In conclusion, pyocyanine-producing *P. aeruginosa* exhibits potent anti-staphylococcal activity even on MRSA and CONS strains. The active substance appears to be pyocyanine. This may be exploited for the development of an effective anti-staphylococcal agent.


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**Community structure of larval trematode fauna of the snail *Thiara tuberculata* from a freshwater stream at Visakhapatnam, Andhra Pradesh**

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Monthly samples of the snail *Thiara tuberculata*, collected from a freshwater stream at Visakhapatnam, were examined for larval trematode infections. Cercarial infections occurred in 38.2% of the snails. Nineteen species of cercariae belonging to 10 families were found, with xiphidiocercariae as dominant members. Fifteen species of cercariae belonged to allogenic category and four species were autogenic. Four species are identified as having zoonotic potential with fish serving as second intermediate hosts. No seasonal pattern is exhibited in the overall prevalence of infection and the community diversity.

The freshwater bodies of tropical countries harbour dense populations of snails that serve as intermediate hosts for a wide range of digenetic trematodes infecting various groups of vertebrates including man. Investigations dealing with analysis of larval trematode fauna of snails, their transmission patterns and host–parasite relationships are receiving considerable attention. From the Indian region, studies relating to larval trematode fauna of snails have received attention ever since the publication of the monumental work by Sewell¹. The approach so far has been taxonomic in nature. Information available on ecological aspects of parasitism in snails is very scanty.

In recent studies, much emphasis has been given to investigations dealing with analysis of community structure of larval digenean infections in snails²–⁸. The community with reference to parasites has been defined as the complex assemblage of parasites occurring within a host. Terms such as infracomunity, component community and compound community are in use, to define various hierarchical levels, the infracomunity to include all the parasites in a single host, the component community including all the parasites in a single population of hosts and the component community denoting all the parasite communities within an ecosystem⁹. The parasitic community within a host population is considered as complex and a result of continuous interaction of host–parasite and environment. Its species composition and diversity are under the control of a complex set of biotic and abiotic factors which have direct impact on the transmission patterns. An analysis of this relationship is expected to be useful in understanding the forces which operate in structuring the parasite communities.

In the course of our studies on larval trematode infections of freshwater snails of Visakhapatnam region, it was found that the snail *Thiara tuberculata* in a local freshwater stream serves as a suitable host for a wide range of larval digeneans. An investigation has, therefore been undertaken during 1992–1994, to study the organization of larval trematode fauna of the snail including the species composition, their diversity, dominance and seasonal changes.

The study area is a small freshwater stream originating from Mehadrigadda reservoir flowing in a north-easterly direction, to ultimately join the creek near a fishing harbour. The snail *T. tuberculata* forms dense populations in the stream throughout the year. The collection spot located adjacent to the reservoir is surrounded by mango trees on which nestle a number of resident birds like pond herons, egrets and kites. Ducks are also common. Domestic animals like sheep and cattle visit the area.
The presence of freshwater snakes was also occasionally noted. The snails, totalling 3173 in number, were collected as monthly samples during the period October, 1992 to September, 1994 and each monthly sample contained 86 to 168 snails. The snails were isolated individually in petri dishes and infected snails were identified by examining the water for the presence of cercariae. The snails which were not emitting cercariae were crushed and digestive gland examined for the presence of cercarial infections. Data on the number of snails examined with each variety of cercariae were recorded for each monthly sample.

From the data collected, the overall prevalence of infection with larval trematodes, the prevalence of infections with individual species of cercariae, in the monthly samples were determined. The community structure of larval trematode fauna was analysed employing various indices that have been used by earlier workers. The species richness, the dominance and the Shannon–Wiener’s diversity index were used as indices of community diversity. Species richness was determined for each monthly sample. The Shannon–Wiener’s diversity index was calculated using the formula

\[ H' = -\sum (p_i \times \ln p_i), \]

where \( p_i \) is the proportion of snails infected with each species of cercaria in the monthly sample. The snail was found to host 19 species of cercariae distributed over 10 families (Table 1). Information on the prevalence of infection with various cercariae and their life cycle pattern is given in Table 2. Among the cercariae encountered, the xiphidiocercariae represented by seven species constituted the most dominant members of the cercarial fauna. Infections with cercariae of Procerovum variarum, Haplorchis spp. and Centrocestus formosanus capable of infecting humans with fish as intermediate host, occurred in 11.91% of snails. Cercariae of Transversotrema patialense, Philophthalmus nocturnus, Atrophecaecum burminis and Haplochoides mehrai occurred fairly commonly. Infections with striegid, schistosome and renicolid cercariae were rare.

