Publications


ACOUSTIC signals play a very important role in the breeding activity of frogs and toads and are regarded as one of the key characters responsible for reproductive isolation and specification events in the animal group (Wells, 1977). Male anurans use vocalization to advertise their species identity, sex and location to females for the purpose of breeding. The Western Ghats of India have been identified as one of the hot spots of biodiversity in the world. It harbors more than 100 species of anurans (Daniels, 1997a,b). However, bioacoustic studies on Indian anurans are limited to only a few species (Kanamadi, 1996). The Indian Bronzed Frog *Rana temporalis* is widely distributed in Western Ghats of India (Daniels, 1997), and also found in Sri Lanka (Dutta, 1992, 1997). Except for the distribution records (Inger & Dutta, 1989) there are practically no other reports on this species. In the present study we describe the advertisement call of *R. temporalis* for the first time.

Field studies were carried out from 1996-1999 in different parts of the Western Ghats. Calling sites were marked based on the vocalization around Sagar (16° 37' N 76° 51' E), Jog (14° 45' N 74° 53' E), Shimoga (13° 56' N 75° 38' E), Sringeri (13° 25' N 75° 15' E) and Kollur (13° 53' N 74° 53' E). A few calling frogs were collected for taxonomic studies. The frogs were identified in the laboratory by using available taxonomic keys (Boulenger, 1890., Daniel & Sekar, 1989). Later they were confirmed by the Zoological Survey of India, Southern Regional Station, and Dr. M.S. Swaminathan Research Foundation, Chennai. Advertisement calls were recorded on SONY, Super FE cassette tapes using AKAI AJ 490 FS tape recorder (4.8cm/s speed) and AKG, D707, C/190 directional microphones. Microphones were held at a distance of 4-6 cm away from the frogs. Sound pressure level was measured from a distance of 1m by using a LUTRON SPL meter. Air temperature and relative humidity of the calling sites were also recorded. Calls of 10 frogs were analysed at the 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.

*Rana temporalis* is a medium sized frog (male SVL=x=55.3mm, n=10). Vocalization began after 2 to 3 heavy monsoon showers (June/July) and the maximum activity was observed in the early phase of monsoon (June-August). Males possess single subgular vocal sacs and emit advertisement calls by sitting on the floating vegetation or under the submerged grass. Daily calling activity began when it grew dark and continued late into the night. Calls were given in series with a long call interval (Fig. 1A). Each call consisted of a single pulse group, and the pulses within each pulse

---

Table 1. Acoustic features of advertisement call of *R. temporalis* (calls of 10 randomly selected individuals were used for statistical analysis)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample size</th>
<th>Mean ± s</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call duration (ms)</td>
<td>120</td>
<td>62.8 ± 0.8</td>
<td>47-88</td>
</tr>
<tr>
<td>Call interval (s)</td>
<td>102</td>
<td>1.41 ±0.09</td>
<td>0.54 - 5.68</td>
</tr>
<tr>
<td>Call period (s)</td>
<td>101</td>
<td>1.46 ±0.09</td>
<td>0.60 - 5.80</td>
</tr>
</tbody>
</table>

---

8 Herpetological Bulletin - Number 73
Advertisement calls of the Indian ranids, *Rana crassa* (Kanamadi, Hiremath & Schneider, 1992), *R. limnocharis* (Kanamadi et al., 1995) and *Tomopterna rufescens* (Kadadevaru, Kanamadi & Schneider, 2000) consist of a series of pulse groups, whereas in *R. tigrina*, *T. breviceps* (Kanamadi et al., 1994), and *Indirana beddomii* (Kadadevaru et al., 2000) the call consists of a single pulse group. Similarly, in *Rana temporalis* also the call consists of a single pulse group. The call interval of *R. temporalis* (ranging between 0.54s and 3.5s) is high compared to *R. tigrina* and *T. breviceps*, but it is low when compared with *I. beddomii*, where the call interval extends up to 35.12s. Amongst the Indian ranids described so far the frequency spectra of *R. tigrina* and *I. beddomii* consist of two energy bands. In *R. temporalis* also the frequency spectra consists of two bands of energy. The energy spectra of *R. temporalis*, extending between 37 and 7200 Hz, is comparable with that of *I. beddomii* (37 to 6820 Hz). In both the frogs, the spectra consists of indistinct harmonics. Variations in the spectral and temporal features in the advertisement call and absence of sympatric species isolate *R. temporalis* from other frogs and helps in species recognition.

**ACKNOWLEDGEMENTS**

The study was supported by a grant from DST (No. SP/SO/C-23/93) awarded to R.D.K. and partly by the SAP-II UGC grant, New Delhi. We thank University Grants Commission, New Delhi, India and German Academic Exchange Service, Bonn, Germany, for selecting the second author for study visit (1997). We also thank Dr. M.S. Ravichandran of Zoological Survey of India, Southern Regional Station, Chennai and Dr. Ranjit Daniels of Dr. M.S. Swaminathan Research Foundation, Chennai, for confirming the identifications of the frogs.

**REFERENCES**


THERMOREGULATION AND ACTIVITY PATTERNS IN CAPTIVE GROUND IGUANAS (*CTENOSAURA SIMILIS*)

KYLIE GREENWOOD, STEPHEN CRANSTON, HELEN DARLINGTON
AND LAUREN GOMERSALL

The Herpetological Unit, Huddersfield Technical College, Huddersfield, U.K.

