International Journal of

Zoological Research

ISSN 1811-9778

Academic Journals Inc.

www.academicjournals.com

International Journal of Zoological Research 7 (5): 369-375, 2011
ISSN 1811-9778 / DOI: 10.3923/ijzr.2011.369.375

Ecological Approval for Cave Habitat: The Occurrence of Regressed Stridulatory System in Cavernicolous *Homoeogryllus* sp.

[1]Khushi Ram Sahu, [2]Jayant Biswas, [3]K. Venu Achari and [4]Krishna Mohan Sinha
[1]Government E. Raghvendra Rao P.G. Science College, Bilaspur (C.G.) 495006, India
[2]National Cave Research and Protection Organization, Central Zone, Raipur, C.G., India
[3]School of Life Sciences, Pt. Ravishankar Shukla University, Raipur, C.G. 492010, India
[4]Govt. P.G. College, Ambikapur (C.G.) 497001, India

Corresponding Author: Jayant Biswas, National Cave Research and Protection Organization, Central Zone, Raipur, C.G., India

ABSTRACT

Subterranean caves are always characterized by several uncommon ecological factors due to which a high degree of biological adaptation is always required to establish any population in it. In the present work, the morphology of the sound producing organ of a cave cricket *Homoeogryllus indicus* has been studied and the ecological importance of the same has been tried to correlate with its habitat. Fifty adult male individuals of *H. indicus* were collected from Kachhuwa-Pahar cave and preserved separately in plastic veil containing 4% formalin. Complete stridulatory apparatus was studied under a binocular microscope and the sketches of the tegmina and teeth were drawn by using camera lucida mounted on the microscope. The total number of teeth present in both the files were found to be comparatively less in number than the other members of the same genus which represents an example of regressed evolution. However, a comparatively regressed stridulatory system observed in this species along with other reported morphologically regressive characteristics has been discussed from the perspective of ecological fitness for cave life.

Key words: Cavernicoles, troglomorphism, stridulation, syllable, pre-adaptation

INTRODUCTION

Subterranean environment is characterized by perpetual darkness, low organic input, constant temperature, high humidity and often having low air current which altogether demands a high level of adaptation to cave conditions for survival. In spite of this, few organisms choose a subterranean mode of life in order to enjoy the privileges of easy availability of prey, less predation pressure and even the negligible effects of natural environmental calamities (Biswas and Shrotriya, 2011). In general cave dwelling/adapted organisms usually evolve from ancestral species with pre-adapted biological traits, favouring the cave life (Racovitza, 1907; Gunn, 2004; Culver and White, 2004). Cave dwelling organisms are basically of two types; the obligatory cave dwelling organism and the opportunistic or non-obligate cave dwellers (Gunn, 2004; Culver and White, 2004; Biswas, 2009, 2010). Cave adapted organisms leading completely a subterranean mode of life, fail to establish their populations in the external environmental conditions are referred to as obligatory cave species. Nevertheless, the organisms which use caves only for shelter, feeding, breeding, roosting, hibernating or any other respective biological needs but mostly depend on the external environment could be referred as non-obligatory or opportunistic type. As per, Kane and Culver (1992), the opportunistic cave dwellers act as empirical models of natural selection and adaptation in the subterranean environment.

The members of the family Phalangopsidae are highly hygrophilous in nature, excluding few deviants they usually avoid dry habitats (Desutter-Grandcolas, 1995a). The concealment place preferences often play a major role in its classification and on the same basis few genera are strictly categorized as cavernicolas; i.e., having a cave habitat (Desutter-Grandcolas, 1995a; Biswas, 2010). Though, few members of *Homoeogryllus* have already been found to be cavernicolous in nature, the basic generic characteristics do not show any such trait which could be referred to as pre-adapted to cave life. Earlier, the members of this genus were tightly restricted to some of the regions of Africa but later few species have been recognized from several other parts of the world, specifically adjacent to the older tropics [http://www.globalspecies.org/ntaxa/2092595].

Communication is a major factor for behavioural ecology and evolutionary biology (Krebs and Davies, 1997). Ensifera produce sound mainly by stridulation; the phenomenon completed by the friction of mechanized body parts (Dumortier, 1963). The morpho-functional diversity in stridulatory apparatus is also an important trait of Phalangopsid crickets (Desutter-Grandcolas, 1995a; Otte, 1992). Various modifications in the stridulatory apparatus to strengthen the mode of communication have been observed in the members of this group which possibly developed independently as per their habitat and requirements (Masaki *et al.*, 1987; Desutter-Grandcolas, 1995b). In addition to attracting mates, stridulatory systems are useful for inter specific interactions, such as competition between *Acoustic* species (Schatral, 1990) and also to escape from predation (Riede, 1987). Air circulation is generally low in most of the subterranean caves and which certainly dampens the airborne sounds. This could be the reason due to which the proper development of stridulatory system in *Ensifera fails* in such environment. Nevertheless, the subterranean mode of life could be more suitable for those species which have either absent or very weak active stridulatory systems and which could be also referred as pre-adapted traits for them to adapt a cave life (Culver and White, 2004).

