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SEASONAL VARIATIONS IN THE ENVIRONMENTAL FACTORS AND SNAIL POPULATIONS IN FOUR DIFFERENT HABITATS AROUND LAHORE*

AKHTAR TANVEER AND DALER KHAN**
Department of Zoology, University of the Punjab, Lahore

Abstract.- Ecological investigations in terms of seasonal distribution and fluctuations in the population densities have been worked out for four different local snails species: *Lymnaea acuminata, Gyraulus convexiusculus, Physa acuta* and *Bellamaya bengalensis*. For this purpose, two natural and two artificial habitats were explored. The parameters, like temperature (atmospheric and water), humidity, rainfall, pH, fauna and flora, dissolved oxygen content, water chemistry, oxygen consumption by individual snails, parasitic infections and relationship between snail populations, natality and mortality were studied. The results indicate that each snail species has its own characteristic life pattern depending upon a complex of environmental factors.

Key words: Freshwater snails, intermediate host, ecological investigations.

INTRODUCTION

Keeping in view the medical and economical importance, different parameters of molluscan physiological ecology have been investigated under various environmental conditions. The details can be seen in recent reviews of Aldridge (1983); Burky (1983); Hoffmann (1983); McMahon (1983); Riddle (1983) and Summers (1983).

More recent work on the same aspect has been carried out by Thomas and Tait (1984); DeKock (1985); De Kock and Van Eeden (1985); Joubert and Pretorius (1985); Buckley (1986); Eric and Jokinen (1986); Lazaridou-Dimitriadou and Kattoulas (1986); Ribi and Gebhardt (1986); Ribi *et al.* (1986); Li-Lian and Chang, (1987); Li-Lian *et al.* (1987); Madsen (1987); Madsen *et al.*, (1987); Gebhardt and Ribi (1987); Abdul Karim (1988); Tanveer (1989, 1990a,b).

Majority of the work cited above dealt with the biology and ecology of snails in their natural habitats and on species not found in Pakistan (except Tanveer, 1989, 1980a,b). Very few studies compared the effect of environmental factors on the performance of snails both in the laboratory and in the field.

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** Vice Chancellor Quaid-E-Azam University, Islamabad.

The climatic conditions of Pakistan are favourable for the development and growth of freshwater snails. These snails are found in abundance in water streams and ponds, almost through out the year, with the exception of a small period of dormancy in severe winter and summer.

Despite their prevalence, wide distribution and economic importance, their physio-ecological desciplines remained totally neglected in Pakistan. It was therefore considered desirable to explore various environmental factors, important for growth and well being of these snails, before they can be kept for longer periods of time in the laboratory conditions for various experimental purposes. This study will open new avenues for further research and enable us to recommend effective snail control measures.

MATERIALS AND METHODS

Snails constitute an important part of the fauna of both temporary and permanent water bodies. Ecological investigations pertaining to seasonal distribution of snails and fluctuations in their densities were worked out in two natural and two artificial habitats. In order to obtain an idea of the snail population densities, a preliminary general survey was conducted in Lahore and adjoining areas in 1982 and 1983. Keeping these observations in view, detailed ecological studies on selected types of habitats were conducted. The following habitats were taken into consideration.

Natural habitat

1. National Ravi Park, adjacent to river Ravi at Shahdara, Lahore.
2. Ibrahimabad drain of Mustafabad in Kasur district, Lahore, Division.

Artificial habitat

3. Bansi-Sagar Fish Pond, Dharampura, Lahore Cantt, Lahore.
4. Botanical Garden Pond, Punjab Univeristy, New Campus, Lahore.

These habitats differ in their biotic and abiotic parameters and were maintained by authorities for different reasons.

Description of the habitats

National Ravi park (fish pond)

This is a natural pond situated adjacent to the river Ravi and is fed by the seepage of water from the river. It is a fishing pond (angling only) with stocks, of major carps, i.e. *Labeo rohita,* (Hamilton), *Cirrhinus mrigala* (Hamilton), *Catla catla* (Hamilton) and *Cyprinus carpio* (Linnaeus). The fish was stocked by the Punjab Fishries Department. The water depth changed with season and lot of emerged and submerged vegetation was present in the pond.

Ibrahimabad drain

This is a long drain in Mustafabad (Kasur District) measuring 23332 ft. in length, 5.0 ft. wide, with total depth of 1.90 ft. and with a discharge of 13 cusecs (Irrigation Department data). In most of its way this drain is without shady trees, but along its sides it has dense accumulation of *Leptodenia sparticum* mixed with *Cynodon dactylon*. The water source of this drain is a canal used for agricultural purposes and rainfal.

Bansi sagar fish pond

This is an artificial pond, situated in Dharampura, Lahore Cantt. It covers an area of two acres and has a depth of 3-8 ft. The pond is mainly kept for fish culture and *Cyprinus carpio* is stocked here. Stocking of fish in the year 1983-84 were upto 5200 (Fishrics Department, Data). On one side, this pond is surrounded with old trees of *Ficus religiosa*, and dead fallen leaves and fruits of these trees were always found in the pond water. The level of pond water was maintained mainly by canal water and rain. Human water contact involvement on one side of the pond was also present.

Botanical garden pond

This is an artificial pond situated in the Botanical Garden, Punjab University, Quaid-Azam Campus, Lahore. The pond dimensions are 8x12x4 ft. The water source is from a tubewell. it is rich in common aquatic vegetation and algae.

Sampling method

In each habitat, snails were collected from three different collection sites measuring an area of one square meter each. These sites were separated from each other by at least 5 meters except for Botanical garden pond. Snail population densities were recorded on the basis of the number of snails collected per "man-hour". Sixty minutes were spent on each site for snail collection and this time was kept constant throughout the year. The snails were collected by scoop nets or by hand at weekly intervals during the months of January, February and

March. This interval was later extended to fortnightly (except for the month of September). The time of collection remained the same throughout the sampling period.

Dead fallen leaves, inundated vegetation, aquatic vegetation, sub-merged stones, floating objects, bottom and sides of Littoral zone were also examined carefully for snails. Snails, whether dead, or alive were collected in polythene bags alongwith some pond water and vegetation. They were then brought to the laboratory for further studies.

A record of the kind of day at the time of collection/sampling, water level at the sampling sites, air temperature, humidity and rainfall (from the meterological Department data) was kept throughout the year. Surface water temperature was measured at three collection points where maximum number of snails were found and has been reported as mean ± S.D. The pH of water was noted by Beckman pH meter.

At each sampling point zooplanktons, macroscopic and microsopic vegetation (algae) of the habitat was brought to the laboratory and identified. For zooplankton and micro-vegetation 10.0 ml of pond water was fixed with 1.0 ml of 1% Formalin.

In the laboratory each snail was put in a separate glass tube of 3" x 1" half filled with water, and kept as such for 24 hours. They were then exposed to artificial light in order to encourage the shedding of cercariae. Occasionally, a drop of water from the specimen tube was oberved under the microsope to check for infeciton. After 24 hours, the snails were removed from the tubes and were later returned to the containers where they were kept for further studies.

The length of snail shell was measured to the nearest 0.1 millimeter, across the largest diameter of the shell, with the help of a caliper equipped with vernier scale. Each snail was also weighed to the the nearest 0.1 mg. From this data, condition factor (Pekarranin, 1983) was calculated according to the formula.

All measurements of *Bellamaya bengalensis*, *Lymnaea acuminate, Physa acuta* indcate the height of the shell, while the measurements for *Gyraulus convexiusculus* indicate the width of the snail.

According to the lenght ranges, the following categories were selected

For *B. bengalensis* the lengths were catagorized into five groups ranging from 1.0-1.4 cm, 1.5-1.9 cm, 2.0-2.5 cm, 2.6-3.0 cm, 3.1-4.0 cm. For *L. acuminata* groups (categories) were from 0.5-0.8 cm, 0.9-1.2 cm, 1.3-1.6 cm, 1.7-2.0 cm, 2.1-2.4 cm, for *Physa acuta* 5 groups were from 1.0-2.9 mm, 3.0-4.9 mm, 5.0-6.9 mm, 7.0-8.9 mm, 9.0-12.0 mm. The length (width) ranges of *G. convexiusculus* were from 1.0-2.0 mm, 2.1-4.0 mm, 4.1-6.0 mm, 6.1-8.0 mm, 8.1-10.0 mm.

Oxygen consumption of individual snail

Oxygen consumption of individual snails of each species was measured by putting snails in a cylinder of one litre capacity filled with tap water.

Each time, three replicates of single snail were used and the oxygen consumption was measured for 3 hours taking samples after every hour. Winkler's method (Hoar and Hickman, 1967) was used to calculated the O_2 consumption.

The total amount of dissolved oxygen present in the water sample had already been determined at the time of collection. This was done by adding 1 ml of manganese sulphate to a 250 ml air tight reagent bottle filled with pond water. In the laboratory the oxygen contents of the water sample was measured by Winkler's method (Hoar and Hickman, 1967).

RESULTS

The annual mean and maximum temperature, rainfall and humidity is presented in Fig. 1.

Water temperature

The water temperature of the 4 habitas depends on th mean air temperature, intensity of solar radiation as well as presence and absence of shade or shaddy plants in the habitats. In all the habitats, the surface water temperature was minimum during the month of January while the maximum temperature was in July for Ravi Pond, Bansi-Sagar fish pond and Botanical garden pond. In the Ibrahimabad drain the maximum water temperature was found during the month of August (Fig. 2). During the present investigation environmental temperature range at which the snails collected was 12.0-34.0°C for the year 1984.

Water pH of the habitats

Like all other animals the distribution and sruvival of snails is closely associated with the hydrogen ion concentration of the ambient water.