[correspondence to R. Meek at same address]

The iguanas of the genus *Ctenosaura* are a conspicuous element of the Central American herpetofauna. Herpetologists have studied certain aspects of the biology and ecology of several species including one of the larger forms *Ctenosaura similis* (e.g. Henderson, 1973; Fitch, 1973; Fitch & Henderson, 1978; van Devender, 1979; Janzen & Brodie, 1995). The results have indicated that *C. similis* is associated with dry open woodland and savannah (Fitch, 1973, van Devender, 1979; Fitch & Hackforth-Jones, 1983), and is both terrestrial and arboreal using hollows in tree trunks, tree roots, old buildings or rock piles as retreat sites (Fitch, 1973; Burger & Gochfield, 1991). The juveniles are mainly insectivorous, but as growth proceeds shift to a mainly herbivorous diet, although when resources are scarce, may consume small vertebrates and large insects (Fitch, 1973; van Devender, 1979). Under certain circumstances they are known to travel distances to feed (Fitch & Henderson, 1978; Fitch & Hackforth-Jones, 1983).

Field workers have commented on the difficulties of studying this species under natural
ADVERTISEMENT CALL OF INDIAN FUNGOID FROG, RANA MALABARICA

Girish G. Kadadevaru, Ravishankar D. Kanamadi* and Hans Schneider**

Department of Zoology Karnatak University, Dharwad 580 003, India

** Zoologisches Institut, University of Bonn, Germany.

* For correspondence (e-mail: kannam@karunia.vsnl.net.in)

ABSTRACT:

Rana malabarica is distributed in many parts of Western Ghats. Advertisement call has been studied from 1995-1999. Males emit advertisement call during breeding season. Call comprises two components. First component consists of series of pulse groups and the number varied between 7-17. Second component also consists of series of pulse groups. First pulse group of the second component is always large when compared to remaining pulse groups. Sound energy is concentrated between 75 and 7500 Hz with five energy bands and harmonics. Energy spectra show frequency modulation. The acoustic features of advertisement call of R. malabarica differ from other Indian ranids: Rana tigrina, Rana limnocharis and Indirana beddomii but its frequency spectra shows some similarities with Tomopterna rufescens.

INTRODUCTION

Acoustic communication constitutes an important and conspicuous part of breeding biology of anurans. Many species of anurans rely on vocal signals for their intraspecific communication. These animals have developed discrete, stereotyped vocal repertoires used in such behavior as attraction of mates, communication of alarm and distress and, in some species, establishment and maintenance of territories (Bogart, 1960). Of these vocal signals, the male anuran's species-specific mating or advertisement call has received most attraction in ethological research (Simmons 1984). Indian sub continent harbours 180 anuran amphibians (Dutta, 1992). Bioacoustic studies in Indian anurans over a decade have provided information about calls and calling behaviour of few species (Kanamadi, 1996). Rana malabarica is distributed in different parts of India (Daniel, 1975, Dutta, 1992). Studies on this species are limited to distribution records. In the present work we describe advertisement call of the frog from Western Ghats of India.
I. METHODS:

Field observations were carried between 1995 and 1999 in different parts of Western Ghats. Based on vocalization calling sites were marked around Sagur (16° 37'N 76° 51'E), Jog (14° 45'N 74° 53'E), Shinoga (13° 56'N 75° 38'E), Sringeri (13° 25'N 75° 15'E), and Karwar (14° 48'N 74° 11'E). Few calling males were collected and brought to the laboratory for identification. Preliminary identifications were done using available taxonomic keys (Boulenger, 1890, Daniel, 1975). Later they were confirmed by Zoological Survey of India, Chennai and M.S. Swaminathan Research Foundation, Chennai. Calls were recorded on SONY Super EF cassette tapes using AKAI, AI 490 FS tape recorder (4.8cm/s speed) and AKG D-707 C, 19C directional microphones. Microphones were held at about 5-10cm away from the subjects. Sound pressure level of the calls were recorded from a distance of 1m from the frogs, by using LUTRON SPL meter. Digital thermometer was used to measure air and water temperature. Calls of 10 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.

