

**STUDIES ON SNAILS AS VECTORS OF PARASITIC
DISEASES IN BOMBAY AND MOLLUSCICIDAL PROPERTIES
OF SOME INDIGENOUS PLANTS**

**THESIS SUBMITTED
UNIVERSITY OF BOMBAY**

**FOR THE DEGREE OF
MASTER OF SCIENCE
IN
APPLIED BIOLOGY**

**SUBMITTED BY
KEDAR SHRIKANT BHIDE**

**UNDER THE GUIDANCE OF
DR. B. D. SATHE**

**DEPARTMENT OF ZONOSIS
HAFFKINE INSTITUTE FOR TRAINING, RESEARCH & TESTING
BOMBAY**

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9/11/95.

(Dr. B. D. Sathe)

Signature of the Guide

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INTRODUCTION

Teeming millions of world population, especially those in developing countries, are still groaning under the relentless and corrosive ravage of what are known as vector borne diseases. These diseases are predominant largely, if not exclusively, in developing countries. Because, distinctive climatic conditions, poor environmental sanitation, low socio economic status, lack of health education and many other factors here enter into unholy combination to favor their flourish. It will be important to realise that observed and demonstrable prevalence of vector borne diseases does not disclose total dimension of the problem they represent. It is perhaps only a tip of the iceberg. Many of these while not rapidly fatal, work in slow but stubborn manner, over a prolonged period, affect the community at large rather than individuals, sap the vitality of a large segment of a population , producing mass incapacity in endemic areas. The problem of these vector borne diseases constitutes a great hindrance to socioeconomic development in the developing areas of the world.

Among the most common vector borne diseases in the world are, malaria , filariasis, schistosomiasis, leishmaniasis and trypanosomiasis. These diseases require insects, molluscs, arthropods and other invertebrate animals as vectors. Malaria , filariasis and several other parasitic diseases are transmitted by insect vectors. On the other hand diseases like schistosomiasis and fascioliasis are transmitted by molluscan vectors, like snails and slugs.

Many species of snails and slugs serve as intermediate hosts of different kinds of helminth parasites. These helminth worms are dependent

on the snails and slugs to complete their life cycle. As these parasitic worms are causative agents of many human and animals diseases, study of the life history of these worms is necessary from public and animal health point of view.

Many human diseases, caused by these helminth parasites have been reported from time to time. Similarly several molluscs have been recorded serving as the intermediate hosts from different parts of the world, (TABLE 1, Raut, 1986). Since the development of worms depends on the availability of molluscan host, the distribution of worm is largely governed by the presence or absence of the molluscan host

Among snail borne diseases, schistosomiasis is the most prevalent parasitic disease in the world. Two hundred million people are affected by schistosomiasis in a population of six hundred million in seventy four developing countries (W.H.O. , 1995). From times immemorial, schistosomiasis has caused untold sufferings to the human race, producing grossly debilitating morbidity and also high mortality in different parts of the world. Transmitted by snails of specific varieties, this infection has played havoc, tragically enough, greatly facilitated by rural development projects in Egypt, Sudan, Ghana, Nigeria etc., where newly constructed dams, artificial lakes and irrigation canals, served as an amplifier, spreading the infection over wide and distant areas. These developements have brought about distinctive changes in epidemiology of schistosomiasis and new geographical approaches are required to promote prevention and control , with the spread of infection to large tracts of the world.

TABLE 1

HELMINTHS PARASITES OF MAN, DISEASES CAUSED BY THEM, THEIR INTERMEDIATE SNAIL HOSTS AND THE COUNTRIES WITH THE PREVALENCE OF THESE DISEASES.

WORM	DISEASE	MOLLUSCAN HOST	COUNTRY
Liver fluke <i>Fasciola hepatica</i>	Fasciolasis, biliary colic diorrhoea, pharyngeal fasciolasis	<i>Lymnaea truncatula</i> , <i>L. palustris</i> , <i>L. pereger</i> , <i>L. glabra</i> , <i>L. stagnalis</i> , <i>L. philippinensis</i> , <i>L. swinhoei</i> , <i>L. launcestonensis</i> , <i>L. alfredi</i> , <i>L. traskii</i> , <i>L. luteola</i> , <i>L. acuminata</i> , <i>L. viatrix</i> , <i>L. pervia</i> , <i>L. japonica</i> , <i>Amphipeplea cumingiana</i> , <i>Simlimnaea tomentosa</i> , <i>Galba bulimoides</i> , <i>G. bulimoides techella</i> , <i>G. ferrugines</i> , <i>G. cubensis</i> , <i>Fossaria modicella</i> , <i>Pseudosuccinea columella</i>	India, Japan, Syria, Argentina, Phillippines, New Zealand, Australia, many European and American countries
Giant intestinal fluke <i>Fasciolopsis buski</i>	Fasciolopsiasis	<i>Hippeutis cantori</i> , <i>Segmentina</i>	India (West Bengal, China, Assam, Manipur, Bihar); Strait Settlement, Bangladesh,

WORM	DISEASE	MOLLUSCAN HOST	COUNTRY
Oriental liver fluke <i>Clonorchis sinensis</i>	Clonorchiasis or Endemic jaundis	<i>Parafossarulus manchouricus</i> , <i>Alocinma langicornis</i> , <i>Bulimus fuchsianus</i> , <i>Bithynia</i> sp., <i>Gabbia</i> sp.	Japan, Korea, Formosa, South China, Indo-China
Cat liver fluke <i>Opisthorchis felineus</i>	Non pathogenic to man	<i>Buinus tentaculatus</i> , <i>Bithynia</i>	Prussia, Poland, Siberia, India, Japan
Von Siebold's fluke <i>Heterophytes heterophyes</i>	Heterophyiasis	<i>Pirenella conica</i>	Egypt, Palestine, Formosa, Japan
Yokogawa's fluke <i>Metagonimus yokogawai</i>	Metagonimiasis	<i>Melania libertina</i> , <i>M. Ebenina</i>	Korea, Formosa, Japan, China, North provinces of Siberia Balkan states of Egypt, India
Oriental lung flukes <i>Paragonimus westermani</i> , <i>Gastrodiscoides hominis</i>	Paragonimiasis, Endemic haematoptysis, Mucous diarrhoria	<i>Melania libertina</i> , <i>M. obliquegranosa</i> , <i>Helicorbis coensus</i>	Japan, Korea, Formosa, China, India, Malaya, Bangladesh, British Gunia
Vesicle blood fluke <i>Schistosoma haematobium</i>	Vesicle schistosomiasis, endemic haematuria	<i>Bulinus truncatus</i> , <i>B.(Physopsis) africanus</i> , <i>B. cernicus</i> , <i>Planorbis dufourii</i> , <i>Planorbarius comeus</i> <i>metidjensis</i> , <i>Bulinus litratus</i> , <i>Ferrissia tenius</i>	The Nile vally, Parts of Africa, Arab, Palestine, Mesopotamia , Portgal, Madagaskar, Mauritius, India (Gimvi of Maharashtra)

WORM	DISEASE	MOLLUSCAN HOST	COUNTRY
Oriental blood fluke <i>Schistosoma japonicum</i>	Intestinal and hepatic schistosomiasis	<i>Oncomalania nosophora</i> , <i>O.hupnsis</i> , <i>O.quadrasi</i> , <i>O.formosa</i>	China, Japan, Formosa, Phillippine, Paole district of Celebes, Shan states of Burma

TABLE 2

Global distribution of Food borne tramatode infection

DISEASE	FOOD ITEM	PARASITE	NO. OF COUN - TRIES	POPULA - TION AT RISK (X 10 ⁶)	PERS - ON S INFE - CTED (10 ⁶)
<i>Clonorchiasis</i>	Fresh water fish	<i>Clonorehis sinensis</i>	9	290	7
<i>Opisthorchiasis</i>	Fresh water fish	<i>Opisthorchis felineus</i>	2	14	1.5
		<i>Opisthorchis vivorini</i>	2	50	9
<i>Paragonimiasis</i>	Fresh water crab	<i>Paragonimu s species</i>	39	195	21
<i>Fascioliasis</i>	Water cress	<i>Fasicola gigantea</i> <i>Fasicola Hystatica</i>	61	180	2.4

Food borne trematode infections acquired by raw or inadequately processed fresh water fish, shell-fish and aquatic plants, affect more than forty million people through out the world. Over 10 % of global population is at risk of infection (Table 2 , W.H.O.,1995). The first stage larvae of these digenic trematodes are very narrowly specific to snail hosts. These diseases represent a new global challenge for food safety and parasitic disease control programs due to globalisation of food transport.

The snail transmitted nematode, *Angiostrongylus cantonensis*, the causative agent of human eosinophilic meningitis has expanded globally (Kliks and Palumbo, 1992). The use of molluscs and crustacea as favored delicacies and folk medicines has resulted in numerous outbreaks and isolated infections of *Angiostrongylus cantonensis*, all over the world. The penetration of this parasite into tropical and subtropical areas of Africa, the Indian subcontinent, the Caribbean and Gulf coast region of the united states is of considerable public health importance (Kliks and Palumbo, 1992).

Although a global problem, Schistosomiasis and food borne trematode infections are not very common in India. Human schistosomiasis caused by *Schistosoma hematobium* is restricted to a small village in Maharashtra state with *Ferrisia tenuis* as its intermediate host. (Sathe *et al*, 1981) Fasciolapsiasis, caused by *Fasciolapsis buski*, is common in India and has been recorded from many parts of the country (Gita Biswas, 1991). Human infection with trematode parasite, *Artyfehinostomum mehrai*, *Paryphostomum sufrartifex* and *Gastrodiscoids hominis* have also been reported from India (W.H.O.,1995).Opisthorchiasis due to the infection of

Clonorchis sinensis has been reported in man in India although the occurrence of the parasite *Paragonimus westermani*, the causative agent of Paragonimiasis has been reported in India, the disease is yet to be recorded in man (Raut,1986).

Apart from above infections snail borne diseases like, animal schistosomiasis, fascioliasis, amphistomiasis, dicrocoeliasis, notocotylidae infections, heterophyes infections, echinostome infections, prosthogonimus infections and troglotroma infections constitute major veterinary health problems in India (Gita Biswas, 1991).

Cercarial dermatitis, a world wide problem, which is because of the exposure to cercaria, results in sensitization which on renewed contact with cercariae and their penetration of the dermis, produces according to the degree of sensitization, at first the burning sensation followed by severe dermatitis. This is commonly called as Swimmer's itch and is common in India (Gita Biswas, 1991).The fercocercous cercaria, the causative agent of animal schistosomiasis and human cercarial dermatitis was reported from Bombay region (Soparkar, 1920 ; Niphadkar, 1975).

The incidence of eosinophilic meningoencephalitis caused due to the attack of *A.cantonensis*, a nematode transmitted by snails and slugs, has been reported from Pacific and South east Asian countries (Alicata, 1969).In India though outbreak of this disease is not on record, a nematode worm removed from human eye in Calcutta had been identified as *A.cantonensis* (Parmeter and Chowdhury, 1966). In Bombay, a clinical study recorded the infestation of human subjects with *A.cantonensis* (Sharma et al, 1981).

These findings were later confirmed when occurrence of *A.cantonensis* in rat population of Madras (Parmeter and Chowdhury, 1966) and in the rat and snails/slugs population of Bombay was recorded (Renapurkar et al, 1982).

As we have seen above a large number of trematode and nematode parasites involved in the transmission of human and animal infections need snails and slugs as their intermediate hosts. A comprehensive knowledge of the ecology, taxonomy, population dynamics and seasonal variation of the snail host becomes absolutely necessary in order to understand the epidemiology of the disease caused by these parasites and initiate control measures against them.

Thus snails and slugs are important both from medical and agricultural view points . In India , the members of the families *Lymnaeidae* and *Planorbidae* are registered as intermediate host of number of helminth parasites which cause diseases in man and domestic animals. Of the terrestrial molluscs, the Giant African snail, *Achatina fulica* and the slug, *Laevicaulis alte* are known to cause serious damage to agri-horticulture plants. Besides these land slugs/snails have also been registered as the intermediate hosts of the nematode parasite, *A.cantonensis*, causative agent of the disease eosinophilic meningoencephalitis, both in man and monkey.

In recent years Bombay city has experienced increase in snail nuisance. Infestation with Giant African snail , *Achatina fulica* has assumed enormous proportions in some parts of Bombay (Joshi, 1990).This snail is a serious vector of *A.cantonensis* in Pacific islands (Alicata , 1969) , Taiwan

(Chiu, 1964), Japan (Nishimura and Yogore, 1965) and Philippine (Arombule and Yogure, 1966).

The increase in snail population may prove hazardous to public health, because of their role as vector of parasitic diseases. The threat of introduction of snail borne diseases, like schistosomiasis, fascioliasis, clonorchiasis etc., in India is omnipresent, because of swiftness of modern travel and bilateral movement of population to and from areas, where snail borne diseases are endemic. And also because of the changing food habits of the population. This is mainly because of the fact that, many of the Indian snail species serve as the vector of trematode and nematode parasites.

Snail control assumes primary significance in areas affected by snail borne infections, because snail control is one way of interrupting the life cycle of the parasite and thus preventing human and animal infections.

Snail control by molluscicide is a rapid and effective means of reducing transmission, as described by W.H.O. (W.H.O., 1980). The molluscicides in use are essentially synthetic derivatives and plant based products. Although there are several synthetic molluscicides, molluscicides of plant origin are also being employed in Egypt and other countries, where schistosomiasis is endemic. This is mainly because molluscicides of plant origin pose less environmental hazards and are rapidly biodegradable. Despite this very little work has been carried out to assess the susceptibility of Indian snails to molluscicide of plant origin.

Many plant species have been reported to exhibit molluscicidal activity and of these the most thoroughly studied is *Phytolacca dodecandra* (endod). Although endod has been found to be somewhat less cost effective than synthetic molluscicides, its use can obviate importation of synthetic chemicals since the substance does not require industrial synthesis and can be easily produced locally. A number of other molluscicides of plant origin have also been reported in the literature, There is thus dire need to develop plant based molluscicides considering their low cost , low toxicity and rapidly bio-degradable action.

This present work is carried out to throw light on prevalence of various vector snail/slug species and their importance as vectors of parasitic diseases in the city of Bombay. In addition efforts are also made to evaluate some plant based molluscicides for their use in control of molluscs.

REVIEW OF LITERATURE

Several molluscs are known to serve as the intermediate host of different kinds of helminth parasites. These helminth worms are dependent on the snails and slugs to complete their life cycles. Although helminthology is taught as a specialisation in many of our universities, malacology does not find an important place. Medical malacology, a new branch of the biological science is almost neglected in India.

From the parasitological point of view four classes of Mollusca namely, Gastropoda, Scaphopoda, Bivalvia and Cephalopoda are important since all of the known molluscan hosts belong to these classes. Cephalopoda are only known host for the dicyemid mesozoa. About 30 species of cephalopoda are reported to have been infected with larval and adult trematodes (Overstreet and Hocbert, 1975). From a medical point of view, the gastropoda is the most important of the six classes of molluscs, since several members act as the intermediate hosts for various important parasites such as blood flukes, liver flukes and lung flukes, which cause considerable problems in human and domestic animals. Some of the snails also acts as the agricultural pests, especially the group called slugs.

The gastropods are divided in to three subclasses, Prosobranchia, Opisthobranchia and pulmonata. The latter is more important than any other group since majority of the species implicated as intermediate hosts of helminth parasites belong to it. In fact out of 100 species recorded as intermediate hosts only 18 are prosobranchs and remaining all are pulmonates. The pulmonata comprises two orders , Bassomatophora and Stylommatophora.

Some of bassomatophores are, *Lymnaea* species, which in India transmit *Schistosoma incognitum* and *Schistosoma nasale* to cattle and pigs. Species of *Segmentina* and *Hippeutis* are intermediate host of *Fasciolopsis buski* in India. Another genus *Indoplanorbis*, primarily known from India, is the intermediate host of *Schistosoma spindale*, *Schistosoma nasale* and *Schistosoma indicum* in cattles. A species of *Ferrisia* has been found as intermediate host of *Schistosoma hematobium* in India. Among stylammatophores are species of *Achatina*, *Laevicaulis* and *Macrochlymus* which transmit *Angiostrongylus cantonensis* in rats and are also major agricultural pests.

The snail is an essential first intermediate host, or only intermediate host of different digenic trematodes. The presence of susceptible snail host is the primary requirement for the establishment of trematode infections. Along with trematodes, snails also harbor some nematodes and nematomorphs. But these are encountered less frequently than trematodes in gastropods.

The nematode fauna of snails have received attention of helminthologist from very early days, but the subject was subsequently rather neglected. Such peculiar phenomenon as the ability of so called "free living" and plant parasitic nematode to survive passage through the intestine of the snails, and occurrence in snails of nematodes belonging to the same genera as nematodes found in amphibia, have raised interesting problems in host-parasite relationship of these nematodes. Chitwood and Chitwood (1937)

attacked this problem by separating the nematodes found in snails into six groups on the basis of the mode of life of the nematode involved.

- 1) Nematodes normally free living and plant parasitic which may pass through the digestive tract uninjured.
- 2) Nematodes living as obligatory parasites in the digestive tracts.
- 3) Nematodes living as parasitic larvae in the foot muscles and having a free living adult stage.
- 4) Adult nematodes living in the genital organs.
- 5) Agamic nematodes and nematomorpha which live in the body cavity and leave the host upon reaching maturity, subsequently passing the remainder of their life as free living forms.
- 6) Nematode parasites of vertebrates, the larval stages of which occur in snails.

The members of the first group are free living and plant parasitic nematodes. Since they do not, under ordinary conditions, pass any part of their life cycle in snail, their association with snails can best be considered as facultative or casual parasitism.

The second group, obligatory parasites living in the intestinal tract of the snails, contains representatives of two families of nematodes, the Rhabditidae and the Cosmocercoidea. The genera *Angiostoma* of family Rhabditidae occasionally found in the intestine of the salamander and in snails. Chitwood and Chitwood (1937) had collected members of family Cosmocercoidea from two snail hosts. Generally members of family Cosmocercoidea are known as parasites of amphibians and reptiles. It is not

uncommon for invertebrates to serve as intermediate host of vertebrate parasites, but *Angistoma* and *Cosmocercoides* appear to be the first genera of nematodes known to contain species which are parasites of both vertebrates and invertebrates.

The third and the fourth group, parasites living as larvae in the foot muscles and having a free living adult stage and nematodes parasitising the snails genital organs, have very few representatives (Chitwood and Chitwood, 1937).

The fifth group, nematodes and nematomorphs, which live as agamic forms in the body cavity and leave the host upon reaching sexual maturity, contains several representatives like, *Gordius aquaticus* and *G. villoti*.

The sixth group, the most important from medical point of view, is represented by super families Protostrongylidae, Angistongylidae and Filaroididae. The members of these families utilise the molluscan intermediate host for completing a part of their development.

The Protostrongylidae includes a number of genera among which most widely spread are genus, *Protostrongylus* and *Pneumstrongylus*. All of the members of this family are either parasitic in the respiratory or circulatory system of mammals.

The members of the genus *Protostrongylus* are parasitic in the lungs of herbivores and rarely of carnivores. Most are of considerable importance as pathogens in domesticated and wild ungulates. There are about twenty-seven species, and all have indirect life cycles involving a molluscan intermediate hosts. Most important example of this genus is *Protostrongylus*

rufescens. This nematode occurs in the trachea , branchia and bronchioles of the sheep, goats and hares. This is a fairly common parasites in North America, Europe, Iran, Cyprus, Turkey, Israel, India, Africa and USSR.

This nematode commonly called as red-lung worm because of its color due to the ingested blood. The other genera, *Pneumostongylus* have only one member, i.e., *P.tenuis*, parasite of white tailed deer and moose in Canada.