The species *Homoeogryllus indicus* was described by Agarwal and Sinha (1987). It inhabits a subterranean cave, Kachhuwa-Pahad cave, located in the central part of India (21°59' N; 83°06' E). This particular place comes under hot Torrid Zone and is well demarcated as one of the hottest zones of central India. Possibly, the preference for cavernicolous habitat for this endemic population is just for intolerance of desiccation of its cuticle which is a well known fact for some other cavernicolous insects (Biswas, 2010). In the present study, the sound producing organ of this species has been studied and the results along-with the other relevant morphological traits have been discussed from evolutionary point of view, acclimated for cave life.

MATERIALS AND METHODS

Species collection: Inside the deeper zone of the cave, the male cricket *Homoeogryllus indicus* could be easily located by their frequent stridulation round the clock. During three visits in the year 2007, fifty adult male individuals of the same species were collected from Kachhuwa-Pahar cave. Each individual was preserved separately in plastic veil containing 4% formalin.

Laboratory work: After transporting to the laboratory, the tegmina of each insect were first of all unfolded, cut off from their base and than spread out as much as possible. Each tegmen was further treated with dilute potassium hydroxide (KOH), cleared in Acetic acid (CH_3COOH). After dehydration via xylol, each tegmen was mounted separately in Canada balsam and covered with glass slide. Wing venations could be studied without the addition of an adhesive but for permanent protection, a glass cover slip was placed over the wing and attached at its edges with transparent methacrylate.

Stridulatory structure: Complete stridulatory apparatus was observed under a binocular microscope (Wild M5). Pencil sketches of the tegmina and teeth were completed by using camera lucida (drawing tube) mounted on the microscope. Further, the sketches were scanned digitally and then placed as a template layer in Adobe Illustrator® for final rendering.

Wing venation was studied under normal magnification (40x) of the microscope, whereas for counting and to sketch the shape and size of the teeth 100 to 400x magnification under oil immersion was taken into contemplation.

Wing venation terminology follows the Comstock- Needham system (Comstock, 2010) which has been further standarized for cricket wings by Ragge (1955).

RESULTS

The sound producing organ (stridulatory system) is present in the tegmina of male crickets only. It consists of the stridulatory file, made by a row of transverse teeth, the mirror (inactive for calling), the stigma and the harp. Females bear tegmina with no stridulatory system. Each tegmen covers up to the seventh abdominal segments of the insect. A pair of wing-buds was seen to appear in the last instar in males and no trace of the stridulatory system was noticed in the wing-bud. Possibly, the stridulatory systems appear only at the time of the imaginal moult. The file (Fig. 1a) is present in the first anal vein (1A). In the left tegmina, the numbers of teeth were found to vary among different individuals, ranging from 25 to 44 (mean number = 35.52, i.e., 25 teeth in 12 tegmina, 28 teeth in 37 and 44 teeth in 10 tegmina), whereas in the right tegmina 88 teeth were apparent in all the 50 individuals. The teeth project approximately at right angles to the lower surface of the tegmina. The teeth at the outer end of the file were smaller than those in the middle and on the base of the tegmina but structurally were found to be similar (Fig. 1c). Each tooth was a round, arch-like structure, having a central oval part with no lateral projections (Fig. 1d). The Mirror (Fig. 1a, b) was composed of the branches of the anterior cubitus (CuA) which further divided into three or four veins (Fig. 1a). All the harp, mirror and diagonal veins arise from CuA. It was also observed in some cases that the mirror is divided by four veins (Fig. 1b). The stigma (Fig. 1a, STG) is not thick but seems to be strengthened by the fusion of the anterior media and posterior media veins and participate in stridulation.