II. RESULTS

*Rana malabarica* is a medium sized frog (male SVL \( \bar{x} = 62.3 \text{ mm} \), \( n =10 \)) distributed in many parts of Western Ghats. Calling activity begins after 2-3 heavy monsoon showers (June/July), and reaches its peak in the beginning of the monsoon. Later the calling activity decreases. Daily calling activity begins in the evening at about 19.00 hrs to 20.00 hrs and continues up to the midnight. Males emit advertisement call by sitting on floating vegetation, submerged grass or sitting to the edge of water bodies containing weeds. Advertisement call consisted of two components: component 1, and component 2. The first component consists of series of pulse groups and the number varied between 10 and 17. The pulse group duration, pulse group interval and pulse group period varied from 31 - 52ms, 611 - 3143ms and 658 - 3178ms respectively. Pulses within the pulse groups are overlapped. The amplitude of the pulses is low in the beginning, which rises quickly to maximum and then it gradually decreases (fig.1A). The second component is complex, and consists of many pulse groups and the number of pulse group varied between 4 and 14. The first pulse group of the second component is always large in comparison to other groups. The pulse group duration, pulse group interval and pulse group period varied from, 93 - 245ms, 32 - 145ms and 166 - 386ms respectively. The pulses are without pulse interval. Amplitude of the pulses in the pulse group was characteristically modulated. It was low in the beginning and rises quickly later it falls down to certain extent and further gradually increases to maximum and at the end it was lowest (fig2A). Remaining pulse groups in the second component are uniform. The duration of the pulse group, pulse group interval and pulse group period ranged from 26 - 42ms, 72 - 173ms and 108 - 209ms respectively. The amplitude is low in the beginning and reaches its peak in the middle later gradually decreases to its lowest. The acoustical features of the advertisement call are summarized in table1. Sound energy is concentrated between 75 and 7500Hz with five
energy bands and harmonics (fig.1B). The first pulse group of the second component shows frequency modulation, and the harmonics are clear (fig2B) compared to other pulse groups of the mating call. Acoustical features of the advertisement call are summarized in table1. The sound pressure level varied between 67 and 80 dB.

III. DISCUSSION

The advertisement call may function in a number of capacities in breeding activity of anurans. It helps in orientation of the species to the breeding site and formation of breeding aggregation, Sex discrimination and location of the male by female, reproductive isolation and facilitation of breeding (Salthe and Mecham, 1974). The advertisement call of Rana tigrina (Kanamadi et al.,1994) and Indirana beddoinii (Kadadevaru et al., 2000) consists of single pulse groups whereas in Rana limnocharis (Kanamadi et al.,1995) and Tomopterna rufescens (Kadadevaru et al., 2000) the advertisement call consists of series of pulse groups. The advertisement call in Rana malabarica also consists of series of pulse groups similar to R. limnocharis (Kanamadi et al.,1995) and T. rufescens (Kadadevaru et al., 2000) but it is divided in to two components. Both the components of the call differ in call parameters. Frequency spectra of R. tigrina (Kanamadi et al., 1994), R. limnocharis (Kanamadi et al.,1995) and I. beddoinii (Kadadevaru et al., 2000) consists of two energy bands and range between 200-311 Hz, 1500-3500 Hz and 37-6820 Hz respectively. The frequency spectra of R. malabarica ranges from 75 - 7500Hz and has five energy bands with harmonics, which is comparable to the energy spectra of T. rufescens (Kadadevaru et al., 2000) having the range of 100-7500 Hz with five bands of energy and harmonics. However the spectra in R. malabarica shows frequency modulation. Though the mating call is categorized in to two components on the basis of call parameters the categorization should be regarded as provisory since the male emits these calls persistently during vocalization. Complex vocal behaviour and variations in the spectral and temporal features of the advertisement call isolates the R. malabarica from other ranids and act as a tool for the female to locate the mate.

ACKNOWLEDGEMENTS: The work is supported by DST/SP/SC-23/93 and UGC SAP II grants. We thank University Grants Commission, New Delhi, India and German Academic Exchange Service, Bonn, Germany, for selecting the second author for study visit (1997). We also thank Dr. M.S. Ravichandran of Zoological Survey of India, Southern Regional Station, Chennai and Dr. Ranjit Daniels of Dr. M. S. Swaminathan Research Foundation, Chennai, for confirming the identifications of the frog.
Table 1. Acoustic features of advertisement call of *Rana malabarica*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st component</th>
<th>2nd component</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pulse group</td>
<td>1st pulse group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample size</td>
</tr>
<tr>
<td>Pulse group duration (ms)</td>
<td>40</td>
<td>38.5 ± 0.99</td>
</tr>
<tr>
<td>Pulse group interval (ms)</td>
<td>20</td>
<td>1320 ± 136</td>
</tr>
<tr>
<td>Pulse group Period (ms)</td>
<td>20</td>
<td>1358 ± 136</td>
</tr>
</tbody>
</table>

Figure 1. Oscillogram (A) and sonogram (B) of a pulse group from the 1st component of the advertisement call of *R. malabarica*.

Figure 2. Oscillogram (A) and sonogram (B) of first pulse group and one of the remaining pulse group of 2nd component of the advertisement call of *R. malabarica*.
REFERENCES


Advertisement Call and Breeding Period of the Frog, *Kaloula pulchra* (Microhylidae)

Ravishankar D. Kanamadi
Department of Zoology, Karnatak University, Dharwad 580 003, India

Girish G. Kadadevaru
Department of Zoology, Karnatak University, Dharwad 580 003, India

and

Hans Schneider
Zoologisches Institut, University of Bonn, Bonn, Germany

The Western Ghats region of India has been identified as one of the 18 biodiversity hot spots of the world (WCMC 1988), and harbors 205 species of amphibians (Daniels 1992). *Kaloula pulchra* is a medium-sized burrowing frog (mean male SVL = 67.3 mm, N = 20) distributed in parts of Western Ghats. Although *K. pulchra* is a common microhylid of this region, we have limited knowledge about this species from the Western Ghats. In particular, very little is known about its reproductive biology. We investigated the breeding period and advertisement call of this species.