The second family Angiostrongylidae includes several genera and are mostly lung worms. The members of *Heptojarakus*, however occur in the inferior vena cava of rats. Most important of genus of this family in medical point of view is *Angiostrongylus*. Up to present 19 species of the genus *Angiostrongylus* have been reported from various animals (Bhaibulaya, 1979). Out of these 19 species, two are most important because they cause diseases in human. These are , *Angiostrongylus cantonensis* and *Angiostrongylus costaricensis*. These parasites cause human eosinophilic meningitis and abdominal angiostrongyliasis respectively.

In recent years, *A.cantonensis*, the rat lung worm, has come into medical prominence since it has been reported as a causative agent of a type of human meningoencephalitis in Hawaii, certain south Pacific islands and south east Asia (Alicata ,1969). In India though the outbreak of this disease is not on record, a nematode worm removed from human eye in Calcutta has been identified as *Angiostrongylus cantonensis* (Parmeter and Choudhury ,1966). Its other incidence was recorded in Bombay. In this case

clinical study suspected the attack of *A.cantonensis* (Sharma et al, 1982) which was confirmed by parasitological findings.

Mackerras and Sandars (1955) had studied the life cycle of *A.cantonensis* in the laboratory and stated that it is of indirect type. Natural host of *A.cantonensis* is rat, but in accidental hosts like man or monkeys, parasite reach only to the fourth stage, i.e. brain stage and dies ,causing eosinophilic meningitis. Mode of infection is through ingestion of infected molluscan host.

The third family Filaroididae includes the genus *Filoroids* which utilises the gastropod molluscs as the intermediate host. One of the representative of this genera is *Filarioides martis*.

The trematodes transmitted by snails are from the class Digenea. They are commonly called as flukes. In Digenea, the first intermediate host is always molluscs. And in case of man and domesticated animals it is always a snail . While the definitive host is always a vertebrate. Some of the well known trematode diseases transmitted by snails in India are amphistomiasis and fascioliasis.

In India the snail borne diseases are not very recent ones. Vedic literature was the first of its kind where such diseases have been mentioned. Shushruta in his treatise entitled ' Krimi Roga Pratishedh' has referred to twenty types of worms . Charka and Veb-Prakash have also dealt the group with considerable importance.

Leiper, head of bilharzia mission in Egypt and middle east first drew the attention of Government of India to the possibilities of the spread of

human infection in India , through the heavily infected Indian soldiers who were returning back after the first world war from middle east and south Africa (Baugh , 1978). Existence of endemic focus of schistosome diseases, subsequently the spread of human schistosomiasis in India was feared and surveyed by parasitologist and medical practitioners from beginning in this country. First to find was whether the intermediate molluscan hosts reported in other countries as vectors for schistosome could be found in India. Secondly it was to confirm whether the locally available snails were capable of harboring the schistosome cercaria.

Kemp and Gravely (1919) after an exhaustive survey concluded that the intermediate snail host reported in other countries, belonging to the genera *Bullinus*, *Physopsis* and *Hypsobia* are not represented in India. The other genus *Planorbis* though found in India is not capable of harboring human schistosomes.

Sewell (1922) studied the various cercariae found in Indian snails with a view of knowing if at all human infecting schistosome cercariae naturally existed in India. But he failed to discover the human schistosome cercariae in any common Indian snail. The monograph of Indian cercariae viz., "cercariae Indicae" which he subsequently published was the outcome of the efforts that he had made to find out if at all human schistosome cercariae naturally occur in any indigenous snail.

Annandale and Sewell (1920), with a view of studying the etiology of human schistosomiasis occasionally appearing in India ,made an extensive survey of the fresh water gastropods mainly of the plains of India, namely

Hydrabad, Secundarabad, Madras, Bombay, Punjab, Ranchi, Calcutta etc. and also of Baluchistan. As troops were stationed at some of these places, a danger was foreseen of human schistosome being introduced in India through infected army personel. Fortunately, however he found *Bulinus*, species of which elsewhere mainly serves as vectors of *S. hematobium*, to be non-existent in India. Further he discovered that *Bulinus* was once existent in India, but became extinct later. On the basis of Annandale's findings it was concluded that human schistosomiasis can not ordinarily gain a footing in India.

Soparkar (1919), too investigated the possibility of human schistosomiasis spreading in India. In an attempt to find human schistosome cercariae in indigenous snails, Soparkar (1921) studied the cercarial fauna of the snail living in the vicinity of Bombay city, and he found as many as 17 species of cercariae, including cercariae of a cattle infecting schistosome, parasitizing them, but not any of human schistosome.

Towards the end of the first half of the present century, De Sa and Moneria (1949), Gadgil and Shah (1952) reported the outbreak of human schistosomiasis among the people of village, Gimvi, Ratnagiri district, Maharashtra. The infection was due to human schistosome species *S.hematobium* . The snail *Ferrisia tenuis* served as the intermediate host for the worm *S. hematobium*. Their findings further proved that snails other than *planorbidae* can act as intermediate hosts of schistosomiasis.

Just two decades back, the existence of one more endemic focus of human urinary schistosomiasis came to light due to the efforts of Santhana

Krishnan and Sundararajuhi (1967). This endemic focus was located in 'Tirupparankundaram' village in Madurai district in Madras state. Srivastava and Arora (1969) reported yet another focus of human schistosomiasis in Raipur district of Madhya Pradesh.

Sathe *et al* (1981) resurveyed the endemic focus of schistosomiasis in Gimvi village, of Ratnagiri district of Maharashtra state and confirmed the existence of the focus and the *Ferrisia tenius* as a vector. They further observed that the focus was still existing despite control measures initiated by the Public Health Department, Maharashtra state.

Animal schistosomiasis is known to occur in several states in India, viz., Assam, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Rajasthan, Tamilnadu and Maharashtra. Liston and Soparkar (1918) found a true schistosoma cercariae parasitising *Indoplanorbis exustus* in the environs of Bombay. They experimentally raised its adult in goat and Guinea pig and it turned out to be *S. spindale*. Malkani (1932) reported a form of nasal schistosomiasis in which Cauliflower like growth developed on the nasal septum of cattle. Rao (1934) named this parasite a *S. nasalis*. Occurrence and etiology of *S. indicum* was discussed by Datta(1933) and others from various parts of the country.

In the sixties and seventies, several veterinarians made varied contributions to our knowledge of animal schistosomiasis in India. Niphadkar and Rao (1967) reported the finding of *S.spindale* in *Bandicota bengalensis* in Bombay. This is a new host record of this species . Rodents

are known in Africa, America and Formosa to be parasitised by human schistosome. But this is a first report of schistosoma from rodent in India.

The upshot of the foregoing discussion of the works done by various investigators is that only one species of human schistosome causing urinary schistosomiasis has been found in India, where as infection of as many as seven species of animal infesting schistosomes are enzootic in this country.

Fascioliasis is an infection caused by liver flukes viz., *Fasciola hepatica* and *F. gigantica*, which occur in the bile duct of cattle, buffaloes, sheeps, goats, pigs, rabbits elephants and rarely in man.

In India *F. hepatica* occurs at high altitudes like Darjeling, Kashmir its intermediate host being *Lymnaea accuminata*. *F. gigantica* occurs in plains. Most of the reports of human infection refer to single cases or to very small number. Only two endemic foci one in Malawi (2.4 %) and other in Peru (4.5-34%) have been reported so far (Gita Biswas, 1991).

Amphistomiasis is caused by several species of the family Paramphistomidae. In India *Indoplanorbis exustus* mainly acts as intermediate host. Animals affected are cattle, buffalo, sheep, goat etc. Immature fluke causes acute to peracute infection leading to death. Amphistome species *Gastrodiscoids hominis* has zoonotic potentialities. The trematode occurs in the intestine of pig and man. Endemic focus has been found in Assam. The life history of *G. hominis* was studied in detail by Dutt and Srivastava (1972).

The infective stage of amphistomes is cercariae. The amphistome cercariae found in India have been reported by Mukherjee, (1986). There are

around fifteen amphistome parasites reported from India (Mukherjee ,1991). Dicrocodiasis, caused by *Dicrocodium dendriticum* occurs in the bile duct of sheep, goat, cattle, pig, donkey and rabbit and rarely in man. Many a time human patients show false positivity after consumption of infected liver as the eggs are not affected by digestive juice. So for confirmation the patient must stop eating meat at least for three days. In India, *Macrochlymus Candida* a land snail, acts as first intermediate host and *Formica* sps. serves as second intermediate host.

The Opisthorchiasis (clonorchiasis) caused by *opisthorchis sp.* is wide spread in Asia and Europe. Dog, cat, pig and man acts as definitive host. In India this fluke is very common.

Paragonimiasis caused by lung fluke *Paragonimus* is a harmful disease with suggestive symptoms of tuberculosis in man and animals. In India it has been reported from Mongoose (Ravikumar et al, 1979) in Palm civet (Gulati,1926) in Dogs (Rao,1935), in Cats (Srivastava, 1938) in Bear cat (Dutt and Gupta, 1978).

Cercarial dermatitis caused by fercocercous cercaria is very common in India (Gita Biswas,1991),chiefly in Assam. In Assam, it is called as rice field dermatitis, and it is an occupational health problems in Assam. The afflicted paddy fields workers develop exanthema on the exposed parts of their skin mainly legs and arms when they come in contact with water in rice fields. It was found that *Planorbidae* snails were infected with animal schistosome cercariae, and they caused cercarial dermatitis in rice field workers (Narain et al, 1994).

MOLLUSCICIDE AND CONTROL OF MOLLUSCS

Snail control by molluscicides is a rapid and effective way of reducing transmission described by W.H.O.(1980).Its efficiency is likely to be enhanced, if it is combined with other methods of control. There are now substantial scientifically acceptable data to show that incidence prevalence and intensity of infection are greatly reduced when molluscicides are used in combination with other methods in schistosomiasis control programme. An enormous literature has accumulated on molluscicides of chemical and biological origin . The most widely used synthetic molluscicides are niclosamide (Baluscide) and m-trify morpholine (Frescon).

The successful application of molluscicide results in rapid interruption of the transmission of infection , an obvious advantage not afforded by other control measures. If the chemical is effective also against snail eggs, the cycle of transmission continues to be interrupted until the reinvasion of treated area occurs . Reapplication of molluscicide at the requisite intervals will in the long term reduces intermediate snail host population and the level of infection in the exposed population.

Recently there has been increasing interest in the study of plant molluscicide in the hope that they may prove cheaper and more readily available than synthetic chemicals. Many developing countries are reluctant to embark on chemical snail control programme, using costly synthetic compounds brought from industrialized nation with scarce hard currency (Daffalla and Amin, 1979). Whereas synthetic chemicals biodegrade slowly and preliminary evidence suggests that some population of snail hosts may

have developed resistance to them (Al.Azzawil and Banna, 1980), plant extracts quite rapidly reduced to simpler substances (Lemma and Yau ,1974). Some recent studies of plant molluscicides give preliminary indications that they may be applied effectively in different habitats using techniques available in , and appropriate to, developing countries. Moreover the use of indigenous , rather than imported, material is desirable.

Research on plant molluscicides has become multidisciplinary and as a consequence , the finding has been reported in wide variety of journals. Interest in plant molluscicides dates from the 1930's when Archibald (1933) and Wagner (1933) advocated planting the desert palm, *Balinites aegyptica* and *Balinites maughamii* along the water courses of Sudan and Southern Africa respectively. The laboratory and field trials of these scientists indicated that the fruit which fell into water inhibited the snail population density. Mozley (1939) considered this and two other saponin containing plants, *Sapindus saponaria*, the berries of which were widely used in Africa and Southern America as a fish poison, to be among the most promising vegetable molluscicides. In South America, preliminary studies by Luttermoser (1946) in Venezuela, and by Pinto and Almeida (1944) in Brazil, showed that the berries of *S.saponaria* were lethal to numerous microscopic organisms, as well as to the host snails of *Schistosoma* and *Fasciola*.

None of these plants were further exploited for the control of snails. Not until the mid - 1960's was the first plant, *Phytolacca dodecandra* used for control of schistosomiasis in an endemic focus in Ethiopia (Lemma et al , 1978). Stimulated by these early studies , the search for plants with

molluscicidal potential was intensified as exemplified by extensive screening and general improvement of methods and techniques.

Amorin and Pessoa (1962) randomly screened fresh material of nine plants indigenous to Alagous state, Brazil, for its molluscicidal activity. Silva et al (1971) screened another 30 species indigenous to Brazil, of which four were toxic to *Biomphalaria straminea*, but only one , *Agonandra brasiliensis* was molluscicidal at 100 ppm. Medina and Woodbury (1979) tested 198 plants indigenous to Puerto Rico and two of the Dominican Republic. The plants selected for screening were from genera known to have molluscicidal activity. Plants with medicinal and toxic effects in man or domestic animals, as well as some species randomly selected from areas infested with snails. All parts of the plants were tested . Thirty species were found to be lethal to *Lymnaea cubensis* and *Lymnaea columnella* in water extract of 1000 ppm.

The most extensive plant screening programme has been carried out in China, where nearly 600 indigenous herbs were tested for snail toxicity . Fewer than 20 were mildly toxic in concentrations of 10,000 ppm and lower, no plant was considered to be cost effective for large scale use (Maegraith ,1958).

Endod, *Phytolacca dodecandra*, remains the most thoroughly studied example of molluscicide of plant origin (Lemma ,1970). And this work on endod has been known to the world as Grass roots attack on Bilharzia (Muller, 1974). Some other well studied molluscicidal plants are *Acacia nilotica* (Hussein Ayoub , 1982), *Jatropha spp.* (Amin et al, 1972) and *Canna indica* (Mahran et al , 1974).

In India, molluscicidal plants were rarely studied. Anantaraman (1955) proposed that fruit and leaves with molluscicidal properties falling from trees planted along water courses, might control snail population. Muley (1978) found that the fruit extracts of plants like, *Acacia arabica*, *Acacia species*, *Acacia concinna*, *Sapindus emarginatus* and *Neem morgosa* posses the molluscicidal activity. Rao et al (1980) studied the effect of aqueous tobacco extract on the host snail *Lymnaea luteola*.

Another problem in developing molluscicidal plants is the lack of information on their toxicity to man, domestic animals and non target aquatic fauna and flora. Kloos and McCullough (1982) had provided general guidelines and recommendations relevant to further research on plant molluscicides and their role in control programs.

The use of plant molluscicides may not only eliminate the expanses of importing costly synthetic molluscicides, but could also stimulate growth of small scale industries in developing countries. More emphasis however must be placed even from the beginning on agronomic and organisation aspects, including community participation, if plant molluscicides are to be applied successfully in long term and self sufficient snail control programs.

MATERIALS AND METHODS

I. SNAIL POPULATION STUDIES -

1) General Survey ->

A general survey of snails present in Bombay area was done before studying them in detail . The objectives of this survey were to find out the habitats of snails and mark their distribution. In this survey snails were collected , preserved and identified .

A. Collection of snails - Snails were collected for observing their distribution and investigating their role as possible vectors of human and animal parasitic diseases . A record was maintained with regards to the type of habitat frequented by snails. The emphasis was put on detailed and intensive search for their presence in study area . The collection method involved , visual search in case of terrestrial snails and use of sieve in case of aquatic snails.

B. Preservation of snails - Snails collected from different locations, were preserved for identification . Snails were preserved by placing them in a container of water in which a few crystals of menthol have been added . The container was then covered and kept for 24 hours. Because of menthol , snails were anesthetized and partially extended . Then they were placed in preservative . The preservative was prepared by adding two parts of 75% ethyl alcohol to one part of 40% formaline. These preserved snails were further used for anatomical studies for their identification . To study the shell of snail for their identification , the body of snail was removed from the shell by boiling them in water and then shell was washed and dried at room temperature .

C. Identification of snails - Snails were identified as per the key provided in The Handbook of fresh water fauna of India (Subba Rao, 1989). The preserved specimens of snails and their shells were sent to the Malacology department of, Zoological survey of India, Calcutta for confirmation and identification of snails was confirmed .

2) Study of Population Dynamics and Seasonal variation of snails ->

A. Selection of study areas - On the basis of general survey following ten sites were selected for annual density studies . The selected sites consisted of five areas for terrestrial snails (1-5) and five areas for aquatic snails (6-10).

- 1) Museum Garden - Fort.
- 2) Haffkine Institute Campus - Parel.
- 3) Shivaji Park - Dadar.
- 4) Nandadeep Garden - Bandra.
- 5) Ram-Mandir Road - Borivali.
- 6) Irla Lake - Vile-Parle.
- 7) Powai Lake - Andheri.
- 8) Vihar Lake - Andheri.
- 9) Sewage Canal - Sion - Dharavi .
- 10) National Park River - Borivali.

B. Estimation of the population density of the snails - Snails were collected every month for a period of one year from selected sites, for estimating their

population density in respective study areas. The technique used in this study was Fractional technique (Oliver and Scheinderman,1956)

In this technique a marked area was searched , visually in case of terrestrial snails and with help of standard sieve in case of aquatic snails , over a measured interval of time.

For studying the density per square meter of the study area, each study area was demarked into three main zones , that is , A, B and C. These three main zones (A,B and C) were again divided into three sub zones of one sq.meter each. That is, A1 ,A2 and A3 ; B1, B2 and B3 ; C1,C2 and C3 by using natural indicators like tree, stones etc. as markers.

These demarked areas were searched once in every one month for 15 minutes by the same collector for avoiding human error. At the end of the 15 minutes , the number of snails collected were recorded. The number of snails collected from these demarked areas were counted and average density per sq.meter per month was calculated.

C. Study of seasonal variation - An year was divided into three seasons, that is , Summer , Rainy seasons and Winter. The average density per sq.meter per month was plotted on graph to get the maximum and minimum density peak through the year studied.

II. STUDY OF PARASITES HARBORED BY SNAILS AND SLUGS -

To study parasites from the snails and slugs , they were brought to laboratory from study areas . The parasites harbored by these snails and slugs were isolated and identified. Monthly infection rate of these parasites in snails and slugs was calculated .

1) Transportation of snails to the laboratory ->

Snails were transported from their habitat to the laboratory, in a plastic container , in which atmosphere was kept humid by placing moist leafy vegetation and little water.

2) Laboratory maintenance of snails for short period ->

A. For aquatic snails - Snails were held in the laboratory for a short period in a glass aquaria which was aerated properly.

B. For terrestrial snails - Snails/slugs were kept in plastic container , having openings for air passages.

3) Examination of snails and slugs for parasites ->

A. For aquatic snails -

a) Isolation method - The snails were placed in water singly, and then exposed to indirect sunlight. The water was then checked once or twice a day for the presence of emerged cercariae.

b) Crushing method - Examination of snails by crushing method was performed as follows -:

i) Three to five snails were placed at intervals near the edge of suitable container , a Syracuse watch glass for the small species and a petri-dish for large ones .

ii) One or two drops of water were added for each crushed snail.

iii) Each snail was minced with a pair of dissecting needles which were wiped after each dissection.

iv) The remains of each snail were examined under the microscope.

v) Questionable objects were placed on a slide and examined with compound microscope.

B. For terrestrial/land snails and slugs -

a) Pepsin digestion method - Isolation of parasitic larval stages from snails and slugs, was carried out as per the method described (Kamath *et al*, 1987).

In this method , snails and slugs were singly mixed with sufficient quantity of 0.2 % Pepsin in 0.7 % HCl, and digested for six hours, at 37°C, The larvae were then concentrated by Baermann's apparatus (Lim and Ramchandran , 1979).

4) Morphological studies of larval stages ->

Cercariae, the larval stages of trematodes, were fixed in 5% formalin and stained with neutral red and mounted in glycerin and observed under the microscope.

Other parasites and larval stages of nematode were fixed in 5% formalin and stained with acetocarmine and mounted in glycerin and observed under the microscope.

5) Identification of parasites and larval stages ->

Trematode cercariae and other parasites were identified on basis of their morphological characters. Larval stages of nematode were identified on their morphological characters and the identification was confirmed by growing adult stage in laboratory animals.

For trematode cercariae the identification key used was from the book 'Animal Parasites' (Wilford Olsen, 1974).

