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.

1. Leisinger, T. and Margraff, R., *Microbiol. Rev.*, 1979, **43**, 422–442.
2. Emmerich, R. and Low, D., *Z. Hyg. Infektionskrank*, 1899, **31**, 1–65.
3. Smirnov, V. V., Churkina, L. N., Kravetsan and Garagulia, A. D., *Antibiot. Khimioter.*, 1993, **38**, 3–5.
4. Boyce, J. M., *Infect. Control Hosp. Epidemiol.*, 1990, **11**, 639–642.
5. Kloos, W. E. and Bannerman, T. L., in *Manual of Clinical Microbiology* (ed. Murray, P. R.), ASM Press, Washington DC, 1995, 6th edn, p. 284.
6. Barrow, G. I. and Felthan, R. K. A. (eds), *Cowan and Steel's Manual for the Identification of Medical Bacteria*, Cambridge University Press, Cambridge, 1993, 3rd edn, pp. 109–116.
7. Stokes, E. J. and Ridgway, G. L. (eds), *Clinical Microbiology*, Edward Arnold, London, 1987, 6th edn.
8. Lovrekovich, L., Lovrekovich, H. and Jenkins, D. C., *J. Clin. Pathol.*, 1972, **25**, 94–95.
9. Pitt, T. L., in *Topley and Wilson's Principles of Bacteriology, Virology and Immunity* (eds Parker, M. T. and Duerden, B. I.), Edward Arnold, London, 1990, 8th edn, vol. 2, pp. 256–257.
10. Kumar, D. B. S. and Bezbaruah, B., *Indian J. Microbiol.*, 1996, **36**, 45–48.

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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 Sewell[1]. 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 snails[2–8]. The community with reference to parasites has been defined as the complex assemblage of parasites occurring within a host. Terms such as infracommunity, component community and compound community are in use, to define various heirarchical levels, the infracommunity 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 ecosystem[2]. The parasite 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 Mehadrigedda 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 steam 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[2,5,6]. 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

$$H' = -\sum(p_i \times Inp_i),$$

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 varium*, *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 strigeid, 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. taichui*, *P. varium* 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 1 *a*). The numbers of cercarial species in each sample varied from 10 to 15 with an average of 12 species (Figure 1 *b*). 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 1 *c*).

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[9–11] and abroad[12,13]. 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 1. List of cercariae collected from *Thiara tuberculata* from the stream

Family: Strigeidae Railliet, 1919
Cercaria Thiara I Swarnakumari, 1992
Family: Schistosomatidae Poche, 1907
Cercaria Thiara n.sp.
Family: Transversotrematidae Yamaguti, 1953
Cercaria of *Transversotrema patialense* (Soparkar, 1924)
Family: Philophthalmidae Travassos, 1918
Cercaria of *Philophthalmus nocturnus* Looss, 1907
Family: Psilostomidae Looss, 1900
Cercaria of *Grysoma indica* Umadevi and Madhavi, 1995
Family: Eumegacetidae Travassos, 1922
Cercaria of *Eumegacetes artamii* Mehra, 1935
Cercaria of *Eumegacetes* sp.
Cercaria of *Orthetrotrema monostomum*, Macy and Basch, 1972
Cercaria Thiara III Swarnakumari, 1992
Cercaria Thiara IV Swarnakumari, 1992
Family: Lecithodendriidae Odhner, 1910
Cercariae Indicae LXVII Murty, 1976
Cercaria Thiara V Swarnakumari, 1992
Family: Renicolidae Dollfus, 1939
Cercariae Indicae XIV Sewell, 1922
Family: Heterophyidae Odhner, 1914
Cercaria of *Centrocestus formosanus* Nishigori, 1924
Cercaria of *Haplorchoides mehrai*, Pande and Shukla, 1976
Cercaria of *Haplorchis pumilio* (Looss, 1896)
Cercaria of *Haplorchis taichui* Nishigori
Cercaria of *Procerovum varium* Onji and Nishio, 1916
Family: Acanthostomidae Poche, 1926
Cercaria of *Atrophecaecum burminis* Bhalerao, 1926

Table 2. Overall prevalence and life-cycle pattern for the guild of larval trematodes in the snail *Thiara tuberculata*