Both field observations during the breeding season and characterization of the male call parameters were conducted near Dharwad (15°27′N, 75°05′E). From 1989 to 1997, we recorded male calls with directional microphones (AKG, D-707/190 C, D-1000 I) and tape recorder (AKAI AI 490 FS, 4.8 cm/s) at water temperatures of 19–21°C and relative humidities between 90 and 93%. We used a LUTRON SL 4001 SPL meter (fitted with Bruel & Kjaer multifunction acoustic calibrator, 4226) to measure the sound pressure level (re 20 μPa, “fast” root-mean-square [RMS], C weighting) from a distance of 1 m. Calls of 20 males were analyzed by the acoustic analyzer computer program MOSIP* spectro analysis V6.8, 41/89, MEDAV GmbH, at Zoological Institute, University of Bonn, Germany; statistical analysis was carried out with Statgraphics (STSC, Statistical Graphic Corp., Knoxville, Tennessee, USA).

Calling activity began after the first two to three heavy pre-monsoon showers (April/May) during 1990, 1991, 1992 and 1996. When the pre-monsoon rains failed to occur during 1993, 1994, 1995, and 1997, the calling began with the onset of monsoon rains (June/July) and continued until August. Observations over a period of eight years indicated that the males emit the advertisement call from April to August. During the same period amplexed pairs also were observed in the field. Hence, in the absence of reports on the gonadal cycles, we suggest that April to August may be the breeding period of *K. pulchra*. The calls were given while males floated on the water surface. Calling was in chorus, however adjacent calling males alternated their calls (N = 50). Advertisement calls were emitted in series with variable call intervals. Each call occurred in a single pulse group of 28–56 pulses (mean ± SE, 42 ± 1; Fig. 1A) and the number of pulses per second varied between 54 and 114 (mean ± SE, 84.2 ± 6.1). The pulse interval was very short and could not be recorded. The amplitude varied slightly from call to call (Fig. 1B). The call began with a pulse of low amplitude and reached the maximum after the 6th to 10th pulse (Fig. 1A). Subsequently it decreased gradually. The call duration, call interval, and the call period varied from 318 to 932 ms (mean ± SE, 579 ± 14; N = 20), 207 to 1078 ms (mean ± SE, 541 ± 27; N = 20) and 797 to 1672 ms (mean ± SE, 1140 ± 31; N = 20), respectively. The frequency spectra ranged between 50 and 1760 Hz with two bands (Fig. 1C). The dominant frequencies were between 400–1220 Hz (mean ± SE, 704.8 ± 85.1; N = 10). The sound pressure level measured from a distance of 1 m from the frog varied between 54 and 60 dB.

The advertisement calls of breeding male anurans have two main functions: a) intrasexual competitive interactions for calling stations, which in some species are also oviposition sites, and for active (acoustic) space; and b) intersexual attraction of mates (Littlejohn 1977). Additionally, calling sites and call parameters may reflect mechanisms for reproductive isolation among species.

Acoustic communication studies in Western Ghats microhylids are limited to *Microhyla ornata* (Hiremath 1991), *M. rubra* (Kanamadi et al. 1994), *Ramunella variegata* (Kanamadi et al. 1993), and *R. montana* (Kadadevaru et al. 1998).

*Kaloula pulchra, R. variegata, M. ornata, and M. rubra* are sympatric microhylid species at Dharwad. Calling sites of *M. rubra* are on land in open fields near water bodies (Kanamadi et al. 1994), whereas those of *M. ornata* are depressions in muddy areas, and also in spaces under the grass (Hiremath 1991). The advertisement call of *M. rubra* consisted of 66–135 pulses (mean ± SE, 108 ± 2.4; N = 39). The call duration varied from 138 to 228 ms (mean ± SE, 168 ± 3.2; N = 39) and the number of pulses ranged

---

**Fig. 1.** (A) Oscillogram of a single advertisement call of *Kaloula pulchra* (66 mm SVL) showing amplitude modulation. Oscillogram (B) and sonagram (C) of two advertisement calls of *K. pulchra* (66 mm SVL) showing call interval and frequency spectra respectively. Recorded in Dharwad, India. Water temperature 20°C.
between 15 and 21 (mean ± SE, 18.0 ± 2.4; N = 40). In *M. ornata*, the advertisement call comprised 33–40 pulses/s (mean ± SE, 30.0 ± 0.3; N = 28). The call duration varied from 13 to 77 s (mean ± SE, 33.2 ± 5.3; N = 14) and the pulse number ranged between 10 and 14 (mean ± SE, 12.8 ± 0.30; N = 28). Males of *K. pulchra* call from the surface of water bodies, similar to those of *R. variegata* (Kanamadi et al. 1993). It is likely that the different calling sites of *M. rubra* and *M. ornata* contribute to spatial separation of these sympatric species from *K. pulchra* and *R. variegata*. The advertisement call of *R. variegata* consisted of 359–385 pulses/s (mean ± SE, 369 ± 4.6; N = 5). The call duration varied from 187 to 234 ms (mean ± SE, 214 ± 3.6; N = 10) and the pulse number ranged between 74 and 137 (mean ± SE, 96 ± 5.6; N = 11). Its frequency spectra ranged between 300 and 4300 Hz with harmonics and a distinct fundamental frequency (Kanamadi et al. 1993). In the present study of *K. pulchra*, the pulse number (28–56) and the frequency range (50–1760 Hz) are much lower. Although males of both species share common calling sites, the species-specific pulse number and the variation in the frequency range may help in attracting conspecific females. The call duration of *K. pulchra* from Thailand (Heyer 1971) ranged from 560 to 600 ms, consisted of 32–35 pulses/s with 18–21 pulses/call, and the frequency spectra had a dominant band at 250 Hz. Our study of the same species shows differences in the call duration, pulses/s, pulses/call, and the frequency range. The differences in the call parameters may reflect geographic variation, as described in *Rana ridibunda* (Schneider 1973; Nevo and Schneider 1983; Kuhn and Schneider, 1984; Schneider and Sofianidou 1985), *Bombina orientalis* (Akef and Schneider 1985; Schneider et al. 1986), and *M. ornata* (Hiremath 1991).

