1st International Symposium on

Biotremology

Abstract Book

Fondazione Edmund Mach

San Michele all'Adige, Trento, Italy

July 5-7 2016

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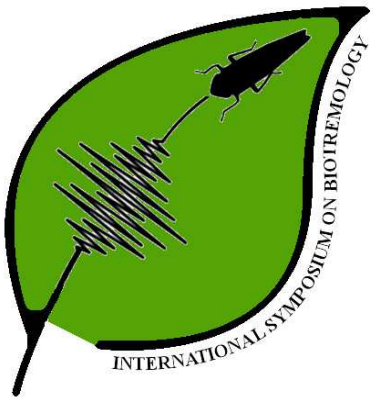

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Welcome to the 1st **International Symposium on Biotremology**!

This is truly an unprecedented and historic event. The Organizing Committee is so pleased that each of you are here to share in the moment and to spend a few days with so many others who care about the work that you do. This is the very first meeting you will have attended where your work is the focus, rather than some small sidebar to a larger conference.

We have researchers from many countries, who have travelled from five continents, in residence for this gathering. Each person has a place and a role to play in the future of our emerging discipline. Our hope is that you enjoy the venue, the talks that have been prepared, and the time together, and when you leave you will take with you the inspiration and strength of our collective spirit.

On behalf of the organizing committee,

Valerio Mazzoni

Peggy Hill

Meta Virant-Doberlet

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PROGRAM

Tuesday 5th – Biotremology Day

08:00 - 08:45: **Registration**

08:45 - 9:00**: Welcome (Dr. Annapaola Rizzoli, Centre Innovation and Research Director, FEM)**

09:00 - 10:00: **Opening Lecture (Ch: Hannelore Hoch)**

- The Growth of Biotremological Thinking – a Proposal for a Common/Unifying Framework and Terminology (Peggy Hill, USA & Andreas Wessel, GER)

10:00 - 10:30: Coffee Break

10:30 - 11:30: **Plenary Lecture: Friedrich G Barth (Introduced by: Matija Gogala)**
THE SUM AND ITS PARTS: LEARNING FROM A SPIDER'S VIBRATORY COURTSHIP

11:30 - 12:30: **Talk Session 1: not Hemipterans (Ch: Matija Gogala)**

- Vibrational Communication in the New Zealand Cook Strait Giant Weta (Dan Howard, USA)
- Vibrational Signals produced by Males of the Spider *Hololena curta* and their Role in suppressing Female Aggression during Courtship (Alenka Zunic Kosi, Slo)
- Seismic Communication in Courting Drosophila Flies (Caroline Fabre, UK)

12:30 - 14:30: Lunch Break

14:30 - 15:30: **Plenary Lecture: Karen M Warkentin (Introduced by Peggy Hill)**
WHAT'S SHAKING? EGG VIBRATIONS AS RISK CUES IN THE ESCAPEHATCHING DECISIONS OF EMBRYOS

15:30 – 16:30: **Talk Session 2: Morphofunctionality & Physiology (Ch: Peggy Hill)**

- Does Morphological Diversity of Vibration-Receptor Organs in Insect Legs reflect Functional Specialisation? (Johannes Strauss, Ger)
- Vibration Transmission along the Orthopteran Leg - a Sensory Drive for the Vibratory Organ Development? (Natasa Stritih, Slo)
- Vibration sensitivity of adults of the cicada *Okanagana rimosa* (Reinhard Lakes-Harlan, Ger)

16:30 - 17:00: Coffee Break

17:00 – 17:40: **"Insect Drummer Award" (Wessel, Hoch, Cokl, Lakes-Harlan)**

17:40 – 19:00 Steering Committee

Wednesday 6th – Social Day

9:00 - 10:00 **Plenary Lecture: Peter M Narins (Introduced by Lakes-Harlan)**
GROUND SOUND DETECTION IN GOLDEN MOLES: COMPENSATING FOR REDUCED VISION WITH GEOPHONE EARS

10:00 – 10:40: **Talk Session 3: Social Insects 1 (Ch: Lakes-Harlan)**

- A Review on the Ability of Termites to use Substrate Vibrations (Sebastian Oberst, Aus)
- African Vibes – Vibrational Signals in African Stingless Bees (Katrina Krausa, Ger)

10:40 - 11:00: Coffee Break

11:00 – 12:20: **Talk Session 4: Social Insects 2 (Ch: Roland Mühlethaler)**

- He's giving me Good Vibrations – The Role of Vibrations in Population Divergence of the Red Mason Bee *Osmia bicornis* (Taina Conrad, Ger)
- Different Strategies in breaking the Ant's Vibrational Code by Social Parasitic Beetles (Patrizio Tratzi, Ita)
- Evolution of Lycaenid Vibroacoustic Signals (Luca P. Casacci, Ita)
- Study on Vibrational Signals in Paper Wasp *Polistes dominula* and in its Social Parasite *P. sulcifer* (Irene Pepiciello, Ita)

12:20 – 14:30 Lunch Break

14:30 – 18:00 Excursion: Monte Bondone

18:00 – 21:30 Social Event: MUSE Show

Thursday – Bug Day

08:40 - 09:40 **Plenary Lecture: Meta Virant-Doberlet (Introduced by Andrej Cokl)**
LEAFHOPPERS: TINY BUT MIGHTY - POWER OF DIVERSITY

09:40 – 10:20: **Talk Session 5: Vibrations for natural interactions (Ch: Andrej Cokl)**
- The Effectiveness of Masking Signals in Aphrodes makarovi (Anka Kuheli, Slo)
- The Natural Vibrational Soundscape of the Leafhoppers from the Genus Aphrodes (Hemiptera: Cicadellidae) and the Effect of Biotic Noise on Male Behaviour (Rok Sturm, Slo)

10:20 – 10:50 Special coffee Break – Celebration of Klaus Kalmring

10:50 – 12:30 **Talk Session 6: Vibrations for interference and pest control (Ch: Virant-Doberlet)**