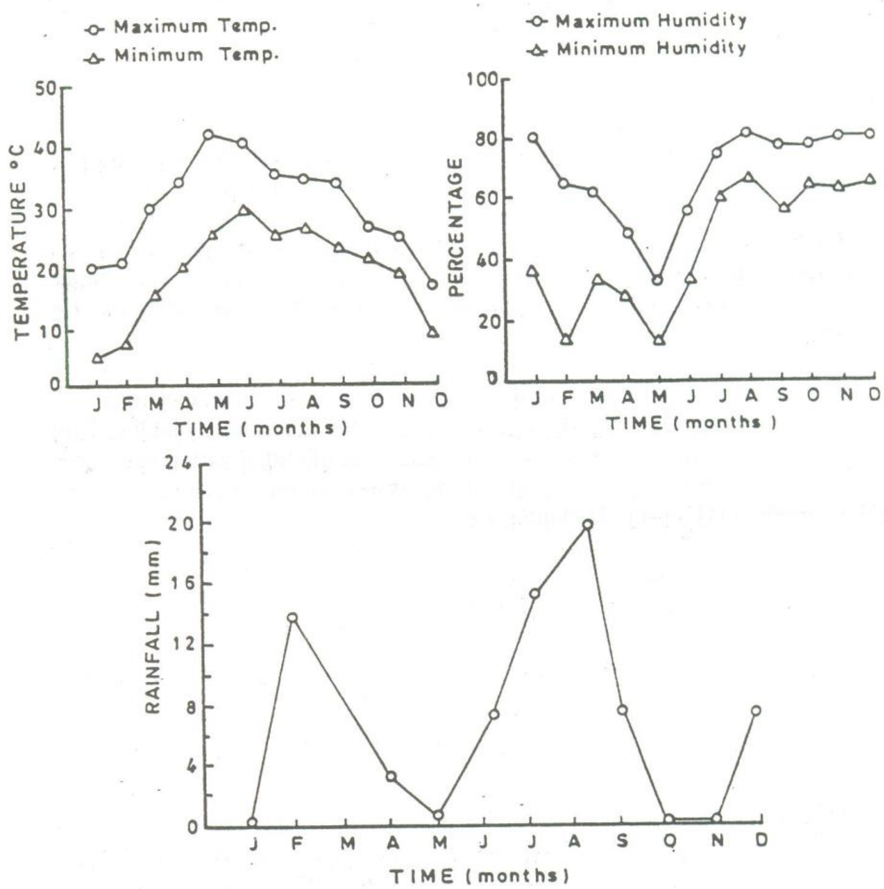

Fig. 1. Temperature, humidity and rainfall for Lahore region for the year 1984.

pH values for water of the four habitats are given in Fig. 2. It is clear that the pH of the habitats remained within the range of 6.0 and 7.14 throughout the year. The minimum fluctuations were seen in the Botanical Garden pond while the Ibrahimabad drain showed seasonal fluctuations in water pH (Fig. 2).

Vegetation of the habitats

The algae found in these ponds belonged to the families *Cynophyceae, Chlorophyceae* and *Charyophyceae*, while the prevailing vegetation of the habitats constituted various species of the families *Potamagetonaceae, Hydrochantacae, Utriculariceae, Grminaea* and *Convolvolaceae*. Dead fallen leaves of *Dilbergia sisso* and *Ficus religiosa* were always found in the waters of Ibrahimabad drain and Bansi-Sagar fish pond.

Zooplankton and other fauna of the habitats

Various local zooplanktons, flagellates, ciliates, platyhelminth eggs, rotifers, crustaceans, insect larvae, fish and amphibians were constant features of the food chain in the ponds.

Dissolved oxygen contents of the water of the habitats

The dissolve oxygen contents of all the four habitats were directly related to the air and water temperature. The results (Fig. 3) showed that there is apparently no relatinship between dissolve oxygen and population densities of snails.

Oxygen consumption by different snail species

The results of oxygen consumption by individual *L. acuminata, G. convexiusculus, P. acuta* and *B. bengalensis* have been given in Figs. 4-7.

Oxygen consumption by the snails depend upon the amount of dissolved oxygen and temperature of the ambient water. The effect of pH on the oxygen consumption by the snails was not clear due to the little variation/fluctuations in the pH of these habitats.

Condition factors

Figures 8-11 present the condition factor of *L. acuminata, G. convexiusculus, P. acuta* and *B. bengalensis*.

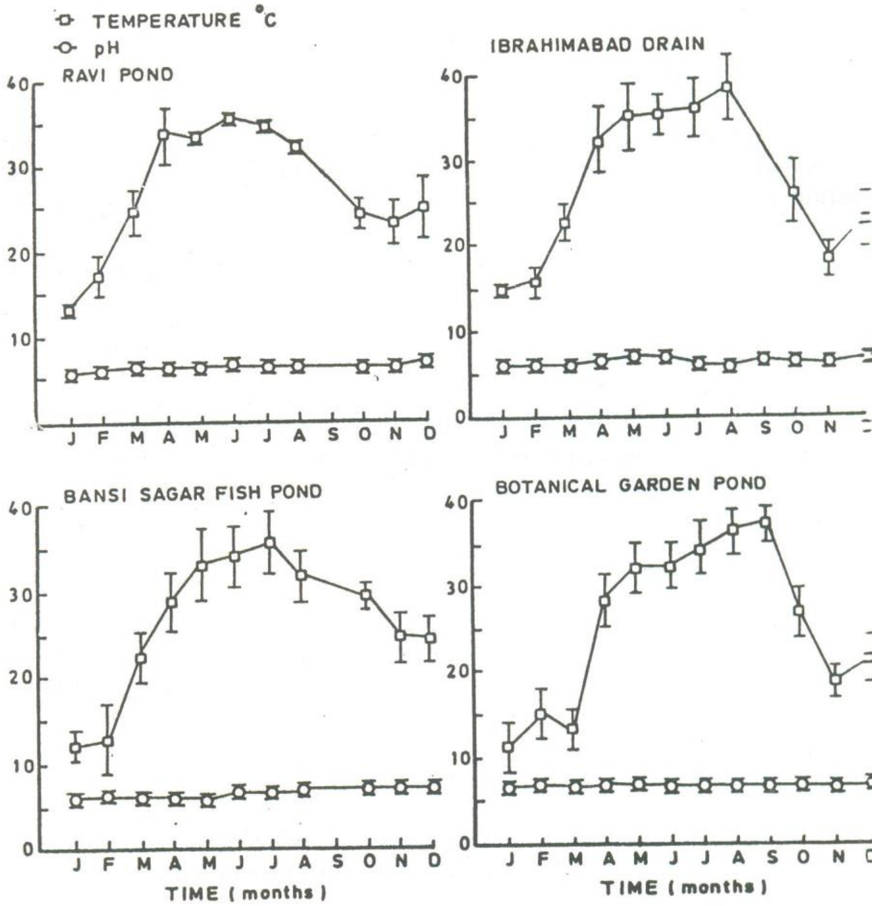

Fig. 2. Water temperature and pH of the four habitats for the year 1984. Values given are mean ± S.D. of three readings from each habitats.

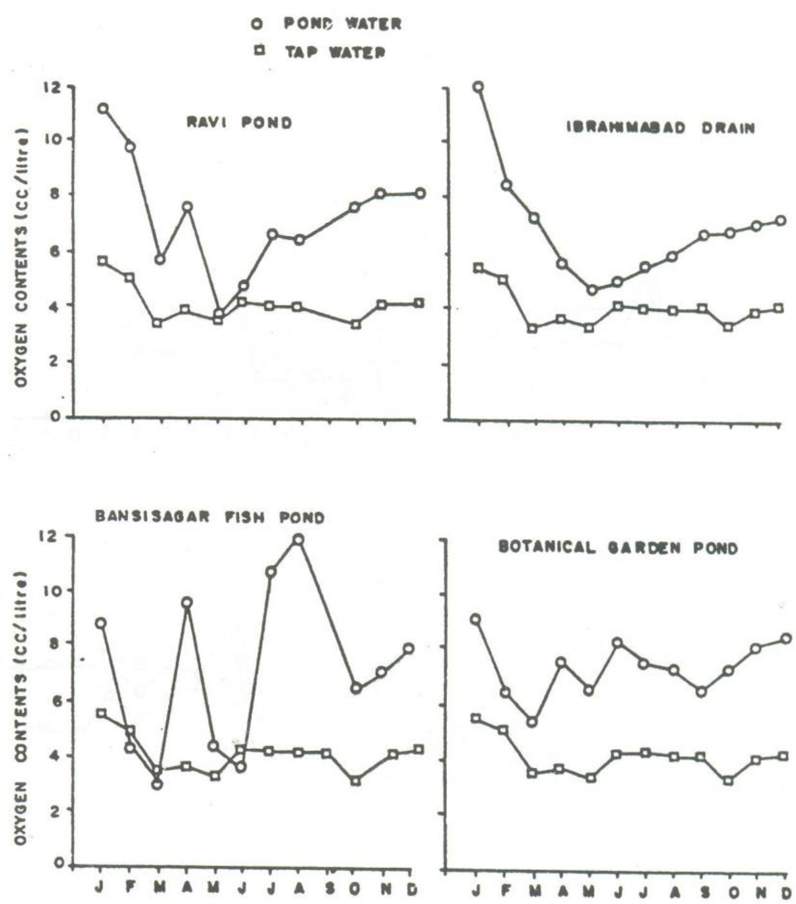

Fig. 3. Dissolved oxygen contents in the water of four habitats for the year 1984.