Acknowledgments.—The study was supported by a grant from Department of Science and Technology (No. SP/SOC-23/93) awarded to R.D.K. and partly by the Special Assistance Program II grant, funded by University Grants Commission (UGC), New Delhi. We also thank UGC, New Delhi and German Academic Exchange Service, Bonn, Federal Republic of Germany, for selecting the first author for study visit (1997).

Literature Cited


Littlejohn, M. J. 1977. Long range acoustic communication in anurans:


Littlejohn, M. J. 1977. Long range acoustic communication in anurans:
Amphibian fauna of India comprises as many as 228 species, of which 121 inhabit the Western Ghats. Many aspects of biology of these species remain unknown. Studies on bioacoustics of Indian anurans are restricted to a few species, whereas those on their breeding biology are even more scarce. Limnonectes syhadrensis is widely distributed in the Western Ghats and peninsular India. It is also found in Pakistan and Nepal. 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), Sagur (16°37'N, 76°51'E), Jog Falls (14°45'N, 74°53'E), Shimoga (13°36'N, 75°38'E), Srigeri (13°25'N, 75°55'E), Kodur (13°35'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 A1 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, 418/89, MEDAV GmbH. The statistical analysis was carried out with Statgraphics 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 rainstorms 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 partly submerged 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample size</th>
<th>Mean ± SE</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call duration (ms)</td>
<td>25</td>
<td>903.6 ± 48.4</td>
<td>447-1547</td>
</tr>
<tr>
<td>Call interval (ms)</td>
<td>22</td>
<td>2457.0 ± 177.0</td>
<td>1243-4169</td>
</tr>
<tr>
<td>Call period (ms)</td>
<td>21</td>
<td>3224.5 ± 211.2</td>
<td>1485-5227</td>
</tr>
<tr>
<td>Pulse groups/call (N)</td>
<td>32</td>
<td>13.2 ± 0.9</td>
<td>7-28</td>
</tr>
<tr>
<td>Pulse group duration (ms)</td>
<td>140</td>
<td>32.1 ± 0.8</td>
<td>19-74</td>
</tr>
<tr>
<td>Pulse group interval (ms)</td>
<td>140</td>
<td>51.4 ± 1.7</td>
<td>19-125</td>
</tr>
<tr>
<td>Pulse group period (ms)</td>
<td>140</td>
<td>84.3 ± 2.2</td>
<td>43-176</td>
</tr>
</tbody>
</table>
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 his 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. (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 ridibunda9, R. lessonae10, R. perezi11, Euphlyctis cyanophlyctis12 and Hoplobatrachus crassa 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 group14 and H. crassa of 2–4 pulse groups per call15. 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 harmonics13. The frequency spectra of L. syhadrensis is broad and consists of indistinct harmonics as observed in L. limnocharis15 and Tomopterna rufescens16. 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 Nepal1. 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).
Role of nematodes as bioindicators in marine and freshwater habitats

The utility of bioindicators has been established in recent times. 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, acanthocephalans and larval nematodes have dominated in the role of parasite indicators. But the host-parasite relationships involving adult nematodes have rarely been reported in the investigations identifying parasites as indicators.

The subject of this investigation has been catfishes of two zoogeographically different regions within the same country. Adult roundworms of genus Rostella-scaris 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. 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. 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).

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, for confirming the identifications of the frogs. G.G.K thanks UGC, New Delhi for the award of FIP fellowship. DST/SIP/371-23/93 (DST), SAP-II and COSSIST (UGC) grants supported the work.

Received 26 November 2001; revised accepted 18 January 2002

GERISH G. KADADEVARU* RAVISHANKAR D. KANAMADI*/2 HANS SCHNEIDER**

*Department of Zoology, Karnataka University, Dharwad 580 003, India
**Zoologisches Institut, Universitat Bonn, D-5300 Bonn 1, Germany
For correspondence e-mail: karnatakuniversity@yahoo.com
Figure 3 Map of peninsular India and Sri Lanka showing distribution of *Philautus variabilis* ('x' marks indicate earlier reports and 'O' marks indicate the extended distribution).