A) Experimental infection in laboratory animals -

For experimental infection with nematode larvae, albino rats were used . These rats were provided by HBPCL animal house.

Eight to ten weeks old albino rats of either sex were orally given , 1 ml of nematode larval suspension (50 L/rat). The rats were fed on laboratory food. The rats were sacrificed after 10 days, 20 days, 30 days and 40 days , post infection . Lungs , brain , heart, digestive system and circulatory system were checked for presence of worms . The worms recovered were mounted in glycerin and morphological characters were studied for identification. Identification was done as per the key (Yamaguti, 1961).

III. SCREENING OF PLANTS FOR MOLLUSCICIDAL ACTIVITY -

1) Selection of plants ->

Review of literature on plant based molluscicides and insecticides was done , and following plants were selected. These plants are very common throughout India. They have been reported to possess insecticidal and medicinal properties (Hussain et al, 1992).

Plant species	part studied
<i>Jatropha curcuss</i> (Mogali erand)	Seeds
<i>Agave americana</i> (Ghypat)	Leaves
<i>Acacia nilotica</i> (Babula)	Fruits
<i>Anacardium occidentale</i> (Kaju)	Seeds

2) Extraction procedure ->

The plant material was brought from the local market. The material was dried and ground to a fine powder and extracted by standard Soxhlet extraction method , with the solvents, methanol, acetone, benzene and petroleum ether. Aqueous extraction was carried out by hot decoction method.

All the extracts were then concentrated by evaporating solvents at their respective boiling points.

The plant extracts thus obtained were stored in the refrigerator till further use for screening their molluscicidal activity.

3) Screening of molluscicidal activity ->

A) For aquatic snails -

Stock solution of 20,000 µg/ml was prepared by dissolving 0.5 gms of extract in 25 ml of distilled water. The insoluble extracts were first dissolved in 0.5 ml of Tween 80 and then mixed with 24.5 ml of distilled water.

Evaluation of molluscicidal activity of these extracts was then carried out as per WHO standard method (WHO, 1961) [TABLE 3] against aquatic snail *Indoplanorbis exustus*.

B) For terrestrial snails/slugs ->

Stock solution of 50 mg/ml was prepared by dissolving 5 gms of extracts in 100 ml of distilled water. The insoluble extracts were first dissolved in 1 ml of Tween 80 and then mixed with 99 ml of distilled water.

Evaluation of molluscicidal activity of these extracts was then carried out as per the standard WHO method (WHO, 1961) [TABLE 3] against vector slug *Laevicaulis alte* .

TABLE 3**FLOW CHART FOR MOLLUSCICIDAL SCREENING (W.H.O. STANDARD METHOD).**

SNAIL SOURCE	Laboratory reared snails or uninfected local snails
Nature of container	500 ml beakers for aquatic snails, Petri dish (150 x 75mm) for land snails.
Volume / snail	40 ml water for aquatic snails, 10 ml water for land snail.
No of containers	4 containers at each concentration with 5 snails each.
Snail age	Young and mature snails with uniform size and weight. In our experiments we used aquatic snails of 3-4 mm in length and 400-500 mg in weight and land snails of 2-3 cm in length and 1.5-2.5 gms in weight.
Water	Dechlorinated tap water.
Concentration	Dilution series of 50 to 500 µg/ml for aquatic snails and 10 to 200 mg/ml for land snails.
Light	Normal diurnal light changes.
Temperature	Room temperature.
Period of exposure	24 hours
Washing	Rinsing under tap water
Recovery period	24 hours
Criteria of death	By examination (discoloration, activity of muscles) and/or by crushing.
Snail control	2 containers with 5 snails at lower and higher concentration and for solvents.
Molluscicidal control	Copper sulphate was used as standard molluscicide.
Determination of LC50 and LC90	Plotting concentration - mortality graph on probit graph paper (Litchfield and Wilcoxon, 1949).

RESULTS

I. SNAIL POPULATION STUDIES-

1) General survey ->

A) Aquatic snails -: Following species of aquatic snails were observed to be prevalent in all the aquatic locations studied.

i) *Indoplanorbis exustus* (Figure 1)

Phylum - Mollusca

Class - Gastropoda

Subclass - Pulmonata

Order - Basommatophora

Family - Planorbidae

Subfamily - Bulinae

Genus - *Indoplanorbis*

Shell is discoidal, large and thick. Sutures are deeply impressed. Aperture is ear shaped. Animal is sinistral. Foot is relatively broad and short, leaf shaped, broadly rounded anteriorly and pointed posteriorly. Branchial process is lobed.

Total number collected : - 1283.

Average weight : - 0.25 gms.

Average length of the shell : - 5 mm.

Distribution in Bombay area -> It had been found in Powai , Vihar and Irla lake through out the year.

ii) *Bellamya bengalensis* (Figure 2)

Phylum - Mollusca

Class - Gastropoda

Subclass - Prosobranchia

Order - Mesogastropoda

Family - Viviparidae

Subfamily - Bellamyinae

Genus - *Bellamyia*

Shell is thin, more or less smooth, with three or more color bands. Embryonic shell delicate and thin with three primary rows of cheatae. The ridges are low. The lower most is well developed, sometimes developing in to a keel.

Total number collected : - 1278.

Average weight : - 1 gms.

Average length of the shell : - 1.5 cms.

Distribution in Bombay area -> It had been found in Powai and Vihar lake through out the year.

iii) *Lymnaea luteola* (Figure 3)

Phylum - Mollusca

Class - Gastropoda

Subclass - Pulmonata

Order - Basommatophora

Family - Planorbidae

Subfamily - Lymnidae

Genus - *Lymanaea*

Shell is generally thin. Body whorl is large. Spire of shell is not much pointed. Shell is ovate with a narrow ovate aperture.

Total number collected : - 49.

Average weight : - 0.075 gms.

Average length of the shell : - 1 cms.

Distribution in Bombay area -> In Bombay It had been only found in Powai lake.

iv) *Thira tuberculata* (Figure 4)

Phylum - Mollusca

Class - Gastropoda

Subclass - prosobranchia

Order - Mesogastropoda

Family - Thiaridae

Subfamily - Thiarinae

Genus - *Thira*

Shell is with high spire and moderately large body whorl. Whorls are evenly rounded. Shell surface has dark red brown dots and flames, either irregularly distributed or longitudinally arranged on the shell surface. Shell surface is sculptured with vertical ribs and spiral striae, distinct and raised on the upper whorls, but flatter on lower ones.

Total number collected : - 663.

Average weight : - 0.2 gms.

Average length of the shell : -1.2 cms.

Distribution in Bombay -> It had been found prevalent in Powai lake and Sion-Dharavi sewage canal.

v) *Paludomus obesus* (Figure 5)

Phylum - Mollusca

Class - Gastropoda

Subclass - Prosobranchia

Order - Mesogastropoda

Family - Thiariidae

Subfamily - Paludominae

Genus - *Paludomus*

Shell is strong, oblong-globose. Aperture is larger than the spire. Inner lip or columella is very thick.

Total number collected : - 1447.

Average weight : - 0.25 gms.

Average length of the shell : - 6 mm.

Distribution in Bombay -> It had been observed in Sion-Dharavi sewage canal and Borivali National Park river.

vi) *Gabbia orcula* (Figure 6)

Phylum - Mollusca

Class - Gastropoda

Subclass - Prosobranchia

Order - Mesogastropoda

Family - Bithyniidae

Subfamily - Bithyniinae

Genus - *Gabbia*

Shell is more or less globosely conic with some what tumid whorls.
Body whorls are four and large. Sutures are wide, imperforate. Operculum is thick and calcareous.

Total number collected : - 6.

Average weight : - 0.015 gms.

Average length of the shell : - 2 mm.

Distribution in Bombay area -> It had been found only ones in the month of August at Powai lake.

vii) *Turbinicola saxea* (Figure 7)

Phylum - Mollusca

Class - Gastropoda

Subclass - Prosobranchia

Order - Mesogastropoda

Family - Pilidae

Genus - *Turbinicola*

Shell is small and regularly ovate. Aperture relatively high and narrow.
Generally found in Hill streams. The lung is well developed and more efficient.

Total number collected : - 357.

Average weight : - 2 gms.

Average length of the shell : - 1 cms.

Distribution in Bombay -> It had been observed only at Borivali National Park river.

B) Terrestrial snails/slugs -:

Following species of terrestrial snails and slugs were found prevalent in Bombay area.

i) *Laevicaulis alte* (Figure 8)

Phylum - Mollusca

Class - Gastropoda

Order - Systellommatophora

Family - Veronicellidae

Genus - *Laevicaulis*

It's body is generally black on the dorsal surface. It doesn't have external shell. It is nocturnal and during day it generally hides under foliage or debris avoiding direct sunlight. It frequents damp and wet places. It is common pest in vegetable garden.

Total number collected : - 4293.

Average weight : -4 gms.

Average length: -3 cms.

Distribution in Bombay area -> It had been observed in all the terrestrial habitats studied.

ii) *Achatina fulica* (Figure 9)

Phylum - Mollusca

Class - Gastropoda

Subclass - Pulmonata

Order - Stylammatophora

Family - Achatinidae

Subfamily - Achatininae

Genus - *Achatina*

Shell ovate conoid and pale yellowish, streaked transversely with brown, some what glossy bands. Spire is convex. Suture is impressed and apex is acute. Whorls are 8 in no. and convex. It is much common agricultural pest in Bombay and neighborhood.

Total number collected : - 1852.

Average weight : - 28 gms.

Average length of the shell : - 3 cms.

Distribution in Bombay area -> It had been present at Museum garden , Fort, Shivaji park garden, Dadar and Ram mandir garden, Borivali.

iii) *Macrochlymus indica* (Figure 10)

Phylum - Mollusca

Class - Gastropoda

Subclass - Pulmonata

Order - Stylommatophora

Family - Ariophantidae

Subfamily - Macrochlaymidinae

Genus - *Macrochlymus*

Shell is perforate, depressed and smooth. Shell color is translucent, pale brownish tawny. Shell is not distinctly striated but with microscopic longitudinal impressed lines. Spire is low and conoid. Suture is slightly impressed. Whorls are 5 and 1/2, slightly convex above.

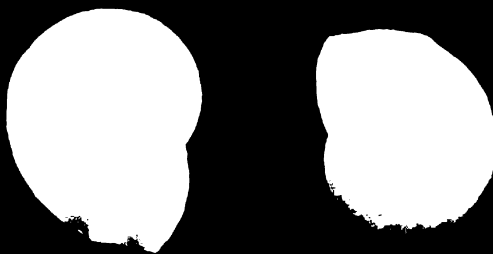


FIGURE 1 - *Indoplanorbis exustus*



FIGURE 2 - *Bellamya bengalensis*



FIGURE 1 - *Indoplanorbis exustus*

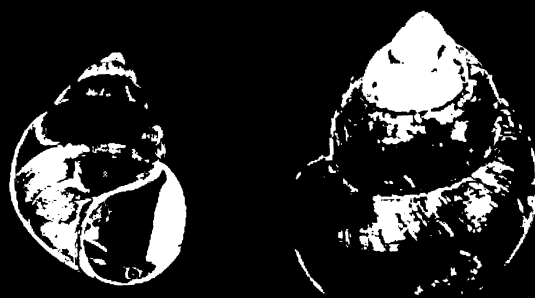


FIGURE 2 - *Bellamya bengalensis*



FIGURE 3 - *Lymnea luteola*



FIGURE 4 - *Thira tuberculata*



FIGURE 5 - *Paludomus obesus*

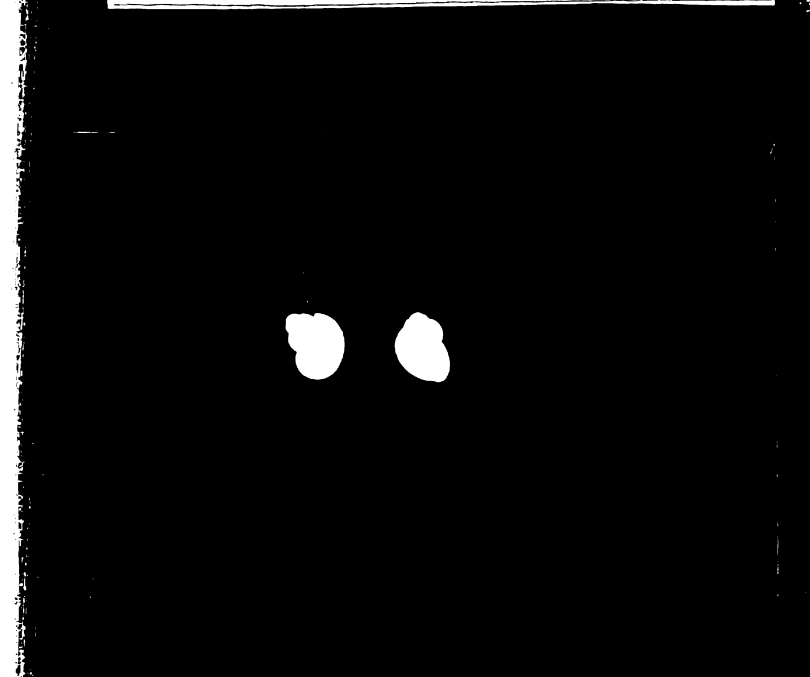


FIGURE 6 - *Gabbia orecula*



FIGURE 7 - *Turbinicola saxea*

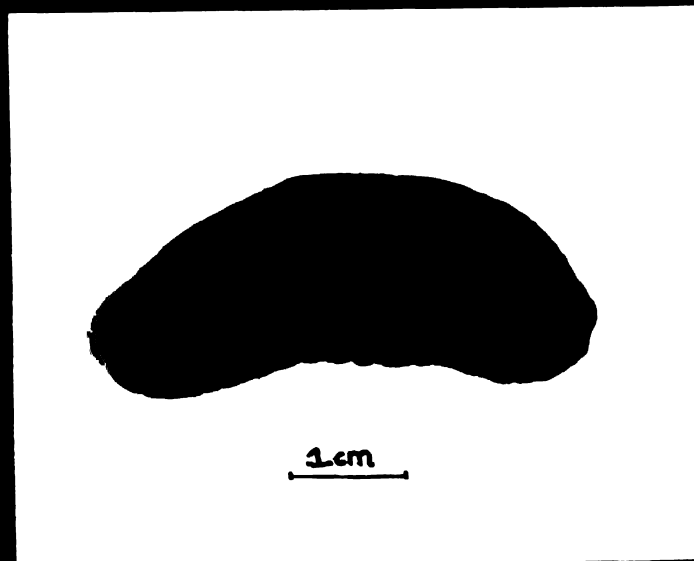


FIGURE 8 - *Laevicaulis alte*

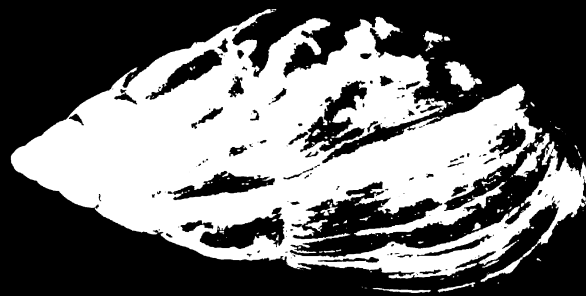


FIGURE 9 - *Achatina fulica*



Total number collected : - 1033.

Average weight : - 0.5 gms.

Average length of the shell : - 8 mm.

Distribution in Bombay area -> It had been observed in all the habitats studied.

II. STUDY OF THE PARASITIC LARVAL STAGES HARBORED BY SNAILS AND SLUGS -:

Larval stages of three parasite species were harbored by snails in Bombay area. These were harbored by *Indoplanorbis exustus*, *Bellamya bengalensis*, *Lymnaea luteola*, *Achatina fulica* and *Laevicaulis alte*. Other species of snails did not show any presence of parasites. The parasites recorded were as below -:

1) Amphistome cercariae -> (Figure 11)

Amphistomes cercaria which causes Amphistomiasis in ruminants was observed in *Indoplanorbis exustus* from Powai and Irla lake, and in *Lymnaea luteola* from Powai lake.

These cercariae are characterised by the presence of ventral sucker, which is the larger and is located at the posterior end of the body. They are the largest of the cercariae. There are two types, pigmenta with stellate melanophores and diplocotylea with abundant pigmentation in the anterior region of the body.

2) Larval stages of nematomorpha (Horse hair worm) -> (Figure 12)

Larval stages of nematomorpha were observed in *Bellamyia bengalensis* and *Indoplanorbis exustus* from Powai lake. These resemble with the horse hair and hence are commonly called as horse hair worm. They are narrow and dark brown in color. They possess a degenerate, non-functional digestive tract. Anterior end is translucent with a dark ring behind the clear area. The posterior end is bi-furcate in male.

3) Larval stage of *Angiostrongylus cantonensis* -> (Figure 13)

Third stage larvae of *Angiostrongylus cantonensis* were isolated from *Achatina fulica*, *Laevicaulis alte* and *Macrochlamys indica* from Museum garden, Fort and in *Achatina fulica* and *Laevicaulis alte* from Ram mandir garden, Borivali. Prevalence of *A.cantonensis* was also observed in *Laevicaulis alte* from Nandadeep garden, Bandra and Haffkine institute campus, Parel.

Third stage larvae showed the rhabditoid esophagus with cuticular lining, nerve ring, excretory pore and anus. The genital rudiment was situated at approximately two third of the body length from the posterior end. The intestine tapered sharply from behind the esophagointestinal junction, extending to the anus as a narrow structure between two sub ventral glands.

Experimental infection of third stage larvae of *A.cantonensis* in rats :-

Third stage larvae were given orally to four batches of ten rats each. After 10,20,30 and 40 days post infection one batch of rats was checked for

the presence of parasites respectively. The nervous, respiratory and circulatory systems were checked for the presence of worms. After 30th day, worms were recovered from the brains of rats (Figure 14). They were identified as fifth stage larvae of *A.cantonensis*. After 40 days post infection adult worms were recovered from heart and lungs of the rats (Figure 15). They were identified as *A.cantonensis* on the basis of morphological characters. These are narrated below.

Morphological description -

Body is filariform and tapers slightly at both ends. Epidermis is smooth and bears transverse striae, transparent when alive. The head is simple, possessing three lips (Figure 16).

Male - (Average length - 1 cm) Caudal bursa is well developed, kidney shaped, single lobed. Bursal rays are well developed (Figure 16 a).

Female - (Average length - 1.6 cm) In living specimens, the milky white uterine tubules are spirally wound around the intestine and can be seen through transparent cuticle as a 'barber's pole' pattern (Figure 16 b).

A single thin walled vagina commences at the junction of the uterine tubules, extends posteriorly and opens at the vulva. The posterior end of the female doesn't have a minute projection at the tip of the tail.