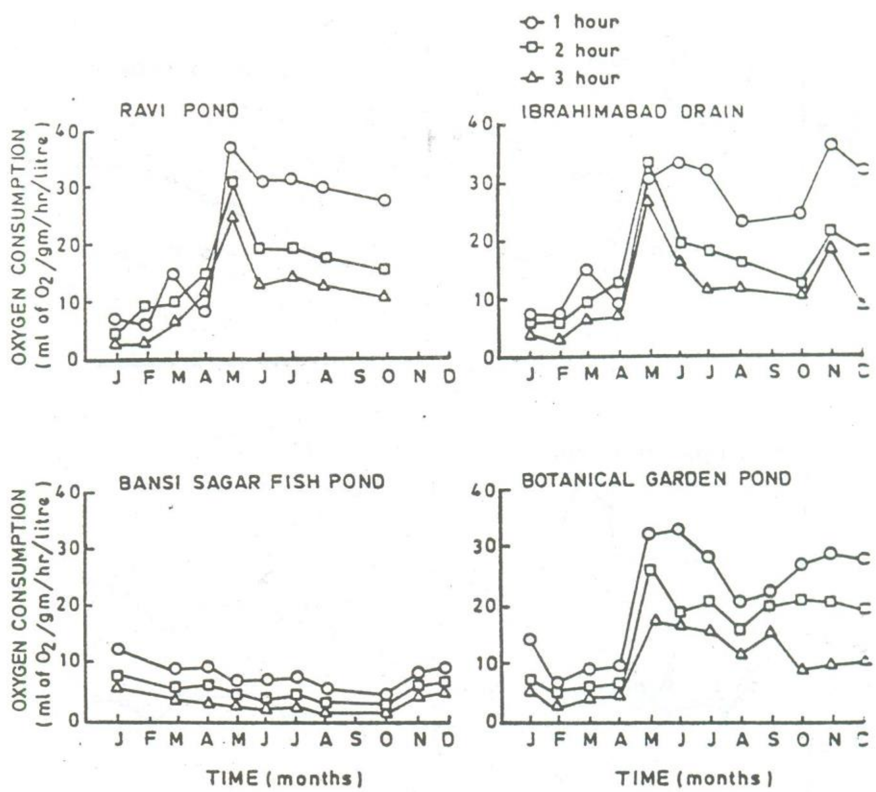

Fig. 4. Oxygen consumption of *Lymnaea acuminata* over three hours through the year 1984, from the four haibtats.

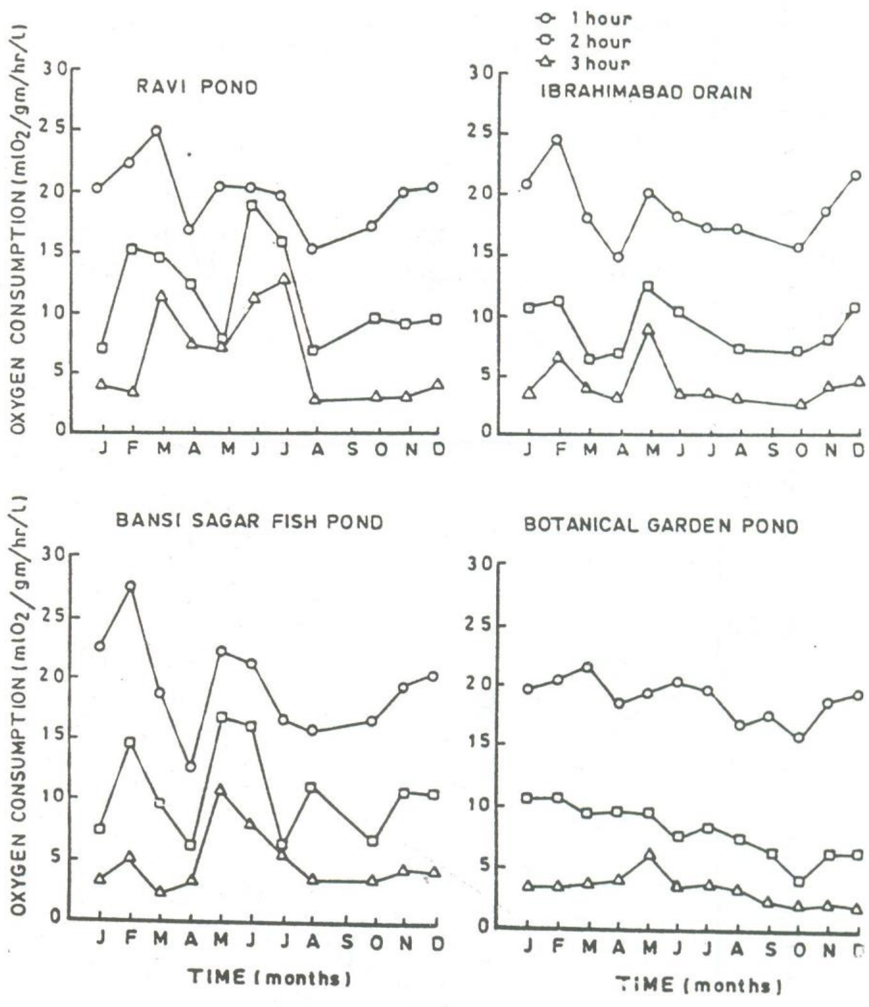

Fig. 5. Oxygen consumption of *Gyraulus convexiusculus* over three hours through the year 1984, from the four haibtats.

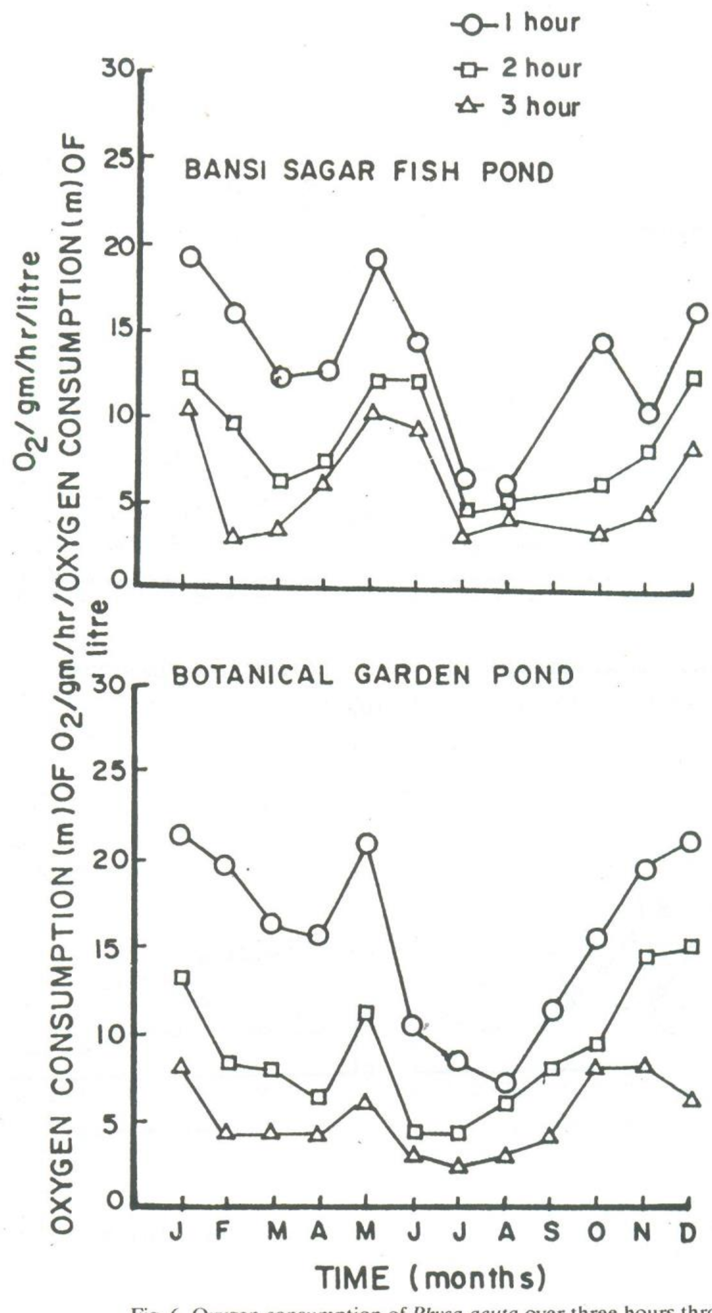

Fig. 6. Oxygen consumption of *Physa acuta* over three hours through the year 1984, from the four haibtats.

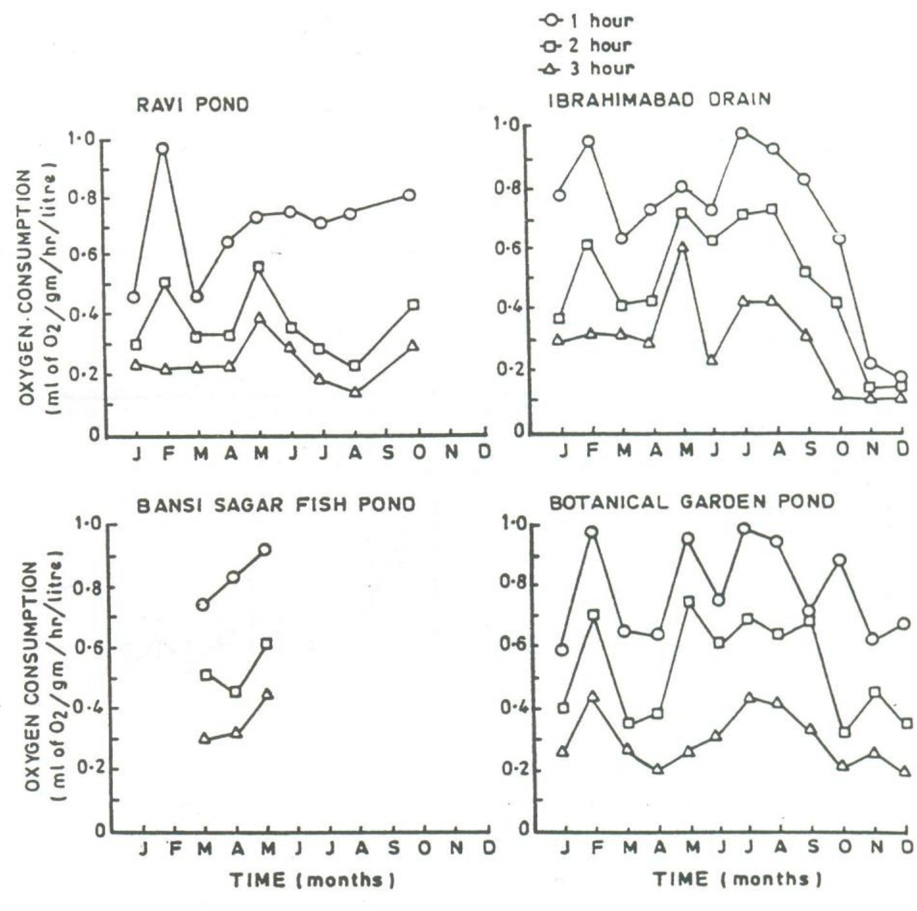

Fig. 7. Oxygen consumption of *Bellamaya bengalensis* over three hours through the year 1984, from the four haibtats.