Received July 24, 2000 Accepted November 21 2000
Table 2 Analysis of the aggressive calls of *P. vanabilis* and its comparison with 6-note, 7-note and 11-note advertisement calls

*P* values were calculated by using Mann-Whitney *U* test. Significant differences compared with aggressive call *P* < 0.05

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample size</th>
<th>Aggressive call Mean ± sX (range)</th>
<th>Advertisement call Mean ± sX (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6-note</td>
<td>7-note</td>
</tr>
<tr>
<td>Pulse number (n)</td>
<td>10</td>
<td>9 ± 0.4 (5-15)</td>
<td>--</td>
</tr>
<tr>
<td>Pulse duration (ms)</td>
<td>10</td>
<td>25 ± 2 (16-33)</td>
<td>45 ± 3.9* (22-62)</td>
</tr>
<tr>
<td>Pulse interval (ms)</td>
<td>10</td>
<td>58 ± 5 (40-98)</td>
<td>129 ± 9* (80-168)</td>
</tr>
<tr>
<td>Pulses/sec (n)</td>
<td>10</td>
<td>8 ± 0.3 (7-10)</td>
<td>3 ± 0.11* (3-4)</td>
</tr>
<tr>
<td>Call duration (ms)</td>
<td>10</td>
<td>725 ± 85 (359-1342)</td>
<td>819 ± 13* (744-855)</td>
</tr>
<tr>
<td>Call interval (ms)</td>
<td>10</td>
<td>335 ± 3 (117-540)</td>
<td>839 ± 11* (779-906)</td>
</tr>
<tr>
<td>Call period (ms)</td>
<td>10</td>
<td>1060 ± 86 (649-1665)</td>
<td>1659 ± 18* (1593-1774)</td>
</tr>
</tbody>
</table>

Acknowledgements: The work was supported by DST/SP/SOC/2339. We thank University Grants Commission, New Delhi, India and German Academic Exchange Service, Bonn, FRG, for selecting the first author for study visit (1997). We also thank Dr. M.S. Ravisankaran of Zoological Survey of India, Southern Regional Station, Chennai and Dr. Ranjit Daniels for confirming the identifications of the frogs.

References

Arak, A (1983) Vocal interaction, call matching and territoriality in a Srilankan tree frog *Philautus leucocoronus* (Bhacophoridae) Anim Behav 31 292-302

Boulenger, G A (1890) Fauna of British India including Ceylon and Burma Reptila and Batrachia London, Taylor and Francis


Daniels, R J R (1997b) A field guide to the frogs and toads of the Western Ghats India Cobra 27 1-25

Daniels, R J R (1997d) A field guide to the frogs and toads of the Western Ghats India Cobra 28 1-24

Daniels, R J R (1997c) A field guide to the frogs and toads of the Western Ghats India Cobra 29 1-13

Dutta, S K (1992) Amphibians of India Updated species list with distribution record Hamadryad 17 1-13

Dutta, S K (1997) Amphibians of India and Srilanka (check list and bibliography), Bhubaneshwar, Orissa, Odyssey


maximum number of notes per call is reached (Heyer, 1971). It differs from *P. leucorhinus* where males increase a portion of multi note call in response to social interaction (Arak, 1983). Though the calling pattern of *P. variabilis* matches with *P. parvulus*, their spectral and temporal features differ. The frequency spectrum of *P. parvulus* is spread over between 2250 and 3250 Hz (Heyer, 1971), whereas in *P. variabilis*, it is concentrated between 37 and 3900 Hz, with two bands. Male anurans produce calls that match the temporal characters of neighbors’ calls in natural conditions or in playback calls (Arak, 1983). This behaviour results in graded changes in vocalization leading to aggressive interactions as observed in *Hyperolius marmoratus* (Grafe, 1995), *Pseudacris crucifer* (Schwartz, 1989) and *Hyla ebraccata* (Wells, 1989). Similarly, *P. variabilis* exhibits graded changes in vocalization. The aggressive calls of *P. variabilis* are similar to those of *H. ebraccata* where males give such calls only when immediately threatened by an intruder (Wells and Schwartz, 1984). Increase in the portion of aggressive calling in response to other calling males and playback calls by *P. variabilis* is as observed in *P. leucorhinus* (Arak, 1983) but there are no compound calls consisting of advertisement and aggressive notes as reported in *H. ebraccata* and *P. leucorhinus*. The complex vocal interactions of *P. variabilis*, shifting from single-note to multi-note advertisement call and from multi-note to aggressive calling may facilitate male-male interactions and help the female to choose the potential mate.
The amplitude of the first pulse was low and subsequent pulses gradually increased in amplitude. After reaching a 4-note call, the amplitude remained almost constant throughout. The call interval was long in the beginning ($\bar{x} \pm s$, 1302 ±105 ms, $n = 10$), gradually decreasing and ending with short intervals ($\bar{x} \pm s$, 476 ±15 ms, $n = 10$). In a group, a frog that initiated a single note advertisement call stimulated other nearby males to call. The frogs shifted from single-note to multi-note calling gradually in alternation and at the end the calls overlapped. Acoustic features of the advertisement call are summarized in Table 1. The frequency spectra showed two bands between 37 Hz and 4370 Hz. The fundamental frequency lay in the first band between 37 and 127 Hz and the dominant frequency in the second band between 1900 and 4370 Hz.