- Vibrational Communication of the Brown Marmorated Stink Bug (*Halyomorpha halys*) and its Potential Use in Pest Control (Jernej Polajnar, Slo)
- Effect of Background Noise on Reproductive Behavior of Stink Bugs: Prospects for Pest Management (Raul A. Laumann, Bra)
- Playback Interference of Glassy Winged Sharp Shooter Communication (Shira Gordon, USA)
- The role of Substrate-Borne Vibrations in Pair Formation and Mating Disruption of the Leafhopper *Empoasca vitis* (Göthe) (Rachele Nieri, Ita)
- Structural design of signal generators for mating disruption by vibrational signals (Stefano Signetti, Ita)

12:30 – 14:00 Lunch Break

14:00 – 15:20: **Talk Session 7: Hemipteran Insects (Ch: Jernej Polajnar)**
- Some unsolved Questions about Vibrational Communication in Heteroptera (Matja Gogala, Slo)
- What we know and what do not know about Stink Bug Communication (Andrej Cokl, Slo)
- Mating Behaviour of *Psammotettix alienus* Dahlbom (Hemiptera: Cicadellidae) (Maja Derlink, Slo)
- Substrate-Borne Vibrational Calls of Male *Aacanthocnema dobsoni* (Hemiptera: Triozidae) vary with Body Size and Age but Females are indifferent (Umar Lubanga, Aus)

15:20 – 17:00 **Flash Talks (Ch: Casacci & Gordon)**

17:00 – 17:30 Coffee Break

17:30 – 18:00 **Springer Young Researcher Awards**

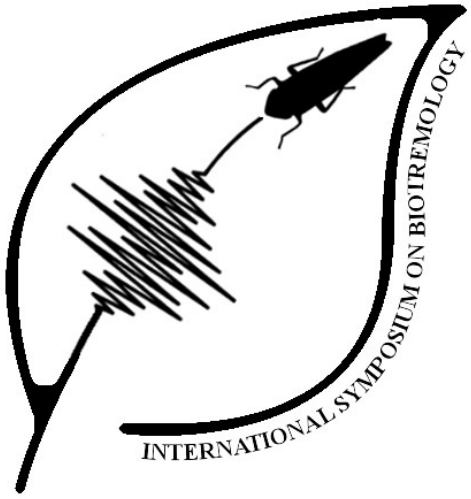
18:00 – 19:00 **Workshops (Hall, Hoch, Omologo)**
- Authentic Research in the Classroom: Transforming your course into a Coursed-Based Research Experience (CURE) for undergraduates (Carrie Hall, USA)
- Engineering, Mechanics and Informatics meet Entomology: Communication, Interference and Disruption by Vibrational Signals (Pugno & Omologo, Ita)
- Making a worldwide and robust Network in Biotremology (Hoch & Wessel, Ger)

19:00 – 19:10 End of Works (Mazzoni, Hill, Virant-Doberlet)

LIST OF POSTERS / FLASH TALKS

1. SABIOD Project: Bioacoustics and Ecoacoustics for Research, Monitoring and Conservation of Terrestrial Habitats (Gianni Pavan, Ita) (5th July)
2. A universal platform for in vivo functional neuroimaging in insects (Albrect Haase, Ita)
3. Can we make an Artificial Leafhopper Female? (Gašper Korinšek, Slo)
4. Comparative Neuroanatomy of the Scolopidial Accessory Organ, a putative Receptor for Low Frequency Vibrations in Orthopteroid Insects (Johannes Strauss, Ger)
5. Vibration-Sensitivity of the Stick Insect *Sipyloidea sipylus* in different Stimulatory Paradigms (Johannes Strauss, Ger)
6. Physiology of the femoral chordotonal organ of *Drosophila melanogaster* (Reinhard Lakes-Harlan, Ger)
7. Mechanosensory organs in the legs of mantis (*Hierodula membranacea*) (Reinhard Lakes-Harlan, Ger)
8. Good or bad vibrations: impacts of man-made vibration upon marine invertebrates (Louise Roberts, UK)
9. Vibration and Acoustic Songs in the *Acanthoscelides obtectus* (Coleoptera: Bruchidae) (Lev Shestakov , Rus)
10. Vibroacoustic Communication in *Crematogaster scutellaris* Ant (Alberto Masoni, Ita)
11. Context depending Directional Vibration Sensing in *Atta sexdens* (Felix A. Hager, Ger)
12. Feel the Women`s Vibes: Cues used for Directional Vibration Sensing in *Nezara viridula* (Felix A. Hager, Ger)
13. Reducing the noise: Uncovering the morphological and behavioural evolution of Hemipteran vibrational signals (Leonidas Davranoglou, UK)
14. Vibratory Communication and Reproductive Isolation in two Sympatric Stink Bug Species (Hemiptera: Pentatomidae: Pentatominae) (Raul A. Laumann, Bra)
15. Why does Mother Burrower Bug shake her Egg Mass? Maternal Hatching Regulation mitigates the Risk of Future Cannibalism (Hiromi Mukai, Jap)
16. Substrate-borne vibrational communication in the vectors of Apple Proliferation *Cacopsylla picta* and *C. melanoneura* (Homoptera: Psyllidae) (Tiziana Oppedisano, Ita)

PLENARY LECTURES



5TH JULY – 10:30

THE SUM AND ITS PARTS: LEARNING FROM A SPIDER'S VIBRATORY COURTSHIP

Friedrich G. BARTH

Department for Neurobiology, Faculty of Life Sciences. University of Vienna, Althanstr.14, 1090 Vienna.

In the life of most spiders substrate vibrations play an important role making them an ideal example for studies in related behavior. Some years ago we chose a large Central American wandering spider (*Cupiennius salei* Keys.) and its closest relatives to analyze vibratory courtship. A rich blend of reductionist laboratory work and field work in the spider's natural habitat revealed many of the basic properties, which one wants to understand when studying this type of communication and aiming at an insight into the numerous selective pressures having shaped it during evolution: (i) The signals: their generation by the sender, properties and transmission to the receiver; (ii) the vibration sensors of the receivers: structure and function; (iii) neural responses to the vibrations: in the periphery and the CNS; (iv) the meaning of the messages of the signals for male and female behavior, respectively, and (v) the relation of all this to the ecology, habitat and general questions about ultimate functions in a broader biological context (like species recognition and reproductive isolation). I will first try to summarize these analyses, mainly to illustrate how all the parts fit together to end up as a well-organized whole.

