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**VIDEO ANALYSIS OF WING CLICKING IN CICADAS  
OF THE GENERA *CICADATRA* AND *PAGIPHORA*  
(HOMOPTERA: AUCHENORRHYNCHA: CICADOIDEA)**

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**Abstract** - Wing clicking or clapping sound producing mechanism has been investigated in cicadas *Cicadatra atra*, *C. persica* and *Pagiphora annulata*, using a low cost HS (high speed) video camera. The main conclusion is that clicks are not produced by banging tegmina against each other, the body or substrate. Sounds occur when the front wings or tegmina are in the half open position. This fact, the occurrence of preclicks some milliseconds before the main click and some other data suggest the existence of a bistable clicking mechanism in the front wings.

**KEY WORDS:** *Cicadatra atra*, *Cicadatra persica*, *Pagiphora annulata*, sound production, wing clicking, bioacoustics, HS (high speed) video

**Izvleček** - ANALIZA VIDEO POSNETKOV POKANJA S KRILI PRI ŠKRŽADIH RODOV *CICADATRA* IN *PAGIPHORA* (HOMOPTERA: AUCHENORRHYNCHA: CICADOIDEA)

Samci škržadov vrst *Cicadatra atra*, *C. persica*, *C. platyptera* in *Pagiphora annulata* se oglašajo z uporabo timbala in tudi s pokanjem s krili. Drugi mehanizem v podrobnostih ni bil raziskan, zato smo uporabili visokofrekvenčno video tehniko za analizo njegovega delovanja. Pojoče živali vrst *C. atra*, *C. persica* in *P. annulata* smo snemali v kletki z amatersko digitalno video kamero JVC 9800E, ki omogoča snemanje do 200 posnetkov v sekundi ob ustrezno nižji ločljivosti. Po umeritvi sistema smo analizirali serije posnetkov v programu Photoshop in jih po predhodni ločitvi poslik primerjali z oscilogrami istočasno posnetega zvoka. Analiza je pokazala, da se pri obeh preiskovanih vrstah rodu *Cicadatra* pojavijo poki takrat, ko so sprednja krila razprta ali se spet začnejo zapirati, nikakor pa ne nastane zvok ob udarcu kril

ob telo ali ob podlago, kakor so domnevali različni avtorji. Notranji rob kril ostane med oglašanjem zataknen v žleb na mezonotumu, zato tudi ni verjetno, da bi zvok nastal ob sunkovitem izprožanju krila iz tega žleba ali ob ponovni vložitvi vanj, kar so domnevali drugi. Drugi par kril vsaj pri vrsti *C. persica* pri tem ne sodeluje. Najverjetneje pokanje s krili temelji na preprostem bistabilnem sistemu v krilih, ki deluje kot nekakšen timbal. Pri vrsti *P. annulata* smo lahko dokazali, da se v napevu poleg timbalnih zvokov prav tako pojavlja pokanje s krili, ob katerem živali razločno privzdigujejo sprednja krila. Za natančnejšo analizo pa je 200 slik v sekundi pri tej vrsti premalo, saj se pokanje s krili ponavlja okoli 130 - 140-krat v sekundi.

**KLJUČNE BESEDE:** *Cicadatra atra*, *Cicadatra persica*, *Pagiphora annulata*, oglašanje, pokanje s krili, bioakustika, HS (visokohitrostni) video

## Introduction

In 1998 we published a paper on acoustic behaviour of *Cicadatra persica* with a description of the courtship song comprising single short tymbal echemes followed by a long series of clicking sounds produced during wing movements (Gogala & Trilar 1998). Similar wing clicks were described previously by Boulard (1992) for the close related species *Cicadatra atra* and by some other authors for cicadas from various parts of the world (see Discussion). A convincing description of wing click mechanism has not been published till now. Therefore we decided to investigate this additional sound producing mechanism in the cicadas *C. persica*, *C. atra* and *Pagiphora annulata*, available in Slovenia and the Balkans, using a commercial high speed video camera.

