blood feeding species which is collected in large numbers from the park in canopy trap and from livestock in the surrounding area.

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ACKNOWLEDGEMENTS.We are grateful to Dr R. V. Swamy, Chief Controller, Research and Development, DRDO HQ, New Delhi and Dr D. K. Jaiswal, Director, DRDE, Gwalior for their keen interest and constant encouragement during this work. We also thank Mr P. R. Sinha, Member-Secretary, Central Zoo Authority, New Delhi and Mr Vinod Kumar, Director, Nandankanan Biological Park, Bhubaneswar, for providing necessary facilities and co-operation during the study.

Received 5 October 2001; revised accepted 28 January 2002

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Advertisement call, courtship and mating behaviour of the frog, *Limnonectes syhadrensis* from Western Ghats, India

Amphibian fauna of India comprises as many as 228 species, of which 121 inhabit the Western Ghats[1]. Many aspects of biology of these species remain unknown. Studies on bioacoustics of Indian anurans are restricted to a few species[2], whereas those on their breeding biology are even more scarce. *Limnonectes syhadrensis* is widely distributed in the Western Ghats and peninsular India[3]. It is also found in Pakistan and Nepal[4–6]. Despite its relatively broad range and high abundance in some regions, very few studies have been made on this species. In this paper we describe the advertisement call, courtship and mating behaviour of the frog in the Western Ghats.

During the monsoon season, fieldwork was undertaken to study the breeding biology and bioacoustics of *L. syhadrensis*. Tape recordings of the calls were made in several parts of the Western Ghats between 1995 and 1999. The study areas included places around Sirsi (14°34′N, 74°32′E), Sagar (16°37′N, 76°51′E), Jog Falls (14°45′N, 74°53′E), Shimoga (13°56′N, 75°38′E), Sringeri (13°25′N, 75°15′E), Kollur (13°53′N, 74°53′E), Londa (15°60′N, 74°53′E) and Karwar (14°48′N, 74°11′E). Calls were recorded on Sony cassette tape using AKAI AJ 490 FS tape recorder and AKG, D 707C/190C, D-1000 I directional microphones. Microphones were held within a distance of 10 cm from the calling frogs. Air and water temperatures were measured at the time of recording using a digital thermometer. LUTRON SPL meter was used to measure the sound pressure level. Calls of 20 frogs were analysed at Zoological Institute, University of Bonn, Germany, by using the computer program MOSIP (R) Spectro analysis V6 8, 41/89, MEDAV GmbH. The statistical analysis was carried out with Statagraphics Program, STSC Inc., Knoxville, USA. Observations on courtship and mating behaviour were made around Jog Falls between June and August 2000–01.

L. syhadrensis is a small-sized frog, male snout to vent length (SVL): 17.5–19.1 mm (18.3 ± 0.82, $n = 10$), female SVL: 20.7–22.8 mm (21.3 ± 0.63, $n = 10$), distributed in a large portion of the Western Ghats. Males, using a single subgular external vocal sac (Figure 1), emit advertisement call during the breeding season along with the sympatric species *Limnonectes limnocharis*. Calling activity begins after one or two heavy pre-monsoon (April/May) or monsoon (June) rains and continues up to the end of the rainy season (September/October). The males call mainly during night beginning at 18.00 to 20.00 h and continue until the morning of the following day (6.00 h). Occasionally, calls were heard during daytime. They prefer to call from temporary shallow water pools. Calling is in chorus, rarely individual calling males are observed. Calls are emitted from the surface of the ground as the males sit under partly submerged grass or paddy. The calling position is upright, the head held upwards with the help of stretched forelegs and the hind legs are folded and totally immersed in water. Though there is chorus-calling, a regular distance ranging between 0.5 and 1.0 m (0.82 ± 0.33, $n = 10$) is maintained between any two calling individuals. Calls are antiphonal between the two nearest calling males.

The advertisement call of *L. syhadrensis* consists of a series of pulse groups and the number of pulse groups per call varies between 7 and 28. The first pulse group is the largest, consisting of 9–11 pulses and the remaining pulse groups

Table 1. Acoustic features of advertisement call of *Rana syhadrensis*. Calls of 20 randomly selected individuals were used for statistical calculation