Trematode species	Prevalence (1992–94)	Definitive host	Life-cycle pattern	Category
Strigeid cercaria	0.13	Birds	Snail–fish–piscivorous birds	Allogenic
Schistosome cercaria	0.09	Birds	Snail–birds	Allogenic
Transversotrema patialense	2.45	Fish	Snail–fish (Progenetic)	Autogenic
Philophthalmus nocturnus	2.02	Birds	Snail–external–birds	Allogenic
Grysoma indica	0.47	Ducklings	Snail–snail–ducklings	Allogenic
Xiphidiocercariae	11.31			Allogenic
Cercaria of *Eumegacetes artamii*		Birds	Snail–aquatic insect–bird	Allogenic
Cercaria of *Eumegacetes* sp.		Birds	Snail–aquatic insect–bird	Allogenic
Cercaria of *Orthetrotrema monostomum*		Dragon fly naiads	Snail–dragonfly naiads	Autogenic
Cercaria Thiara III		Birds	–	Allogenic
Cercaria Thiara IV		Birds	–	Allogenic
Cercaria Thiara V		Birds	–	Allogenic
Cercariae Indicae LXVII		Birds	–	Allogenic
Renicolid Cercaria	0.28	Birds	Snail–fish–birds	Allogenic
Centrocestus formosanus	2.68	Birds	Snail–fish–birds	Allogenic
Haplorchoides mehrai	4.03	Birds	Snail–fish–fish	Autogenic
Haplorchis pumilio	3.34	Birds	Snail–fish–birds	Allogenic
H. taichui	2.43	Birds	Snail–fish–birds	Allogenic
Procerovum varium	3.46	Birds	Snail–fish–birds	Allogenic
Atrophecaecum burminis	6.40	Water snake	Snail–fish–snake	Autogenic

