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Acoustic Communication in Orthopteran and Hemipteran Insects

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ABSTRACT

Animal communication is ubiquitous and a conspicuous aspect of the behavior of all the animals. Acoustic communication among animals utilizes sounds to signal information between the insects. The present study was carried out to identify the sexual receptiveness of the females towards the males. The advertisement calls of Cicadas and katydids belonging to orders Hemiptera and Orthoptera were recorded using TASCAM DR-100MK Linear PCM recorder connected to AKG D1000i directional microphones held approximately 15-30 cm away from the calling males. Sound levels of the calls were taken using TES sound level meter 1350A. Humidity and temperature were noted using digital hygrometer and thermometer respectively. Katydids produce their calling songs by rubbing their forewings together. This causes the hardened plectrum on the posterior margin of one wing to strike against the teeth of a stridulatory file on the other wing, thus producing sound. The sound producing organs in cicadas are the drum like tymbals. Though it seems like the calls are continues without any call intervals but there are minute call intervals that can be heard with carful observations. Each call consists of several pulse groups and is from 186-274 with an average of 223.5±39.534pulse groups/sec. At the level of biological species, acoustic studies have been widely and effectively used to establish the status of related populations of a wide variety of insects. In addition bioacoustics plays a major role in sexual behavior in many insects that help in mate searching, recognition and courtship.

Keywords: Acoustics, cicada, hemiptera, tymbals, courtship

All animals interact with their environment, including individuals or groups of either the same or of different species. Animal communication is ubiquitous and a conspicuous aspect of the behavior of all the animals. Communication is the result of any action or display by one individual the sender that functions as a signal and affects the current or future actions/displays of another individual the receiver. Acoustic communication among animals utilizes sound to signal information from one individual to another. Many animals use acoustic signals for intraspecific communication. E.g. Birds produce song, frog croak, and crickets chirp.

Across several taxa from insects to mammals, animals that produce acoustic signals aggregate spatially to form choruses (Gerhardt *et al.* 2002, Burt *et al*. 2005, Bradbury *et al*. 2011.) A functional chorus requires acoustic interactions between its participants. In Orthopteran choruses, individuals, usually one sex (typically the male), use acoustic signals to attract Conspecific mates over a long distance, leading to intra-specific sexual competition (Gerhardt *et al.* 2002). However, calling behavior is energetically expensive and may also attract predators and parasites (Gerhardt *et al.* 2002, Zuk, Kolluru 1998). Energetic demands of calling and predation risk thus constitute the major costs of acoustic signaling. For females to assess potential mates based on their calling song, callers need to be actively signaling at least during the assessment period. The temporal pattern of chorusing can thus affect a female's mate search Strategy (Callander 2013). Pair formation during mating requires conspecific males and females to find each other. Since females use the male calling song over long distances to localize potential mates, it is more likely that the males remain stationary while the female searches for mates.

While calling effort determines the amount of sexual signaling acoustic signals have multiple temporal and spectral features that can be energetically costly and important for mate attraction as well (Gerhardt *et al.* 2002; Prestwich 1994). In katydids, calling song chirp rate is energetically expensive and co- varies positively with the immediate nutritional condition of the male (Wagner *et al.* 1999; Whattam *et al.* 2011; Bailey *et al.* 1993). Calling song sound pressure level (SPL), which is a measure of its loudness, is also known to be energetically expensive (Gerhardt *et al.* 2002). Thus, similar to calling effort, signal Components such as SPL and chirp rate are energetically costly and also function as mate attraction cues. Male calling song SPL has been shown to playa critical role in female phonotaxis in complex acoustic scenarios, with females preferring louder calls (Mhatre *et al.* 2007; Mhatre *et al.* 2008). Amount of calling activity (calling effort) is a strong determinant of male mating success in species such as Orthopterans and Hemipterans that use acoustic communication in the context of mating behavior. Calling activity (proportion of time spent calling per night) is an important measure of katydid behavior. Males with high calling activity are therefore expected to be at an advantage in mating, either because females choose males that are able to sustain high levels of calling (Walker, 1983) or more possibly, because males that call a lot are more likely to be calling when a searching female passes by (Zuk and Simmons, 1997). The female may then evaluate male quality based on song structure elements such as pulse rate, frequency, and intensity (Pollack and Hoy, 1981; Doolan and Pollack, 1985). For calling activity to be a reliable indicator of male performance, it must be repeatable, varying among males but remaining relatively consistent within males (Boake, 1989). Repeatability is important not only because it gives an indication of individual male stereotypy (Boake, 1989), but also because it sets an upper limit to heritability (Falconer, 1989). In addition to calling activity levels, nightly calling patterns in crickets may have important consequences for male reproductive success (Walker, 1983). For example, males should reach a peak in calling activity at the same time during the night that receptive females reach a peak in searching activity (Walker, 1983; Gita Raman Kolluru, 1997). Calling effort and calling song SPL are critical aspects of signaling behavior that could be under sexual selection via different operative mechanisms (Forrest *et al.* 1994). Thus, variation in calling effort and its correlation with other signal components provide the basis for exploring the role of sexual selection in the evolution and maintenance of acoustic communication (Diptarup Nandi *et al.* 2016).