Parameter	Sample size	Mean ± SE	Range
Call duration (ms)	25	903.6 ± 48.4	447–1547
Call interval (ms)	22	2457.0 ± 177.0	1243–4169
Call period (ms)	21	3224.5 ± 211.2	1485–5227
Pulse groups/call (*N*)	32	13.2 ± 0.9	7–28
Pulse group duration (ms)	140	32.1 ± 0.8	19–74
Pulse group interval (ms)	140	51.4 ± 1.7	19–125
Pulse group period (ms)	140	84.3 ± 2.2	43–176

are smaller, with 4–7 pulses per group. The first pulse in the first pulse group is always small and is separated from the remaining pulses by a short pulse interval (Figure 2 *a*) and the remaining pulses are without pulse intervals. The amplitude of the first pulse within the first pulse group is the lowest and in the remaining pulses it is slightly high in comparison with amplitude in other pulse groups. In the latter, there is no significant amplitude modification. Acoustic features of the call are given in Table 1. The sound energy is concentrated within 75–9320 Hz with three energy bands and indistinct harmonics (Figure 2 *b*). The fundamental frequency lies in the first energy band and ranges between 75 and 412 Hz. The dominant frequency lies in the second band between 3642 and 4420 Hz. The sound pressure level varies between 105 and 120 dB. Water and air temperature at the time of recording varied from 16 to 19° and 17 to 21°C, respectively.

We observed 20 pairs for courtship and mating behaviour and 13 pairs were followed through amplexus and oviposition. Pair formation reached its peak in the first few weeks after the heavy rains (June/July), but was observed throughout the season (August/September). Gravid females preferred choruses rather than individual or few calling males. Courtship was initiated when a gravid female approached the calling male and made a physical contact with it. The male stopped calling and immediately jumped on the back of the female and clung to it by holding it below the armpits with the forearms and formed an axillary amplexus (Figure 3). In few cases ($n = 3$) the males that were calling nearby attacked the amplexed pair and tried to dislodge the mounted male. The amplexed male in turn kicked the intruder with its hind limbs. Though the courtship was initiated in the evening, it reached its peak at about midnight (Figure 4 *a*). Oviposition occurred early the following day. The amplexed pair moved to a small, shallow water pool on the ground within the locality where the spawning occurred. The earliest hour that a pair was observed to begin depositing the eggs was between 5 and 6 a.m. and the latest was between 10 and 11 a.m. The oviposition reached its peak between 6 and 7 a.m. (Figure 4 *b*). Females required 40 to 120 min to complete the oviposition. The clutch size varied from 62 to 87 (71.5 ± 7.68, $n = 10$). Egg mass contained large amounts of elastic jelly, by which they were attached to the substrata. Eggs were grey coloured and the average size was 0.725 ± 0.26 mm ($n = 80$).

Mating calls of *Rana ridibunda*[9], *R. lessonae*[10], *R. perezi*[11], *Euphlyctis cyanophlyctis*[12] and *Hoplobatrachus crassa*[13] consist of a series of pulse groups. The number of pulse groups varies from species to species. Among Indian ranids, *Hoplobatrachus tigerina* and *Tomopterna breviceps* have advertisement calls consisting of single pulse group[14] and *H. crassa* of 2–4 pulse groups per call[14]. In *E. cyanophlyctis* and *L. limnocharis*, the number of pulse groups per call varies from 9 to 17 (ref. 12) and 9 to 25 (ref. 15), respectively. Advertisement calls of *L. syhadrensis* consisting of a series 7–28 pulse groups, are similar to those of *E. cyanophlyctis* and *L. limnocharis*.

In Ranidae, the frequency spectrum is generally continuous or broad and rarely with indistinct harmonics[15]. The frequency spectra of *L. syhadrensis* is broad and consists of indistinct harmonics as observed in *L. limnocharis*[15] and *Tomopterna rufescens*[16]. However, *L. limnocharis* exhibits two energy bands extending up to 3800 Hz and *T. rufescens* has five energy bands ranging between 100 and 7500 Hz. The frequency spectra of *L. syhadrensis* having three bands of energy and the range extending up to 9200 Hz are well above all the Indian ranids studied so far.

The spectral and temporal characters of advertisement call of *L. syhadrensis* revealed in the present study differ from the calls described for the same species from Nepal[7]. Though the frequency spec-

Figure 1. Male *Limnonectes syhadrensis* with single subgular external vocal sac (Photo: G.G.K.).

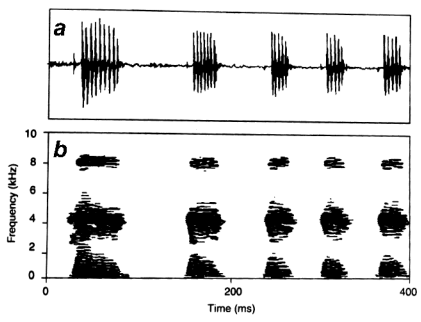

Figure 2. Oscillogram (***a***) and sonogram (***b***) of the advertisement call of *L. syhadrensis* (SVL 18 mm) recorded at Sagar (16°37′N, 76°51′E). Water temperature, 19°C; air temperature, 21°C.

Figure 3. Axillary amplexus of *L. syhadrensis* (Photo: G.G.K.).