Aggressive calls
Aggressive calling was a consequence of a male moving within a distance of 20-30 cm of an established caller ($n = 20$). Calling males when placed within a distance of 25-40 cm in the field and in captive conditions also resulted in aggressive calling ($n = 10$). As an intruder approached progressively closer to the resident male, the resident male gradually altered the temporal structures of the advertisement call and produced aggressive signals. Each call consisted of a series of notes (each note consisted of a single pulse) and the number of notes per call varied between five and 15. The amplitude of the first pulse was always low, it raised quickly in the next pulse and then it decreased a bit and later gradually increased (Fig. 2a). Acoustic features of the calls are given in Table 2. The spectral bandwidth ranged between 37 and 3900 Hz with two prominent bands (Fig. 2a). Fundamental frequency lay in the first band between 37 and 1250 Hz and the dominant frequency lay in the second band between 2700 and 3900 Hz. The aggressive calls showed significant variation (Table 2) when compared with 6-note, 7-note and 11-note advertisement calls ($P < 0.05$).

Distribution
Based on calling behaviour, it was observed that *P. variabilis* is distributed in many parts of Western Ghats which included the areas around Sirsi (14°34'N 74°32'E), Sagar (16°37'N 76°51'E), Jog (14°45'N 74°53'E), Shimoga (13°56'N 75°38'E), Sriniger (13°25'N 75°15'E), Kollur (13°53'N 74°53'E) and Londa (15°60'N 74°53'E). Fringe areas included Dharwad (15°27'N 75°05'E) and Belgaum (15°52'N 74°34'E), and the area around Miraj (16°49'N 74°30'E) and Sangli (16°52'N 74°36'E). Our study revealed that it is not only restricted to some limited parts of the Western Ghats (Dutta, 1992, 1997; Daniels, 1997) but also widely distributed over many parts of it including the fringe areas and nearby plains (Fig. 3).

Complex vocal interactions that are found in *P. variabilis* are similar to those of other rhacophorids such as *Polypedates maculatus* (Kananadhi et al., 1993), *Polypedates leucomastax* (Kuramoto, 1986) and *Philautus leucorhinus* (Arak, 1983). The advertisement call of *P. variabilis* begins with a single note like that of *Philautus parvulus* (Heyer, 1971). *P. leucorhinus* and *P. maculatus*. Later it is affected by the social interaction and changes to multi-note structure as observed in *P. parvulus* and *P. leucorhinus*. Calling pattern matches with that of *P. parvulus* where males add notes to calls in response to other male’s calls until
Figure 1 (A-C) Oscillogram and (a-c) sonagram of advertisement call of *P. variabilis*, single note to 12-note call. Recorded at Dharwad, Air temperature 21°C.
Calling behaviour  Calling activity began after a few days of heavy monsoon rains in the month of June and continued up to the end of the monsoon (October), reaching its peak in the middle of the season (July and August). Male frogs possessed a single subgular vocal sac that attained a spherical shape during calling. They preferred to call from branches, leaf surface of shrubs, bushes and small trees. The height of calling site was $x, s, 69 \pm 38 \text{ cm}$ ($n = 50$) from the ground. Calling occurred intensively for four to five hours after dusk and for a short period at dawn. Calling intensity was less in between. On cloudy days calls were also heard during the daytime. Calling activity was less on days without rain. Calling males maintained an inter-male distance of $x, s, 3.2 \pm 0.3 \text{ m}$ ($n = 10$). Males emitted two types of calls: advertisement calls and aggressive calls.

Advertisement calls  Calling began with a single note (each note consisted of a single pulse) and after giving a few single note calls males switched to multi note calls containing 2 to 19 notes per call (fig 1). Later in the evening sometimes as many as 29 notes per call were observed. Calls began as feeble sounds ($x, s, 67 \pm 0.33 \text{ dB}, n = 40$) and increased in intensity in response to the nearest calling male ($x, s, 103 \pm 0.41 \text{ dB}, n = 35$).

Table 1  Analysis of the advertisement calls of *P. variabilis* (One call each of 10 randomly selected individuals were used for statistical calculation)

<table>
<thead>
<tr>
<th>Call type</th>
<th>Sample size</th>
<th>Call duration (ms) Mean ± $s_2$ (range)</th>
<th>Call interval (ms) Mean ± $s_2$ (range)</th>
<th>Call period (ms) Mean ± $s_2$ (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single note call</td>
<td>10</td>
<td>$25 \pm 3$ (15-39)</td>
<td>$1302 \pm 105$ (750-1884)</td>
<td>$1327 \pm 113$ (789-1876)</td>
</tr>
<tr>
<td>2-note call</td>
<td>10</td>
<td>$157 \pm 3$ (138-174)</td>
<td>$1060 \pm 53$ (860-1279)</td>
<td>$1205 \pm 66$ (1000-1569)</td>
</tr>
<tr>
<td>3-note call</td>
<td>10</td>
<td>$325 \pm 9$ (290-383)</td>
<td>$905 \pm 21$ (790-1000)</td>
<td>$1226 \pm 24$ (1065-1325)</td>
</tr>
<tr>
<td>4-note call</td>
<td>10</td>
<td>$506 \pm 11$ (453-564)</td>
<td>$837 \pm 15$ (720-1081)</td>
<td>$1376 \pm 36$ (1205-1639)</td>
</tr>
<tr>
<td>6-note call</td>
<td>10</td>
<td>$819 \pm 13$ (744-895)</td>
<td>$839 \pm 11$ (729-906)</td>
<td>$1659 \pm 18$ (1593-1774)</td>
</tr>
<tr>
<td>7-note call</td>
<td>10</td>
<td>$1102 \pm 21$ (1034-1197)</td>
<td>$739 \pm 19$ (651-837)</td>
<td>$1844 \pm 19$ (1754-1929)</td>
</tr>
<tr>
<td>11-note call</td>
<td>10</td>
<td>$1456 \pm 26$ (1348-1569)</td>
<td>$476 \pm 15$ (418-558)</td>
<td>$1935 \pm 24$ (1838-2056)</td>
</tr>
<tr>
<td>19-note call</td>
<td>10</td>
<td>$3706 \pm 23$ (3606-3790)</td>
<td>$-$</td>
<td>$-$</td>
</tr>
</tbody>
</table>