MATERIALS AND METHODS

Study Area: For the present investigation to study the bioacoustics of insects two different geographical regions were selected (Plate I). Location I is agricultural fields in the outskirts of Bellary (15^{0}09′ 30.01″ N 76^{0}56′50.92″ E elev 498 m) location II is Karnatak University campus Dharwad (15^{0}26′ 38.2″ N 74^{0}59′ 01.17″ E elev 738m and 15^{0}26′ 31.31″N 74^{0}58′ 59.74″ E elev746m).

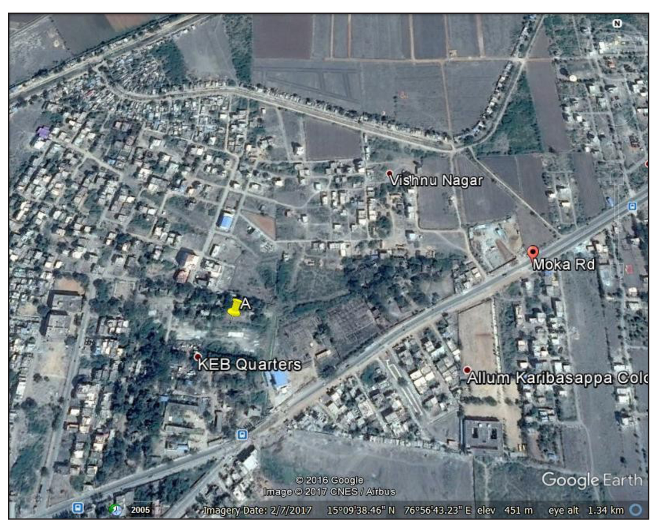


PLATE I

Methods: The advertisement calls of insects were recorded using TASCAM DR-100MK LINEAR PCM RECORDER connected to AKG D1000i directional microphones which were held approximately 15-30cm away from the calling insects. Sound level of the calls was taken using TES SOUND LEVEL METER 1350A. Humidity and atmospheric air and temperature were noted using digital hygrometer and thermometer respectively. The insects used in this study are common species distributed throughout India in agricultural and suburban areas and is not listed as endangered. The study was conducted on a wild population of the insects (Katydids and Cicadas) in agricultural fields and sub rural areas in the southern Indian state of Karnataka, in the breeding season between the months of January, April and May. The insects (katydids)nocturnal and males are acoustically active. The recording was carried out from 1930 to 2130 hrs. But cicadas are diurnal and the recording was carried between 1000 to 1330 hrs. The records were voice-cued with information about the insect, call number and vertical sound pressure level. Audacity and Sound ruler software were used to visually examine the recorded calls, analyse and develop the spectra.

RESULTS AND DISCUSSION

KATYDID: *Mecopoda elongate* (Plate II Fig. I)

Katydids are often large, with body lengths that range from 1 to more than 6 cm. They have a thick body, and long thing legs. The hind legs are longer than the front or middle legs, and are often used for jumping.

