mon
Density of Molluscs	$F_{2\ 21}$ 40.83	480.6 ± 59.39	648.8 ± 62.4	1154 ± 39.95
Sp. Richness	$F_{2\ 21}$ 25.23	2.63 ± 0.26	3.88 ± 0.30	5.38± 0.26

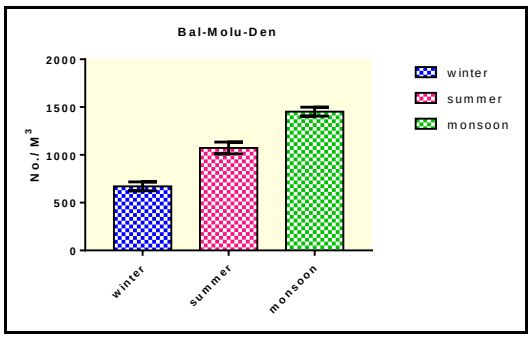
Fig.6.1 Seasonal variations in density and species richness of molluscs at three reservoirs in North Maharashtra

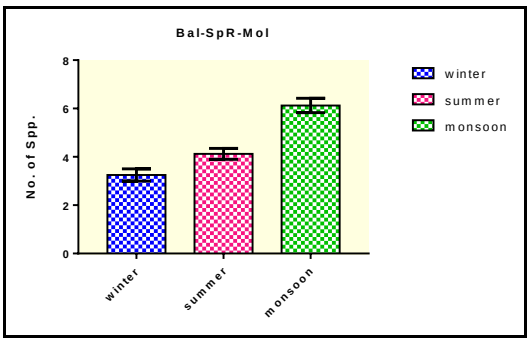
Malpur Dam



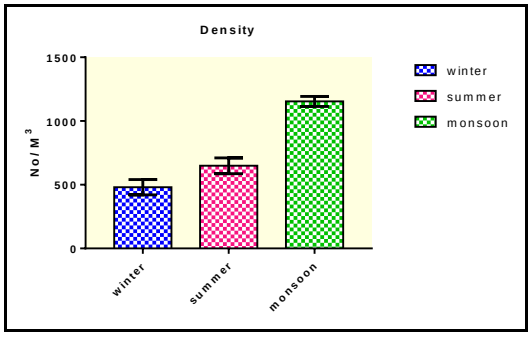


Baldane Reservoir





Krishna Park Reservoir



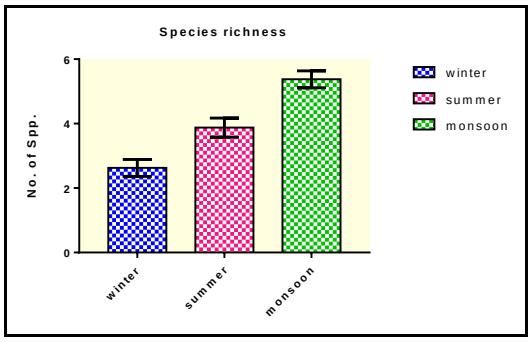


Table 2. Correlation between Mollusc density and species richness and various Physicochemical and biotic parameters parameters.

Malpur Dam

	DEN MOL	SPR MOL
AT	.339	.327
CA	-.265	-.292
CL	-.346	-.393
CO2	.434*	.393
DENMOL	1.000	.877**
DENPHYTO	-.820**	-.770**
DO	-.367	-.275
HUMID	.778**	.741**
MG	-.141	-.123
NO3	.641**	.589**
PH	-.619**	-.557**
PO4	.445*	.552**
RF	.856**	.788**
SO4	-.382	-.329
SPRMOL	.877**	1.000
TDS	-.324	-.356
TH	-.481*	-.426*
TRAN	-.909**	-.833**
TS	.737**	.620**
TSS	.874**	.792**
WC	.207	.354
WT	.406*	.427*

Baldane Reserviour

	Density Molluscs	Molluscs Sp.Rich
AT	.577**	.433*
CA	-.228	-.304
CL	-.295	-.494*
CO2	.516**	.278
DENMOL	1.000	.896**
DENPHYTO	-.610**	-.711**
DO	-.497*	-.273
HUMID	.700**	.804**
MG	-.186	-.314
MOLSPR	.896**	1.000
NO3	.168	.065
PH	-.500*	-.652**
PO4	.413*	.585**
RF	.741**	.827**
SO4	-.178	-.302
TDS	.071	-.166
TH	-.299	-.498*
TRAN	-.851**	-.787**
TS	.695**	.541**
TSS	.824**	.829**
WC	.215	.431*
WT	.542**	.345