III. SEASONAL VARIATION IN POPULATION DENSITY AND INFECTION

RATE OF DIFFERENT SNAIL SPECIES AT DIFFERENT LOCATIONS :-

1) Aquatic habitat ->

FIGURE 11 - Amphistome cercaria



FIGURE 12 - Posterior end of Nematomorpha

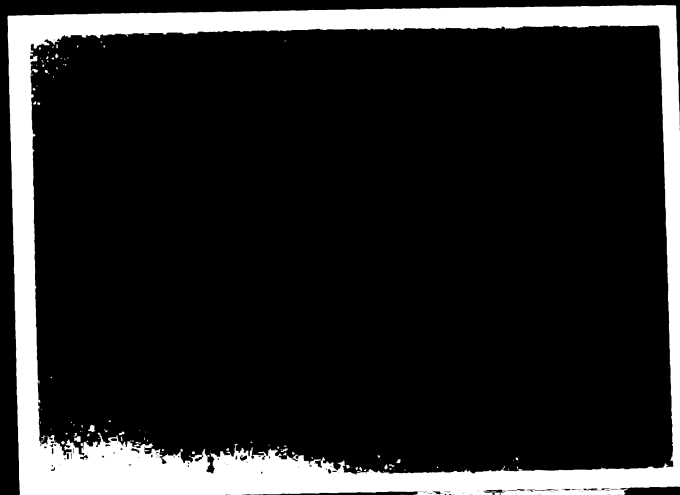


FIGURE 13 - 3rd stage larva of *Angiostrongylus cantonensis*



FIGURE 14 - 5th stage larva of *A. cantonensis* in brain of exp. rat



FIGURE 15 - Adult *A. cantonensis* in lung and heart of exp. rat



FIGURE 16 - Anterior end of *A. cantonensis*



FIGURE 16a-

Posterior end of

female *A. cantonensis*

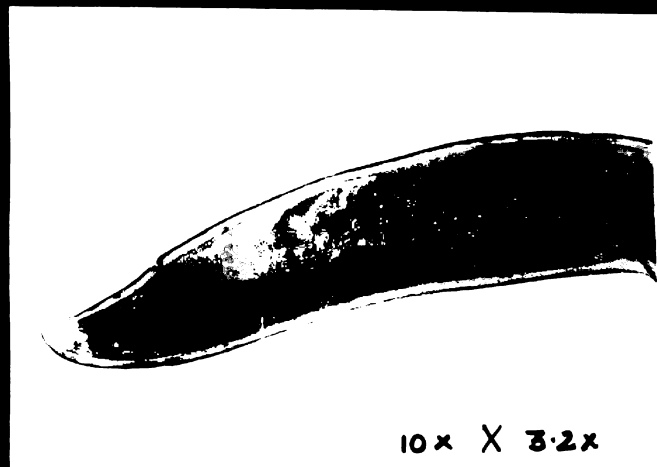
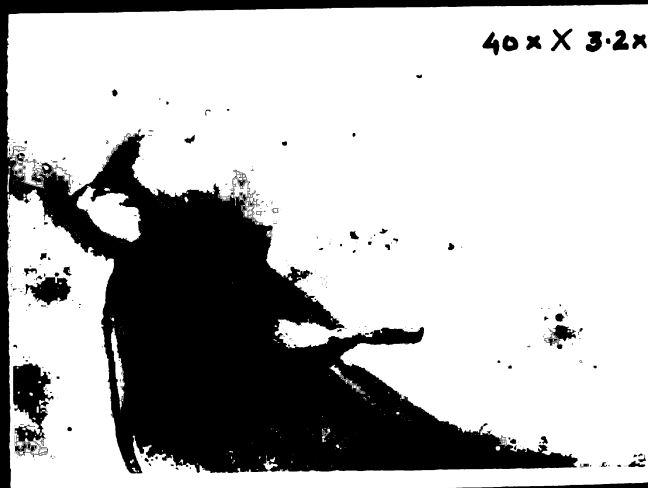


FIGURE 16b-

Posterior end of

male *A. cantonensis*



Tables 8 and 8A show snail population and infection rate of Amphistome cercaria at Irla lake, during the period January-December 1994. Figure 17 shows the seasonal variation in snail population and Amphistome infection at Irla lake.

Annual snail population and infection rate of Amphistome cercariae along with Nematomorpha sp. during the year 1994, at Powai lake is shown in Tables, 9,9A and 9B respectively. Seasonal variation in snail population and parasite load are also expressed in Figures 18,18A and 18B.

Tables 10,11 and 12 and Figures 19,20 and 21, reveal the actual snail population and its seasonal variation at Vihar lake, Sion-Dharavi Sewage canal and Borivali national Park river respectively.

2) Terrestrial habitat ->

Tables 13 and 13A show actual snail population and infection rate of *A.cantonensis* during the year 1994. Figure 22 shows the seasonal variation of snail population and *A.cantonensis* infection rate during January-December 1994.

Actual snail population and *A.cantonensis* infection rate at Haffkine Institute in 1994 has been shown in Tables 14 and 14A. Seasonal variation of the same can be seen in Figure 23.

Table 15 and Figure 24 show the snail population and its seasonal variation during the year 1994 at Shivaji park garden, Dadar.

Snail population and infection rate of *A.cantonensis* at Nandadeep garden, Bandra and Ram Mandir garden, Borivali has been shown in Tables 16, 17, 16A and 17a respectively.

Figures 25 and 26 show the seasonal variation of the snail population and *A.cantonensis* infection during the year 1994 at Nandadeep garden, Bandra and Ram Mandir garden, Borivali.

IV. SCREENING OF PLANTS FOR MOLLUSCICIDAL ACTIVITY -:

Four indigenous plants, viz., *Jatropha curcuss*, *Agave americana*, *Acacia nilotica* and *Anacardium occidentale* were studied for their molluscicidal activity against aquatic snail sp. *Indoplanorbis exustus* and a species of land slug *Laevicaulis alte*.

LC₅₀ and LC₉₀ values of these plant extracts were calculated by probit graph method. Copper sulphate was used as standard molluscicide. Results are given in Table 18 and 19.

TABLE 4

Area wise percentage of aquatic snail species collected from Bombay during Jan 94 to Dec 94.

AREA	Total snails collect ed	PERCENTAGE OF DIFFERENT SNAIL SPECIES COLLECTED						
		<i>I.exust.</i>	<i>B.benga</i>	<i>T.tuberc.</i>	<i>L.luteola</i>	<i>G.orecula</i>	<i>P.obesus</i>	<i>T.saxea</i>
Irla lake	1068	47.16	52.84	-	-	-	-	-
Powai lake	2172	42.35	41.12	11.45	4.84	0.24	-	-
Vihar lake	863	36.79	31.83	31.38	-	-	-	-
Sion-Dha. sewage	295	-	-	22.40	-	-	77.60	-
Borivali National Park river	683	-	-	-	-	-	64.87	35.13
Total	5081	25.26	25.16	13.05	0.97	0.05	28.48	7.03

TABLE 5

Month wise percentage of aquatic snail species collected from Bombay during Jan 94 to Dec 94.

MONTHS	Total snails collect ed	PERCENTAGE OF DIFFERENT SNAIL SPECIES COLLECTED						
		<i>I.exust.</i>	<i>B.benga.</i>	<i>T.tuberc.</i>	<i>L.luteola</i>	<i>G.orecula</i>	<i>P.obesus</i>	<i>T.saxea</i>
JAN	334	64.02	27	7.86	1.12	-	-	-
FEB	382	47.53	19.64	32.70	0.13	-	-	-
MAR	399	40.63	21.86	20.60	1.92	-	15	-
APR	344	30.13	15.66	21.73	2.07	-	30	-
MAY	352	24.92	19.83	17.35	0.98	-	36.92	-
JUN	476	14.21	31.18	17.98	0.47	-	24.54	11.61
JUL	432	9.78	41.87	6.82	1.61	-	25.17	14.83
AUG	528	8.44	42.85	11.82	-	-	21.82	15.07
SEP	669	21.05	26.14	16.96	0.78	-	20.51	14.56
OCT	506	31.82	20.64	6.69	0.28	0.57	26.51	13.49
NOV	387	27.16	26.47	5.22	1.15	-	25.26	14.74
DEC	272	39.45	47.93	9.39	3.23	-	-	-
TOTAL	5081	25.26	25.16	13.05	0.97	0.05	28.48	7.03

TABLE 6

**AREA WISE PERCENTAGE OF TERRESTRIAL SLUG / SNAIL SPECIES
COLLECTED FROM BOMBAY DURING JAN 94 TO DEC 94**

AREA	TOTAL SNAILS COLLECTED	PERCENTAGE OF SNAILS SPECIES COLLECTED		
		<i>A. fulica</i>	<i>L. alte</i>	<i>M. indica</i>
Museum Garden, Fort	2504	34.84	54.19	10.97
Haffkine Institute Campus	442	-	83.86	16.14
Shivaji Park Garden	1542	41.18	50.09	8.73
Nandadeep Garden, Bandra	865	-	66.58	33.42
Ram Mandir Garden, Borivali	1826	52.94	44.33	2.73
TOTAL	7179	25.80	59.81	14.39

TABLE 7

**MONTH WISE PERCENTAGE OF TERRESTRIAL SLUG / SNAIL SPECIES
COLLECTED FROM BOMBAY DURING JAN 94 TO DEC 94**

MONTHS	TOTAL SNAILS COLLECTED	PERCENTAGE OF SNAILS COLLECTED		
		<i>A. fulica</i>	<i>L. altae</i>	<i>M. indica</i>
Jan	446	27.78	54.64	17.58
Feb	561	21.65	63.08	15.27
Mar	639	24.88	66.92	8.20
Apr	798	27.37	66.18	6.45
May	735	23.16	69.26	7.58
Jun	496	17.65	75.72	6.63
Jul	551	19.68	58.40	21.92
Aug	648	29.40	45.44	25.16
Sep	703	33.85	41.28	24.87
Oct	668	31.41	45.09	23.50
Nov	531	27.20	63.78	9.02
Dec	403	25.49	69.76	4.75
TOTAL	7179	25.80	59.81	14.39

TABLE - 8

MONTH WISE PERCENTAGE OF SNAILS SPECIES COLLECTED FROM IRLA LAKE

MONTHS	SPECIES WISE PERCENTAGE		DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>I. exustus</i>	<i>B. bengalensis</i>		
Jan	61.39	38.61	11	101
Feb	66.06	33.94	12	109
Mar	61.21	38.79	13	116
Apr	64.29	35.71	9	84
May	71.19	28.81	7	59
Jun	40.96	59.04	10	83
Jul	21.59	78.41	10	88
Aug	12.50	87.50	8	72
Sep	23.47	76.53	11	98
Oct	33.33	66.67	10	90
Nov	51.14	48.86	10	88
Dec	51.74	41.25	9	80

TABLE 8 A

**MONTHLY INFECTION RATE (%) OF *Amphistome* SPECIES IN
SNAIL/SLUG SPECIES FROM IRLA LAKE.**

MONTHS	<i>I. exustus</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	-	50
Feb	-	50
Mar	-	50
Apr	6	50
May	-	50
Jun	-	50
Jul	-	50
Aug	10	50
Sep	12	50
Oct	10	50
Nov	-	50
Dec	-	50
TOTAL	3.16	600

PERIOD OF STUDY = JAN - DEC 1994.

FIGURE 17 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL POPULATION AND
INFECTION RATE OF IRLA LAKE DURING JAN - DEC 1994.

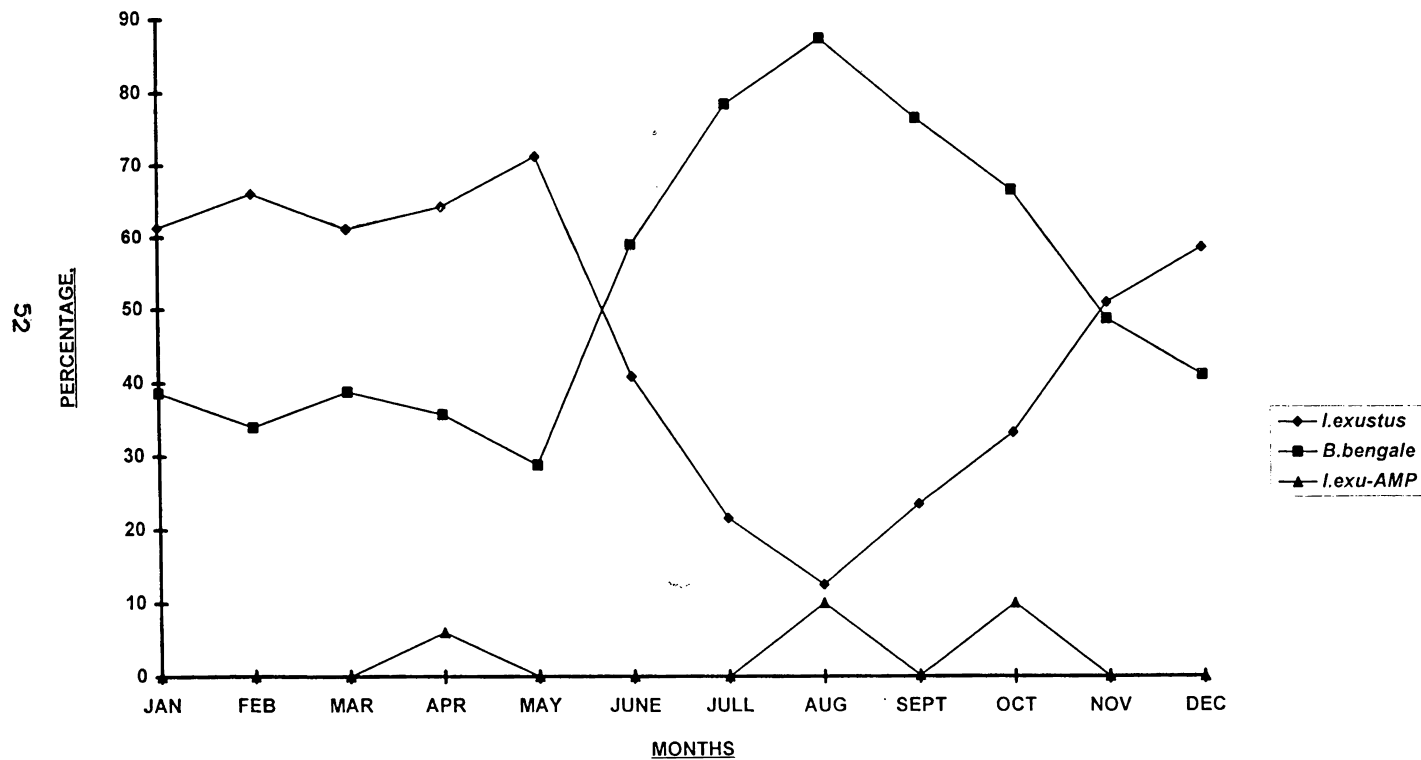


TABLE -9

MONTH WISE PERCENTAGE OF SNAILS SPECIES COLLECTED FROM POWAI LAKE

MONTHS	SPECIES WISE PERCENTAGE				DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLEC TED
	<i>I. exustus</i>	<i>B. bengale nsis</i>	<i>T. tubercul ata</i>	<i>L. luteola</i>		
Jan	63.42	26.86	6.29	3.43	19	175
Feb	66.49	24.08	8.90	0.53	21	191
Mar	55.99	26.79	9.56	7.66	23	209
Apr	53.05	21.95	14.63	10.37	19	164
May	35.37	38.41	21.34	4.88	19	164
Jun	22.75	48.34	26.54	2.37	26	211
Jul	13.87	71.53	6.57	8.03	15	137
Aug	18.30	77.12	4.58	0	17	153
Sep	50.20	32.94	12.54	3.92	27	255
Oct	64.62	21.22	9.90	1.42	22	212
Nov	40.38	44.23	9.62	5.77	18	156
Dec	23.45	60.00	6.90	9.65	16	145

PERIOD OF STUDY = JAN - DEC 1994.

REMARKS: *G. oreola* was observed once in a month of October, six specimens collected, (2.84%)

FIGURE 18 = SHOWING SEASONAL RISE AND FALL OF SNAIL POPULATION FROM POWAI LAKE
DURING JAN-DEC 1994.

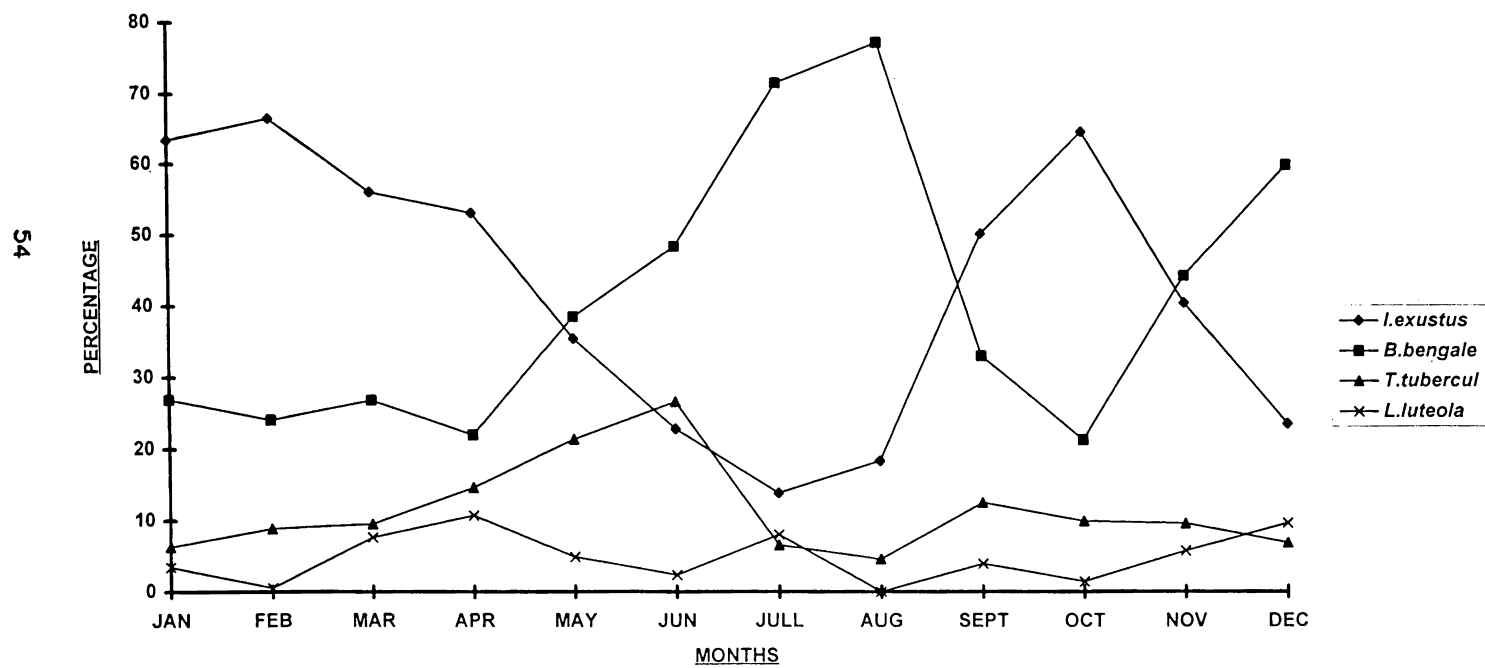


TABLE 9 A

MONTHLY INFECTION RATE (%) OF *Amphistome* CERCARIAE IN SNAIL/SLUG SPECIES FROM POWAI LAKE.

MONTHS	<i>I.exustus</i>	<i>L.luteola</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	-	-	50
Feb	10	-	50
Mar	6	-	50
Apr	4	-	50
May	8	20	50
Jun	6	10	50
Jul	2	10	50
Aug	4	-	50
Sep	16	10	50
Oct	22	-	50
Nov	-	-	50
Dec	-	-	50
TOTAL	6.5	4.16	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE 9 B

MONTHLY INFECTION RATE (%) OF *Nematomorpha* SPECIES IN SNAIL/SLUG SPECIES FROM POWAI LAKE.

MONTHS	<i>I.exustus</i>	<i>B.bengalensis</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	-	36	50
Feb	-	28	50
Mar	-	32	50
Apr	-	22	50
May	-	34	50
Jun	-	10	50
Jul	-	40	50
Aug	10	62	50
Sep	14	48	50
Oct	-	14	50
Nov	-	24	50
Dec	-	24	50
TOTAL	2	31.16	600

PERIOD OF STUDY = JAN - DEC 1994.

FIGURE 18 A = SHOWING SEASONAL RISE AND FALL OF SNAIL *I.exustus* AND IT'S INFECTION RATE FROM POWAI LAKE DURING JAN-DEC 1994.