On the head they have long thin antennae that reach back at least to the abdomen of the insect. They are usually green, sometimes with brown markings. They typically are found living on trees, bushes, or grasses often matching the appearance of their surroundings. Katydids are primarily leaf-eaters. They sometimes eat other plant parts (especially flowers). They also sometimes eat dead insect eggs or slow-moving insects like aphids. During copulation the male deposits sperm onto the females' genital opening. Within 15-20 minutes, the sperm enters the females' body. The female then lays the fertilized eggs. It normally takes 2-3 months for the eggs to hatch. Since the average lifespan is about 1 year, their only social behavior includes courtship and mating. Katydids produce their calling songs by rubbing their forewings together. This causes the hardened plectrum on the posterior margin of one wing to strike against the teeth of a stridulatory file on the other wing, thus producing sound. For tettigoniids, the fore wings are used to sing. Tettigoniids produce continuous songs known as trills. Species of Katydids chew holes or notches on the edges of leaves which rarely causes serious damage to established woodyplants.

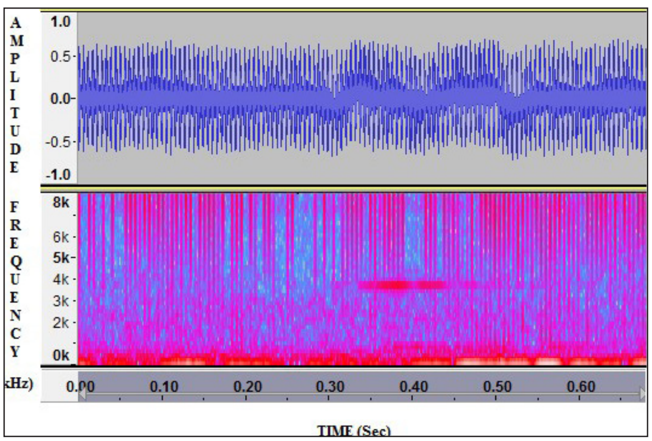
CICADA: *Platypleura polita* (Plate II Fig II)

The adult insect, known as an imago is 2 to 5 centimetres (1–2 in). Cicadas have prominent compound eyes set wide apart on the sides of the head. They also have three small ocelli located on the top of the head in a triangle between the two large eyes. Cicadas use a variety of strategies to evade predators. As being coloured like tree bark, they are disruptively patterned to break up the attention of predators. Most genera are restricted to a single bio geographical region and many species have a very limited range. Cicada nymph's drink sap from the xylem utilizing their sucking mouthparts of various species of trees, including oak, cypress, willow, ash, and maple. After mating, the female cuts slits into the bark of a twig where she deposits her eggs. When