## Material and Methods

The male cicadas, used in this investigation were *Cicadatra atra* (Olivier 1790) collected in Strunjan, Slovenia in July 2002, *C. persica* Kirkaldy 1909, collected in Radika gorge in Macedonia in June 1999 and *Pagiphora annulata* (Brullé 1832), collected during the same time period in the vicinity of Skopje and Ohrid in Macedonia (FYROM). We made our video recordings of *C. atra* in Slovenia and of both other species in Skopje, Macedonia, shortly after catching the animals.

The digital video camera JVC GR-DVL9800 was the only low cost camera available to us capable of making high speed recordings also in the field or under simple laboratory conditions. It has the HS (high speed) mode, sharing 4 (or 2) smaller interlaced subframes in one normal frame. After deinterlacing with a suitable software we get 8 (or 4) noninterlaced subframes, corresponding to 200 (100) frames per second (Fig. 1). Each subframe has a resolution of 293 by 222 pixels, the exposure time was 5 ms per sub-frame or shorter, depending on available light intensity.

For a selection of suitable recordings and their analysis we used the editing software CineStream 3.0.1 (Media 100, Mac OS 9) on Apple PowerMac G3 or G4 com-

puters. Short selections were exported as image sequences into the Adobe Photoshop 6 and the corresponding sounds as AIFF files to Canary 1.2.4. In Photoshop we used a de-interlacing filter to extract odd or/and even lines into a final de-interlaced sub-frames.

The sound file was visualized as oscillogram in the Canary program and saved as PICT file. In the next step we combined the picture of the oscillogram with corresponding video frames. For the purposes of display, we rotated the oscillogram through 90°

During tests of this method we found out that there is a standard delay between the extracted sound and video tracks. To measure this delay we constructed a simple device to accelerate a table-tennis ball laterally in a perpendicular plane against a wooden (chess) plate. The bouncing ball has been video-recorded in a HS mode together with the sound by a detached microphone 25 cm away from the sound source like in the actual experiments with the animals. After the analysis of a series of 19 such video recordings we estimated the delay of video frames in our setup to be in average  $20,4 \pm 0,51$  ms in comparison with a sound track. This delay depends on the software used and is for example around 46 ms when we used the software Final Cut Express (Apple iMac, OS X). The delay measured in the editing software CineStream was then taken into account in comparison of sound and video tracks by sliding the video track vertically through the appropriate distance.

## Results

### *Cicadatra persica*

We have chosen this species for investigation of the clicking mechanism because it uses this system of sound production in one type of song most extensively with the repetition rate of approximately 11 Hz (Gogala & Trilar 1998). We analyzed 35 clicks from many hundred recorded ones. We are showing one representative picture with a combination of corresponding audio and video tracks (Fig. 2), as an illustration for our conclusions. Other 34 combined pictures support our findings, therefore we did not have to use statistical methods for evaluation.

From oscillograms of the sound tracks it is evident, that about 5.5 - 6 ms before every click a soft preclick occurs.

The clicks occur always in connection with the opening and closing of the forewings. The hindwings remain during this cycle more or less in the same position. In the maximally open phase the forewings do not reach the normal flight position but reach the horizontal plane approximately parallel to the dorsal body surface. The inner edge of clavus or anal field seems to remain in contact with the mesonotum or at least close to it. Unfortunately, this detail has not been clearly seen in our video recordings of this cicada species due to unsuitable viewing angles.

The preclick occurs during opening of the wings and the main click a few milliseconds after the maximally open phase of the wings but clearly before wings are closed again (Fig. 2).

### *Cicadatra atra*

The video recordings of the clicking (courtship) song of *C. atra* with one wing click between short tymbal echemes supports our findings described above on *C. persica*. We tried to photograph also the singing animals from various angles to see the position of inner edges of the tegmina during clicking.

Also in this species clicks occur always in connection with the opening and closing of the forewings, but the hind wings move somewhat as well. The inner edges of the tegmina remain during the whole cycle attached to the mesonotum and the forewings open to the approximately horizontal plane with wing tips raised above the abdomen (Figs. 3 & 4).

The preclick occurs during opening of the wings and the main click a few milliseconds later than in the case of *C. persica*, but clearly before wings are completely closed again (Figs. 3 & 4).