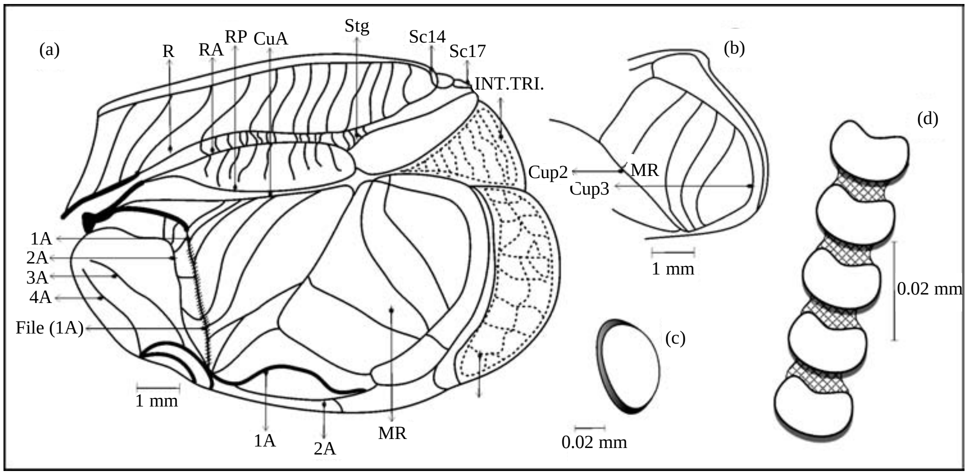

Fig. 1(a-d): (a) Wing venation of *H. indicus*, (b) Mirror; divided by four veins, (c) Single tooth and (d) File showing the arrangement of teeth. R: Radius system, M: Media system, Cu: Cubitus system; Analis system. RA: Anterior radius; RP: Posterior radius; CuA: Anterior cubitus; CuP: Posterior cubitus; A1: First anterior analis; A2: Second anterior analis and so on, Sc: Subcosta; Stg: Stigma; MR: Mirror

DISCUSSION

Caves are always unusual environments, deprived not only of light but also of sounds. Inner habitat only sounds by dripping water, wings flapping of bats or stridulance of Ensifera. Stridulation is an important phenomenon exists in almost every Ensifera which not only helps them to attract the mates but also used for inter-specific interactions (Schatral, 1990), threaten the predators (Riede, 1987) etc. when they reside in usual epigean environmental conditions. Inside a cave, except to attract the mates stridulatory system is indeed needless, interestingly in some cave crickets (*Hadenoecus subterraneus* and *H. cumberlandicus*) the females which are ready to mate releases an olfactory attractant to attract the males (Parzefall, 2005). Due to stressful life only a limited types of organisms adapt cave life and due to which the predator pressure is always negligible. In addition, following the same reasoning the inter-species interaction is also limited.

In the present study, the total number of teeth present in both the files of *H. indicus* were found to be comparatively less in number than the other members of the same genus, though it was just double in number while compared to *Homoeogryllus cavicola* (Chopard 1950) the well-known cavernicolous member of this group from an African cave (Desutter, 1985). The variability in the number of teeth is often considered as the diagnostic characteristic for related species; however such variations due to the differences in file sizes and the existing gap between the teeth could not be ruled out (McIntyre, 1977; Otte and Alexander, 1983; Masaki *et al*., 1987).

Though, the existence of the useless teeth in the left tegmen is only to maintain the bilateral symmetry of the body plan (Masaki *et al*., 1987), the existence of almost double the difference in number of teeth between the two tegmina in *H. indicus* is quite interesting and such variation has never been reported earlier in other related species. The retrogression of the left file and the modification in the tooth number on the same could be an independent evolutionary phenomenon which indeed is hard to explain at the present scenario.

Cave organisms usually exhibit several morphological alterations (troglomorphy) viz., loss of eyes, pigmentation, wings attenuation of appendages, stunted sizes of tegmina, thinning of the chitinous layer etc. (Gunn, 2004; Culver and White, 2004; Biswas, 2010), which directly reflects their respective stages of adaptations in cave habitats induced by different regimens of selective pressure and even genetic factors (Wilkens, 1992; Culver *et al.*, 2011; Slaney and Weinstein, 1997). In the present context, tiny size and faint body colouration (Agarwal and Sinha, 1987; Desutter, 1985), are some of the earlier reported common morphological characteristics which have been seen to be common between two geographically isolated cavernicolous species of *Homoeogryllus* (*H. cavicola* and *H. indicus)* and which somehow indicate the sign of troglomorphisms and/or pre-adapted trait for cave life in both the species. Further, the occurrence of smaller number of teeth in the stridulatory organs of both the species; *H. cavicola* (40-45: right FW) and *H. indicus* (88: right FW) might strengthened the ability for a particular form of sound producton. Based on the structures it could be suggested that both of these species are only able to emit shorter syllables as compared to the other epigean *Homoeogryllus* species. Concluding, in spite of attracting mates the rest of the possible reasons due to which the Ensifera generally operates its stridulatory system are not obvious for a cave environment.

CONCLUSION

Inside the cave, in spite of attracting mates the rest of the possible reasons due to which the Ensifera generally operates its stridulatory system are found to be worthless. On the basis of the present discussion two possibilities could be derived to speculate the above phenomenon. Based on a Vandelism view (Vandel, 1965), that cave-adapted organisms are ancient groups which have lost the genetic power to adapt to epigean environments and either live in caves or similar protected habitats or become extinct; (1) ability to produce weak syllable have compelled them to adapt to the cave life, where other than attracting mates all the other reasons due to which these Ensifera generally produces sound are not necessary. Nevertheless, as per Darwinsim; (2) after adapting to the cave life, the occasional uses of the stridulatory system resulted in a reduction in the number of teeth, representing an example of retrogressive evolution.

ACKNOWLEDGMENT

We are very grateful to Dr. Laure Desutter-Grandcolas of Museum national d'histoire naturelle, Departement Systematique and Evolution, Paris, France for not only her critical review to the earlier version of this manuscript but also for her help to proper labeling the diagram and other valuable suggestion.

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