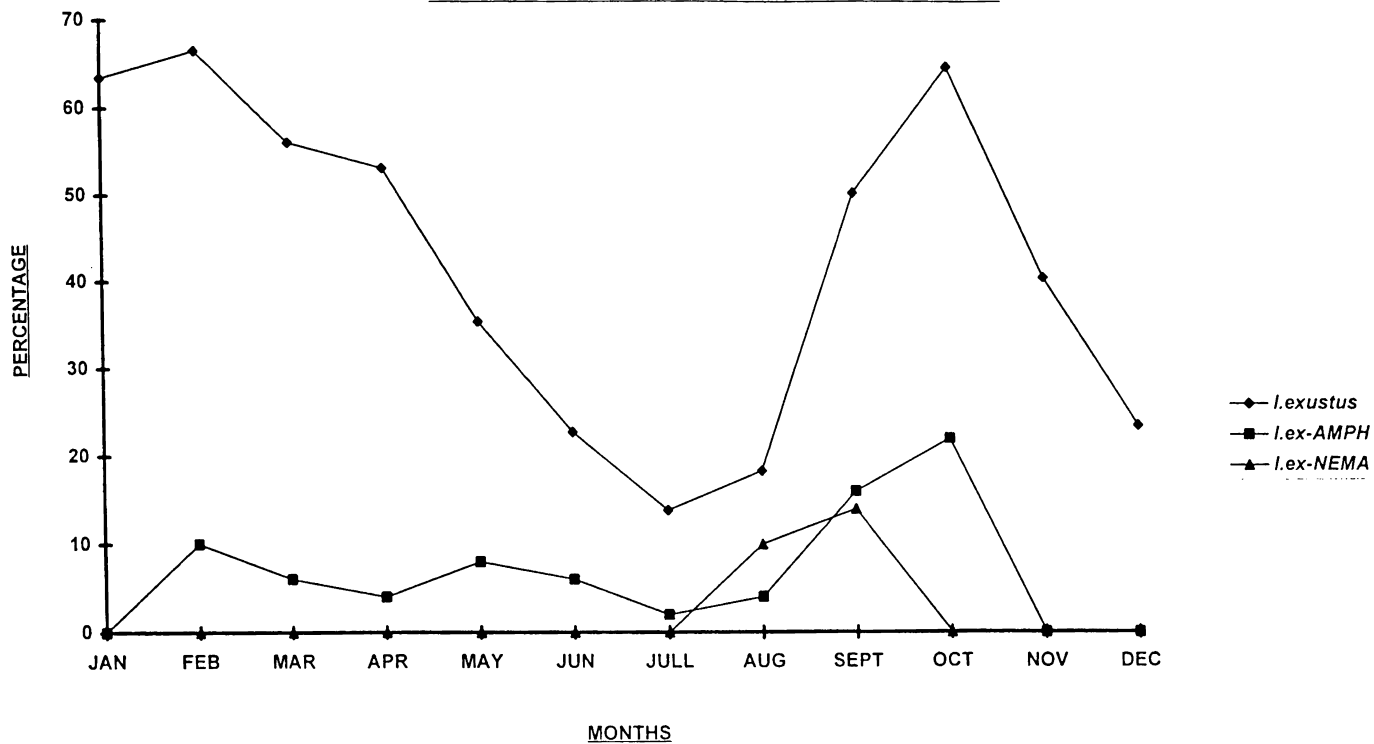


FIGURE 18 B = SHOWING SEASONAL RISE AND FALL OF SNAIL POPULATION AND INFECTION
RATE FROM POWAI LAKE DURING JAN-DEC 1994.

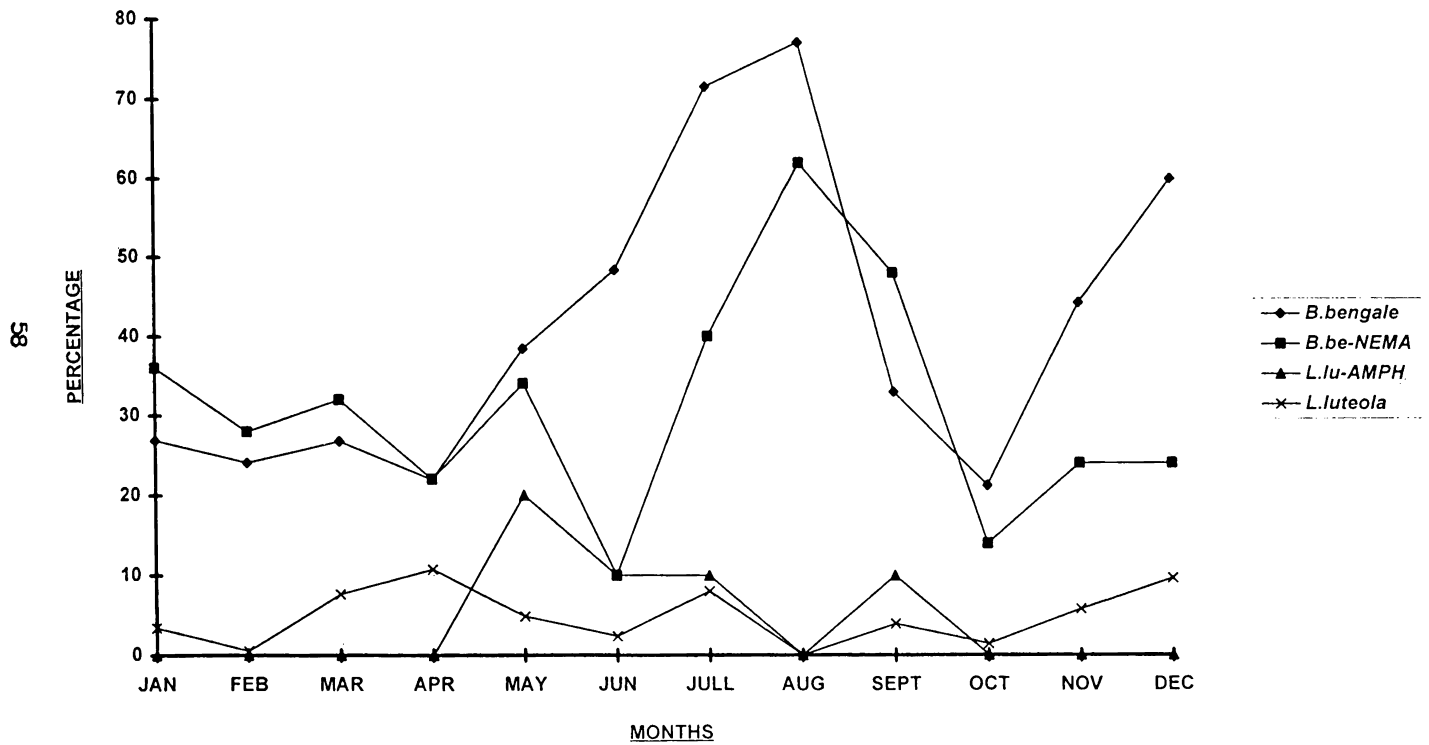


TABLE -10

MONTH WISE PERCENTAGE OF SNAILS SPECIES COLLECTED FROM VIHAR LAKE

MONTHS	SPECIES PERCENTAGE WISE			DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>I. exus.</i>	<i>B. bengal.</i>	<i>T. tuber.</i>		
Jan	67.24	15.52	17.24	6	58
Feb	57.53	20.55	21.92	9	73
Mar	45.31	21.87	32.82	7	64
Apr	33.33	20.63	44.04	7	63
May	18.05	31.95	50.00	8	72
Jun	7.35	48.53	44.12	8	68
Jul	13.04	59.42	27.54	7	69
Aug	11.42	45.63	34.95	11	103
Sep	36.59	20.73	42.68	9	82
Oct	61.18	15.29	23.53	9	85
Nov	44.30	39.24	16.46	9	79
Dec	36.17	42.55	21.28	6	47

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 19 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL POPULATION OF VIHAR
LAKE DURING JAN - DEC 1994.

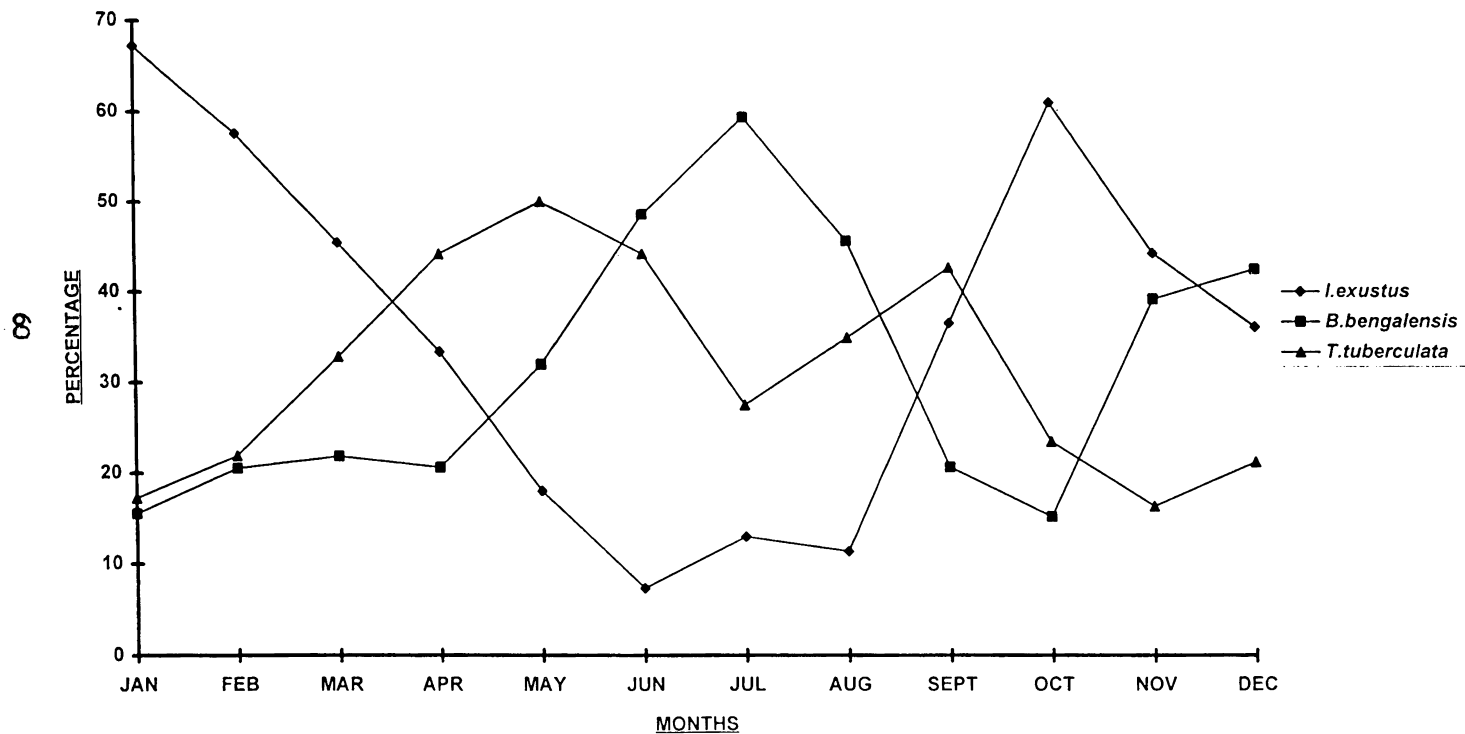


TABLE - 11

**MONTH WISE PERCENTAGE OF SNAILS SPECIES COLLECTED FROM
SION DHARAVI SEWAGE CANAL**

MONTHS	SPECIES WISE PERCENTAGE		DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>T.tuberculata</i>	<i>P.obesa</i>		
Jan	-	-	-	-
Feb	100	-	1	9
Mar	40	60	1	10
Apr	50	50	3	24
May	15.39	84.61	5	39
Jun	19.23	80.77	6	52
Jul	-	100	2	18
Aug	19.57	80.43	5	46
Sep	24.56	75.44	7	57
Oct	-	100	4	33
Nov	-	100	1	7
Dec	-	-	-	-

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 20 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL POPULATION OF SION-DHARAVI SEWAGE CANAL DURING JAN-DEC 1994.

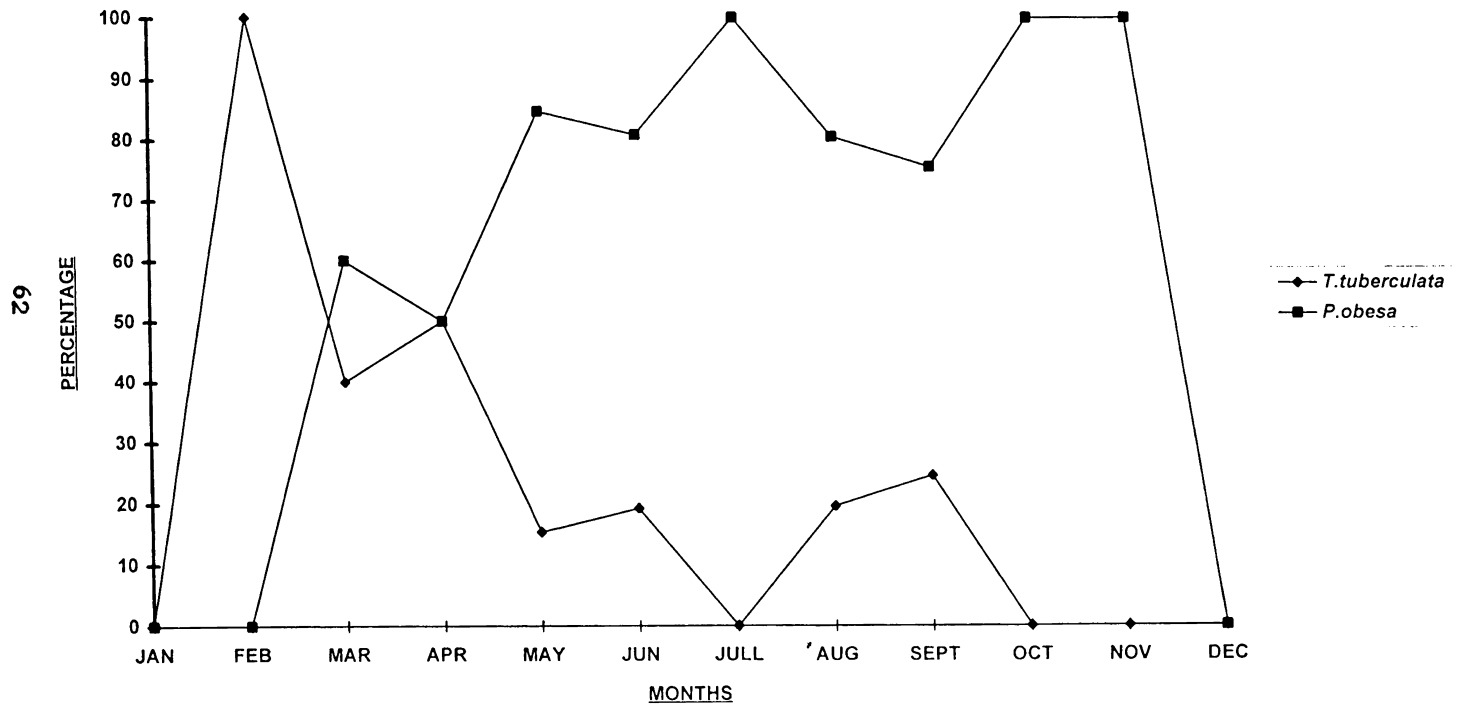


TABLE 12

**MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM
BORIVALI NATIONAL PARK RIVER**

MONTHS	SPECIES WISE PERCENTAGE		DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>T. saxea</i>	<i>P.obesa</i>		
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	100	1	9
May	-	100	2	18
Jun	58.06	41.94	7	62
Jul	74.17	25.83	13	120
Aug	75.32	24.68	16	154
Sep	72.88	27.12	19	177
Oct	67.44	32.56	10	86
Nov	73.68	26.32	7	57
Dec	-	-	-	-

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 21 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL POPULATION OF BORIVALI NATIONAL PARK RIVER DURING JAN-DEC 1994.

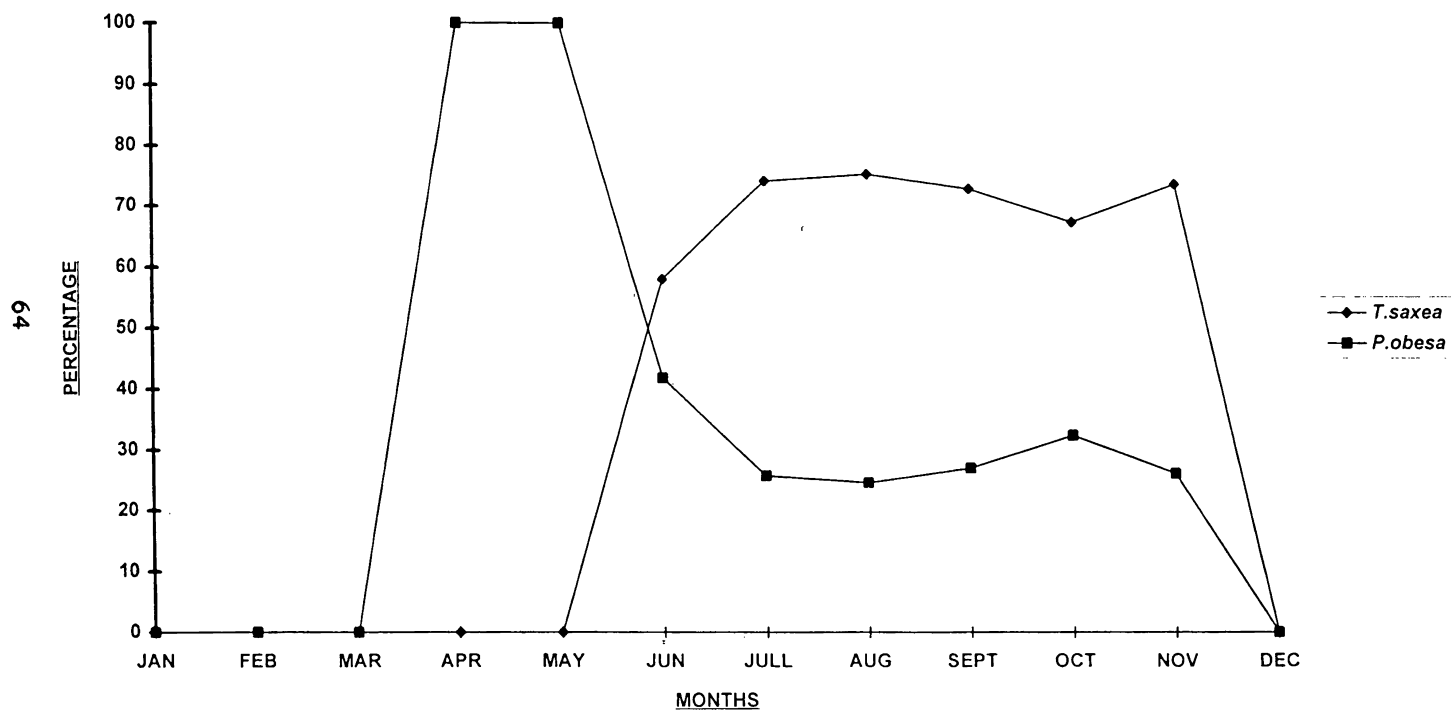


TABLE 13

**MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM
MUSEUM GADEN, FORT**

MONTHS	SPECIES WISE PERCENTAGE			DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>A. fulica</i>	<i>M. indica</i>	<i>L. alte</i>		
Jan	31.82	12.73	55.45	12	110
Feb	31.49	10.50	58.01	20	181
Mar	40	8.40	51.60	28	250
Apr	40.87	8.98	50.15	36	323
May	37.29	8.58	54.13	32	303
Jun	23.89	5.56	70.55	20	180
Jul	28.11	12.97	58.92	21	185
Aug	44.02	12.92	43.06	22	209
Sep	46.72	18.34	34.94	27	229
Oct	41.29	15.28	52.43	29	264
Nov	27.59	13.21	59.20	20	174
Dec	25	4.17	70.83	12	96

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 22 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL/SLUG POPULATION OF
THE MUSEUM GARDEN , FORT DURING JAN-DEC 1994.