KrishnaPark

	Density Molluscs	Sp Rich mollus
AT	.486*	.395
CA	-.448*	-.314
CL	.327	.420*
CO2	.334	.377
DEN.MOL	1.000	.840**
DENPHYTO	-.796**	-.633**
DO	-.283	-.242
HUMID	.840**	.669**
MG	-.394	-.147
NO3	.127	.092
PH	-.751**	-.547**
PO4	.606**	.426*
RF	.867**	.728**
SO4	-.325	-.202
SPRMOL	.840**	1.000
TDS	-.069	.001
TH	-.461*	-.361
TRAN	-.850**	-.702**
TS	.732**	.686**
TSS	.948**	.838**
WC	.360	.261
WT	.475*	.469*

AT-Atmospheric Temperature, CA-Calcium Hardness , C L -Chlorides, CO2-Carbon Dioxide, DENMOL- Density of Molluscs, DENPHYTO-Density Phytoplankton, DO-Dissolved Oxygen, HUMID-Humidity, MG-Magnesium Hardness, NO3-Nitrate, PH- pH, PO4-Phosphate, RF-Rain fall, SO4- Sulfates, SPRMOL-Species richness Molluscs, TDS-Total dissolved solids, TH-Total Hardness, TRAN-Transparency, TS-Total solids, TSS-Total suspended solids, WC- Water Cover, WT-Water Temperature

Discussion

Freshwater biodiversity patterns are closely related to local geographical features and physicochemical biotope structure, together with biological interactions and historical factors (Palmer 1999; Hoeinghaus *et al*., 2007, Juan, 2011). In recent years there is a greater emphasis world over for better understanding of benthic environment, its communities and productivity (Pennak 1989; Jindal and Sing, 2005; Garg, *et al.*, 2009). The local communities are structured around the sum of multiple factors including local factors such as predation stress, and regional factors such as dispersal and connectivity (Huston, 1999; Mouquet and Loreau, 2003; Heino and Muotka 2006). Environmental factors like physicochemical parameters (Garg *et al.*, 2009, Ekhande *et al*, 2010; Patil, 2011) availability of food, competition, predator-prey interaction (Lassen, 1975, Dillon and Robert, 2004), substrate architecture and macrophytes (Lodge *et al*.,1987; Zealand and Jeffries, 2009; Pip 2006) also affect species composition and abundance of benthic fauna including freshwater molluscs.

The physico-chemical properties of water are determinants of aquatic ecosystem although greatly influenced and modified by climate and other local factors (Hutchinson, 1975; Ekhande *et al*., 2010; Patil, 2011). Among these properties temperature seems to be an important factor for shaping the community and distribution of molluscs. Increased water temperatures invigorate the process of decomposition at the bottom of a wetland, in turn increasing macrophytes and settled organic matter. The maximum abundance of decomposers at the bottom of a wetland forms the organic sediments (Malhotra *et al.*, 1996). Bath *et al*. (1999) have reported higher abundance of molluscs with increased water temperature and decomposed organic matter. In present study also the significant positive correlation is established (Table-2) between temperature and density as well as species richness for molluscs at all the three wetlands. Further, increase in temperature in observed range may favour the growth of molluscs. Michael, (1968); Malhotra *et al*. (1996) and Ekhande *et al*., 2010., Patil, 2011) have also shown positive correlation between Temperature and Molluscan density. While Srivastava, (1956) have shown negative correlation between temperature and molluscs. Studies reported (Dorlikar, *et al*., 2014) that there was a moderate positive correlation between the gastropods and temperature, TDS and chlorides while significant positive correlation between alkalinity and hardness. However, during summer months benthos is affected by cumulative effect of high temperature, alkalinity and food, the probable causes of decline as is suggested by Michael (1968).