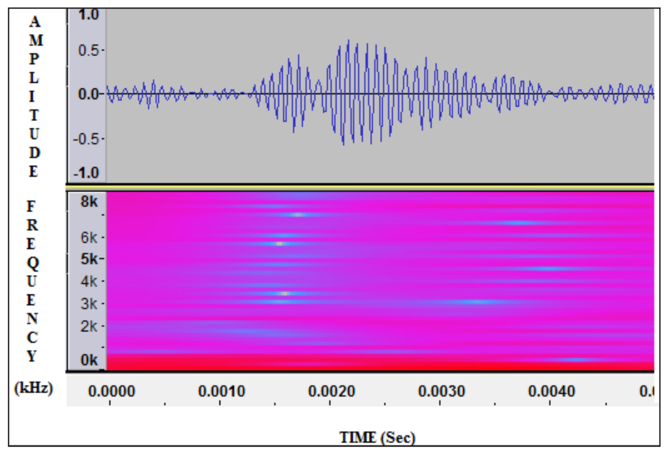
Fig. I

Fig. II

PLATE II

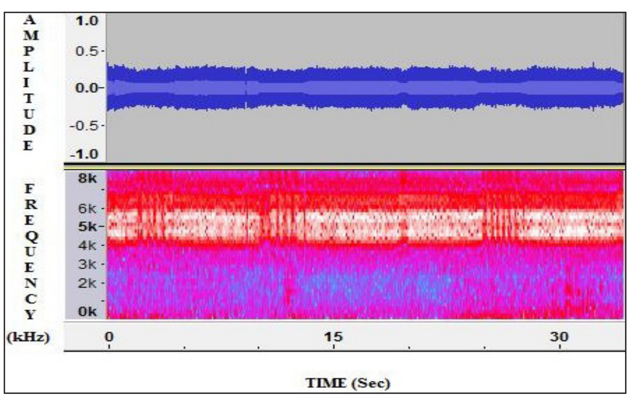


KATYDID: **Fig. 1(A)** Multiple pulse groups

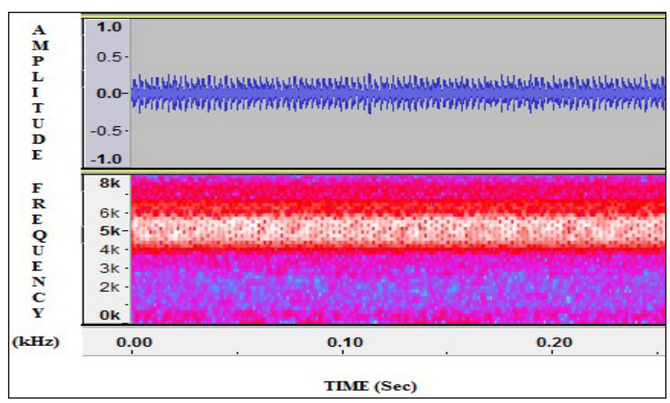


KATYDID: **Fig. 1(B)** Single pulse group

PLATE III



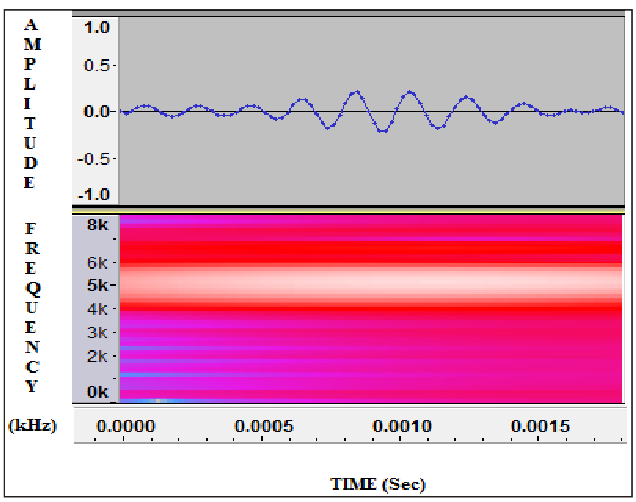
CICADA: **Fig. 2(A)**



CICADA: **Fig. 2 (B)** Multiple pulse groups

PLATE IV

the eggs hatch, the newly hatched nymphs drop to the ground and burrow. Cicadas live underground as nymphs for most of their lives. Most cicadas go through a life cycle that lasts from two to five years. Some species have much longer life cycles ranging from 13-17yrs. Cicada sound-producing organs consists of cover-plates, drum like tymbals, muscles that vibrate tymbals when singing. Some species have turned from wild grasses to sugar cane, and this has affected the crop adversely, and in a few isolated cases, females have oviposited on food crops such as date palms, grape vines, citrus trees, asparagus and cotton. The biggest concern about 17 year cicadas is their potential to damage youngtrees.



CICADA: **Fig. 2 (C)** Single pulse group

PLATE V

INSECT BIO-ACOUSTICS

Two insects were studied for the acoustical features. The spectral and temporal features of the insects are presented below.

Katydid: *Mecopoda elongate*

The males of tettigoniids have sound-producing organs (via stridulation) located on the hind angles of their front wings The sound is produced by rubbing two parts of their bodies together, called stridulation. Tettigoniids produce continuous songs known as trills. They prefer to call from leaf surface of shrubs and bushes. Calling occurs intensively for several minutes after dusk .Calls begin as feeble sounds and increase in intensity in response to the nearest calling male. Each call consists of about 32-101 pulse groups which are shown in table 1 and the call duration ranges from 7-21 with a mean of about 14.211±5.915. Each call consists of call period, pulse group interval and pulse group period with a mean of about 33.097±22.372, 0.33±0.024 and 0.569±0.025 respectively. Acoustical features of the calls are summarized in table 1. The frequency is ranged between 1688-7301. The fundamental frequency lies at 3421 Hz and dominant frequency at 6843 Hz. Oscillogram and Sonogram are described in fig. 1(A) & (B). Sound pressure level varied between 69-73dB.