The soft preclick was not always detectable but where it was clearly seen it occurred 8 - 9 ms before the main click.

### *Pagiphora annulata*

During the song of this species in some last and loudest echemes in each sequence clicks of broad frequency range appear in the last parts of each tymbal echeme presumably associated with the movement of the wings (Gogala & Trilar 2000). These clicks appear only roughly synchronized with tymbal clicks i.e. with the similar repetition frequency but with small delays, therefore appearing most frequently in the pauses between them.

Since the wing clicks in the song of *P. annulata* appear with the very high repetition frequency of approximately 130 - 140 Hz, our method with the highest frame rate of 200 per second did not allow us to see details of this type of sound production.

Nevertheless, our HS video recordings prove that the additional clicks with broad frequency range appear only in connection with wing flapping. During the parts of song produced purely by tymbal the wings remain in a closed position.

It is evident that the forewings move in a similar way as in the case of both investigated species of *Cicadatra* (Fig. 5).

## Discussion

Wing clicking or crepitation appears to be more common sound production method in singing cicadas than thought previously. Males of some species use it exclusively (*Frogattoides* after Moulds 1990) or in addition to the tymbal sound production (*Cicadatra atra* Boulard 1992, *C. persica* Gogala & Trilar 1998, *C. platyptera* – Gogala & Trilar unpublished data, some New Zealand cicadas of the

genus *Amphipsalta* Dugdale & Fleming 1969, *Aceropyga pterophon* from Fiji islands Duffels 1988, some North American species, e.g. *Okanagana rimosa* Huber et al. 1980 or asian *Cicadetta sinuatipennis* - Popov 1981). L. Popple (2002) mentions in his web site (<http://www.zen.uq.edu.au/entomology/ins-info/mec.htm>) wing clapping and flicking as additional sound production mechanisms in a series of australian cicadas (e.g. *Urabunana verna*).

In addition to this, there are recently many reports on female sounds of cicadas, which apparently use the same or similar mechanism to respond acoustically to male courtship song since they lack a tymbal apparatus (*Magicicada septendecim* - Cooley & Marshall 2001, *Tibicina nigronervosa* – Sueur 2002).

Morphologically, many wing clicking species can be recognized by the form of the tegmina, which have usually thick and curved or even angular costal vein (e.g. *Cicadatra persica*, *Urabunana verna*, *Frogattoides* spp.).

Although many authors came to the conclusion that cicadas can produce sounds using their wings, there is no consensus about how the sound is produced by the wings. Dugdale & Fleming (1969) assumed for New Zealand cicadas that they bang with costal edge against the substrate. Boulard (1992) speculates for *C. atra* similarly or explains alternatively that they might bounce against the body. Popov (1981) investigated the clicking species *Cicadetta sinuatipennis* and explains that the sound appears during detachment of the clavus from the mesonotal furrow. He made also ablation experiments and the animals with cut innermost vein of the clavus did not produce clicks any more. Nevertheless, it is not easy to understand, how the animals can repeatedly and very fast insert the edge of clavus into the mesonotal furrow and pull it out again.

According to our and Boulard's observations (1992), this part of tegmina (clavus) remain in the attached position during the whole wing flapping cycle. So, what can be our explanation of the click production during the wing movement?

The existence of preclicks during wing opening in *Cicadatra persica* speaks by itself for existence of bistable structure in their wings or in wing articulation. Click mechanisms exist in articulations of some higher insects and are important in wing-beat processes (Chapman 1998).