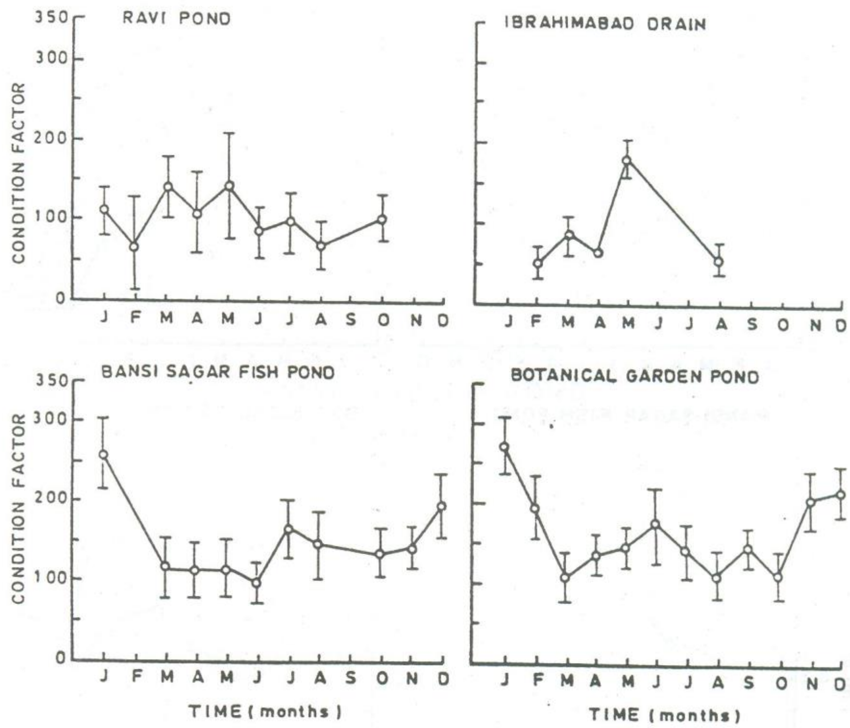

Fig. 8. Effect of habitat on the condition factor of *Lymnaea acuminata*. Values given are mean ± S.D. of all the samples.

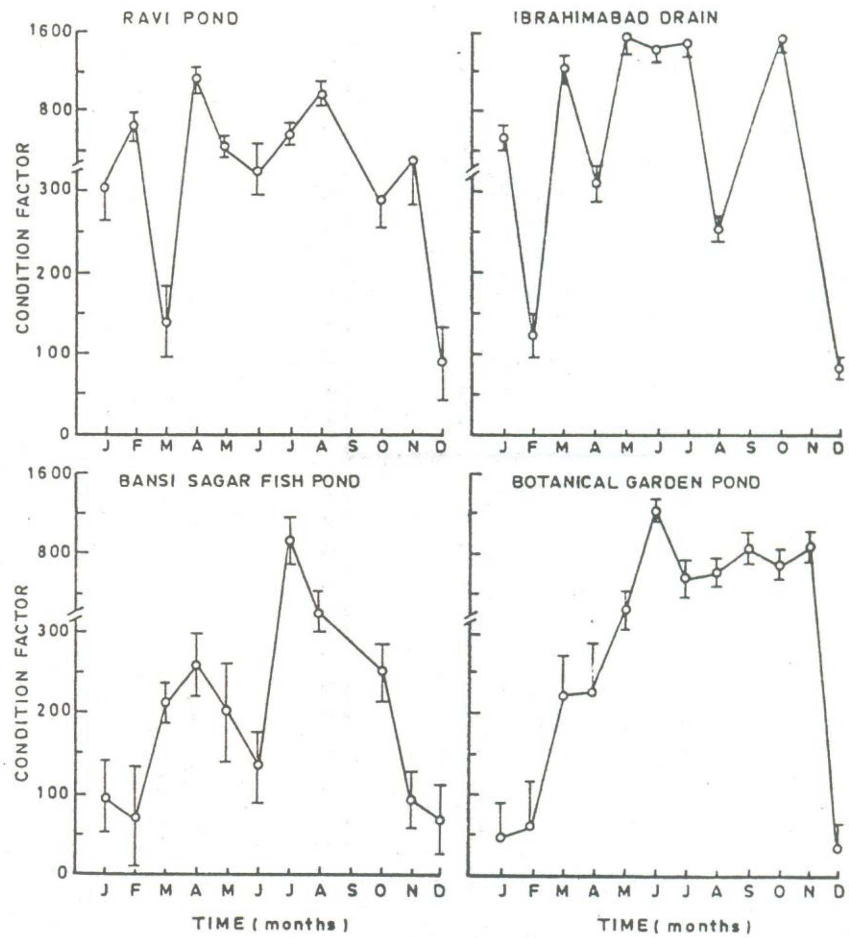

Fig. 9. Effect of habitat on the condition factor of *Gyraulus convexiusculus*. Values given are mean ± S.D. of all the samples.

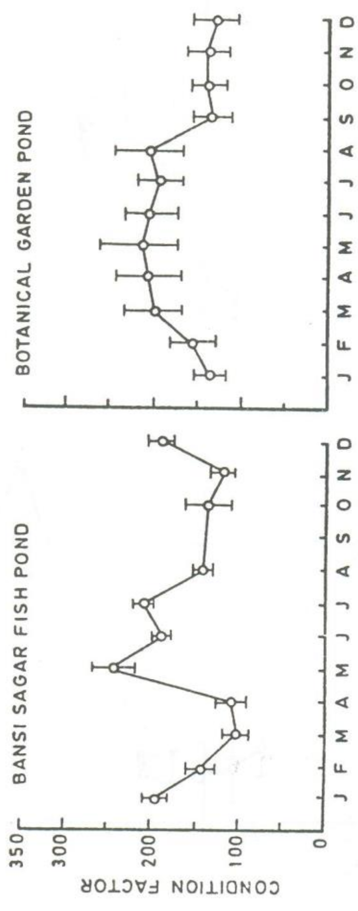

Fig. 10. Effect of habitat on the condition factor of *Physa acuta*. Values given are mean ± S.D. of all the samples.

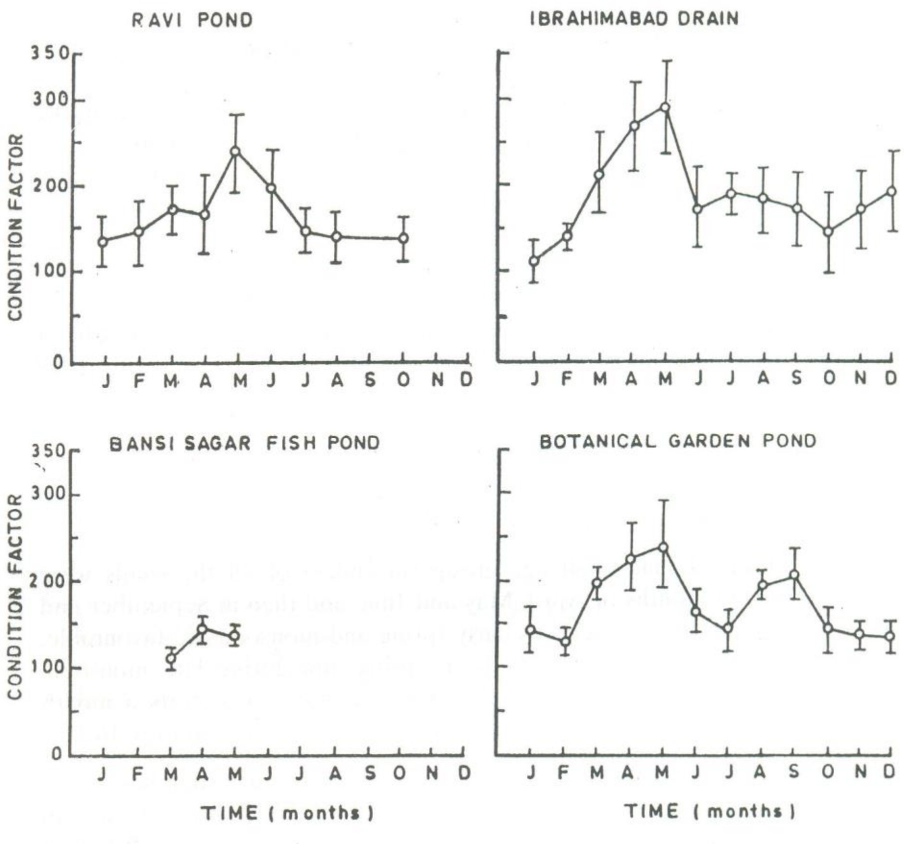

Fig. 11. Effect of habitat on the condition factor of *Bellayama bengalensis*. Values given are mean ± S.D. of all the samples.

The condition factor was maximum when the environmental conditions of temperature (air and water) were suitable and relative humidities were minimum. For *B. bengalensis* (Fig. 11) the maximum condition factor for three habitats was observed in the month of May, showing that during this month there was maximum increase in weight of the snail while comparatively less increase in length.