Table 1: Katydid acoustical features

Parameter	Sample size	Mean ±SD	Range
Call duration (sec)	6	14.21175 ± 5.915255	07.389-21.344
Call period (sec)	6	33.097 ± 22.37241	09.341-53.765
Pulse groups/ call (N)	6	56.8 ± 37.34568	32-101
Pulse group duration (sec)	6	0.14033 ± 0.017996	0.131-0.177
Pulse group interval (sec)	6	0.33 ± 0.024199	0.288-0.354
Pulse group period (sec)	6	0.569429 ± 0.025032	0.524-0.590

Table 2: Cicada acoustical features

Parameter	Sample size	Mean ±SD	Range
Call duration (sec)	6	4.062±1.793	0.558-7.91
Call period (sec)	6	3.408±1.655	0.633-4.993
Pulse groups/call(N)	6	223.5±39.534	186-274
Pulse group duration (sec)	6	0.009±0.001	0.008-0.012
Pulse group interval (sec)	6	0.006±0.001	0.005-0.008
Pulse group period (sec)	6	0.016±0.001	0.015-0.018

Cicada: *Platypleura polita*

The sound producing organs in cicadas are the drum like tymbals. Daily calling activity begins from early morning to late evening and maximum calling activity is observed from 10.00 to 3.00 hrs. Though it seems like the calls are continues without any call intervals but there are minute call intervals that can be heard with carful observations. Each call consists of several pulse groups and is from 186-274 with an average of 223.5±39.534. Acoustical features of the call are summarized in table 2. Call duration is separated from the remaining calls by negligible call interval (fig. 2A) and the call duration lasts with a mean of 4.062±1.793 T0 0.558-7.91. Call period and pulse group interval ranged between 0.633 and 4.993 and 0.005-0.008 respectively. The frequency is ranged between 1200 and 6300 Hz. The fundamental frequency lies at 2765 Hz and dominant frequency at 5531 Hz. The *Oscillogram* and *Sonogram* are described in Fig. 2 (A), (B) & (C). The sound pressure level varied between 95- 99dB.

Studies on Orthopteran insects have investigated many important aspects of animal behavior, from the neural basis of behavior to the ecology of acoustic communication (Gwynne and Morris, 1983; Huber *et al.* 1989; Bailey and Rentz, 1990; Field, 2001; Gwynne, 2001). Calling activity under natural conditions is a significant predictor of female attraction. In most cases males produce sound and females locate the singing males. Sound (and vibration) signals are produced by elytro –elytralstridulation, and in most cases contain a broad range of frequencies starting in some species at frequencies as low as 3 to 4 kHz and ranging up to 80 kHz.

In cicada the call is continuous with series of pulse groups the pulses (4-6) are without pulse interval the amplitude modulation was low in the beginning gradually reaches to its peak in the middle and gradually decreases. Frequency spectra lie between 1200 to 6300 Hz With the dominant frequency at 5531Hz.

In Katydid calls are given in series of pulse groups having two components which starts with a small unit having 4-7 pulses followed by a large group having 17-14 pulses. In the first unit the amplitude starts with lowest and gradual increase after five to six pulses and suddenly decreases to lowest. This is followed by the second group where again there is increase in the amplitude in the first two or three pulses and then gradually it decreases. The frequency band extends from 1020 Hz to 8000Hz with dominant frequency at 3200 Hz. Nityananda and Rohini (2006) observed five distinct song types in genus Mecapoda. The present calling pattern resembles with that of "Chirper" type of song described in their study. However in the present Katydid *Mecopodaelengata* there is a reverse pattern having the small pulse group in the beginning followed by the large group. The two insects that were studied show variations in the call pattern both in spectral and temporal properties.

SUMMARY AND CONCLUSION

The present work is an attempt to study the bioacoustics of insects from two different locations of North Karnataka representing two climatic zones. The two insects that were studied show distinct pattern in call properties with varied spectral and temporal features. Some of these insects have been used as a model system for studies on speciation and acoustic communication (Huber *et al.* 1989; Gerhardt and Huber, 2002). At the level of biological species, acoustic studies have been widely and effectively used to establish the status of related populations of a wide variety of insects. In addition bioacoustics plays a major role in sexual behavior in many insects that help in mate searching, recognition and courtship. Further studies are needed to evaluate the geographical variations in the calling pattern in the seinsects.

REFERENCES

Bailey, W.J. and Rentz, D.C.F. 1990. *The Tettigoniidae, Biology, Systematics and Evolution.* Crawford House Press, Bathurst, Australia.

Bailey, W.J., Withers, P.C., Endersby, M. Gaull, K. 1993. The Energetic Costs of Calling in the Bush cricket *Requena verticalis* (orthoptera: Tettigoniidae: Listroscelidinae). *J. Exp. Biol.*, **178**: 21-37.