More recent work regarding proximate mechanisms related to some surprisingly small details of the vibration receptor's micromechanical properties will not only add to our appreciation of the richness and multi-functionality of adaptations at work. It will also stress the value of interdisciplinary work and again underline the importance of taking into consideration the details AND the ordered sum of them, before we can hope to understand the entire story and the biophysical effectiveness of a communication system reasonably well.

5TH JULY –14:30

WHAT'S SHAKING? EGG VIBRATIONS AS RISK CUES IN THE ESCAPEHATCHING DECISIONS OF EMBRYOS

Karen M. WARKENTIN

Boston University & the Smithsonian Tropical Research Institute

Many animals time hatching in response to environmental cues to escape dangers or exploit opportunities. The arboreal embryos of red-eyed treefrogs hatch rapidly and prematurely to escape egg-predators and other threats, but at a cost of reduced tadpole survival. Vibrations cue hatching in snake attacks, but eggs on rainforest plants also experience benign disturbances in storms. The egg-clutch vibrations caused by both storms and snakes vary substantially, with overlapping frequency, temporal, and amplitude properties creating a discrimination challenge. To solve this, embryos use a combination of at least six different vibration properties to modulate hatching, making vibration-cued hatching a very specific response. However, the amount of information embryos gather before deciding to hatch depends on the risk, or vibration-sampling time, required; their decision is better informed when information is cheap.

Our current research examines developmental changes in embryo behavior. Vibration-cued hatching does not start when embryos first develop a capacity to hatch. It begins later, with vestibular system development, suggesting that ears mediate the hatching response to predators. As embryos develop toward the stage of spontaneous hatching, the cost of induced hatching decreases, reducing selection against false alarms. Thus we expect an ontogenetic decrease in discrimination and a general increase in the hatching response. Nonetheless, some vibration properties are cheaper to assess than others, and ontogenetic changes in decision-making should be sensitive to sampling costs. Consistent with this, discrimination based on a rapidly evident property persists after that based on a property requiring more time to assess has ceased. Vibration-cued hatching offers excellent opportunities to study how animals use messy incidental cues to make high-stakes behavioral decisions, and how this changes with developmentally changing abilities and trade-offs.

6TH JULY – 09:00

GROUND SOUND DETECTION IN GOLDEN MOLES: COMPENSATING FOR REDUCED VISION WITH GEOPHONE EARS

Peter M. NARINS

Departments of Integrative Biology & Physiology, and Ecology & Evolutionary Biology, UCLA, Los Angeles, CA 90095 USA

Golden moles are nocturnal, surface-foraging mammals with rudimentary vision. Several species possess massively hypertrophied mallei that presumably confer substrate-vibration sensitivity through inertial bone conduction. When foraging, *Eremitalpa granti namibensis* moves between sand mounds topped with dune grass that contain most of the living biomass in the Namib Desert. We have observed that foraging trails are punctuated with sand disturbances in which the animal "head dips", presumably to obtain a seismic "fix" on the next mound to be visited.

Seismic playback experiments suggest that in the absence of olfactory cues, golden moles are able to locate food sources solely using vibrations generated by the wind blowing the dune grass on the mounds. Laser measurements of the malleus in response to seismic stimuli reveal a geophone-like ear with peak sensitivity to frequencies below 300 Hz. The middle ear of one southern African species of golden mole responds to both substrate vibrations and airborne sounds. Its design is an elegant solution to the problem of how a middle ear can exploit the inertia of an increased ossicular mass for detecting substrate vibrations at little cost to the animal's airborne sound detection capability. Functionally, golden moles appear to be low-frequency specialists, and it is likely that they detect prey principally through substrate conduction.

7TH JULY – 08:30

LEAFHOPPERS: TINY BUT MIGHTY - POWER OF DIVERSITY

Meta VIRANT-DOBERLET[1], Maja DERLINK[1], Anna ERIKSSON[2], Anka KUHELJ[1], Jernej POLAJNAR[1], Rok ŠTURM[1], Valerio MAZZONI[2]

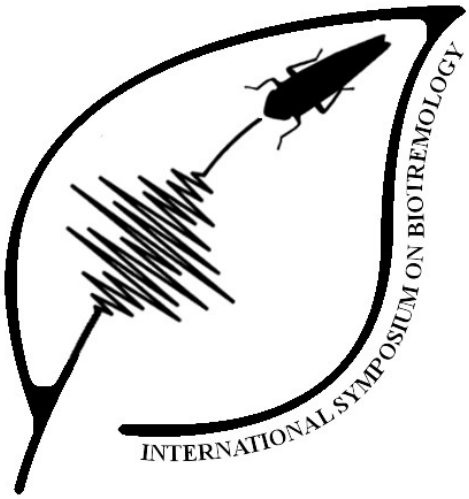
[1] National Institute of Biology Večna pot 111, Ljubljana, Slovenia
[2] Fondazione Edmund Mach, Innovation and Research Centre, via Mach, San Michele a/Adige (TN), Italy

Leafhoppers (Hemiptera: Auchenorrhyncha: Cicadellidae) are small (0.2-1 cm) phytophagus insects and are with more than 22 000 described species one of the most speciose groups. They communicate in a complex biotic landscape that contains other conspecific and heterospecific signaling, as well as rivals and exploiters. Since in this group, mate recognition and location are mediated exclusively via vibrational signals, leafhoppers provide an ideal model system to study interactions shaping the evolution of this communication channel. More detailed work on such diverse, but hitherto largely neglected groups, is likely to provide invaluable empirical data to address some questions that are central to our understanding of communication in general.

Sexual communication is based on a coordinated exchange of species- and sex-specific vibrational signals and species from the genus *Aphrodes* with their highly divergent male calls, similar female replies and divergent duet structures served as a model group to study the role of vibrational signals and duet structure in reproductive isolation. Studies revealed that the species-specific duet structure plays an important role in mate recognition and location and despite its deceptively simple form, vibrational duetting may entail more complex interactions that just temporal coordination. We used these leafhoppers also to explore direct and indirect costs of vibrational signalling. While a higher calling rate increases the probability of locating the female, it also has a detrimental effect on male survival, due to eavesdropping predators and indirect costs arising from high energy expenditure.