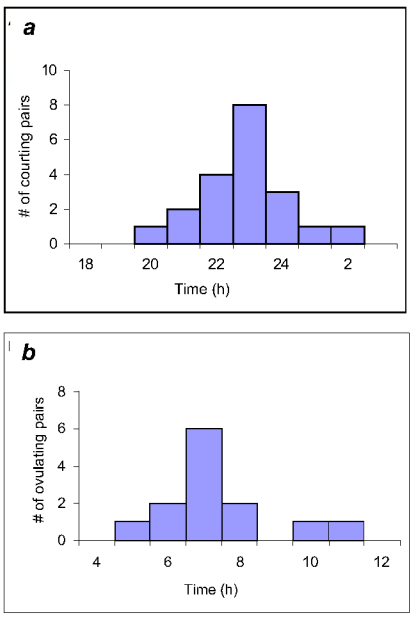

Figure 4. ***a***, Distribution of time when courtship was initiated ($n = 20$); and ***b***, Distribution of time when oviposition began ($n = 13$).

tra of Nepal's frog consist of three energy bands, the upper and lower bands are weak in contrast to the prominent energy bands of the Indian population and the upper maximum of frequency is less than 6000 Hz. These differences may be considered as an indication of geographical variations and the possibility of the existence of a species complex.

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ACKNOWLEDGEMENTS.We thank the University Grants Commission, New Delhi and German Academic Exchange Service, Bonn, FRG, for selecting R.D.K. for a study visit (1997). We also thank Dr M. S. Ravichandran, Zoological Survey of India, Chennai and Dr Ranjit Daniels, *Care Earth*, Chennai, for confirming the identifications of the frogs. G.G.K. thanks UGC, New Delhi for the award of FIP fellowship. DST/SP/SO/C-23/93 (DST), SAP-II and COSSIST (UGC) grants supported the work.

Received 26 November 2001; revised accepted 18 January 2002

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Role of nematodes as bioindicators in marine and freshwater habitats

The utility of bioindicators has been established in recent times[1,2]. The utilization of nematodes as a tool in water quality assessment in the 1970s (refs 3 and 4) was popular and their faunal composition emerged as a useful monitor of environmental conditions and ecosystem function. The parasitic copepods, digeneans, cestodes, acanthocephala and larval nematodes have dominated in the role of parasite indicators[5]. But the host–parasite relationships involving adult nematodes have rarely been reported in the investigations identifying parasites as indicators[6].

The subject of this investigation has been catfishes of two zoo-geographically different regions within the same country. Adult roundworms of genus *Rostellascaris*[7] were recovered in the two-year study (Figure 1) during 1996–98 from *Mystus tengra* of river Ganges, Allahabad. Another catfish, *Arius falcaris*, examined in the Arabian Sea at Goa during 2000–2001 revealed another species of *Rostellascaris* namely *R. oceanica*[8]. Studies making use of biological tags for stock delineation in intraspecific groups within a catfish host population at different geographic locations, are not very frequent. However, their role in substantiating differential spawning, nursery or feeding grounds, and behavioural forms of such groups or stocks within the same area, has been amply demonstrated[6]. The objective of this investigation was to analyse restrictive population distribution behaviour of the nematode parasites and to determine useful discriminants for commercial exploitation in fish and fishery.

The nemic populations survived in marine fish stocks where hydrobiological characteristics were: salinity, 37–40 ppt; hardness, 5900–6300 mg/l; dissolved oxy-

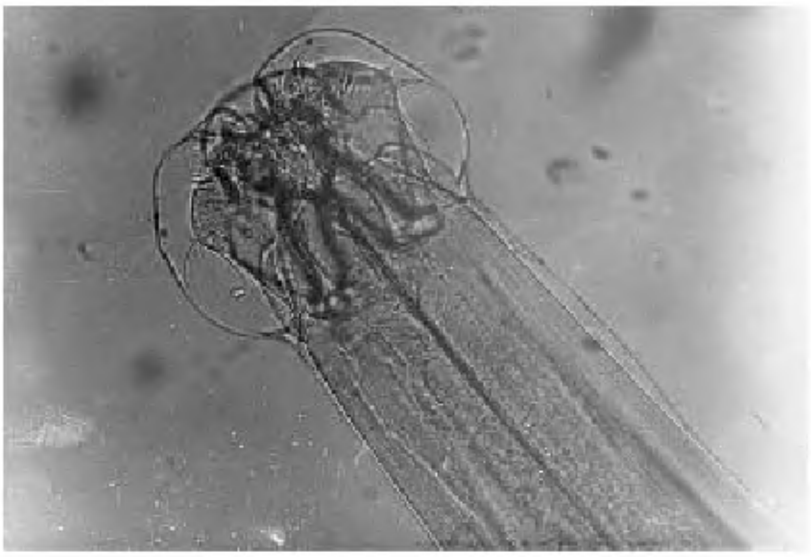

Figure 1. Photomicrograph of the anterior end of the adult female worm *Rostellascaris oceanica* showing cephalic armature (× 620).