Boake, C.R.B. 1989. Repeatability: its role in evolutionary studies of mating behaviour. *Evol. Ecol.,* **3**: 173-182.

Bradbury, J.W. and Vehrencamp, S.L. 2011. Principles of Animal Communication. *Sunderland*, MA: Sinauer Associates.

Burt, J.M. and Vehrencamp, S.L. 2005. Dawn chorus as an interactive communication network. In: *McGregor* PK, editor. Animal communication networks, pp. 320-343.

Callander, S., Kahn, A.T., Hunt, J., Backwell, P.R.Y. and Jennions, M.D. 2013. The effect of competitors on calling effort and life span in male field crickets. *Behav. Ecol.,* **24**: 1251-1259.

Diptarup Nandi, and Rohini Balakrishnan. 2016. Spatio-Temporal Dynamics of Field Cricket Calling Behaviour: Implications for Female Mate Search and Mate Choice Centre for *Ecological* Sciences, Indian Institute of Science, Bangalore, Karnataka, India.

Doolan, J.M. and Pollack, G.S. 1985. Phonotactic specificity of the cricket *Teleogryllus oceanicus:* Intensity-dependent selectivity for temporal parameters of the stimulus. *J. Comp. Physiol., A* **157**: 223-233.

Falconer, D.S. 1989. *Introduction to Quantitative Genetics,* Longman Scientific and Technica.

Field, L.H. 2001. The Biology of Wetas, King Crickets and their Allies. CABI, Wallingford, UK., London.

Forrest, T.G. and Raspet, R. 1994. Models of female choice in acoustic communication.

Gerhardt, H.C. and Huber, F. 2002. Acoustic Communication in Insects and Anurans: Common Problems and Diverse Solutions. Chicago and London: University of Chicago Press.

Gita Raman Kolluru. 1997. Variation and Repeatability of Calling Behaviour in Crickets Subject to a Phonotactic Parasitoid Fly.

Gwynne, D.T. and Morris, G.K. 1983. Orthopteran Mating Systems. Westview Press, Boulder, CO.

Huber, F., Moore, T.E. and Loher, W. 1989. Cricket Behaviour and Neurobiology. Cornell University Press, Ithaca, NY.

Mhatre, N. and Balakrishnan, R. 2007. Male spacing behaviour and acoustic interactions in a field cricket: implications for female mate choice. *Anim. Behav.,* **72**: 1045-1058.

Mhatre, N. and Balakrishnan, R. 2008. Predicting acoustic orientation in complex real- world environments. *J. Exp. Biol.,* **211**: 2779-2785.

Nityananda and Rohini. 2006. A diversity of songs among morphologically indistinguishable katydids of the Genus Mecopoda (Orthoptera).

Pollack, G.S. and Hoy, R. 1981. Phonotaxis to individual rhythmic components of a complex cricket calling song. *J. Comp. Physiol.,* **144**: 367-373.

Prestwich, K.N. 1994. The energetics of acoustic signalling in anurans and insects. *Am. Zool.,* **34**: 625-643.

Wagner, W.E., Jr, Hoback, W.W. 1998. Nutritional effects on male calling behaviour in the variable field cricket. *Anim. Behav.,* **57**: 89-95.

Walker, T.J. 1983. Diel patterns of calling in nocturnal Orthoptera. In Gwynne, D.T. and Morris, G.K. (eds.), Orthopteran Mating Systems: Sexual Competition in a Diverse Group of Insects, Westview Press, Boulder, CO, pp. 45-72.

Whattam, E.M. and Bertram, S.M. 2011. Effects of juvenile and adult condition on long- distance call components in the Jamaican field cricket, *Gryllusassimilis*. *Anim. Behav.,* **81**: 135-144.

Zuk, M. and Kolluru, G.R. 1998. Exploitation of Sexual Signals by Predatorsand Parasitoids. *Q. Rev. Biol.,* **73**: 415-438.

Zuk, M. and Simmons, L.W. 1997. Reproductive strategies of the crickets (Orthoptera: Gryllidae). In Choe, J.C. and Crespi, B.J. (eds.), Mating Systems in Insects and Arachnids, Cambridge University Press, Cambridge, pp. 89-109.