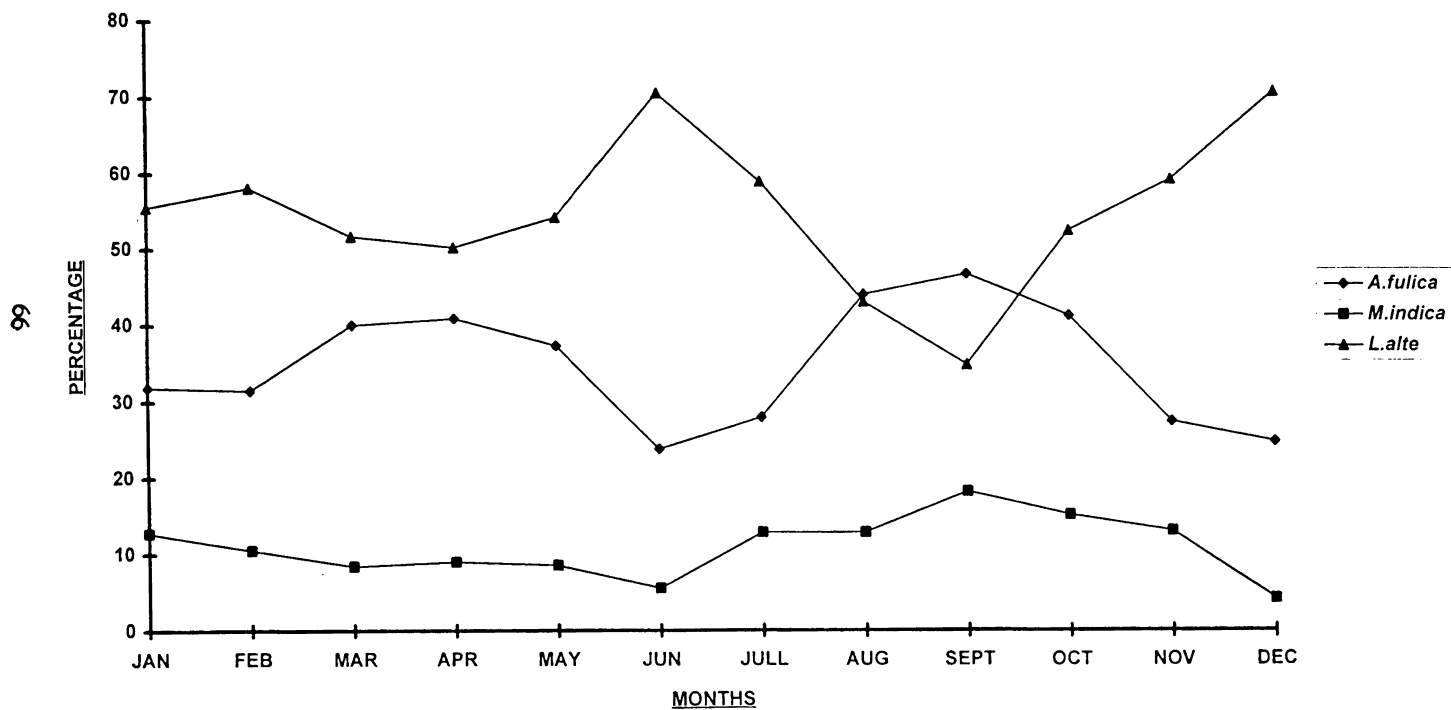


TABLE 13 A

**MONTHLY INFECTION RATE (%) OF *Angiostrongylus cantonensis* IN
SLUG / SNAIL SPECIES OF MUSEUM GARDEN, FORT.**

MONTHS	<i>A. fulica</i>	<i>M.indica</i>	<i>L. alte</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	-	-	4	50
Feb	-	-	16	50
Mar	12	-	28	50
Apr	24	8	44	50
May	20	16	36	50
Jun	-	-	30	50
Jul	-	4	32	50
Aug	24	20	22	50
Sep	26	20	12	50
Oct	-	-	44	50
Nov	-	-	34	50
Dec	-	-	6	50
TOTAL	8.83	5.66	25.33	600

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 22 A = SHOWING THE SEASONAL RISE AND FALL OF THE INFECTION RATE OF
A.cantonensis IN SLUG/SNAIL POPULATION FROM MUSEUM GARDEN, FORT DURING JAN-DEC
 1994.

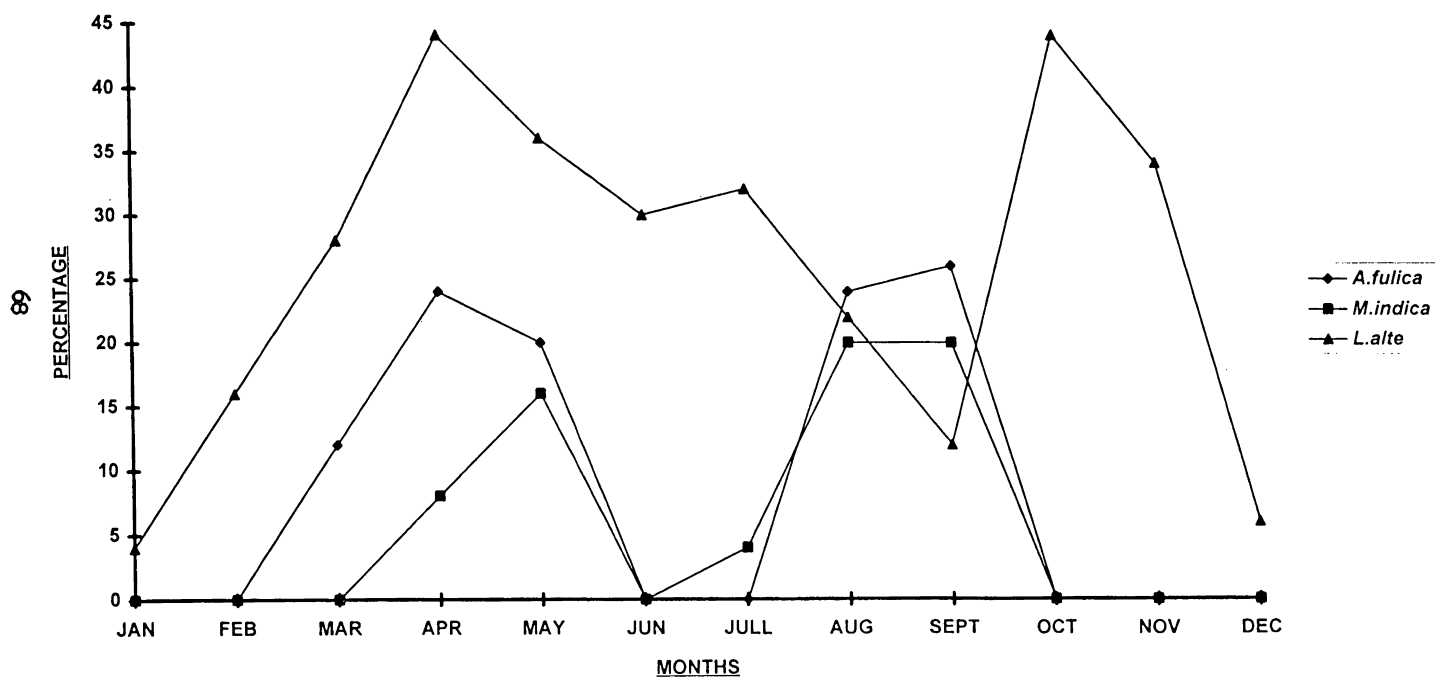


TABLE 14

**MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM
HAFFKINE INSTITUTE CAMPUS**

MONTHS	SPECIES PERCENTAGE		DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>M. indica</i>	<i>L. alte</i>		
Jan	34.78	65.22	3	23
Feb	25	75	4	32
Mar	-	100	2	20
Apr	-	100	4	32
May	-	100	4	37
Jun	-	100	2	13
Jul	33.34	66.66	6	51
Aug	32.88	67.12	8	73
Sep	33.72	66.28	9	86
Oct	34	66	6	50
Nov	-	100	2	19
Dec	-	100	1	6

PERIOD OF STUDY = JAN - DEC 1994

TABLE 14 A

**MONTHLY INFECTION RATE (%) OF *Angistrongylus cantonensis* IN
SNAIL/SLUG SPECIES FROM HAFKINE INSTITUTE, CAMPUS.**

MONTHS	<i>L.alte</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	20	50
Feb	30	50
Mar	20	50
Apr	25	50
May	25	50
Jun	15	50
Jul	40	50
Aug	50	50
Sep	60	50
Oct	35	50
Nov	20	50
Dec	10	50
TOTAL	29.16	600

PERIOD OF STUDY = JAN - DEC 1994.

FIGURE 23 = SHOWING THE SEASONAL RISE AND FALL OF THE INFECTION RATE AND
SNAIL/SLUG POPULATION FROM HAFFKINE INSTITUTE, CAMPUS DURING JAN-DEC 1994.

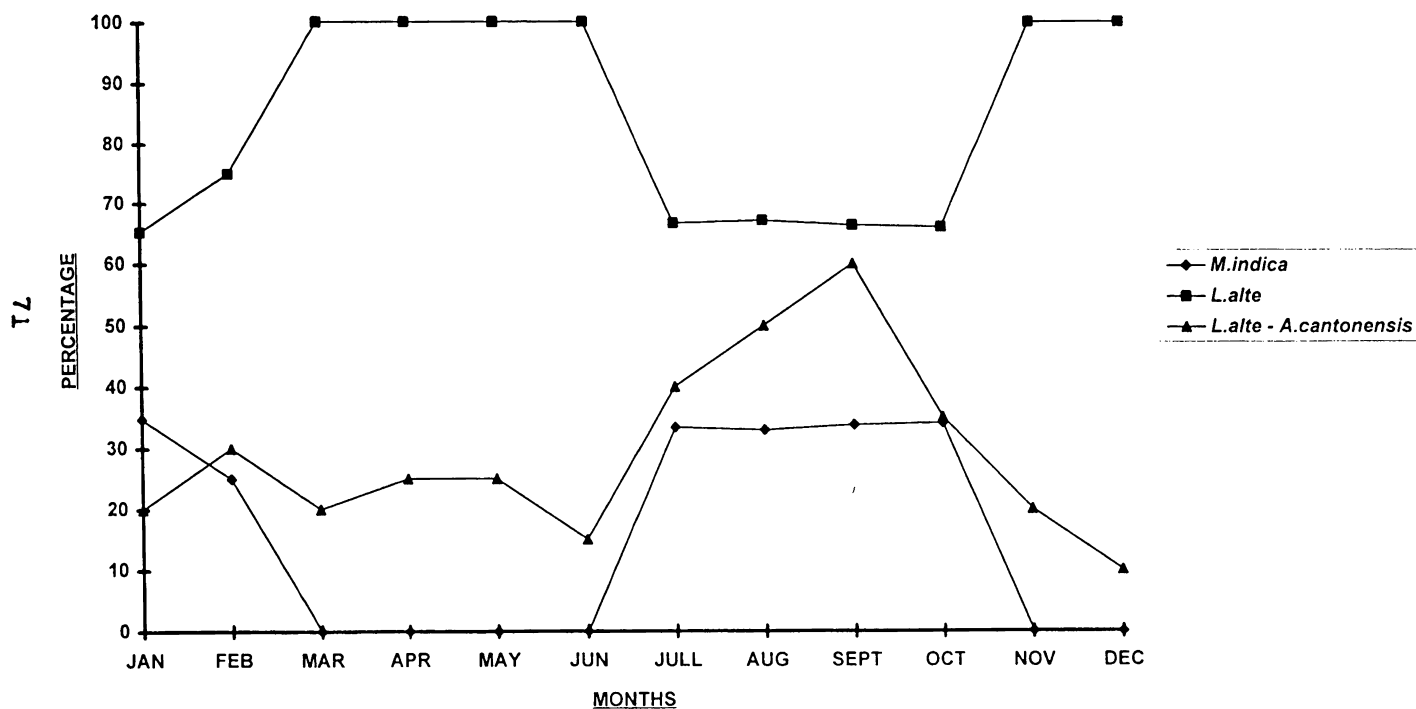


TABLE 15

MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM SHIVAJI PARK GARDEN, DADAR

MONTHS	SPECIES PERCENTAGE WISE			DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTE D
	<i>A. fulica</i>	<i>M. indica</i>	<i>L. alte</i>		
Jan	42	18	40	11	100
Feb	37.14	14.29	48.57	12	105
Mar	48.72	-	51.28	13	117
Apr	43.48	-	56.52	16	138
May	33.12	-	66.88	18	157
Jun	27.05	-	72.95	14	122
Jul	31.34	23.88	44.78	16	134
Aug	47.40	17.53	35.06	17	154
Sep	49.06	15.09	35.85	18	159
Oct	44.89	15.91	39.20	20	176
Nov	45.46	-	54.54	11	99
Dec	44.44	-	55.56	10	81

PERIOD OF STUDY = JAN - DEC 1994

FIGURE 24 = SHOWING THE SEASONAL RISE AND FALL OF THE SNAIL/SLUG POPULATION OF SHIVAJI PARK , GARDEN, DADAR, DURING JAN-DEC 1994.

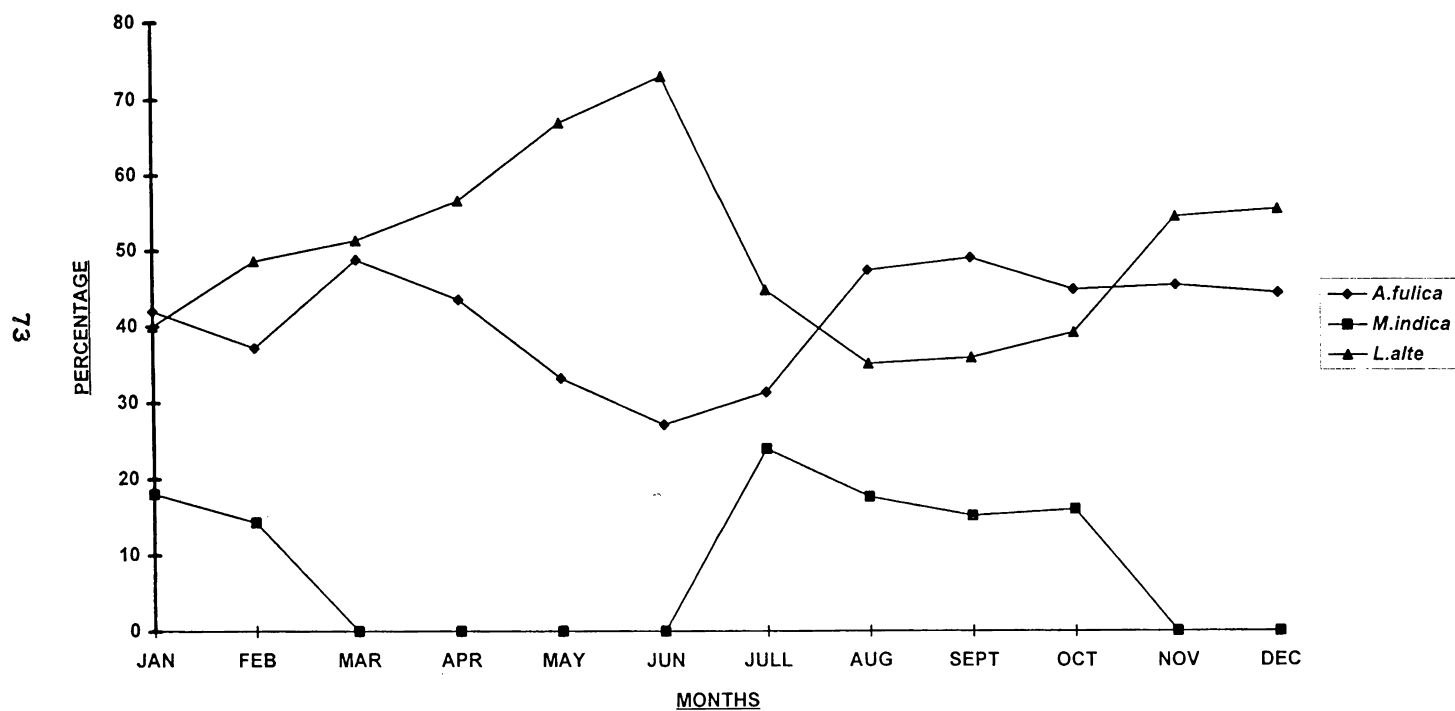


TABLE 16

**MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM
NANDADEEP GARDEN, BANDRA**

MONTHS	SPECIES WISE PERCENTAGE		DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>M. indica</i>	<i>L. alte</i>		
Jan	22.39	77.61	8	67
Feb	26.60	73.40	11	94
Mar	32.63	67.37	10	95
Apr	23.30	76.70	12	103
May	29.33	70.67	8	75
Jun	23.64	76.36	6	55
Jul	28	72	5	50
Aug	50	50	8	68
Sep	52.38	47.62	6	63
Oct	61.33	38.67	8	75
Nov	31.88	68.12	7	69
Dec	19.61	80.39	6	51

PERIOD OF STUDY = JAN - DEC 1994

TABLE 16 A

**MONTHLY INFECTION RATE (%) OF *Angistrongylus cantonensis* IN
SNAIL/SLUG SPECIES FROM NANDADEEP GARDEN, BANDRA.**

MONTHS	<i>L.alte</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	8	50
Feb	10	50
Mar	12	50
Apr	8	50
May	8	50
Jun	10	50
Jul	6	50
Aug	4	50
Sep	16	50
Oct	20	50
Nov	22	50
Dec	8	50
TOTAL	11	600

PERIOD OF STUDY = JAN - DEC 1994.

FIGURE 25 = SHOWING THE SEASONAL RISE AND FALL OF THE INFECTION RATE AND
SNAIL/SLUG POPULATION FROM , NANDADEEP GARDEN, BANDRA, DURING JAN-DEC1994.