Relationship between snail population and habitats ecological factors

Bansi Sagar fish pond holds maximum snail population (3068) among the four habitats. Botanical garden comes second in number (2751 snails). While snail population in Ibrahimabad drain and Ravi pond was 1153 and 429 respectively (Table I).

Maximum snails were collected during the months of March-May, but detailed analysis revealed that the pattern was different for different habitats. The percentage occurance (Fig. 12-15) of dead snails was maximum in the months of January and February and minimum in the months of June and July (this observation seems to be directly related with temperature).

All the snail populations collected were also studied in detail by ranking them according to their length ranges. The collected snails were categorized into five groups as mentioned in Materials and Methods.

It was observed that small age group (juveniles) of all the snails were maximum during the months of April, May and June and then in September and October showing that the two seasons early spring and monsoon are favourable, the snails probably reproduce biannually in spring and during late monsoon. These data also point to the fact that in nature the egg laying starts a month earlier than these months. The details of this data have been given in Figs. 16-19.

Infection rate for the four snail species with larval trematoden have been given in Table I. This Table reveals that *G. convexiusculus*, shows maximum infection (76.02%) and *P. acuta* has 61.11 percent infection. While almost half of the lymnaeid population was found infected with various forms of larval trematodes (52.03 percent infection), it is interesting to note that *B. bengalensis* was almost always found parasite free.

It was also observed that maximum infection rate in the snail species was related to the optimal environmental condition.

However, habitat wise infection rate was maximum (60.3%) for Bansi-Sagar Fish Pond, as compared to 46.74 and 44.1% for Botanical Garden pond and Ravi pond respectively. Infection rate for Ibrahimabad drain was minimum i.e. 2.5%.

TABLE 1. PERCENTAGE INFECTION IN THE FOUR SNAIL SPECIES COLLECTED FROM FOUR HABITATS FOR THE YEAR 1984.

	Ravi pond			Inrahmabad drain			Bansi Sagar Fish Pond			Botanical Garden			Total Snails		
Habitat / Species	Total snails	Infected snails	% infection	Total snails	Infected snails	% infection	Total snails	Infected snails	% infection	Total snails	Infected snails	% infection	Total snails	Infected snails	% infection
L. acuminata	184	87	47.28	10	7	70.0	92	55	59.0	477	248	51.99	763	397	52.03
G. convexiusculus	139	102	73.38	36	22	61.11	376	302	80.3	329	243	73.9	880	669	76.02
P. acuta		absent			absent		2593	1493	57.6	1091	795	72.9	3684	2288	62.11
B. bengalensis	106	-	0	1107	-	9	7	-	0	884	-	0	2104	-	-
Total snails	429	189	44.1	1153	29	2.5	3068	1850	60.3	2781	1286	46.76	-	-	-

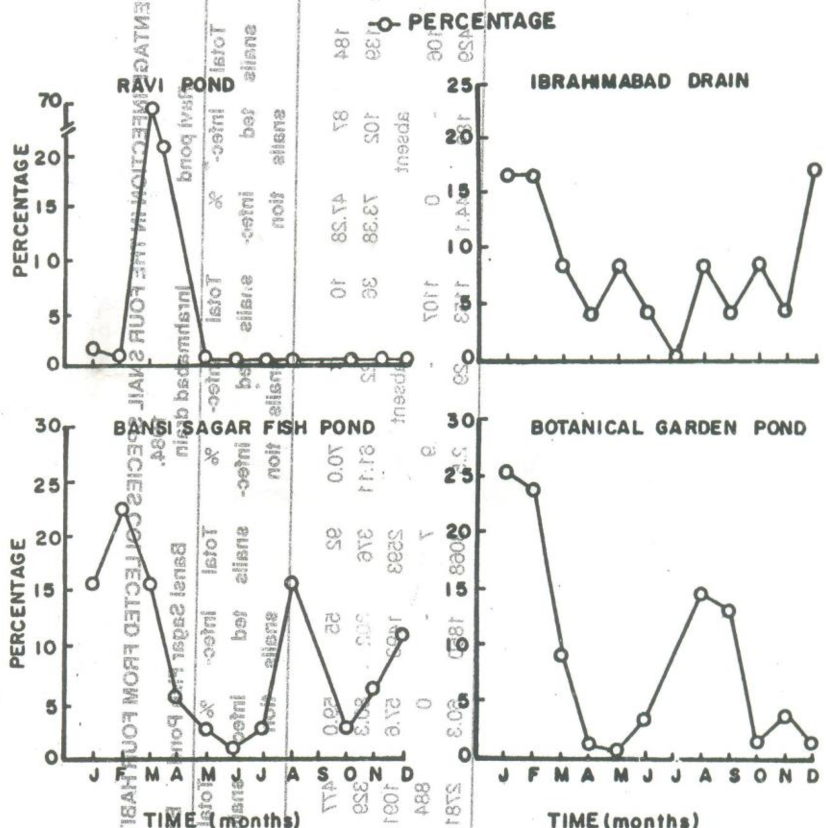

Fig. 12. Percent occurance of dead *Lymnaea acuminata* collected on the basis of total snails collected over the year 1984 from different habitats.

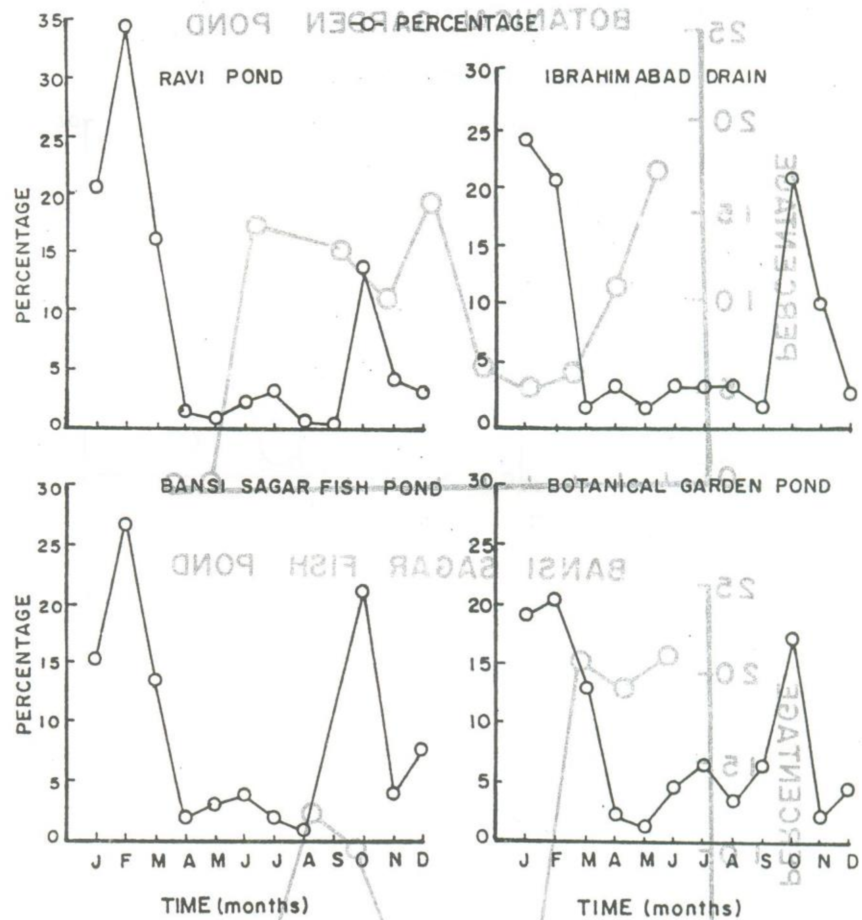

Fig. 13. Percentage occurance of dead *Gyraulus convexiusculus* collected on the basis of total snails collected over the year 1984 from different habitats.

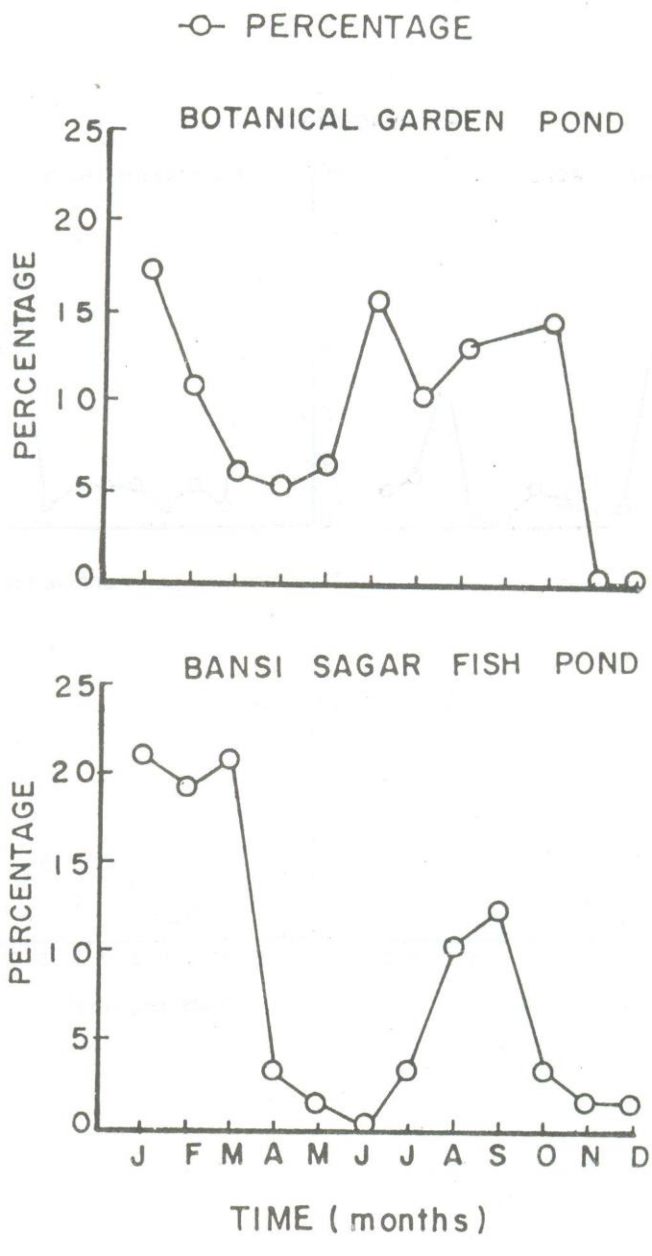

Fig. 14. Percentage occurance of dead *Physa acuta* collected on the basis of total snails collected over the year 1984 from different habitats.