The data reveal that 15 out of 19 cercariae belong to allogenic category with part of their life cycle occurring in terrestrial birds. The remaining four species are autogenic with life cycle operating in hosts that are confined to the stream. The data also reveal that of the 15 species using birds as definitive hosts, 6 species depend on piscine hosts for transmission, 2 species depend on aquatic insects and 1 species on molluscs. Cercariae of 4 species namely H. pumilio, H. taichu, P. variarum and C. formosanus, have zoonotic potential with fish acting as second intermediate hosts.

Out of 3173 snails examined, 1213 individuals, i.e. 38.23% carried patent infections with larval trematodes. Among the 1213 infected snails, 28 carried double infections. The overall prevalence in the monthly samples ranged from a maximum of 46.97% during October 1992 to the lowest of 30.1% during March 1994 (Figure 1a). The numbers of cercarial species in each sample varied from 10 to 15 with an average of 12 species (Figure 1b). Both these parameters exhibited no pronounced seasonal fluctuations, indicating homogeneity in the infection state of snail population in the stream, over different months. Further evidence to the homogeneity of infections was provided by the values of Shannon–Wiener’s diversity index which varied in the monthly samples from 2.1 to 2.5 with an average of 2.3 and showed no marked seasonal changes (Figure 1c).

The study revealed the infection rate of the snail T. tuberculata with larval digeneans to be very high with overall prevalence of 38.23% and larval trematode assemblage comprising as many as 19 species. Both these parameters are far higher than those recorded for the snail from other localities in India and abroad. This indicates that the physico-chemical and biotic features of the local stream, offer ideal conditions for promoting infections in the snail and the locality thus constitutes a natural focus for helminth infections with the snail T. tuberculata playing a prominent role as a vector.

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strigeidae</td>
<td>Raillietia</td>
<td>Cercariae</td>
<td>1919</td>
</tr>
</tbody>
</table>

Table 1. List of cercariae collected from Thiaria tuberculata from the stream
Table 2. Overall prevalence and life-cycle pattern for the guild of larval trematodes in the snail {em}Titiara tuberculata{em}

<table>
<thead>
<tr>
<th>Trematode species</th>
<th>Prevalence (1992–94)</th>
<th>Definitive host</th>
<th>Life-cycle pattern</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strigeid cercaria</td>
<td>0.13</td>
<td>Birds</td>
<td>Snail–fish–piscivorous birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Schistosome cercaria</td>
<td>0.09</td>
<td>Birds</td>
<td>Snail–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Transversotrema paialense</td>
<td>2.45</td>
<td>Fish</td>
<td>Snail–fish (Progenetic)</td>
<td>Autogenic</td>
</tr>
<tr>
<td>Philophthalmus nocturnus</td>
<td>2.02</td>
<td>Birds</td>
<td>Snail–external–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Gyrsona indica</td>
<td>0.47</td>
<td>Ducklings</td>
<td>Snail–snail–ducklings</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Xiphidiocercariae</td>
<td>11.31</td>
<td>Birds</td>
<td>Snail–aquatic insect–bird</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Cercaria of Eumegetes artumii</td>
<td></td>
<td>Birds</td>
<td>Snail–aquatic insect–bird</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Cercaria of Orthocercus sp.</td>
<td></td>
<td>Birds</td>
<td>Dragonfly naiads</td>
<td>Autogenic</td>
</tr>
<tr>
<td>Cercaria Titiara III</td>
<td></td>
<td>Birds</td>
<td>Snail–dragonfly naiads</td>
<td>Autogenic</td>
</tr>
<tr>
<td>Cercaria Titiara IV</td>
<td></td>
<td>Birds</td>
<td>–</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Cercaria Titiara V</td>
<td></td>
<td>Birds</td>
<td>–</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Cercaria Indicae LXVII</td>
<td></td>
<td>Birds</td>
<td>–</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Renicolid Cercaria</td>
<td>0.28</td>
<td>Birds</td>
<td>Snail–fish–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Centrocestus formosanus</td>
<td>2.68</td>
<td>Birds</td>
<td>Snail–fish–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Haplorchis melhui</td>
<td>4.03</td>
<td>Birds</td>
<td>Snail–fish–fish</td>
<td>Autogenic</td>
</tr>
<tr>
<td>Haplorchis pamilo</td>
<td>3.34</td>
<td>Birds</td>
<td>Snail–fish–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>H. taichii</td>
<td>2.43</td>
<td>Birds</td>
<td>Snail–fish–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Procercus varium</td>
<td>3.46</td>
<td>Birds</td>
<td>Snail–fish–birds</td>
<td>Allogenic</td>
</tr>
<tr>
<td>Atrophecacium burminis</td>
<td>6.40</td>
<td>Water snake</td>
<td>Snail–fish–snake</td>
<td>Autogenic</td>
</tr>
</tbody>
</table>

Figure 1. Seasonal changes in the community parameters of larval trematode infections in the snail {em}Titiara tuberculata{em}, from a freshwater stream at Visakapatnam. a. Prevalence; b. Species richness; c. Shannon–Wiener’s diversity index (H').