Call interval and call period of 19-note calls were not recorded.
and Kanamadi, 1997) Thirty species in the genus are distributed in different parts of the subcontinent (Dutta, 1992), of which 24 species are found to occur in the Western Ghats (Daniels, 1991). Few species are also reported from other Asian countries such as Thailand (Heyer, 1971), Sri Lanka, Myanmar, China and Bhutan (Dutta, 1992). Despite the large number of species in this group, most investigations are limited to distribution records *Philautus parvulus* (Heyer, 1971) and *Philautus leucorhinus* (Arak, 1983, Patil et al., 1996) are the species among the genus examined so far, for vocal interactions, call matching, territoriality and bioacoustics.

*Philautus variabilis* is a medium sized bush frog (male SVL $\bar{x}$, $s$, 22.3 $\pm$ 0.34 mm, $n = 10$), distributed in many parts of the Western Ghats inhabiting Ponnumadi Hills (Kerala), Palams and Nilgiris (Tamil Nadu), Kempholey (Karnataka) and also in some parts of the Eastern Ghats (Shevroy$^s$) of India. It is also reported from the neighboring country of Sri Lanka (Dutta, 1992, 1997, Daniels, 1997c). Studies on this species are limited to parental care (Kanamadi et al., 1996) and direct development (Patil and Kanamadi, 1997). In this paper we describe calling behaviour, analysis of calls, distribution and range extension of the species based on vocalization.

**Study area** Based on the earlier reports of the species distribution we started our field observations in 1995 in selected localities of the Western Ghats. Frogs were located based on vocalization and a few calling frogs were collected for taxonomic studies. The frogs were identified in the laboratory by using the taxonomic keys (Boulenger, 1890, Dutta, 1992, Daniels, 1997a, b, c). When we continued our observations, we were surprised to note that the species was restricted not only to some specific areas of the Western Ghats but also distributed in many parts of it, including its fringe areas. These observations incited us to look for populations in other areas of the Western Ghats, fringe areas and the nearby plains.

**Recording and analysis of the calls** Recordings were done at Dharwad (15°27' N 75°05'E). Calls were recorded on SONY Super EF60 cassette tapes using an AKAI AJ 490FS tape recorder (4.8 cm/s speed) and AKG — D707C/190 C, D-1000 i directional microphones. Microphones were placed/held within a distance of 15 cm from the calling frogs. A LUTRON SL 4001SPL meter (fitted with Bruel & Kjaer multi function acoustic calibrator, 4226) was used to measure the sound pressure level (re 20 $\mu$Pa, “fast” root-mean-square, A weighing) from a distance of 1 m. At the time of recording the air temperature varied between 20 and 23°C and the relative humidity between 87 and 93%. The calls of 10 frogs were analysed for spectral and temporal features at the Zoological Institute, University of Bonn, Germany, using a computer based acoustic analyser program (MOSIP (R) spectro analyses V6 8, 41/89, MEDAV GmbH). Analysis was carried out for the note calls, which occurred repeatedly. The variables studied were pulse duration, pulse interval, pulses/sec, call duration, call interval, call period, fundamental frequency and dominant frequency. Statistical analysis was done with Statgraphics Program STSC, Inc., Knoxville, TN, USA. The non-parametric Mann-Whitney U test was used to compare
Calling behaviour, bioacoustics and distribution of a rhacophorid frog, *Philautus variabilis* (Gunther, 1858)

Ravishankar D Kanamadi¹, Girsh G Kadadevaru¹, Hans Schneider²

1 Department of Zoology, Karnatak University, Dharwad-580 003, India
2 Zoologisches Institut, Universität Bonn, Bonn, Germany

Acoustic signals play a very important role in the successful breeding activity of frogs and toads, and are regarded as one of the key characteristics responsible for reproductive isolation and speciation events in these animal groups. Male anurans use vocalization to advertise their species identity, sex and location to the females (Wells, 1977). The presence of advertisement calls that may function in both mate attraction and inter-male spacing is an almost ubiquitous feature of anuran communication (Wells, 1977). The importance of aggressive vocalization in communication between conspecific males has been examined in many anurans (Arak, 1983; Wells, 1989; Schwartz, 1989; Grafe, 1995). The observations on structure and function of these calls provide an important tool in understanding and investigating the basic concepts of vocal communication within anurans.

Members of the genus *Philautus* are the most abundant and conspicuous group of frogs in India, and it is the only group in which direct development has been recorded (Patil...