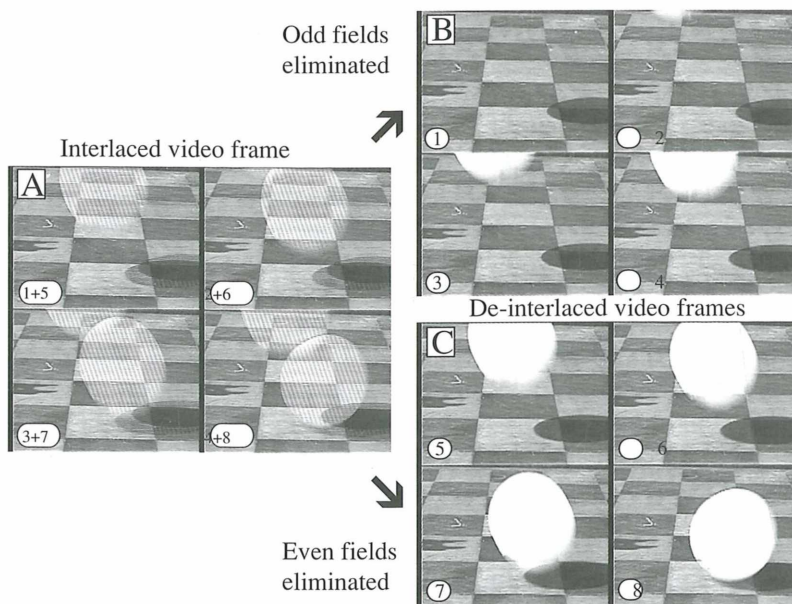
The second fact is, that according to our analyzes of video recordings the main clicks appear before the tegmina (forewings) return to their starting position. This at least in species investigated by us also excludes the possibility, that the clicks would be produced by banging the tegmina against the body or the substrate.

Therefore, our most probable explanation of the clicking mechanism is the bistable system in the forewings or in their articulations. For the bending or deformation of the clicking part of the wing the insertion of the claval edge to the mesonotal furrow might be important. This would explain the results of the ablation experiments of Popov (1981) in the species *Cicadetta sinuatipennis*.

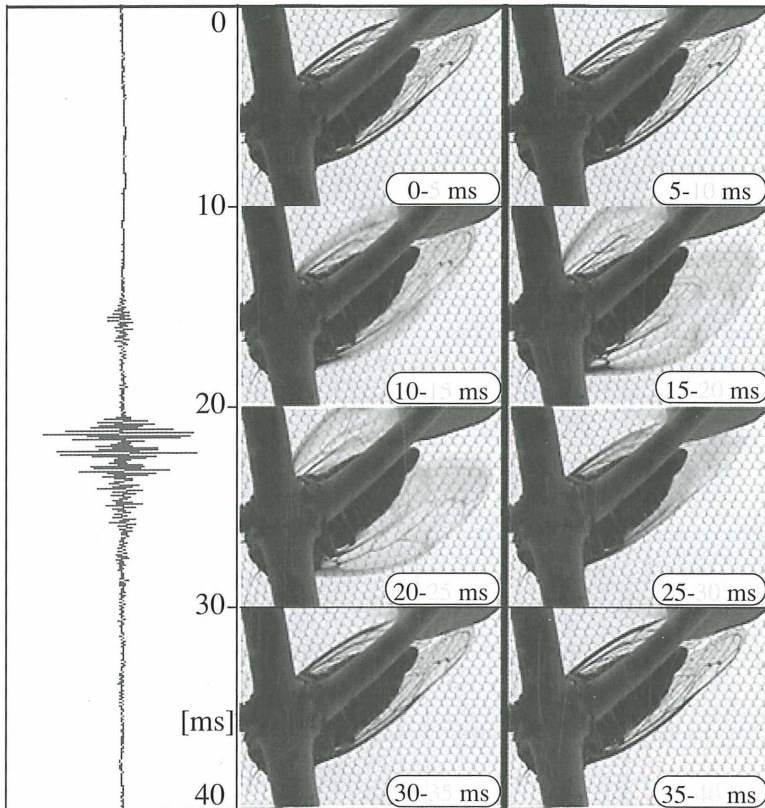
For the full understanding of the clicking mechanism, especially in the fast clicking *Pagiphora annulata* further experiments like ablation experiments or a use of a high speed camera with up to 500 frames per second would be needed.