Leafhoppers are also among the most important vectors of plant diseases. The grapevine pest *Scaphoideus titanus* was chosen as a model species for developing an environmentally friendly approach to manage insect pests based on playback of species-specific disruptive vibrational signals used by males to interfere with the courtship of the rivals.

ORAL PRESENTATIONS



THE GROWTH OF BIOTREMOLOGICAL THINKING – A PROPOSAL FOR A COMMON/UNIFYING FRAMEWORK AND TERMINOLOGY

Peggy S. M. HILL[1], Andreas WESSEL[2]

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Over the past six or seven decades scientists, mostly working in isolation, have discovered and described substrate-borne signaling in a variety of animal taxa. Often these behaviors were considered negligible and/or unique to the group, such as 'juddering' in scorpions or the 'tremble dance' in honeybees. Up to now, the cooperation between researchers studying different taxa from different points of view is severely hampered by the lack of a unifying framework and a common use of terminology.

Here we propose and discuss a terminology for the consistent description of communication by mechanical waves. We try to define the scope of biotremology as well as its relationship to bioacoustics. Special emphasis will be given to the role of perception in understanding vibrational and multimodal communication.

We believe that the consistent use of terminology not only helps to interpret the different taxon-specific behaviors in a common evolutionary ecological framework, but enables us to develop concepts that will lead to the discovery of a whole new world of communication. Our proposal aims to stir up a debate in the growing biotremology community and to foster interdisciplinary work on all relevant taxa.

VIBRATIONAL COMMUNICATION IN THE NEW ZEALAND COOK STRAIT GIANT WETA

Ashley SCHMIDT[1], Carrie HALL[2], Andrew MASON[3], Daniel HOWARD[2]

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[3] University of Toronto Scarborough Department of Biological Sciences, 1265 Military Trail, Toronto, Ontario, Canada M1C 1A4, Canada

The Cook Strait giant weta, *Deinacrida rugosa*, is an endangered New Zealand Orthopteroid insect belonging to an endemic genera whose communication systems remains poorly understood. Field observations of intraspecific interactions in *D. rugosa* provided preliminary evidence that individuals produce substrate-borne vibrational signals in unknown contexts.

We conducted laboratory experiments to investigate: 1) the acoustic structure of vibrational signals, 2) the biomechanics of signal production, 3) sexual dimorphism in signaling behavior and signal structure, 4) if substrate-borne signals transmit information regarding sender morphology, 5) the primary social context in which vibrational signals are produced, and 6) the function of vibrational signaling. We tested the model that substrate-borne signals in *D. rugosa* function in both intra- and intersexual communication, related to courtship and inter-male aggression.

Using laser Doppler vibrometry we show that *D. rugosa* produce low frequency substrate-borne vibration (36.73±6.34 Hz) for intraspecific communication, with males generating signals through dorso-ventral tremulation. Males were observed signaling while in the presence of a male-female duo, most commonly engaging in inter-male vibrational duets. Vibrational responses to playback signals were only solicited from males in male-male-female social contexts, and both sexes exhibited negative walking vibrotaxis to playback signals. Male vibrational duetting bouts resulted in one male abandoning the trio, leaving the winning male with possession of the female. While we found that vibrational signal structure was not closely related to signaler size, larger males that initiated duetting bouts held a significant advantage in competitive encounters.

We infer from our findings that substrate-borne vibrational signaling in *D. rugosa* serves to lower costs associated with inter-male competition for mates, with contests settled without escalation into costly fights.

SEISMIC COMMUNICATION IN COURTING DROSOPHILA FLIES

Caroline FABRE

University of Cambridge, Downing Street, United Kingdom

Seismic vibratory signalling is crucial to courtship in Drosophila flies; during courtship, males rapidly quiver their abdomens and produce seismic vibrations in the substrate that are sensed by females. Females respond by remaining stationary and allowing the males to copulate. *Drosophila melanogaster* is the ideal model to investigate the genetic and neuronal bases underlying this mode of communication in flies. Using a combination of behavioural and play-back assays, laser vibrometry and neuroanatomy, I am now investigating the neuromuscular circuitry responsible for the generation of these seismic signals and the sensory systems needed for their reception.

VIBRATIONAL SIGNALS PRODUCED BY MALES OF THE SPIDER *HOLOLENA CURTA* AND THEIR ROLE IN SUPPRESSING FEMALE AGGRESSION DURING COURTSHIP

Alenka ŽUNIČ KOSI[1], Yong-Hong XIAO[2], Long-Wa ZHANG[3], Jocelyn G.MILLAR[4]

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Females of many web-spinning spiders primarily stay in their webs, while males wander in search of potential mates. While searching for mates, males are exposed to both predation and to the risk of being killed during courting and mating with the solitary and aggressive females. Our study of the funnel-web spider *Hololena curta* suggests that this species has developed several adaptations to decrease the possibilities of wasted mating effort and sexual cannibalism by conspecific females. Upon contact with the web of a virgin female, males produced stereotyped vibrational signals during courting.

We recorded and compared vibrational signals produced by courting males and a prey species to determine whether male *H. curta* generated characteristic vibrational signals during courting sequences. We also conducted playback experiments and analysed female responses to male-produced vibrational signals. The results showed that the courtship of *H. curta* is composed of a sequence of behaviours including abdominal and pedipalp tremulations, and leg flexing, which are also characteristic of courtship of other agelenid species. The results of playback experiments confirmed that the male-specific vibrational signals induce females to remain motionless while being courting and reduce the aggressive/predatory of females, with females being less likely to attack when stimulated with male vibrational signals.

Further studies could be done by synthetically varying the characteristics of male vibrational signals and quantifying the behavioural responses of females, in order to test the role of these signals in female mate choice.