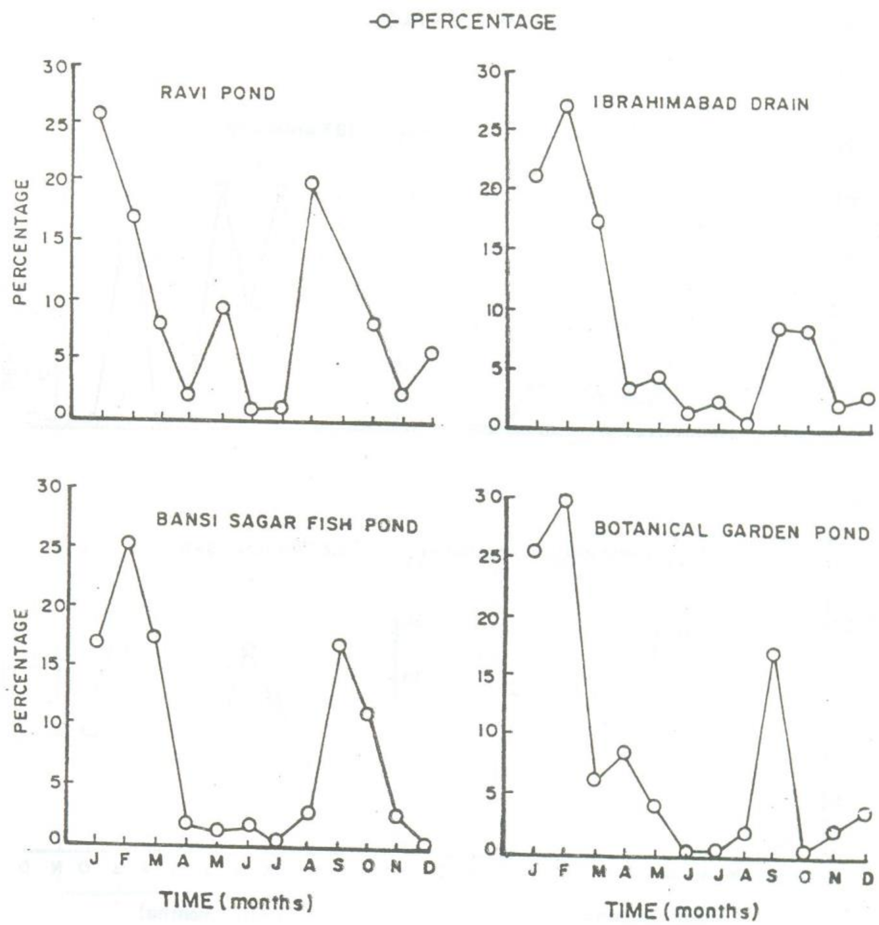

Fig. 15. Percentage occurance of dead *Bellamaya bengalensis* collected on the basis of total snails collected over the year 1984 from different habitats.

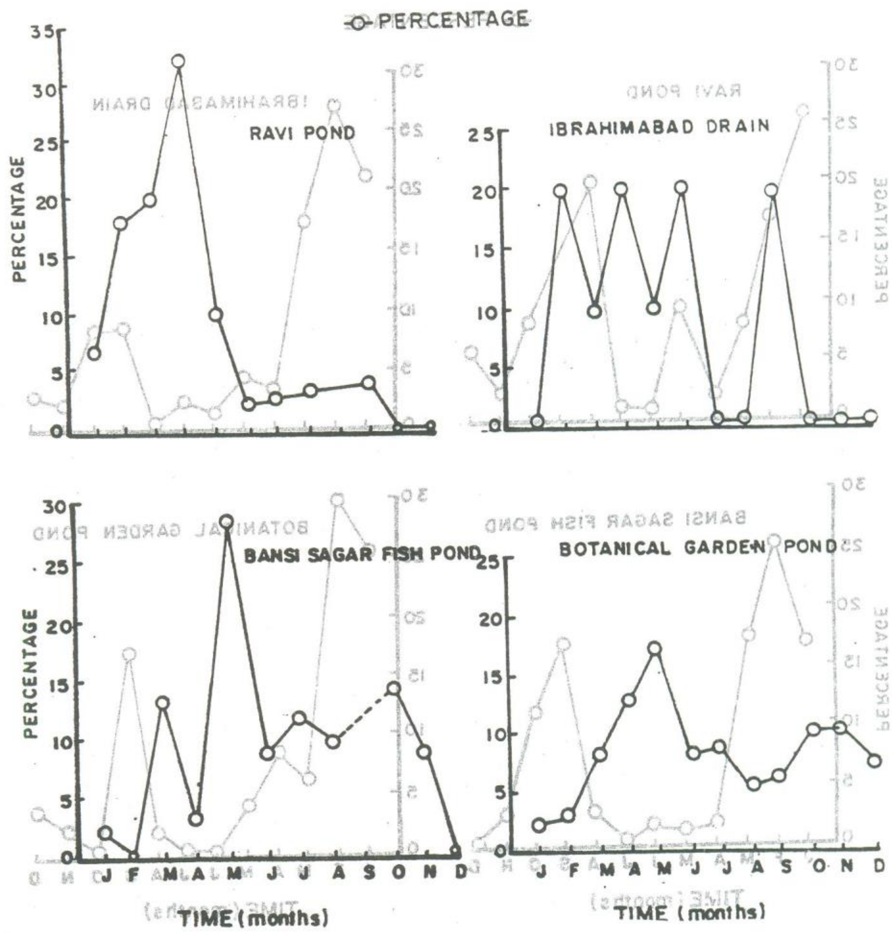

Fig. 16. Percentage occurance of alive *Lymnaea acuminata* collected on the basis of total snails collected over the year 1984 from different habitats.

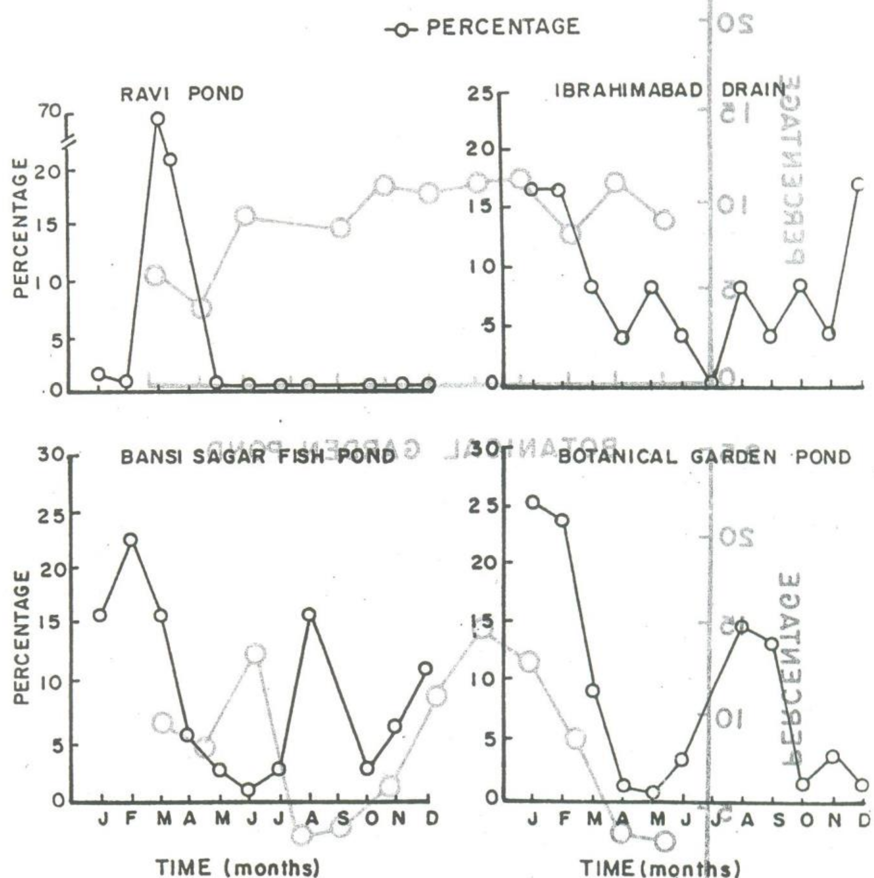

Fig. 17. Percentage occurance of alive *Gyraulus convexiusculus* collected on the basis of total snails collected over the year 1984 from different habitats.