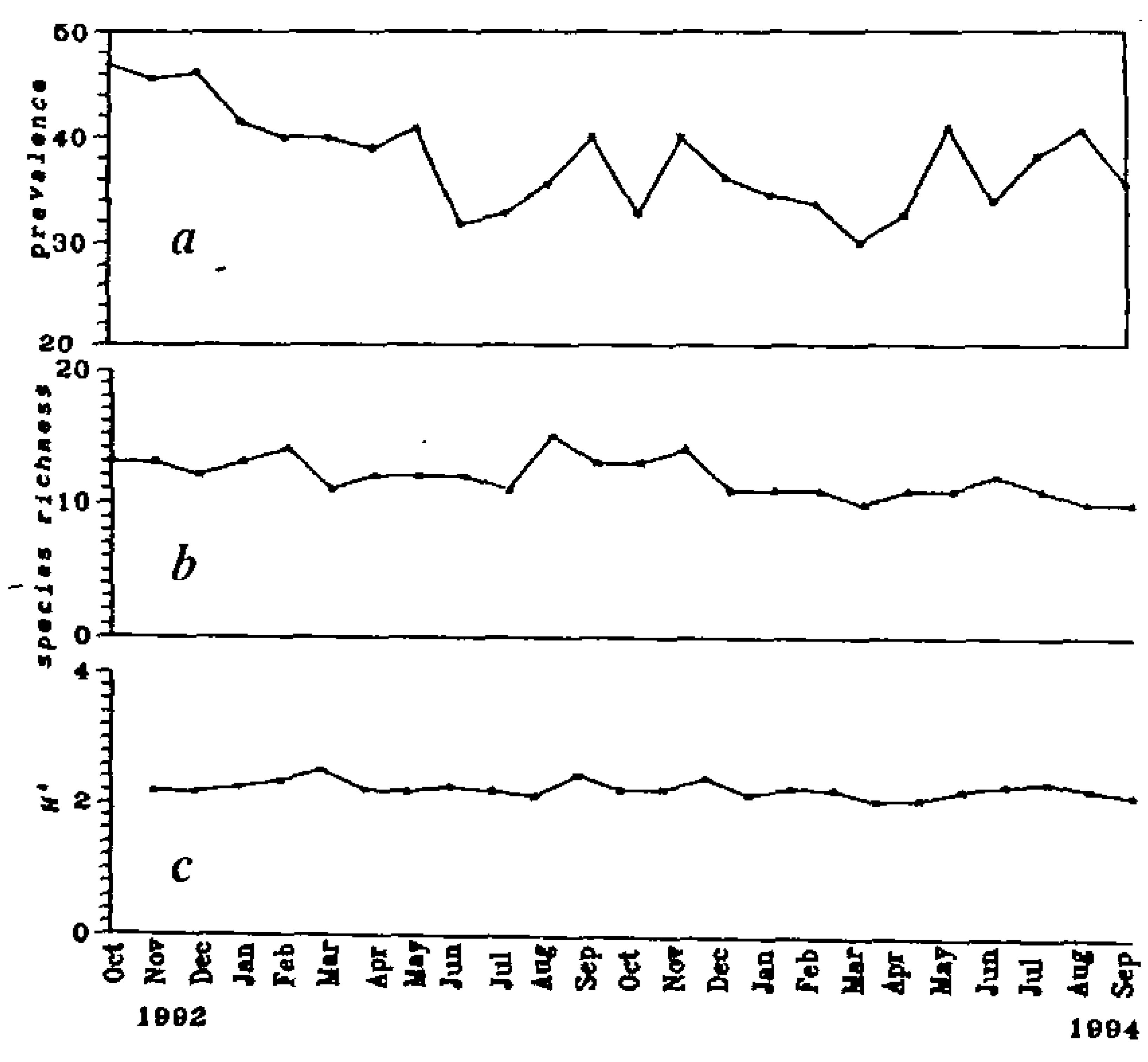

Figure 1. Seasonal changes in the community parameters of larval trematode infections in the snail *Thiara tuberculata*, from a freshwater stream at Visakhapatnam. ***a***, Prevalence; ***b***, Species richness; ***c***, Shannon–Wiener's diversity index (*H'*).

The various larval digeneans infecting the snail exhibited a dominance heirarchy with xiphidiocercariae dominating the parasitic fauna. The dominance of xiphidiocercariae 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 *Atrophecaecum burminis* cercariae the adults of which occur in the water snake *Natrix piscator*. 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 *T. tuberculata* 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]. Pande 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 *Procerovum* sp., *Haplorchis* spp. and *Centrocestus* sp. in the muscles and gills of *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 epizootiological 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.

1. Sewell, S., *Indian J. Med. Res.*, 1922, **10**, 1–327.
2. Sousa, W. P., *J. Exp. Mar. Bio. Ecol.*, 1990, **23**, 273–296.
3. Kuris, A. M., in *Parasite Communities: Patterns and Processes* (eds Esch, G. W., Bush, A. O. and Aho, J. M.), Chapman and Hall, London, 1990, pp. 69–100.
4. Williams, J. A. and Esch, G. W., *J. Parasitol.*, 1991, **17**, 246–253.
5. Fernandez, J. and Esch, G. W., *J. Parasitol.*, 1991, **77**, 528–539.
6. Fernandez, J. and Esch, G. W., *J. Parasitol.*, 1991, **77**, 540–550.
7. Snyder, S. D. and Esch, G. W., *J. Parasitol.*, 1991, **79**, 205–215.
8. Kuris, A. M. and Lafferty, K. D., *Annu. Rev. Ecol. Syst.*, 1994, **25**, 189–217.
9. Mohandas, A., *Folia Parasitol.*, 1974, **21**, 311–317.
10. Mohandas, A., *Ves. Cesk. Spo. Zool.*, 1976, **40**, 196–205.
11. Pande, K. C. and Agarwal, N., *Indian J. Parasitol.*, 1978, **2**, 139–143.
12. Ismail, N. S. and Saliba, E. K., *Riv. Parassit.*, 1985, **46**, 263–271.
13. Ismail, N. S. and Abdel Hafez, S. K., *Helminthologia*, 1987, **24**, 293–301.
14. Miller, H. M. and Northup, F. E., *Bio. Bull.*, 1926, **50**, 490–508.
15. Probert, A. J., *J. Helminth.*, 1966, **40**, 115–130.
16. Erasmus, D. A., *The Biology of Trematodes*, Univ. Press, Belfast, 1972.
17. Africa, C. M., Garcia, E. Y. and Leon, W. De., *J. Philipp. Med. Assoc.*, 1935, **15**, 358–361.
18. Hsu. P. K., *Lignan Sci. J.*, 1951, **23**, 235–256.
19. Martin, W. E., *Trans. Am. Micro. Soc.*, 1959, **78**, 172–181.
20. Pande, B. P. and Shukla, R. P., *Indian J. Anim. Sci.*, 1972, **42**, 971–978.

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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