MALE KATYDIDS USE AIR-BORNE SOUND, SUBSTRATE VIBRATIONS AND BODY TEMPERATURE TO COMMUNICATE WITH FEMALES

Heinrich RÖMER, Bettina ERREGGER, Manfred HARTBAUER

Graz University, Universitätsplatz 2, Austria

Males of a trilling katydid species of the *Mecopoda* complex use true multimodal signalling for communication with females. In addition to continuous, intense calling songs composed of an amplitude-modulated (AM) part and a trill (103 dB SPL at 15cm) they generate three different types of substrate-borne vibrations via tremulation. These vibrations are produced in close temporal relationship with the air-borne sound signal; the duration of the introductory vibration prior to the AM song correlates positively with body size. During singing, the thorax temperature of males increases by more than 8 °C. The strong linear correlation between metabolic rate and temperature increase in males let us suggest that females might use this sensory modality as a further cue for mate choice, in addition to air-borne sound and substrate vibration. The combined information in these different modalities facilitates the evaluation of the quality of a sender, each being effective over different distances to the sender. In a behavioural two-choice test, females prefer the song of a male combined with the increased temperature over the same song presented alone.

We discuss the conditions for the evolution of body temperature in combination with air-borne sound and substrate vibrations as a cue for communication.

DOES MORPHOLOGICAL DIVERSITY OF VIBRATION-RECEPTOR ORGANS IN INSECT LEGS REFLECT FUNCTIONAL SPECIALISATION?

Johannes STRAUSS

Justus-Liebig-Universitaet Gießen, Institute for Animal Physiology, Integrative Sensory Physiology IFZ – Heinrich-Buff-ring 26, 35392 Gießen, Germany

Several vibration-sensitive organs are found in insects. Usually, the subgenual organ, located in the proximal tibia, is considered as the most sensitive vibration receptor in the leg. It consists of scolopidial sensilla which are mechanistically activated by stretch of the sensillum's dendrite in longitudinal direction. The subgenual organ spans the inside of the tibia, making it sensitive to oscillations in the hemolymph of the leg induced by substrate vibrations.

In several lineages of insects, a more elaborate sensory apparatus is found as additional organs locate in close proximity of the subgenual organ, forming the so-called subgenual organ complex. Especially the Orthoptera are a model clade for the diversity of scolopidial organs. In all Orthoptera, there is at least one further scolopidial organ, termed the distal organ or intermediate organ. In addition, a set of linear sensilla, the crista ignalin homolog, occurs most distally and has dendrites traversing the leg in antero-posterior or posterior-distal direction. Finally, the small accessory organ at the level of the subgenual organ in the posterior tibia has dendrites inserting at the cuticle's epidermis. These sensilla should be well suited to pick up vibrations transmitted through the leg's cuticle.

From a comparative view, the homology of organs can be discussed which reveals three common organs (subgenual, distal, and accessory organ). The physiological function is so far not established for all organs, but the anatomical differentiation suggests they are not functionally redundant.

Two main concepts can be evaluated. First, different organs could be adapted for frequency detection, each covering a distinct spectrum with highest sensitivity. Second, different organs could be adapted for vibration detection in different locations on and within the leg. Such specialisations should be considered in anatomical studies and tested in sensory physiological approaches.

VIBRATION TRANSMISSION ALONG THE ORTHOPTERAN LEG - A SENSORY DRIVE FOR THE VIBRATORY ORGAN DEVELOPMENT?

Nataša STRITIH[1], Johannes STRAUSS[2]

[1] National Institute of Biology, Department of Organisms and Ecosystems Research, Ljubljana, Slovenia
[2] Justus-Liebig-Universitaet Gießen, Institute for Animal Physiology, Integrative Sensory Physiology IFZ – Heinrich-Buff-ring 26, 35392 Gießen, Germany

In orthopteran insects, a scolopidial organ complex for detection of sound and vibration signals is present in the proximal tibiae of the legs. The subgenual organ is the main vibration detector that responds to haemolymph acceleration with best sensitivity between 200 – 1000 Hz. In some species, the accessory organ is developed just next to the cuticle in the dorsal part of the tibia, apparently reacting to tension changes in the cuticle with peak sensitivity to vibration below 200 Hz. Using laser vibrometry we investigated transmission of short sinusoidal pulses of different carrier frequencies over forelegs and midlegs in the cave cricket *Troglophilus neglectus* (Orthoptera, Rhaphidophoridae), in which the presence of the accessory organ was recently described. We searched for indications in the leg mechanical properties for the development of the low frequency sensor in apposition to the cuticle posteriorly in the proximal tibia and therewith conducted the first study of vibration transmission over the orthopteran leg.

Strong attenuation of vibrations in the range up to 400 Hz took place by transmission from the shaker onto the leg in some preparations, while these frequencies were transmitted the best along the leg, reaching the highest amplitude at 200–400 Hz on the proximal part of the tibia. Extensive stimuli prolongation was found at 90–130 Hz, apparently resulting from reflections and resonance. These effects were the strongest in the proximal tibia and might have represented a part of the sensory drive for the development of the accessory organ in this part of the leg. No difference, on the other hand, was found between the anterior and posterior part of the tibia to suggest the posterior organ location. There was also no difference in the properties of vibration transmission over the forelegs and midlegs, in line with the segmental arrangement of vibratory organs that are morpho-functionally alike among the legs.

VIBRATION SENSITIVITY OF ADULTS OF THE CICADA *OKANAGANA RIMOSA*

Reinhard LAKES-HARLAN

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Adult cicadas often show a startle response in the habitat. Touching of the twig on which the cicada rests often causes an escape flight. Thus, cicadas are vibration sensitive. However, neither the anatomy, nor the physiologies of such vibration receptors are known to some detail. Here, I present result on adults of the annual cicada *Okanagana rimosa*. The cicada is a common species in the Northeast of the United States. Animals were caught and transported to Germany for investigations.

First, neuronal tracing of the leg nerves reveal the neuroanatomy in the legs. It could be shown that a scolopidial sense organ is present in the proximal tibia. This sense organ consists of about 2 sensory units and is probably homologous to the subgenual organ found in many other insect taxa.

Secondly, the vibration threshold was determined by extracellular recording of the leg nerve. Data on the sensitivity and the tuning will be presented. In summary, cicadas possess mechanosensory organs in their legs, which might be important for triggering the escape behavior.