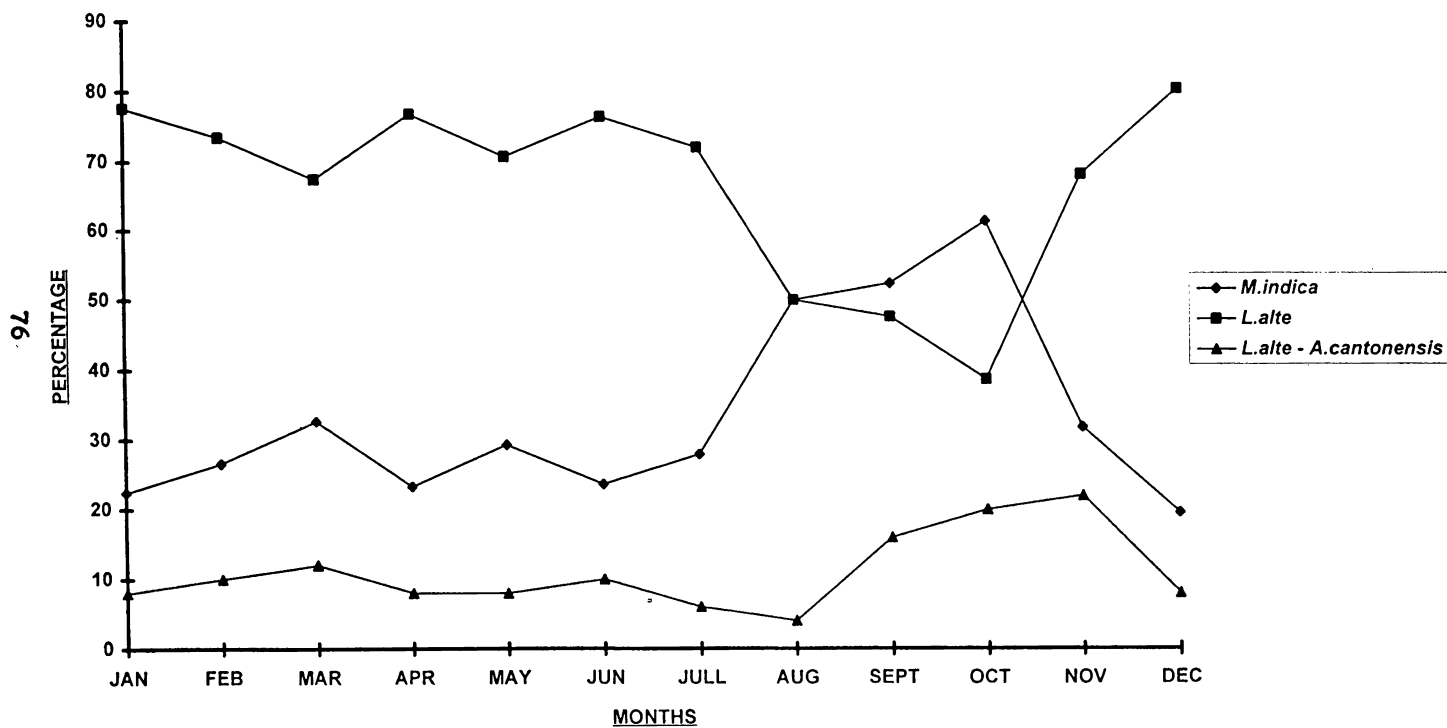


TABLE 17

**MONTHWISE PERCENTAGE OF SNAIL SPECIES COLLECTED FROM
RAM MANDIR GARDEN, BORIVALI**

MONTHS	SPECIES WISE PERCENTAGE			DENSITY / SQUARE METER	ACTUAL NO. OF SNAILS COLLECTED
	<i>A. fulica</i>	<i>M. indica</i>	<i>L. alte</i>		
Jan	65.07	-	34.93	16	146
Feb	39.60	-	60.40	17	149
Mar	35.67	-	64.33	17	157
Apr	52.48	-	47.52	24	202
May	45.40	-	54.60	18	163
Jun	37.30	3.97	58.73	15	126
Jul	38.93	11.45	49.62	15	131
Aug	55.56	12.50	31.94	14	144
Sep	73.49	4.82	21.69	18	166
Oct	70.87	-	29.13	11	103
Nov	62.94	-	37.06	20	170
Dec	57.99	-	42.01	19	169

PERIOD OF STUDY = JAN - DEC 1994

TABLE 17A

**MONTHLY INFECTION RATE (%) OF *Angistrongylus cantonensis* IN
SNAIL/SLUG SPECIES FROM RAM MANDIR GARDEN, BORIVALI.**

MONTHS	<i>A. fulica</i>	<i>L. alte</i>	TOTAL NO. OF SNAILS DISSECTED
Jan	-	-	50
Feb	-	-	50
Mar	-	-	50
Apr	-	20	50
May	-	24	50
Jun	-	16	50
Jul	-	-	50
Aug	20	10	50
Sep	16	24	50
Oct	-	-	50
Nov	-	-	50
Dec	-	-	50
TOTAL	3	7.83	600

PERIOD OF STUDY = JAN - DEC 1994.

FIGURE 26 = SHOWING THE SEASONAL RISE AND FALL OF THE INFECTION RATE AND SNAIL/SLUG POPULATION FROM RAM-MANDIR GARDEN, BORIVALI, DURING JAN-DEC 1994.

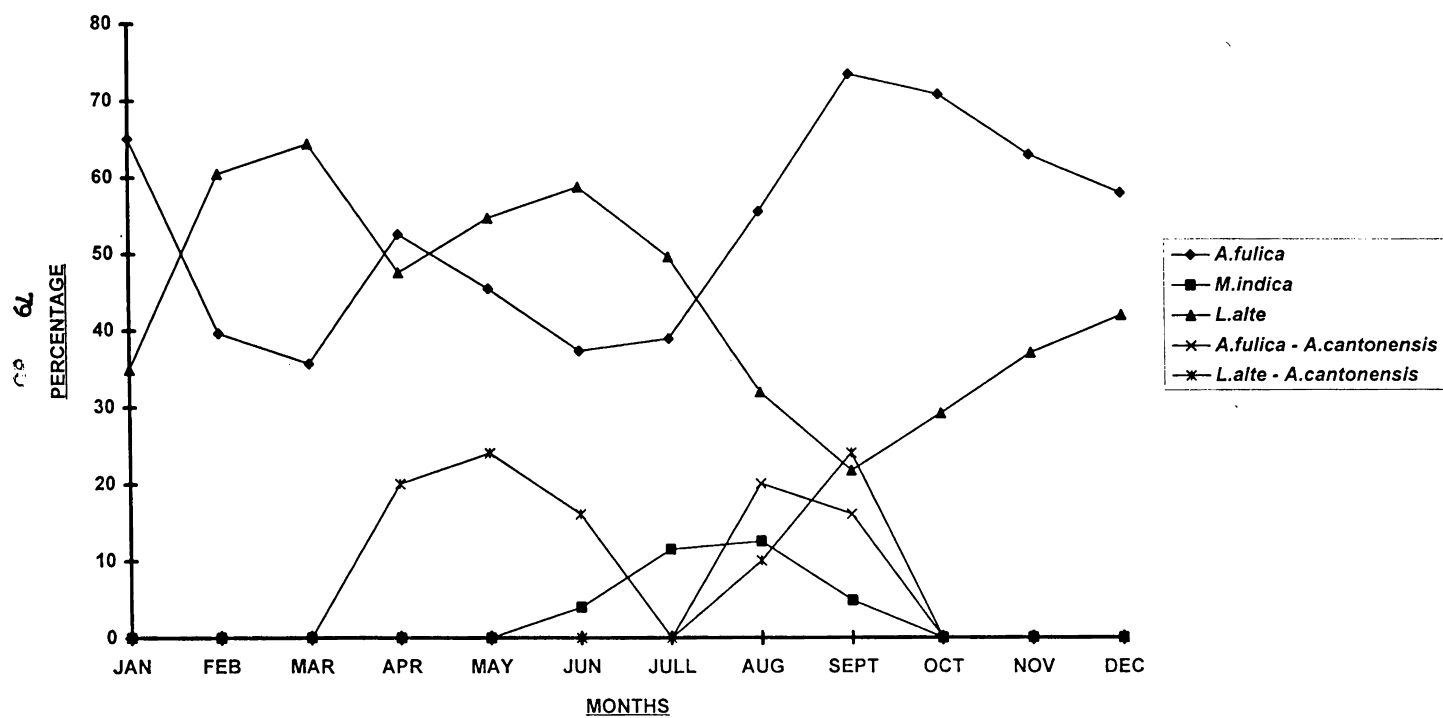


TABLE 18

LC₅₀ and LC₉₀ values of different plant extracts for vector snail *Indoplanorbis exstus*.

EXTRACTS	LC ₅₀ (µg/ml)	LC ₉₀ (µg/ml)
<i>Jatropha curcuss</i>		
a) Methanol	87	140
b) Acetone	90	150
c) Benzene	140	270
d) Pet. ether	240	700
e) Water	220	360
<i>Agave americana</i>		
a) Methanol	86	105
b) Acetone	88	105
c) Benzene	125	470
d) Pet. ether	140	200
e) Water	180	240
<i>Acacia nilotica</i>		
a) Methanol	330	520
b) Acetone	96	125
c) Benzene	66	88
d) Pet. ether	96	125
e) Water	320	440
<i>Annaçardium occidentale</i>		
a) Methanol	45	68
b) Acetone	64	96
c) Benzene	70	115
d) Pet. ether	96	120
e) Water	76	105
Copper Sulphate (Standard)	40	60

TABLE 19

LC₅₀ and LC₉₀ values of different plant extracts for vector slug *Lavicaulis alte*.

EXTRACTS	LC ₅₀ (µg/ml)	LC ₉₀ (µg/ml)
<i>Jatropha curcuss</i>		
a) Methanol	22	36
b) Acetone	25	64
c) Benzene	44	78
d) Pet. ether	39	
e) Water	52	88
<i>Agave americana</i>		
a) Methanol	24	70
b) Acetone	14.5	68
c) Benzene	24	70
d) Pet. ether	24	74
e) Water	46	84
<i>Acacia nilotica</i>		
a) Methanol	54	88
b) Acetone	24	70
c) Benzene	24	74
d) Pet. ether	35	80
e) Water	64	96
<i>Anacardium occidentale</i>		
a) Methanol	24	70
b) Acetone	32	45
c) Benzene	25	68
d) Pet. ether	46	86
e) Water	54	90
Copper Sulphate (Standard)	7	44

DISCUSSION

The spread of snail borne diseases depends on the prevalence of snails. Because of their role as vectors of different parasitic diseases of medical and veterinary importance, the study of snail population and seasonal abundance of different snail species and their part in the disease transmission assumes public health significance. Realising the importance of snails in disease transmission and presence of two important snail borne infection in Bombay area this study was undertaken with a view to understand the relationship between prevalent snail species and parasite infections.

In first phase, general survey of snail population of Bombay and suburbs was done. In all seven aquatic snail species and three terrestrial snail/slug species were found to be prevalent in Bombay area. Among aquatic snails, *I.exustus* and *B.bengalensis* were the most prevalent species followed by *T.tuberculata*, *P.obesus*, *L.luteola*, *T.saxea* and *G.orcula* in order (Tables 4 and 5).

Among terrestrial snails, *Achatina fulica* was found to be most prevalent snail species followed by *M.indica*. *I.alte* was the only species of slug present throughout the study area.

A study of seasonal abundance (table 5) revealed that, among aquatic snails, *I.exustus*, *B.bengalensis* and *T.tuberculata* show their prevalence throughout the year. *I.exustus* showed the maximum density in post winter period i.e. January and February, and minimum density in monsoon period i.e. July and August. *B.bengalensis* has the maximum population during monsoon, i.e. July and August and minimum population

during summer, i.e. April and May. *T.tuberculata* shows the maximum density in post winter period, i.e. february and March and minimum density in post monsoon period , i.e. June to September.

Among the aquatic habitats, Powai lake is the richest in snail fauna with 5 species of snails, *I.exustus*, *b.bengalensis*, *T.tuberculata*, *L.luteola* and *G.orcula*. Vihar lake also reveals the prevalence of all these species except *L.luteola* and *G.orcula*. Irla lake has only *I.exustus* and *B.bengalensis*. Sion Dharavi sewage canal shows the presence of *T.tuberculata* and *P.obesus* and Borivali National park river shows *T.saxea* and *P.obesus* (Table 5).

As *I.exustus* and *B.bengalensis* need lot of vegetation, they are found in all three lakes i.e. Powai, Vihar and Irla. But not in Sion sewage canal and Borivali National Park river since they are lacking in vegetation. *L.luteola* also needs vegetation, but there is no way we could support its absence in Vihar and Irla lake, may be they are not distributed in these lakes. *T.tuberculata* mainly needs rocky substratum with slow moving waters, so it was present in Powai, Vihar lake and Sion sewage canal, but not in Irla lake, which lacks in rocky substratum and in Borivali river which is a fast moving water body. *P.obesus* needs fixed rocky substratum with a flowing water, which was present in Sion sewage canal and Borivali river, hence it was present in these locations. *T.saxea* needs rapid, fast moving water bodies, hence found in Borivali National park river, but not in other habitats. *G.orcula* was found only once in August at Powai lake.

In terrestrial habitats, *A.fulica* was found only in the locations which are situated near the sea shore, i.e. Museum garden, Fort, Shivaji park garden, Dadar and Ram Mandir garden, Borivali, but not inner part of the city. Other snail species *Macrochlymus indica* and slug *Laevicaulis alte* were found in all the habitats studied (Table 6).

Study of seasonal variation shows that slug *L.alte* shows its abundance in pre and post monsoon periods while *A.fulica* and *M.indica* shows maximum density during monsoon period. All the three terrestrial snails/slug were present through out the year 1994(Table 7).

Of the snail and slug population study the presence of helminth parasites was revealed by *I.exustus*, *B.bengalensis*, *L.luteola*, *L.alte*, *A.fulica* and *M.indica*. Overall three types of parasites were harbored by snails and slugs. These were , amphistome cercariae, larval stages of nematomorpha and third stage larvae of *A.cantonensis*.

Amphistome cercariae, which causes amphistomiasis in ruminants were observed from Powai and Irla lake. Both the lakes are used by cattle and buffaloes for drinking and bathing purposes. In domestic ruminants, the morbidity and mortality rates because of amphistomiasis are very high. In sheep, morbidity and mortality rates are reported to be about 15 % to 86 % and 35 % to 90 % respectively. In goats the corresponding figures are 44 % to 69 % and 45 % to 88 % respectively (Mukherjee, 1991). Amphistome cercariae were mainly recovered from the snail of the species *I.exustus* . Other species does not reveal their presence. Therefore it may be said that *I.exustus* serve as major vector in this area. It would be appropriate to study

the life cycle of this parasite in snail population of Powai and Irla lake area considering its veterinary health significance .

Larval stages of nematomorpha were observed in *B.bengalensis* and *I.exustus* from Powai lake. These Nematomorpha are not parasites of vertebrates except *G.aquaticus*. It would be worthwhile to investigate several aspects of life history of this parasite like leaving the host on maturity and its subsequent free living existence. Understanding these factors may throw some light on unknown phenomenon of host- parasite relationship.

The third parasite, third stage larvae of *A.cantonensis* were isolated from *A.fulica*, *M.indica* and *L.alte* from Museum Garden, Fort, *A.fulica* and *L.alte* from Ram Mandir garden, Borivali. Prevalence of *A.cantonensis* larvae was also observed in *L.alte* from Haffkine Institute campus and from Nandadeep garden, Bandra. As this parasite is a causative agent of human eosinophilic meningitis, the study of its life cycle is necessary to understand its mode of infection and public health importance. Although *L.alte* and *M.indica* have been reported to serve as vectors of *A.cantonensis* in Bombay, presence of infection in *A.fulica* in Bombay has been demonstrated for the first time. Study of vector potential shows that *L.alte* is prime vector of *A.cantonensis* in Bombay followed by *A.fulica* and *M.indica*.

In the course of the study it was noted that the infection rate was maximum with all the parasites when snail density was maximum. Only at Irla lake, infection rate with Amphistome was maximum when density of *I.exustus* was minimum. Also in case of *Laevicaulis alte*, infection rate of *A.cantonensis* was maximum when density of *L.alte* was minimum. The

reason behind this may be due to high infection resulting in high mortality in snail population which resulted in low population density.

As snail control by molluscicide is the rapid way of controlling snail borne diseases, molluscicide plays an important role in controlling the disease. In this plant molluscicides may have an advantage over chemical molluscicides because plant molluscicides are cheaper and rapidly biodegradable.

In this study four indigenous plants, viz., *Jatropha curcuss*, *Agave americana*, *Acacia nilotica* and *Anacardium occidentale*, were investigated for their molluscicidal activity. These were evaluated against aquatic snail *L.exustus* which transmits Amphistomiasis in ruminants and land slug *L.alte* which is the known vector of *A.cantonensis* in Bombay.

Methanol and acetone extracts of *J.curcuss* show molluscicidal activity when compared with standard molluscicide Copper sulphate. *J.curcuss* was studied as molluscicide in Egypt (Kloos and McCullough, 1982). The findings of present study further confirm the molluscicidal properties of *J.curcuss*.

Methanol and acetone extracts of *A.americana* and *A.occidentale* also show molluscicidal activity. However molluscicidal activity of these extracts was considerably lower, nearly half when compared with Copper sulphate (Tables 18 and 19). Benzene extracts of *A.nilotica* show high molluscicidal activity. This plant has been studied thoroughly as a molluscicide in Egypt (Hussein Ayoub, 1982)

Among the plants investigated for molluscicidal activity , highest activity was revealed by methanol extract of *A.occidentale*. Similarly molluscicidal activity of *A.nilotica* was very high and compared closely with that of standard molluscicide. However all these extracts are crude extracts and it is necessary to fractionate these extracts and study molluscicidal activity of these fractions. It is hoped that further studies on these lines will be able to provide a potent molluscicidal fraction which could be suitable for molluscan control under field conditions.

SUMMARY AND CONCLUSION

Several species of snails are vectors of human and animal helminthic infections and are thus of immense public health importance. Hence a study of snail population, seasonal variation in their abundance and their role as vector, has been carried out. These studies were confined to Greater Bombay area. In addition to study of prevalence of snail fauna, evaluation of some indigenous plants for molluscicidal activity was also undertaken. The findings of these studies are summarised below.

1) The species of aquatic snails prevalent in Bombay area are :- *I.exustus*, *B.bengalensis*, *T.tuberculata*, *L.luteola*, *P.obesus*, *T.saxea* and *G.orcula*.

The species of terrestrial snails present in Bombay area are :- *A.fulica* and *M.indica*. Only species of slug present in Bombay area is *L.alte*.

2) The examination of snails for the presence of parasitic stages revealed the absence of fercocercous cercaria, causative agent of human schistosomiasis. But however they revealed the presence of, amphistome cercaria, larval stages of nematomorpha and third stage larvae of *A.cantonensis*.

3) The amphistome cercaria was observed at Powai and Irla lake, these were harbored by *I.exustus*. Both these lakes are used by local population and their live stock for washing, drinking and bathing purposes. So the population of this area is vulnerable to amphistome infection.

4) Third stage larvae of *A.cantonensis* were isolated from *A.fulica*, *M.indica* and *L.alte*. Prevalence of *A.cantonensis* infection was observed from the snail and slug of Museum garden, Fort and Haffkine Institute campus, Parel. As *A.cantonensis* is an etiologic agent of human eosinophilic

meningitis, Its prevalence in snails and slug population of Bombay area is hazardous from public health point of view.

5) Study of seasonal prevalence of infection revealed that, Amphistome infection and *A.cantonensis* infection show seasonal prevalence in different parts of Bombay. Amphistome infections were more prevalent in post monsoon period i.e. September and October. *A.cantonensis* infection was maximum during the months of August to November.

6) Study of four indigenous plants, viz, *J.curcuss*, *A.americana*, *A.nilotica* and *A.occidentale*, for molluscicidal activity revealed that all four plants possess molluscicidal activity against vector snail *I.exustus* and slug *L.alte*. Among the extracts, methanol and acetone extracts of *J.curcuss*, *A.americana* and *A.occidentale* and benzene extract of *A.nilotica* show higher molluscicidal activity in comparison to other extract screened.

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SYNOPSIS

A SYNOPSIS
OF THE THESIS
TO BE SUBMITTED TO
THE UNIVERSITY OF BOMBAY
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
APPLIED BIOLOGY

TITLE OF THE THESIS : STUDIES ON SNAILS AS VECTORS OF
PARASITIC DISEASES IN BOMBAY AND
MOLLUSCICIDAL PROPERTIES OF SOME
INDIGENOUS PLANTS.

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INTRODUCTION

Snails and slugs (Mollusca) act as vectors of human parasitic diseases like schistosomiasis, angiostrongyliasis, fascioliasis etc. In the world, schistosomiasis is considered to be one of the most prevalent parasitic disease transmitted by snails. Although a global problem, human schistosomiasis in India is restricted to a small village in Maharashtra state (Sathe and Renapurkar, 1981). Apart from human infections, snail borne animal infections like animal schistosomiasis, amphistomiasis and fascioliasis constitute a serious veterinary health problem in many parts of India (Biswas Gita, 1991).

Infestation with *fercocercus cercaria*, the causative agent of animal schistosomiasis and human cercarial dermatitis, was reported from Bombay region in *Indoplanorbis exustus* (Soparkar 1921) and (Niphadkar 1975). Foci of *Angiostrongylus cantonensis*, rat lung worm were detected in species of snails and slugs of Bombay (Renapurkar et al 1982).