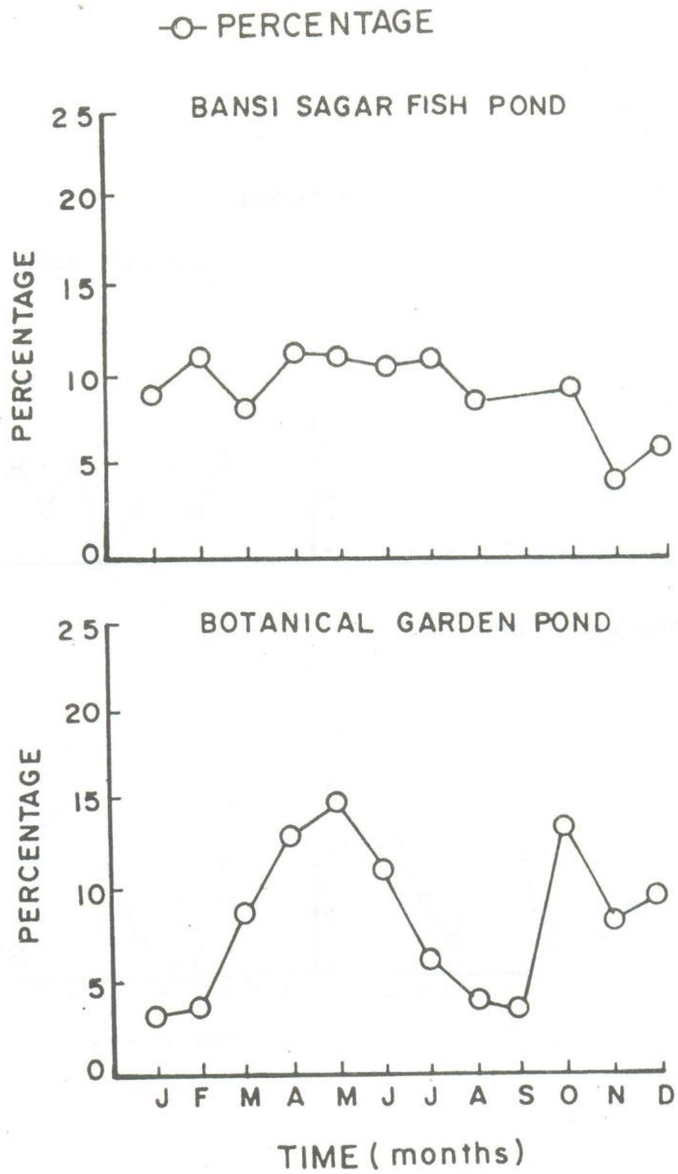

Fig. 18. Percentage occurance of alive *Physa acuta* collected on the basis of total snails collected over the year 1984 from different habitats.

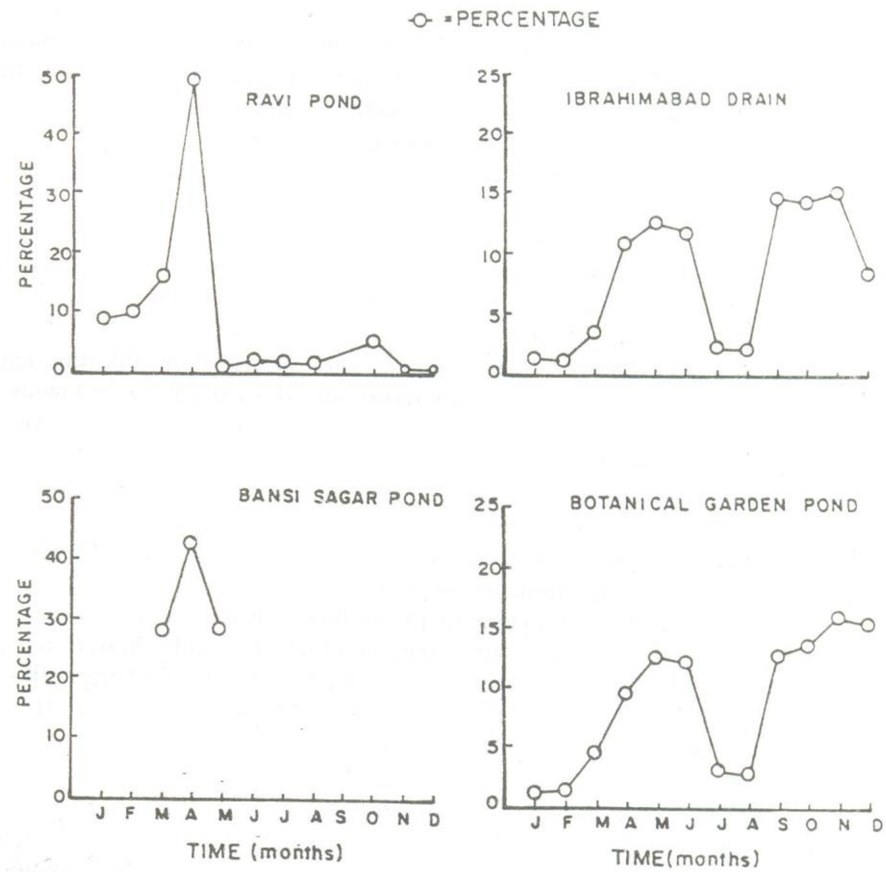

Fig. 19. Percentage occurance of alive *Bellamaya bengalensis* collected on the basis of total snails collected over the year 1984 from different habitats.

DISCUSSION

In nature, physical and chemical parameters of fresh water bodies vary considerably. However, organisms living in these environments have adopted themselves and live happily, despite changes in their ambient environment. it has been seen that various environmental factors bring out changes in the bionomics of the snails and that it is very difficult to single out a factor in this connection. In the present work an attempt has been made to study the possible correlation of environmental factors with the snails ecology.

Temperature

At present, most of the available knowledge regarding association of temperature with snail population densities deal with the pulmonate snail species, and particular consideration have been given to those which are intermediate hosts of various helminth parsites. Various snail species show different degree of tolerance towards the extreme temperature and this extreme is as low as 3.5°C and as high as 46°C with an average temperature range of 15-30°C, when they are quite active (WHO, 1957; McDonald, 1969; Shiff, 1964a; Macan, 1974; Van der Schalie and Berty, 1973).

During the present investigation in a laboratory trial we could not find any of the pulmonate snail (lymnaeid, planorbid or physa) to withstand freezing even for 24 hours but *B. bengalensis* (a prosobranch snail survived freezing for 24 hours. However, the temperature range at which the snails showed activity was between 12-34°C with the optimum range of 24-27°C. Our findings in this regard are in line with earlier published reports (Michelson, 1961; Foster, 1964; Sturrock, 1966; Liang, 1974; Tanveer, 1989 and 1990b).

Seasonal temperature ranges reported for freshwater pulmonates include: *Ferrisia rivularis*, 0-28°C (Nickerson, 1972); *Laevapex fuscus*, 0-31°C (McMahon, 1972, 1976); *Hebetancylus excentricus* Morelet, 10-31°C (McMahon, 1976); *Lymnaea stagnalis*, 0-30°C (Brown, 1979); *L. palustris*, 1-28°C (Brown, 1979); *Physa virgata* Gould, 8-39°C (McMahon, 1975a); *P. gyrina*, 0-35°C (Sankurathri and Holmes, 1976), *P. integra*, 0-31°C (Brown, 1979); *P. hawnii* Lea, up to 36°C (Daniels and Armitage, 1969); *Biomphalaria pfeifferi* and *Bulinus globosus* (Morelet) 7-28°C (Appleton, 1976), *Helisoma trivolvis*, 0.5-28°C (Eversole, 1978).

Temperature seems to exert a powerful dispersal effect on the snail populations. Many reports showed that when snails are kept in vertical temperature gradients, they tend to congregate in this gradient at a point which is near to their optimal temperature (van Eeden *et al.*, 1965; Berrie, 1970; Appleton, 1978). The water temperature and its relationship with the distribution of snails has been given equal importance by various workers (Sturrock, 1965; Berrie, 1966, 1970; van Eeden *et al.*, 1965; Van Eeden and Combrink, 1966).

Majority of the studies reported above are on pulmonate snails. Some studies however are available on prosobranch snails. Issel (1908) reported that *Paludestrina aponensis* could optimally live between 32-36°C and also survived (46°C) in thermal waters. Muley and Nagabhushanam (1975) reported taht another prosobranch snail *Melania scabra* had a tolerance range of 16-37.5°C for 24 hours. They further reported that seasonal variation in the temperature caused the snails to undergo a period of rest in the months of April and May when the temperatue was high. Moreover, at noon, when the temperature was highest during the day, the snails showed migratory trend from surface water towards bottom of the river because of high temperature the dissolved oxygen contents of the surface water decreased. This means that the snails moved from warmer area towards cooler region. Our observations on *B. bengalensis* are also in accordance with those of Muley and Nagabhushanam (1975).

The environmental temperature range reported for three river populations of freshwater prosobranch *Leptoxis carinata* was 1-26°C (Aldridge, 1980) and 1-28°C for river and lake populations of *Goniobasis livescens*, (Payne, 1979). These environmental ranges are generally less than the reported ranges for the freshwater pulmonates. Similarly Shiff (1966) also observed that *Bulinus globosus* was capable of detecting a temperature difference of 4°C within a habitat and in vertical gradient of 16-28°C, the animal tended to cluster towards the warmer water. Chernin (1967) observed that regardless of the initial placement in thermal gradient, well-fed *Biomphalaria glabrata* tended to accumulate horizontally with greatest frequency in zone between 27-30°C.

In natural populations, growth rate was direclty related to the temperature (Burkey, 1971; Clampitt, 1970; DeWitt, 1955; Eversole, 1974; Hunter, 1975, McMahon, 1972,1975a,b, 1976; Nickerson, 1972; Romano, 1980; Streit, 1975). They reported minimum growth rates during cold winter months which increased to a maximum in the summer, with peak rates generally corresponding to periods of maximum ambient temperature. Our observations are in line with the work reported above.

Relative humidity is another important factor which plays an important role in the hibernation and aestivation phenomenon (Muley adn Nagabhushanam, 1975). Dry conditions are usually expected to influence snail populations, especially in our country where they are usually associated with high temperature. Pulmonate and prosobranch snails are found aestivating and hibernating in the extreme environmental conditions of the year. Although various snail species showed varying degree of resistance and desiccation. Kendall (1949) reported that *Lymnaea truncatula* aestivate upto one year in the laboratory but he further added that it is difficult to impose the results of laboratory experiments to field conditions. Olsen (1944) observed in Texas that *L. bulimoides* were found burrowing into soft mud in the fields and observed as such for about 5 months. Borary (1969), reported that all the lymnaeid snails may hibernate or aestivate for considerable time during dry periods at both low and high temperature. He further added that when snails were under hibernation or aestivation they showed reduced metabolic rates. The work done on the physiochemical changes duirng hibernation and aestivation has been reviewed by Hoffmann (1983). He also observed that in times of particular temperature stress, many snails enter a quiescent, estivation, or hibernation condition. Not only the adult snails, but juveniles also are subjected to aestivation or hibernation. Eisenberg (1970) while discussing the role of food in the regulation of the pond snail *Lymnaea elodes*, also reported that young snails of this sepcies aestivate during summer and emerged that following spring and grow to become the reproductive individuals of that year.