All forms of living organisms are significantly influenced by temperature, exerting its action through increasing or decreasing their vital activities, like behaviour, metabolism,

reproduction, ontogenic development and even death (Garg *et al.,* 2009.). Significant seasonal variation in temperature recorded at all three wetlands may be the cause of significant seasonal variations in density and species richness of molluscs (Fig.1). Many species of gastropod need particular temperature range for normal activities and hence at higher temperature many species aestivate (Teles and Marques, 1989). However, in present study moderate density and species richness of molluscs were recorded in summer. The population of some molluscs like *Melonoidea tabercalata* increases with rise in temp and rainfall (Raut, 1981). Minimum density of molluscs recorded in winter, may be due unfavourable conditions for some species forcing them to hibernate or move to deeper soil. Nevertheless, the snails like *L. Lateola* and *L. accuminata* have the ability to withstand winter conditions at the temperature in the range of 6^0C to 22^0C (Gupta *et al*., 1987). McCraw (1961; 1970) recorded that population-size classes of the genus *Limnaea,* that live along the littoral zone of freshwaters show slow but linear growth of overwintering individuals and then very rapid growth in the spring and early summer. Burla (1971) observed that the Bivalve (*Anodonta*) moves seasonally to different water depth in the sediments. However, these movements to the upper littoral zone in spring and early summer, and deeper water in early winter has not been correlated with temperature but with photoperiod, which may be related more to food availability. The growth of mollusc is reduced and development times lengthened in colder temperatures of deeper waters (Hanson *et al*., 1988; Holopainen and Jonasson, 1989). The bivalve in deeper water may not be assessed in sampling of present study and many factors described above might be responsible for lower densities of molluscs at all three wetlands in winter.

The three wetlands under consideration fall in the region which receives rains during Indian southwest-monsoon. Rain is the main driving component in the primary productivity of the area. This rainfall also favours the decomposition of leaf litter, in turn favouring detritivorous species and hence leads to higher density and species richness of molluscs. In present study the rainfall established significant positive correlation (Table 2) with density and species richness of molluscs at all three wetlands. The rains in monsoon directly influence water cover by increasing the area. Many researchers have shown relationship between molluscs and area, thus, drying and a lack of calcium for shell formation are likely strong constraints for non-generalist mollusks. (Brown, 1978; Bronmark, 1985; Pip, 1987; Gee *et al*., 1997; Oertli *et al*., 2002). Fundamental biogeographic principle proposes that the larger lakes support more molluscs species (Carlson, 2001). The rainfall in monsoon increases water cover (area) and this may provide more microhabitat to the macrobenthos (Snails and

Bivalve) and better opportunity for colonization leading to increase in their density and species richness. The action of floods caused due to heavy rain may affect the density of snails (Woolhouse and Chandiwana, 1990). Under such conditions the snail are carried from their original habitat to a distant habitat. Although, water cover did not showed any significant positive correlation with molluscan density and species richness at Baldane reservoir. According to Lassen (1975) lentic fresh water bodies may be regarded as islands, if the area of this island (wetland) is larger, more immigration of species is expected (Mac Arthur and Wilson, 1967) by means of bird or animal vectors (Rees,1965). Larger water bodies are more visited by vectors as compared to smaller, facilitating greater opportunity of arrival of different snail species. Species richness-area show positive correlation (Aho, 1966; Browne, 1981) as is evident in the present study too. The maximum area under water cover in the monsoon had maximum density and species richness. Larger wetlands having greater habitat complexity may facilitate coexistence once immigrants arrive, and the larger populations they support are less likely to go extinct stochastically (Dillon and Robert, 2004).

The moderate species richness and density for molluscs during summer, when 50% of wetland area decreases, may be attributed to decrease in microhabitat with the regressing waterline due to evaporation as well as use of water for irrigation. In drying pond, mollusc try to more towards the water many succumbing to death (Darby *et al*., 2002). During summer accumulation of empty molluscs shell at receding water margin is common. Many bivalve species are restricted to shallow waters and are susceptible to droughts or dry periods (Mc Mohan and Bogan, 2001).

Water clarity values are frequently assigned for biomass, suspended organic matter and other physical disturbances such as boating, bathing and washing (Rekha, 2007). Occurrence of high algae biomass coincided with low clarity in summer, when moderate density and species richness were recorded. In the three reservoirs of present study, located in rain deficient area, transparency established significant negative correlation with density and species richness.. On the other hand the TS and TSS established positive significant correlation. Total suspended solids including suspended matter can affect respiration, growth, parasite infestation and reproduction of the organisms (Rosewarne, *et al*., 2013). Apart from this effect positive correlation between suspended matter and molluscs, in the present study is an indication that the TSS of studied water bodies is within range and does not harm the molluscs.