A REVIEW ON THE ABILITY OF TERMITES TO USE SUBSTRATE VIBRATIONS

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Eusocial insects such as ants and wasps, bees and termites communicate via visual and chemical cues, touch or mechanical vibrations. In particular termites make use of substrate-borne vibrations, to either detect conspecifics such as nest-mates or to locate food competitors. By building solid clay mounds, termites stay well hidden and protected from their many predators; only as a last resort termite soldiers attack nest intruders, often in a suicidal manner. Detecting the dangers as early as possible, exchanging information cryptically and the avoidance of conflicts are therefore the main survival strategies in termites. The secretive feeding signals such as gnawing wood are therefore very different to the soldiers' obvious alarm signal, a repetitive head drumming on the ground.

Camouflaging and building solid constructions are further paramount for the termite colonies' survival against predators such as ants. Termite mounds have been shown to be complex, with much research being conducted on self-organising aspects in their constructions. Recent findings of the mound building, lower termite *Coptotermes acinaciformis*, indicate its ability to detect loaded wood fibres. If necessary the termites supported the wood with solid clay constructions to unlock additional food resources for consumption.

Here we give an overview of the vibro-acoustic experiments we conducted with termites in the past to illustrate their ability to identify promising foraging sites, to eavesdrop on food competitors and to distinguish between loaded and unloaded wood fibres. We discuss the influence of the material properties on vibrational communication and how building activities might influence the quality of the communication channel.

AFRICAN VIBES – VIBRATIONAL SIGNALS IN AFRICAN STINGLESS BEES

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Many bee species make use of their indirect flight muscles to produce thoracic vibrations that are not related to flight. Thoracic vibrations have been reported in the context of buzz pollination, mating and defense. Among the social stingless bees (Meliponini) thoracic vibrations are furthermore used to communicate with nest mates. The signals show a pulsed structure that has led to the idea that information might be encoded in their temporal pattern. To date all studies on stingless bee vibrational communication have been conducted in the Neotropics. This is the first study focusing on the African Meliponini.

This study was carried out in Kenya and South Africa on 6 species: *Meliponula ferruginea*, *M. bocandei*, *Hypotrigona gribodoi*,*Liotrigona bottegoi*, *Dactylurina schmidti* and *Plebeina hildebrandti*. Vibrational signals have been recorded using accelerometers attached to the nests. The temporal pattern and main frequency component of the signals have been analysed. Modulated vibrational signals appear to play a role in the recruitment of stingless bees. The temporal patterns vary considerably in all studied Neotropical stingless bee species. To measure the variation of the temporal pattern in the African stingless bees, we calculated the coefficient of variation. The degree of variation found was much lower than for Neotropical stingless bees species. Furthermore, the degree of variation in the temporal pattern between African species exceeded the intra-signal variation. This might reveal the bees' ability to modulate the temporal pattern and the potential capacity of the temporal pattern of signal modulation to code information. Moreover, foraging activity correlates with pulse production in *M. bocandei*, supporting the hypothesis that the vibrational signals are used in the context of foraging and recruitment.

HE'S GIVING ME GOOD VIBRATIONS – THE ROLE OF VIBRATIONS IN POPULATION DIVERGENCE OF THE RED MASON BEE *OSMIA BICORNIS*

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Differences in female preference for certain male traits can be a driving force for population divergence and speciation. In the red mason bee, *Osmia bicornis*, males show an elaborate mating behavior and females choose suitable males based on, among other criteria, their vibrations.

We investigated whether there is selective mate choice between *O. bicornis* individuals originating from different regions in Europe and whether the male's vibrations play a role in this. We therefore first conducted cross-mating experiments with males and females from England (one suggested subspecies), Germany (another suggested subspecies), and Denmark (a region of overlap), respectively. In order to investigate whether females do indeed use the males' vibrational signals for selective mate choice we then experimentally changed the vibrations in a live male during mating. To achieve this we designed a new and innovative set-up using small magnets glued to a male's thorax and an inductor. Our results clearly show that there is selective mate choice and that females show a strong preference for males from their own region. However, this preference could be significantly altered when changing the male's vibrations. Females paired with a male from a different region, on which we imposed the vibrations of a male from the same region, suddenly accepted the males for copulation.

We therefore conclude that the vibrational signals actually encode not only fitness, as previously thought, but also information about region of origin, indicating that there is already a divergence between different populations of *O. bicornis* in Europe. The demonstrated differences in communication signals might ultimately lead to speciation. Our results give exciting new insights into the scope of vibrational communication in bees, a group previously thought to mostly rely on chemical signals for communication.

DIFFERENT STRATEGIES IN BREAKING THE ANT'S VIBRATIONAL CODE BY SOCIAL PARASITIC BEETLES

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Ground beetles of the genus *Paussus* are highly successful social parasites that use refined chemical, morphological and behavioral strategies to infiltrate and exploit the ant colonies. Remarkably, all 390 *Paussus* species share the presence of stridulatory organs, suggesting that acoustic, i.e. vibrational communication has played a key role in their evolution. We lately demonstrated that stridulatory organs in *Paussus* (*Flagellopaussus*) *favieri* have been evolved as a strategy to break the ants' vibrational communication code. Namely, *Pheidole pallidula* ants parasitised by *P. favieri* are able to produce caste-specific stridulation sounds that are selectively mimed by three signals of these beetles to get free access to the nest resources. Only juveniles of lycenid butterflies were known to exploit the ant's acoustical channel. We recently acquired new evidences of this parasitic strategy in 2 additional *Paussus* species belonging to two very different subgenera, *P.* (*Crenatopaussus*) *piochardi* and *P.* (*Katapaussus*) *thomsoni*, both guests of *Pheidole sinaitica*, another stridulating ant. Sound emissions were recorded via a moving coil miniature microphone and were analyzed with Audacity software. Parameters chosen to characterize the signals were: length, frequency of the most and the second most intense peak, frequency of the lowest peak and difference in frequency between the first and second peak. To highlight similarities and differences between sound profiles a discriminant analysis was used. In all cases, train length and peak frequency were the most discriminant parameters. We found some important differences among these two *Paussus* species in their vibrational signals, possibly mirroring different degrees of host specificity or recent host shifts: *P. piochardi*'s emissions largely overlapped with those of the host's workers, while *P. thomsoni*'s overlapped with the stridulations of all ant castes. Unlike in *P. favieri*, we could not find in these species more than one kind of signal.