In recent years Bombay city has experienced an increase in snail nuisance. Infestation with snails like Giant African snail, *Achatina fulica* has assumed enormous proportion in some parts of Bombay (Joshi, 1990). This snail is a serious vector of *Angiostrongylus cantonensis* in Pacific islands (Alicata, 1962), Taiwan (Chiu et al, 1964), Japan (Nishimura et al, 1965), Phillipinae (Arombule and Yogure, 1966).

The increase in snail population may prove hazardous to

public health, because of their role as vectors of parasitic diseases and absence of organised control measures against them. The threat of introduction of schistosomiasis in India is omnipresent because of swiftness of modern travel and bilateral movement of population to and from schistosoma endemic areas. This is mainly because of the fact that, one of the Indian snail species serves as a vector for human schistosome species.

The detection of the foci of *Angiostrongylus cantonensis* and demonstration of *ferrocercus cercaria* in snail fauna of Bombay further stresses the need for the study of snail population of Bombay as it becomes imperative to elucidate their role in transmission of human parasitic diseases.

In view of their importance in disease transmission snail control assumes primary significance in areas affected by snail borne infections. In control of snails molluscicides serve as principal weapons. The molluscicides in use are essentially synthetic derivatives and plant based products. Although molluscicides of synthetic origin like, Baluscide, Copper sulphate are favoured by public health authorities, molluscicides of plant origin are also being employed in Egypt and other countries where schistosomiasis is endemic. This is mainly because molluscicides of plant origin pose less environmental hazards and are rapidly bio-degradable. Despite this, very little work has been carried out to assess the susceptibility of Indian snails to molluscicides of plant origin.

In order to throw light on prevalence of various vector snails species and their importance as vectors of human parasitic diseases in the city of Bombay, present study was carried out. In this study, work was carried out to record the present status of snail fauna of Bombay region and parasites harboured by them . Efforts were further made to evaluate some indigenous plant based molluscicides for their use in control of molluscs. The specific objectives of the study thus were as defined below.

AIMS AND OBJECTIVES

- I) To study the distribution and prevalence of snail population of Gr. Bombay .
- II) To study the parasites harboured by various species of snails and slugs.
- III) To study some indigenous plants for their molluscicidal activity.

MATERIALS AND METHODS

1) Snail population studies-

A) General survey - Snails were collected for observing their distribution and investigating their role as possible vectors of human and animal parasitic diseases. A record was maintained with regards to the type of habitat frequented by snails. The emphasis was put on detailed & intensive search for their presence in the study area. The collection method involved visual search / use of sieves, depending on the nature of habitat for collecting the snails.

B) Study of population dynamics and seasonal variation -

On the basis of general survey ,following ten sites were selected for annual density studies. The selected sites consisted of five areas for terrestrial snails (1-5) and five areas for aquatic snails (6-10).

- 1) Museum Garden , Fort.
- 2) Shivaji Park Garden, Dadar.
- 3) Haffkine Inst. Campus Garden, Parel.
- 4) Bandra - Nandadeep garden.
- 5) Ram Mandir Garden , Borivali.
- 6) Irla lake , Vile Parle.
- 7) Powai lake , Andheri.
- 8) Vihar lake , Andheri.
- 9) Sion - Dharavi, sewage canal.
- 10) Borivali National Park, River.

Snails were collected every month from these sites by fractional technique (Hairston et al, 1958). In this technique a marked area was searched visually in case of terrestrial snails or with the help of standard sieve in case of aquatic snails, over a measured interval of time (15 min.), every month for a period of one year.

Each study area was demarked into three main zones. i.e. A ,B & C. These three main zones were again divided into three sub zones. i.e. A1 , A2 & A3 ; B1 , B2 & B3 ; C1 , C2 & C3 , using natural indicators like trees, stones etc, as markers.

2) Study of parasitic larval stages harboured by snails and slugs.-

To isolate the parasitic larval stages from the snails and slugs, two different methods were employed, depending on the habitat of the snail and slug species. These are described below.

I) For aquatic snails -

a) Isolation method - The snails were placed in water singly ,and then exposed to indirect sunlight. The water was then checked once or twice a day for the emerged cercariae.

b) Crushing method -Examination of snails by crushing method was performed as follows-

i) Three to five snails were placed at intervals near the edge of the suitable container , a syracuse watch glass for the small species or a petri dish for large ones.

ii) The snails were crushed by using a suitable

instrument. The instrument was wiped before it's use for crushing the next specimen to prevent contamination.

iii) One or two drops of water were added to each crushed snail.

iv) Each snail was minced with a pair of dissecting needles which was wiped after each dissection.

v) The remains of each snail were examined under a microscope.

II) For terrestrial / land snails -

Pepsin digestion method - Isolation of larval stages from the snails and slugs was carried out as per the method described (Kamath et al 1987).

The snails and slugs were mixed with sufficient quantity of 0.2 % Pepsin in 0.7 % of HCl, digested for six hours , at 37°C .The larvae were then concentrated by using Barmann's apparatus (Lim and Ramchandran, 1979).

3) **Morphological studies of the larval stages -**

Cercaria were fixed in 5% formalin and stained with neutral red and mounted in Glycerine and observed under microscope.

Nematode larvae were fixed in 5% formalin and stained with acetocarmine and mounted in Glycerine and observed under microscope.

4) **Screening of Plants for molluscicidal activity -**

a) Following plants were selected to evaluate their molluscicidal

activity against vector snail, *Indoplanorbis exustus* and slug *Laevicaulis alte*. These plants are very common through out India. They have been reported to possess insecticidal and medicinal properties (Hussain et al, 1992).

<u>Plant species</u>	<u>Part Used</u>
<i>Jatropha curcuss</i> (mogli erand)	seeds
<i>Agave americana</i> (Ghaypat)	leaves
<i>Acacia nilotica</i> (Babula)	fruits
<i>Anacardium occidentalae</i> (Kaju)	seeds

The material was ground to a fine powder and extracted by standard Soxhlet Extraction method, with the solvents methanol, acetone, benzene and Petroleum ether. Aqueous extraction was carried out by Hot decoction method. All the extracts were then concentrated extensively by evaporating solvents.

The plant extracts thus obtained were screened for their molluscicidal activity.

b) Screening of molluscicidal activity -

Bioassays were carried out by standard WHO method (WHO,1961) with the snail *Indoplanorbis exustus* and slug *Laevicaulis alte*

LC₅₀ and LC₉₀ values were calculated by plotting mortality against concentration on probit graph paper. (Litchfield and Wilcoxin, 1949) .

RESULTS AND CONCLUSIONS

I) GENERAL SURVEY

1) **AQUATIC SNAILS** -:Following species of aquatic snails were observed to be prevalent in all the aquatic locations studied.

- 1) *Indoplanorbis exustus*.
- 2) *Bellamya bengalensis*.
- 3) *Thira tuberculata*.
- 4) *Lymnaea luteola*.
- 5) *Paludomus obesus*.
- 6) *Gabbia orecula*.
- 7) *Turbinicola saxea*.

Among the aquatic snails *Indoplanorbis exustus* and *Bellamya bengalensis* were the most prevalent species followed by *Thira tuberculata*, *Paludomus obesus*, *Lymnaea luteola*, *Turbinicola saxea* and *Gabbia orecula* in order (Tables 1 and 2).

2) **TERRESTRIAL SNAILS/SLUGS** -:Following species of slugs and snails were found to be prevalent in all the terrestrial habitat studied.

- 1) *Laevicaulis alte*.
- 2) *Achatina fulica*.
- 3) *Macrochlymus indica*.

In terrestrial locations *Achatina fulica* was found to be the most prevalent snail species followed by *Macrochlymus indica*, *Laevicaulis alte* was the only species of slug present throughout the city area of Bombay (Tables 3 and 4).

3) Study of seasonal abundance of snail species -:

A study of seasonal abundance of snail species reveals that, among the aquatic snails, *I.exustus* and *B.bengalensis* are present through out the year. But other aquatic snails are abundant in pre-monsoon and post-monsoon periods (Table 2). Among the land snails and slugs, *L.alte* is present in pre-monsoon and post-monsoon period while *A.fulica* and *M.indica* are abundant in rainy seasons (Table 4).

II) STUDY OF PARASITES HARBOURED BY VARIOUS SPECIES OF SNAILS AND SLUGS.

Larval stages of three parasite species were harboured by snails in Bombay area. These were harboured by *Indoplanorbis exustus*, *Bellamya bengalensis*, *Lymnaea luteola*, *Achatina fulica* and *Laevicaulis alte*. Other species of snails did not harbour any parasites. The species of parasites recorded were as below.

A) *Amphistome cercaria*, which causes Amphistomiasis in ruminants was observed in *Indoplanorbis exustus* and *Lymnaea luteola* from Powai lake and Irla lake.

B) Larval stage of *Nematomorpha* (Horse hair worm) was observed in *Bellamya bengalensis* and *Indoplanorbis exustus* from Powai lake.

C) Larval stages of *Metastrongylidae* nematode were observed in *Achatina fulica*, *Laevicaulis alte* and *Machrochlymus indica* from Museum Garden, Fort and in *Achatina fulica* and *Laevicaulis alte* from Ram-mandir Road Garden, Borivali. Prevalence of

Metastrongylidae nematode larvae was also observed in *Laevicaulis alte* from Bandra-Mahim marshy land & Haffkine Institute Campus, Parel.

Monthly rate (%) of parasitic infections of different snails / slugs species in various study areas is indicated in Tables. [Tables 5 to 11].

III) MOLLUSCICIDAL ACTIVITY OF PLANT EXTRACTS

Evaluation of molluscicidal activity of extracts of *Jatropha curcuss*, *Agave americana* , *Acacia nilotica* and *Anacardium occidentale* against aquatic snail species *Indoplanorbis exustus* and land slug species *laevicaulis alte* revealed that extracts of all four plants demonstrate molluscicidal activity to some degree at different concentrations [Tables 12 and 13]. In all the cases molluscicidal activity was found to be present at different concentrations of the extracts employed [Tables 12 and 13]. These findings emphasise the need for further evaluation of these extracts to find out their suitability in molluscan control in comparison to chemical molluscicides.

TABLE 1

AREA WISE PERCENTAGE OF AQUATIC SNAIL SPECIES COLLECTED FROM BOMBAY
DURING JAN 94 TO DEC 94.

AREA	TOTAL SNAILS COLLECTED	PERCENTAGE OF DIFFERENT SNAIL SPECIES COLLECTED						
		<i>I. exust.</i>	<i>B. beng.</i>	<i>T. tuberc.</i>	<i>L. luteola</i>	<i>G. orecula</i>	<i>P. obesus</i>	<i>T. saxea</i>
IRLA LAKE	1068	47.16	52.84	-	-	-	-	-
POWAI LAKE	2172	42.35	41.12	11.45	4.84	0.24	-	-
VIHAR LAKE	863	36.79	31.83	31.38	-	-	-	-
SION-DHA. SEWAGE	295	-	-	22.40	-	-	77.60	-
B.N.P. RIVER	683	-	-	-	-	-	64.87	35.13
TOTAL	5081	25.26	25.16	13.05	0.97	0.05	28.48	7.03

TABLE 2

MONTH WISE PERCENTAGE OF AQUATIC SNAIL SPECIES COLLECTED FROM BOMBAY
DURING JAN 94 TO DEC 94.

MONTHS	TOTAL SNAILS COLLECTED	PERCENTAGE OF DIFFERENT SNAIL SPECIES COLLECTED						
		<i>I. exust.</i>	<i>B. beng.</i>	<i>T. tuberc.</i>	<i>L. luteola</i>	<i>G. orecula</i>	<i>P. obesus</i>	<i>T. saxea</i>
JAN	334	64.02	27	7.86	1.12	-	-	-
FEB	382	47.53	19.64	32.70	0.13	-	-	-
MAR	399	40.63	21.86	20.60	1.92	-	15	-
APR	344	30.13	15.66	21.73	2.07	-	30	-
MAY	352	24.92	19.83	17.35	0.98	-	36.92	-
JUN	476	14.21	31.18	17.98	0.47	-	24.54	11.61
JULL	432	9.78	41.87	6.82	1.61	-	25.17	14.83
AUG	528	8.44	42.85	11.82	-	-	21.82	15.07
SEPT	669	21.05	26.14	16.96	0.78	-	20.51	14.56
OCT	506	31.82	20.64	6.69	0.28	0.57	26.51	13.49
NOV	387	27.16	26.47	5.22	1.15	-	25.26	14.74
DEC	272	39.45	47.93	9.39	3.23	-	-	-
TOTAL	5081	25.26	25.16	13.05	0.97	0.05	28.48	7.03

TABLE 3

AREA WISE PERCENTAGE OF TERRESTRIAL SLUG/SNAIL SPECIES COLLECTED
FROM BOMBAY DURING JAN 94 TO DEC 94.

AREA	TOTAL SNAILS COLLECTED	PERCENTAGE OF SNAILS SPECIES COLLECTED		
		<i>A. fulica</i>	<i>L. alte</i>	<i>M. indica</i>
MUSEUM GARDEN FORT	2504	34.84	54.19	10.97
HAFFKINE INSTITUTE CAMPUS	442	-	83.86	16.14
SHIVAJI PARK GARDEN	1542	41.18	50.09	8.73
NANDADEEP GARDEN BANDRA	865	-	66.58	33.42
RAM MAND- IR GARDEN BORIVALI	1826	52.94	44.33	2.73
TOTAL	7179	25.80	59.81	14.39

TABLE 4

MONTH WISE PERCENTAGE OF TERRESTRIAL SLUG/SNAIL SPECIES COLLECTED
FROM BOMBAY DURING JAN 94 TO DEC 94.

MONTHS	TOTAL SNAILS COLLECTED	PERCENTAGE OF SNAILS SPECIES COLLECTED		
		<i>A.fulica</i>	<i>L.alte</i>	<i>M.indica</i>
JAN	446	27.78	54.64	17.58
FEB	561	21.65	63.08	15.27
MAR	639	24.88	66.92	8.20
APR	798	27.37	66.18	6.45
MAY	735	23.16	69.26	7.58
JUN	496	17.65	75.72	6.63
JULL	551	19.68	58.40	21.92
AUG	648	29.40	45.44	25.16
SEPT	703	33.85	41.28	24.87
OCT	668	31.41	45.09	23.50
NOV	531	27.20	63.78	9.02
DEC	403	25.49	69.76	4.75
TOTAL	7179	25.80	59.81	14.39

TABLE - 5

MONTHLY INFECTION RATE (%) OF *Metastrongylidae* nematode IN
SLUG/SNAIL SPECIES OF MUSEUM GARDEN, FORT.

MONTHS	<i>A.fulica</i>	<i>M.indica</i>	<i>L.alte</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	-	-	4	50
FEB	-	-	16	50
MAR	12	-	28	50
APR	24	8	44	50
MAY	20	16	36	50
JUN	-	-	30	50
JUL	-	4	32	50
AUG	24	20	22	50
SEP	26	20	12	50
OCT	-	-	44	50
NOV	-	-	34	50
DEC	-	-	6	50
TOTAL	8.83	5.66	25.33	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 6

MONTHLY INFECTION RATE (%) OF *Metastrongylidae* nematode IN
SNAIL/SLUG SPECIES FROM HAFFKINE INSTITUTE , CAMPUS.

MONTHS	<i>L.alte</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	20	50
FEB	30	50
MAR	20	50
APR	25	50
MAY	25	50
JUN	15	50
JUL	40	50
AUG	50	50
SEP	60	50
OCT	35	50
NOV	20	50
DEC	10	50
TOTAL	29.16	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 7

MONTHLY INFECTION RATE (%) OF *Metastrongylidae* nematode FROM
NANDADEEP GARDEN, BANDRA.

MONTHS	<i>L.alte</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	8	50
FEB	10	50
MAR	12	50
APR	8	50
MAY	8	50
JUN	10	50
JUL	6	50
AUG	4	50
SEP	16	50
OCT	20	50
NOV	22	50
DEC	8	50
TOTAL	11	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 8

MONTHLY INFECTION RATE (%) OF *Metastrongylidae* nematode IN
SNAIL/SLUG SPECIES FROM RAM MANDIR GARDEN, BORIVALI.

MONTHS	<i>A.fulica</i>	<i>L.alte</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	-	-	50
FEB	-	-	50
MAR	-	-	50
APR	-	20	50
MAY	-	24	50
JUN	-	16	50
JUL	-	-	50
AUG	20	10	50
SEP	16	24	50
OCT	-	-	50
NOV	-	-	50
DEC	-	-	50
TOTAL	3	7.83	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 9

MONTHLY INFECTION RATE (%) OF NEMATOMORPHA SPECIES IN SNAIL
SPECIES FROM POWAI LAKE.

MONTHS	<i>I. exust.</i>	<i>B. beng.</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	-	36	50
FEB	-	28	50
MAR	-	32	50
APR	-	22	50
MAY	-	34	50
JUN	-	10	50
JUL	-	40	50
AUG	10	62	50
SEP	14	48	50
OCT	-	14	50
NOV	-	24	50
DEC	-	24	50
TOTAL	2	31.16	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 10

MONTHLY INFECTION RATE (%) OF AMPHISTOME CERCARIA IN SNAIL

SPECIES FROM IRLA LAKE.

MONTHS	<i>I. exustus</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	-	50
FEB	-	50
MAR	-	50
APR	6	50
MAY	-	50
JUN	-	50
JUL	-	50
AUG	10	50
SEP	12	50
OCT	10	50
NOV	-	50
DEC	-	50
TOTAL	3.16	600

PERIOD OF STUDY = JAN - DEC 1994

TABLE - 11

MONTHLY INFECTION RATE (%) OF AMPHISTOME CERCARIA IN SNAIL
SPECIES FROM POWAI LAKE.

MONTHS	<i>I.exust</i>	<i>L.luteo</i>	TOTAL NO.OF SNAILS DISSECTED
JAN	-	-	50
FEB	10	-	50
MAR	6	-	50
APR	4	-	50
MAY	8	20	50
JUN	6	10	50
JUL	2	10	50
AUG	4	-	50
SEP	16	10	50
OCT	22	-	50
NOV	-	-	50
DEC	-	-	50
TOTAL	6.5	4.16	600

PERIOD OF STUDY = JAN - DEC 1994.

TABLE - 12

LC₅₀ and LC₉₀ values of different plant extracts for vector snail *Indoplanorbis exustus*.

Extracts	LC ₅₀ (µg/ml)	LC ₉₀ (µg/ml)
<i>Jatropha curcuss</i>		
a)Methanol	87	140
b)Acetone	90	150
c)Benzene	140	270
d)Pet.ether	240	700
e)Water	220	360
<i>Agave americana</i>		
a)Methanol	86	105
b)Acetone	88	105
c)Benzene	125	470
d)Pet.ether	140	200
e)Water	180	240
<i>Acacia nilotica</i>		
a)Methanol	330	520
b)Acetone	96	125
c)Benzene	66	88
d)Pet.ether	96	125
e)Water	320	440
<i>Anacardium occidentale</i>		
a)Methanol	45	68
b)Acetone	64	96
c)Benzene	70	115
d)Pet.ether	96	120
e)Water	76	105
<i>Copper sulphate</i> [Standard]	40	60

TABLE - 13

LC₅₀ and LC₉₀ values of different plant extracts for vector snail *Laevicaulis alata*.

Extracts	LC ₅₀ (mg/ml)	LC ₉₀ (mg/ml)
<i>Jatropha curcuss</i>		
a)Methanol	22	36
b)Acetone	25	64
c)Benzene	44	78
d)Pet.ether	39	
e)Water	52	88
<i>Agave americana</i>		
a)Methanol	24	70
b)Acetone	14.5	68
c)Benzene	24	70
d)Pet.ether	24	74
e)Water	46	84
<i>Acacia nilotica</i>		
a)Methanol	54	88
b)Acetone	24	70
c)Benzene	24	74
d)Pet.ether	35	80
e)Water	64	96
<i>Anacardium occidentale</i>		
a)Methanol	24	70
b)Acetone	32	45
c)Benzene	25	68
d)Pet.ether	46	86
e)Water	54	90
<i>Copper sulphate</i> [Standard]	7	44

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