One of the most significant chemical parameters in freshwater is the dissolved oxygen (DO) (Habib, 1996; Ekhande, 2010; Patil, 2011) that reflects the physical and biological processes

prevailing in the waters. Molluscs have been correlated with DO both negatively (Hurley *et al*., 1995) as well as positively (Van Someren, 1946). Brown (2001) observed that the majority of Pulmonate gastropods are able to deal with long term hypoxia or even anaerobic conditions, such as occurring in the hypolimnion of eutrophic lakes. De Zwann (1983) has reported that aerobic molluscs metabolically degrade glycogen and amino acids, to produce ATP. Metabolic end products are neutralized by erosion of calcareous shells. The dissolved oxygen showed nonsignificant correlation in present study with mollusc density and species richness. However when DO, that shows inverse relationship with temperature, was maximum in winter density and species richness were minimum. Oxygen holding capacity of water is more in winter (colder water) than the warmer water in summer (Welch, 1952; Hutchinson, 1975; Patil, 2011). Some gastropods can crawl to the surface of water and remain in constant contact with the surface membrane during deficiency of oxygen (Piechoki, 1979).

The concentration of CO_2 and pH in surface waters varies both seasonally and vertically in wetlands in relation to loading from allochthonous sources, physical condition, biotic inputs and consumption (Wetzel, 2006). Increased hypolimnetic concentration of CO_2 and bicarbonate decreases pH in hypolimnion. Bivalves and Gastropods avoid water that is strongly acidic (pH< 4) as well as strongly alkaline (pH 10), they prefer slightly acidic, neutral and slightly alkaline waters (Dillon and Robert, 2004). Waters of all three wetlands remained alkaline throughout the study period with small temporal variations. Many authors have recorded alkaline pH of wetlands (Ekhande *et al*, 2010; Patil, 2011). Gastropods do not occur below the pH 6.0 with only few species being able to tolerate as low as 5.2 (Okland, 1979). Many invertebrate groups including molluscs typically decrease or become extirpated where mean pH decreases below 5.7 (Lewis *et al*., 2007). pH has been strongly correlated with invertebrates with decrease impacting up to 50% due to acid deposition (Townsend *et al*., 1983). In the present study, species richness was significantly negatively correlated with pH at all the three wetlands. However, the density and species richness of molluscs were good apart from seasonal variation.

One of the chemical variables, Calcium, is essential requirement for the growth and development of molluscs shell (Wareborn, 1969). Hard waters (rich in Ca) are more preferred by Gastropods and Bivalves than soft waters. Though relationship between molluscs and dissolved calcium has been established (Mackie and Filipance, 1983; Briers, 2003; Ewald *et al*., 2009), above particular range of dissolved calcium (> 5 mg/l) little relationship exists between the two (Lodge *et al*., 1987). The shell of molluscs becomes thinner and easily

crushable in calcium deficient water, making them more vulnerable to predator attacks (Lampert and Sommer, 2007), although the calcium deficiency can be compensated with appropriate diet for molluscs living in soft waters (Fromming, 1956). Notable density and species richness of molluscs were recorded at the three wetlands studied. It can be concluded that the ranges of dissolved calcium in Malpuer dam (7.87±0.55 mg/l in monsoon to 14.53±0.72 mg/l in summer) is more favourable for growth and development of molluscs. However, negative correlation between calcium hardness and molluscs density as well as species richness were recorded at Krishna Park wetland.

Chlorides, serving as an indicator of domestic sewage, occur naturally in all types of waters. However in natural waters its concentration is generally lesser than that of sulphate and bicarbonate (Rekha, 2007). Sharma *et al*. (2013) on recording of positive correlation between chlorides and gastropods have concluded that chloride content of waterbody may favour the survival of Mollusc. However, they recorded negative correlation of chloride with bivalves. Occurrence of *M. tuberculata* has been recorded in the waters receiving animal and human excrement which results in high chloride contents (Ndifon and Vikoli, 1989). However, in present study non significant correlations have been found between chlorides and ovaral molluscs density and species richness.

Total dissolved solids are important in pond water. Pip, (1987) has recorded significantly higher values for TDS and total alkalinity in ponds compared to lakes and lotic waters. The increase in TDS in relation to increase in hardness of water favours the growth of molluscs. Garg *et al*., (2009) have recorded significant positive correlation between TDS and molluscs. However, in present study non significant correlation of TDS and molluscs were recorded. Freshwater mollusc population may be adversely affected by hardness that are too high as well as two low. Studies of Kilgour and Mackie, (1991) revealed that mean *P. casrtanun* abundance increased with hardness to a point, then declined. Hardness selected by these molluscs ranged from 4 mg/l to 225 mg/l. Rooke and Mackie (1984), on the basis of studies from six lakes, have reported significant correlation between hardness and mean shell growth rate (mm/day) as well as population (mg. dry wt./m^2) of mollusc *A. limosa*. Harder water supports more algal diversity and biomass and food produces more molluscs (Blum, 1956; Marker, 1976). Further, detrital decomposition also occurs more quickly in hard waters (Webster and Benfield, 1986). According to Boycott, (1936) most molluscs prefer hard water with richer vegetation than that of corresponding habitat of soft waters. Hard water may provide good supply of soluble salts of which calcium may not be the most important