During the present investigation it was generally observed, that lymnaeid snails could withstand only one hibernation season. They did not require aestivation, most probably due to the tolerable ambient temperature in the water bodies (Fig. 1). Lazaridou-Dimitriadou and Kattoulas (1986) reported that under constant laboratory temperature *Eobania vermiculata* (Mueller) did not hibernate. However, *B. bengalensis* a bottom dweller could aestivate and hibernate two seasons in his normal life cycle and very rarely three. After aestivation or hibernation the death rate in male was greater as compared to the female (unpubished data). Buckely (1986) and Gebhardt and Ribi (1987) also observed high mortality shortly after the snails emerged from hibernation, but they did not mention any sex-difference.

pH of the water of habitats

Like temperature, pH of the habitat has also attracted a fair amount of authors towards this direciton. Major part of these studies, although, done on snails native to European, American and Australian region, point to the fact that the optimum pH range for snails is around neutrality, i.e. 6-8. On the other hand the snail populations have also been seen or reported from habitats having quite diverse pH ranges. So much so, a pH range of 4-10 has also been reported (Boray, 1964; WHO, 1957; Harry and Aldrich, 1958; Malek, 1958; Webbe, 1962). Once again these studies have been predominantly on the pulmonates. In the present study, we also collected data on the pH tolerance of three pulmonate snails (*L. acuminata, G. convexiusculus, P. acuta*) and found that although in nature the pH of the four habitats did not change much (remained between 6-7) the pH tolerance in the laboratory was 5.5-8.0 for *L. acuminata*, 5.0-8.0 for *P. acuta* and *G. convexiusculus*.

As far as prosobranch snails are considered. Muley and Nagabhushanam (1975) suggested that *Melania scabra* could live in pH ranging from 3.5-9.5 showing a braod range of pH tolerance. On the other hand Borary (1964) found that both *Melania* and *Vivipara* spp. showed a narrow range of pH (6.5-7.0) tolerance in Australia. In the present study, in laboratory, the prosobranch snail, *B. bengalensis*, tolerate a pH range of 4.0-8.5 which is slightly broader than the pulmonate snails and further that *B. bengalensis* can tolerate more acidic environments easily than the alkaine environment. (The data not reported here).

In the end, it may be mentioned here that some authorities prefer to give more importance to calcium contents or total alkalinity of the habitat water than the pH (Boycott, 1936).

Rainfall, water level and dissolved oxygen

All the above factors are related to each other and to other abiotic and biotic factors of the habitat. As presented in the results there are dry and wet seasons and during some months precipitation is greater than others. This cause the snail populations to adapt themselves according to their ecological niches. If there is any change in the optimum environmental conditions and rainfall, the snail populations then also are disturbed and change according to the conditions. During 1984, the year for which the data is presented here, due to the erratic rains in March and early April, the snail populations were found to be good, because of early reproduction and young ones were found in abundance during May and June, a time when young ones generally are not found because this part of the year in Pakistan, in general, and in Lahore, in particus is a dry part of the year and snail populations generally comprise adults of the last year progency. These data are in line with earlier data of Webbe (1965), Boray (1969) and Berrie (1970), which showed that rain provides an impetus for reproduction. But tremendous rains can cause havoc in the snail population and many of them can be terminated because of increase in water flow and other changes in the habitat parameters, both abiotic and biotic. However, rain and flooding were found to be principal factors responsible for dissemination of snail vectors (Abdul Karim, 1988).

Another importance intrinsic factor which is helpful in overcoming unfavourable conditions and continuing their population densities is their intensive breeding throughout the year. So if their young population are flushed away due to unfavourable conditions (rainfalls and floods), as is normally the case during the onset of monsoon in July and August, in Lahore and adjoining areas. Out of their large populations, some survived by attaching themselves to suitable objects. In this way the young snails (Junveiles) could also survive, more successfully. On the onset of favourable conditions, the survived, young snails, by their intensive breeding, were capable of maintaining their population density again. The young snails which had survived the unfavourable conditions, in the mean time they were ready for reproduction on the onset of favourable conditions and this regulate their population densities. Chu *et al.* (1967) and Berrie (1970) also observed the same phenomenon in snail populations. On the other hand when the natural snail populations face high mortalitis, due to high temperature, extreme cool or due to sensescens the remaining snails successfully survived by aestivating or hibernating themselves under the dead vegetation, debries or in the mud, till the onset of favourable season.

In the prosobranch snails like *B. bengalensis*, the hard shell and presence of operculum helped them to tolerate the adverse environmental conditions. Due to the presence of hard shell they are more or less protected from the predators and operculum prevents the excessive loss of water which is helpful in their aestivation, hibernation and other activities of normal routine life. It is also a general observation that the snails which had just recovered from their aestivation and hibernation phenomenon, showed greater reproductive capacities as compared to the snails which had not undergone these phenomenons. The same phenomenon have also observed by Chu *et al.* (1967) for *Bulinus truncatus*. Shiff (1964b) after observing populations of *Bulinus globosus* in Rhodesia reported that during cold weather, the population contained relatively large number of adult snails and during hot weather maximum young populations were found.

However Berrie (1968) have related the continuous, rapid and intensive breeding of snails with their ability to exploit brief period of optimum environmental conditions, which he consider an adaptive phenomenon in colonizing water bodies. Another reason for holding maximum population is also associated with alternation of vegetation which in turn increases the variety of trophic status for the snails. In the four habitats studied, maximum snail population was found in the Bansi Sagar fish pond in which human water contact activities were also present, which in turn created suitable biotops for the snails (Madsen *et al.*, 1987).

The rain fall has an important role in the water level of te habitat although temperature also contributes to it by way of evaporation. The water level is quite important in the dispersal and establishment of the snail populations. Increase in the water column of the habitat generally inhibits the snail populations which are absent at greater depths i.e. more than one meter.

Water velocity, can also cause changes in the snail populations. it has been reported that snails have to spend a lot of energy to maintained themselves in the moving water, which in turn exert pressure on their energy producing system and less energy is channelized towards growth and reproduction (Thomas *et al*., 1975; Ndifon, 1979). It may also be mentioned here that moving water is quite deficient in the food as the productivity of moving water is always less than the still water.

Another important factor which plays an influential role in limiting the distribution of snails is low level of dissolved oxygen in the habitat water. Mehl (1932) suggested that low oxygen tension could provoke the snails to leave stagnant pools and migrate to some other site into the same pool or to some other place in the vicinity.

There can be fluctuations in the dissolved oxygen level of the water depending upon the season. The fluctuations are both circadian and circannual. These fluctuations depend on the rainfall and temperature of the habitats. Higher temperatures tend to lower the dissolved oxygen and low temperatures have opposite effect. Another factor of importance in this connection is the presence of different vegetation and eutrophication.

According to Macan (1974) the small column of water shown sudden and violent fluctuations in oxygen contents and the cycle of thermal stratification. For exmple, the thermal stratificaiton which takes a year in lakes may be complete in 24 hours in shallow pond, theraby, affecting the snail populations. Asumu (1975)have reported that snails were absent from the habitats where oxygen levels were below 1.3%. Ndifon (1979) found that all the snail species except *Lanister ibycus* was absent from the habitats with oxygen concentrations of 0.0-10.0%. Recently, Thomas and Tait (1984) have also supported the observations of the above authors.

Oxygen consumption by individual snail

In the present investigation an attempt and been made to correlate the variation in oxygen consumption by individual snails collected from different habitats. The results of our present work showed that the heavier/bigger the animal, the lesser is the amount of O_2 consumed by it. For example, *B. bengalensis* consumed less oxygen as compared to *L. acuminata*, *G. convexiusculus* and *P. acuta*. Similarly juvenile snail species consumed more oxygen than their respective adults. A factor of importance, which exert some influence on the oxygen consumption, is temperature. All the snails showed their maximum oxygen consumption during the months of April-June and then September and October i.e. the time period of the year in which they showed their maximum activities (growth and reproduction), while the minimum oxygen was consumed by the snails during the cold weather, i.e. the time period in which they showed minimum activity. It is clear from the results of present investigation that oxygen consumption by snails was directly dependent on the ambient environemntal condition.

It was also observed that when due to high temperature the oxygen contents of the water of the habitat dropped below a definite level, the snails came up to surface in order to supplement their oxygen requirements from air. The same phenomenon has also been demonstrated by Berg and Ockelmann (1959), Muley and Nagabhushanam (1975) and DeWild (1975). Berg and Ockelmann (1959) and Macan (1974) have also noted that snails consumd more oxygen when the amount of oxygen was less and it decreased with the increase in amount of available oxygen present in the ambeint water. However, our findings in this regard, do not fully endorse the conclusions of these workers in our work, the O_2 consumption of the snail dropped over 3 hours of measurement showing that growing hyoxia was decreasing the O_2 intake. This is probably due to the behavioural adaptation of becoming stationary during this time, thus decreasing their metabolic rate. Fox and Taylor (1955) have discussed the amount of dissolved oxygen and its effects on the oxygen consumption by the sanails. They found that *Lymnaea stagnalis* survived better at 21 percent or 100 percent than 4 percent dissolved oxygen contents, while young *Planorbis corneus* survived fairly well in 21 percent but not so well in 4 percent and badly in 100 percent dissolved oxygen contents. On the basis of our present results we were unable to find any relationship between amount of dissolved oxygen and amount of oxygen consumed by the snails. Further studies in this connection are needed.

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