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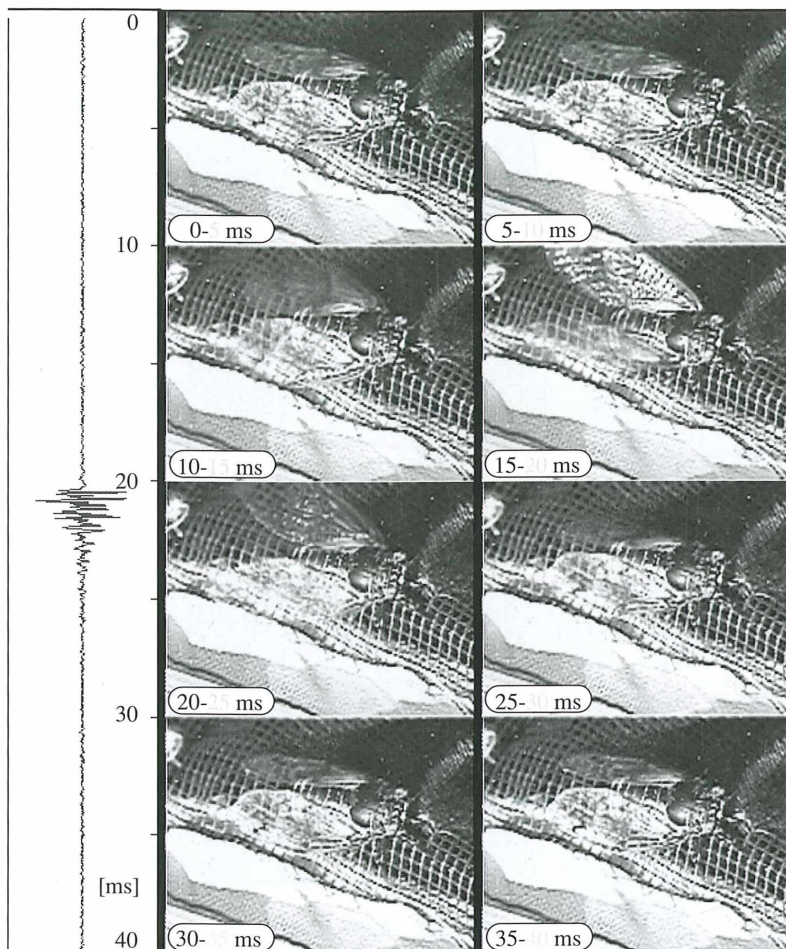


**Fig. 1:** Extraction of 8 de-interlaced subframes (B & C) from one interlaced video frame (A) recorded with the JVC GR-DVL 9800 camera in the HS mode. Recording shows falling table-tennis ball over the chess table. Such setup has been used for the calibration of a system to measure the delay between sound and video track.



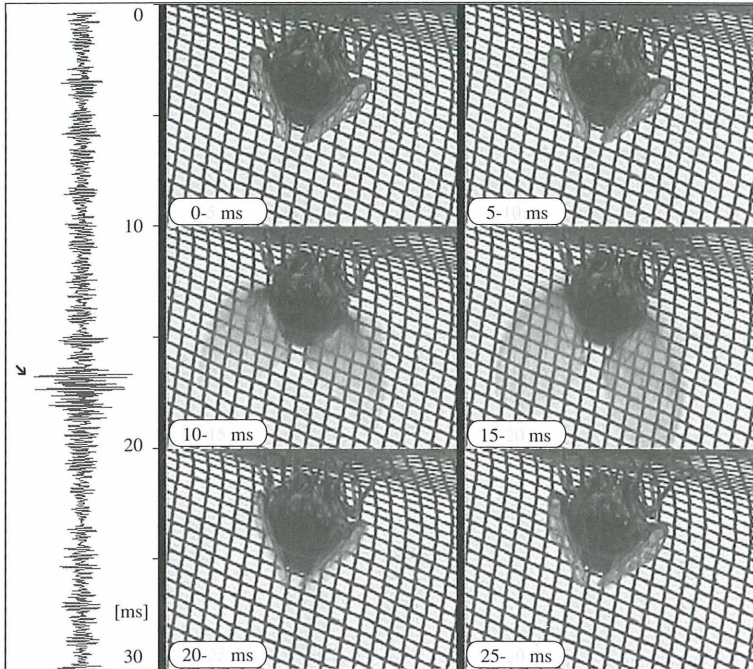
**Fig. 2:** Clicking in the species *Cicadatra persica*. On the left side a sound track with preclick and click is shown. On the right side are the corresponding video subframes showing a sequence of movements during click production. Subframes are 5 ms apart and are for technical reasons arranged in 2 parallel rows. The actual exposure time is adjusted automatically and is therefore not known (typically about 1 - 3 ms). The longest possible exposure duration is written in every subframe (in gray). The click is synchronous with the subframe marked 20-25 ms, shortly after the maximally opened position of tegmina.