The various larval digeneans infecting the snail exhibited a dominance hierarchy with xiphidiocercarids dominating the parasitic fauna. The dominance of xiphidiocercarids is evidently contributed by the abundant occurrence in the habitat of aquatic insects and insectivorous birds that serve as second intermediate and definitive hosts respectively. The influence of aquatic snakes on the cercarial fauna of the snail is also evident by the common occurrence of {em}Atrophecacium burminis{em} cercariae the adults of which occur in the water snake {em}Natrix piscator{em}. The frequent occurrence of heterophyid cercariae seems to be caused by the presence in the stream, of several species of fish that serve as intermediate hosts. It is obvious from the present study that {em}Titiara tuberculata{em} plays a key role in the habitat in the establishment, operation and completion of a number of trematode life cycles. The lack of seasonality, in the overall prevalence of larval trematode infections in the locality is also in contrast with the situation prevailing in many other regions where seasonal fluctuations in the prevalence of infections in snails involving two peak levels were recorded\(^9,14-16\). Lack of seasonality is also exhibited in the diversity of parasite fauna. This seems to be caused by the interplay of several factors including homogeneity in the physico-chemical and biotic features of the stream, the resident nature of the birds, the favourable temperature of tropical climate and continuous availability of young snails that are highly susceptible to the infection.

The high prevalence noted with the four species of heterophyid cercariae having zoonotic potential deserves attention. Human infections with these species transmitted through consumption of fish have been recorded from south-east Asian countries including Philippines, Taiwan and Egypt\(^17-19\). Pand and Shukla\(^20\) have earlier reported the zoonotic significance of heterophyid infections of Indian region and cautioned against consumption of raw fish.

A preliminary survey of fishes in the stream revealed fairly common occurrence of infections with metacercariae of {em}Procercus varium{em}, {em}Haplorchis spp. and {em}Centrocestus{em} sp. in the muscles and gills of {em}Channa spp.,
Gambusia sp., Puntius sp. and Oryzias sp. Although some of these fish are consumed by local communities, no information is available on the prevalence of infections with heterophyid trematodes in the individuals. The situation, however, demands an in-depth epidemiological study involving a detailed analysis on a seasonal basis, the physico-chemical features of the environment, the prevalence of cercarial infections in the snails and metacercarial infections in the fishes, the role of birds as transmitting agents and the extent of human involvement. Moreover, the snail host in the stream with its broad spectrum of larval trematode infections offers a suitable model for the study of host-parasite–environment interactions.


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On the theory and utility of spectral seismograms

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A spectral seismogram enables a quick and detailed analysis of an earthquake waveform in terms of the frequency–time distribution of the radiated energy. In this approach, a broad-band signal is first filtered using various bandpass filters to obtain the corresponding bandpass seismograms. Each of these seismograms is then Hilbert transformed, to obtain the corresponding instantaneous amplitudes with respect to time, for each mid-frequency. The resulting amplitudes are then represented using a colour code or a grey scale to obtain a spectral seismogram. We discuss here, the theory of spectral seismograms and as examples, present the spectral seismograms of 3 earthquakes from the Burmese arc region.

An earthquake source radiates energy over a wide range of frequencies in the form of longitudinal and shear waves. These waves, besides generating various surface waves, get reflected and refracted inside the earth, thereby producing several converted waves. A portion of the seismic energy reaches the surface of the earth, and is recorded by the seismometers. Since the radiated energy spans a wide range of frequencies, it is desirable to sample an earthquake over as wide a bandwidth as possible, for a better understanding of the earthquake source and the medium through which the waves propagate.

Over the past decade, more than 100 broadband seismometers have been operational worldwide, belonging mostly to networks like IRIS, GEOSCOPE and CDSN. The high quality digital data that is being provided by these broadband instruments now form a fairly extensive data set for modelling the seismic sources and the fine structure of the medium. Spectral analysis of earthquake records has evolved as a powerful tool for analysis of digital data, especially for deciphering the source characteristics.

Spectral analysis using the Fourier transform has been the most powerful and standard means of decomposition of a signal into individual frequency components to obtain the energy spectrum sampled by each component. The energy spectrum thus obtained, however, does not contain information about the time of initiation of these frequencies. An estimate of the variation of the spectrum with time is desirable if one is interested in frequency dependent, time limited signals in a waveform. One way of estimating the time-varying spectrum is to compute the discrete Fourier transform of a sequence of overlapping time intervals that step through a larger time series. The spectrogram\(^1\) utilizes this procedure and has been the most widely used tool for the analysis of time-varying spectra. The concept behind it is simple, yet powerful. In order to analyse what is happening at a particular instant of time, a small portion of the signal

\(^1\) Spectrogram