component. Field studies involving both water chemistry and habitat size support views that the effects of calcium are normally indirect (Dillon and Benfield, 1982).

Nutrients like carbon, hydrogen, nitrogen and phosphates are major constituents of cellular protoplasm. Nitrogen is a major nutrient that affects productivity of fresh waters (Wetzel, 2006). Nitrate is a common form of nitrogen entering freshwater from the drainage basin in surface waters, ground water and precipitation. It is assimilated and aminated into organic nitrogenous compounds within the organisms. In the present study it is positively significantly correlated with density and species richness of molluscs at Malpur dam. However, the correlation is insignificant at Baldane reservoir and Krishna Park. NO^{3-} - N turnover is slower in the water than in sediments, where; under anoxic conditions in eutrophic lakes NO^{3-} -N is rapidly denitrified to N_2.

Loading of Phosphorus to freshwaters increases the productivity (Wetzel, 2006). Phosphorous is least abundant and commonly it is the first element to limit the biological productivity. It plays major role in biological metabolism. Orthophosphate (PO_4^{-3}) is the only directly utilizable form of soluble inorganic phosphorus. Significant positive correlation is established between density and species richness of molluscs with phosphate at all three wetlands.

Significant seasonal variations were recorded at all three wetlands studied, apart from that similarities were observed in the seasonal pattern of density and species richness of molluscs (Table 1). However, variations in community composition at different habitat of the wetland (Table 2) indicates effect of habitat preferences by different species. These variations in the domination of particular species in selected biotope may be attributed to the specific available microhabitat which may favor particular species. The highest density and diversity in monsoon was high due to high water cover, moderate photoperiod and temperature it favor the growth of macrophytes. Macrophytes providing both physical habitat to live and varied surface for them to graze the periphyton so have positive influence on snail communities. The macrophytes (submergent, emergent and free floating in the littoral zone) such as *Nymphaea sp., Polygonum barbatum, Ceratophyllum demersum, Ipomoea carnea, Hydrophila schulli,Ipomoea aquatic, Typha domingensis, Sesbania bispinosa, etc*. and other grasses and sedges were recorded. *Lymnea acuminate* and *L. luteola* were found attached on the underside of broad leaves of macrophytes. Brown, (1997) recorded gastropods have preferences for macrophyte species with broader leaves.

Observations of the researcher Zealand and Jetfries, (2009) shows that the factors influence snails directly by providing different architecture and periphyton substrate, apart from that

other local factors such as hydroperiod and water chemistry also influences the density and species richness. Lodge and Kelly, (1985) recorded snail diversity generally increases with increasing macrophyte density and some snails shows specific associations with particular plants. The riverbank of Tigua River is likewise lined with grasses and weeds which serve as depository of egg masses and food. The substrate is also a possible hibernating place during dry seasons (Galan *et al*., 2015) author further stated that the submerged rocks and pebbles in the shallower water are favorable for the accumulation freshwater algae which is food to these grazers (molluscs). Its muddy clay substrate could be favorable for burrows as snails crawl to escape from possible predators like crustaceans, leeches, fishes, and birds.

Substrate type, macrophyte biomass and the amount of detritus were important in bivalve distribution. The bivalve species of genus *Lamellidens, Parreysia* were recorded in the present study. The higher density of macrophyte at muddy soil with detritus and shallowness may support the bivalvia and contribute in the higher density and richness of molluscs (Weatherhead and James., 2001).

The submerged rocks and pebbles in the shallower water are favorable for the accumulation freshwater algae which is food to these grazers. The substrate is also a possible hibernating place during dry seasons (Galan *et al*., 2015). *Thiara tuberculata* and *Indoplanorbis exustus* thrive better at such habitat with rocky substratum were observed in present study.

In conclusion it may be said that the tree manmade wetlands of Khandesh, in the rain deficient regions of north-west Maharashtra support good density and diversity of molluscs.