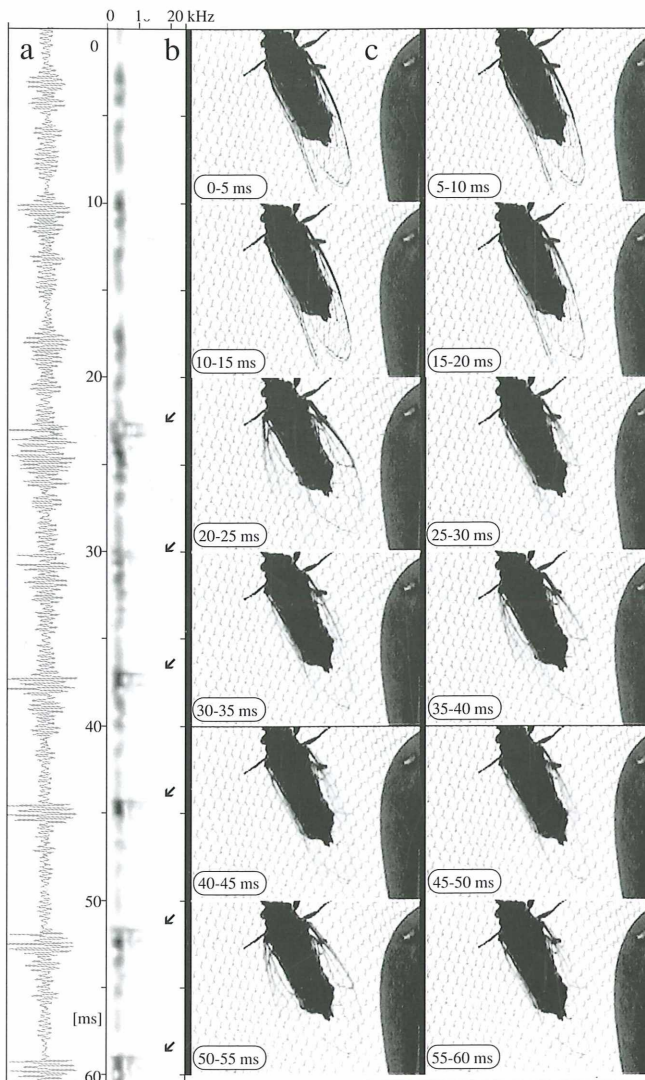


**Fig. 3:** Clicking in the species *Cicadatra atra*. Also in this case the click appears when the wings are raised and are in the phase of closing (subframe 20-25 ms). Inner edge of tegmina (clavus) remains attached to mesonotum. For other explanations see Fig. 2.





**Fig. 4:** Clicking in the species *Cicadatra atra*. Wing flapping accompanied with wing click seen from another perspective to show the position of tegmina during this process. The sound track is in this case less clear due to the strong background noise. The arrow shows the click, which appears during the subframe 15-20 ms. For other explanations see Fig. 2.



**Fig. 5:** Clicking in the species *Pagiphora annulata*. The first two tracks from the left show the oscillogram (a) and sonagram (spectrogram) (b) of the sound selection combined on the right side with the corresponding video subframes (c). In this case the tymbal sound is in the last part of the echemes mixed with wing clicks. They contain more higher frequencies and are better recognized in a sonagram (arrows!). Wing flapping similar to the one described in *Cicadatra* begins at the same time as clicks (subframes between 20–60 ms) but the details can not be resolved due to high clicking repetition frequency. During the emission of pure tymbal sounds the wings are closed (subframes between 0–20 ms). For other explanations see Fig. 2.

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