EVOLUTION OF LYCAENID VIBROACOUSTIC SIGNALS

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Vibroacoustic signalling is a widespread form of intra- and inter-specific communication among insects. Within Lepidoptera, sound and vibratory emissions occur in larvae, pupae and adults and evolved in response to selection on sexual or defensive traits. While moths have been the focus of many acoustic surveys, among butterflies one of the best studied group is the family Lycaenidae. Most of lycaenid butterflies produce vibroacoustic emissions during pre-imaginal development and 75% of the 6000 estimated species show interactions with ants (i.e. myrmecophilous species). Even though the occurrence of this kind of communication between distantly related species is rare, studies performed during the last 20 years suggest that the exchange of these signals plays a fundamental role in lycaenid-ant interactions. These signals were thought to be produced only by myrmecophilous species, but later studies have shown that this ability may be universal among lycaenids.

Using a custom-made recording equipment, we recorded calls of 12 European lycaenid species whose larval vibroacoustic emissions are remarkably varied. The species were chosen to cover the range of all possible degree of symbiotic associations (i.e. from “not myrmecophilous” to “obligate myrmecophilous”). We measured 12 attributes of calls and used multivariate analysis to test whether variation in the signal parameters could be explained by the degree of myrmecophily, taking account of the phylogeny of the study species.

All species produced specific calls whose spectra were characterized by harmonic frequency components, revealing a more complex pattern than previously known. The inter-specific call diversity better reflected the level of association with ants than phylogenetic relationships between species. Our results support the hypotheses that the ability to emit acoustic signals is widespread in lycaenids, and such emissions have a role in myrmecophilous interactions.

STUDY ON VIBRATIONAL SIGNALS IN PAPER WASP *POLISTES DOMINULA* AND IN ITS SOCIAL PARASITE *P. SULCIFER*

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In social insects, for which olfaction are considered the most important communication channel, vibrational signals have been recently included among the communication modes that play a significant role in the colony life. In *Polistes* species, some behaviors producing substrate-borne signals have been observed. Although the meaning of these signals is not clear, it has been suggested that they play a role in caste determination, affecting the future status of the larvae present on the nest (mechanical switch hypothesis). A good model to investigate a possible role of vibrational signals is represented by the host species *Polistes dominula* and its social parasite *P. sulcifer*. Vibrational signals produced by *P. dominula* have been recorded, but nothing is known about its social parasite *P. sulcifer*. The social parasite has no worker caste and parasitizes the brood care of *P. dominula* to rear its own offspring. Unveiling the occurrence e of vibrational signals in the host-social parasite system can lead to novel hints to validate the switch mechanical hypothesis for these species. Therefore, the main aims of our study are to determine the occurrence, describe, and compare the vibrational signals produced by the two species. A laser vibrometer has been used to record the vibrations produced by individuals in parasitized and non-parasitized colonies. Our results show that both species produced signals consisting of a series of pulses (dominant frequency below 100 Hz), but by means of a different behavior: while *P. dominula* abdominal wagging is a horizontal oscillation of the abdomen, *P. sulcifer* drumming consists in hitting the nest surface moving the abdomen perpendicularly to it. Both species perform their behaviors either in presence or absence of adult individuals on the nest.

Our results support the idea that the brood is the main receiver of the vibrational signals, and represent a starting point for future studies aimed at verify the mechanical switch hypothesis.

THE EFFECTIVENESS OF MASKING SIGNALS IN *APHRODES MAKAROVI*

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The rivalry between males for access to females is often a characteristic of reproduction. In leafhoppers mate location is mediated by exchange of vibrational signals. In rivalry situations males often emit masking signals (MS) mainly to hide female replies. We investigated the impact of these signals on males and females of the leafhopper *Aphrodes makarovi*. We focused on the following questions: (a) are males able to localize the female when her reply is partially overlapped by MS; (b) are there any differences in male behaviour in the presence of MS and (c) are there any differences in female replying in the presence of MS?

We tested males in bilateral playback experiments in which in response to emitted advertisement calls we presented males either an average female reply unilaterally or from one side such female reply and from the other one a 5s long MS which overlapped the last 4.6s of a female reply. Females were tested in unilateral playback experiment s in which we played them an average male call followed or not by MS 4s after the end of the call. In both sets of experiments we recorded vibrational signals, as well as leafhoppers behaviour.

In males, we compared the proportion of searching males, time of the onset of searching, number and duration of advertisement calls emitted during the search, emission of MS, time needed to locate the female and success in locating the female. In females, we compared the reply latency and reply duration.

In general, males did not did not respond to presented MS with increased emission of their own MS. However, results showed reduced calling effort and decline in effectiveness in locating the female when her reply was partially overlapped. In the presence of MS, females did not quit replying, although these signals affected reply latency and reply duration. However, the impact of MS depended on female identity. Emission of MS is apparently a successful tactic to prevent a rival male to localize the replying female.

THE NATURAL VIBRATIONAL SOUNDSCAPE OF THE LEAFHOPPERS FROM THE GENUS *APHRODES* (HEMIPTERA: CICADELLIDAE) AND THE EFFECT OF BIOTIC NOISE ON MALE BEHAVIOUR

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An important element of communication networks are incidental receivers (i.e. heterospecific receivers present in the same environment) that do not obtain any information from for the emitter and to which signals represent only biotic noise. The impact of biotic noise on vibrational communication is largely unexplored and the aim of the present study was to determine the effect of biotic noise on mating behaviour of the *Aphrodes bicincta* 'Dragonja' males and to describe the natural vibrational soundscape of these leafhoppers.

In laboratory experiments we placed males and females of our model species on a plant and used vibration exciter to apply vibrations to the plant. As imitation of noise we used vibrational signals of species that live syntopically with *A. bicincta* 'Dragonja' (conspecific duet and 5 different heterospecific duets) and also abiotic noise (wind).

Results showed significant negative impact of biotic noise on triggering of emission of advertisement calls and searching behaviour; however, we did not observe significant effect on other behavioural parameters (calling latency, searching time, proportion of calling during searching). When conspecific duet was applied, males did not express rivalry behaviour and significantly fewer males searched for the female. Playback of abiotic noise had no effect on male behaviour. The level of biotic noise in a natural environment (meadow) was high; and the main frequency band was below 50 Hz. We recorded vibrational soundscape on two consecutive days and we registered at least 18 different signals, including signals of *A. bicincta* 'Dragonja' and *A. makarovi*. In the field, we registered only few cases of overlapping signals and in both days signal overlap was positively correlated with the level of vibrational activity registered in the 30 minute time interval ($r = 0,80$ and $0,85$).

TRANSMISSION OF VIBRATORY SIGNALS BY CALLING FROGS: COULD PROMOTE SPIDER PREDATION?

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In frogs and toads, advertisement calls play an important role in male ecological success. The intense use of mostly auditory (i.e. vibrational) signals for the attraction of mates renders anurans conspicuous prey. Spiders readily capture and eat adult amphibians, especially when they are aggregated at breeding sites. This circumstance could be promoting predation by spiders; especially if we consider that they capture prey relying mainly on vibrational cues. In the spider–frog relationships the sensitivity of a receiver and the properties of the medium probably influence the detection ability by spiders. In order to understand the factors influencing the properties of signal transmission, we recorded audio and substrate vibrations from along the calling perch until the male leaved the plant or was silent and motionless for 5 min. All ~41 plants used in this experiment were naturally used by frogs as calling perches. For each measurement we used an accelerometer (AP19, mass 0.14 g, flat frequency response 0.5–18,000 Hz, AP Technologies, Oosterhout, Netherlands) powered by an charge amplifier, after our own modification. The sensor was affixed to a leave (0.5–1.5 m in height) using masking tape. The accelerometer was attached to 20-25 cm of distance from the frog.

Male frogs produced vibratory signals during calling on leaf surfaces. Very narrow bandwidth and very low frequencies (< 0.1-0.6 kHz) were typical of the vibratory frog signals. Substrate vibrations produced by *Scinax ruber* were particularly intense with broad-band spectral properties. Vibrations from *Dendropsophus sarayacuensis* and *D. triangulum* males were narrower. Acceleration values of the signals varied from -0.4 to 0.6 ms (*D. sarayacuensis, S. ruber*), to -0.2 – 0.4 ms (*D. triangulum*) for each bout of advertisement calls. These results will be important for defining the factors used by spiders to classify sources of vibration, particularly the characteristics of vibrations generated by prey.

VIBRATIONAL COMMUNICATION OF THE BROWN MARMORATED STINK BUG (*HALYOMORPHA HALYS*) AND ITS POTENTIAL USE IN PEST CONTROL

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Communication with substrate-borne vibrational signals is ubiquitous in the family Pentatomidae, but this aspect of biology of the invasive pest *Halyomorpha halys* (Stål 1855) has been unexplored so far, despite the enormous amount of attention the species has received in the past 15 years. To explore the possibility of using vibrations to manage this serious agricultural and household pest, we first set out to describe its basic reproductive behaviour with special reference to vibrational signals. Single animals and pairs were observed on a bean plant and a loudspeaker membrane, while recording substrate vibrations with a laser vibrometer. The males spontaneously emitted long, narrowband vibrational signals to which the nearby females replied with their own vibrational signals, which in turn triggered male searching. During this phase, the animals emitted several song types in various combinations, until they came into physical contact. At this stage the final male song type, characterized by the addition of tremulation, was the only kind of vibratory emission. Females never started singing spontaneously and the mating sequence did not proceed if either partner was silent. Male signals did not attract males nor females, whereas female signals did show clear attractiveness to the males.

We tested the attractiveness of female signals in three different scenarios: potted bean plants, arenas and net cages. Using video analysis software, we measured different behavioural parameters. Our results confirmed a clear attractive effect of the female signal in all performed tests. In general, more than 50% of tested males showed a significant increase of walking speed, walked distance, time spent and number of accesses to playback stimulated areas. These results show promise for developing more efficient trapping techniques against *H. halys* in both agricultural and urban environments.

EFFECT OF BACKGROUND NOISE ON REPRODUCTIVE BEHAVIOR OF STINK BUGS: PROSPECTS FOR PEST MANAGEMENT

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Several species of stink bugs (Hemiptera: Pentatomidae) are serious pests in different crops around the world. In these insects, substrate-bone vibratory signals enable communication between male and female and is essential to couple formation and, consequently, to the reproductive success. The aim of this work was to evaluate the effect of interference vibrations, as background noise, on communication and reproductive behaviour of *Euschistus heros* (F.).

The tests were carried out using soybean plants with two opposite leaves. One male and female, sexually mature and virgins, were released individually in each one the leaves. Background noise was continuous pure tone sequences of different frequencies, ranging from 20 to 200 Hz. These sequences were transmitted individually to plants using a mini-shaker. The bioassays were conducted vibrating the plant, releasing the stink bugs and observing the behaviour during ten minutes. After this period, the behaviour was analyzed for others ten minutes without the influence of noise. As control were executed the same procedure without the noise. Forty repetitions were performed for each frequency and control. All the frequency above 20 Hz reduced significantly the couple formation during their transmission by plants (GLM test $p < 0.001$) (97% on average). On control and 20Hz bioassays the male started the search for females 203 and 173 seconds average after the release of stink bugs. No searching behaviour was observed in males submitted to noise of frequencies higher than 20 Hz.

The results show that background noise can interfere with the reproductive process of *E. heros* and could be applied in biorational control strategies.

PLAYBACK INTERFERENCE OF GLASSY WINGED SHARP SHOOTER COMMUNICATION

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Animal communication is vital to reproduction, particularly for securing a mate. Insects commonly communicate by exchanging vibrational signals that are transmitted through host plants. The glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, is an important vector of *Xylella fastidiosa*, a plant pathogenic bacterium that can kill grapevines. Since GWSS mate selection behaviors rely on vibrational communication, what if signals can be interfered with to prevent communication? If animals fail to locate, recognize, or accept a potential mate they may move away or ultimately reduce population densities due to lack of fertilization. Novel methods to suppress GWSS populations could help prevent spread of *X. fastidiosa*.

Effects of white noise and playback of GWSS female calls on mating behavior, aggregation, and individual female responses were evaluated under laboratory conditions. Both white noise and female calls reduced mating, whereas neither white noise nor female calls had an effect on aggregation. Finally, playbacks did influence the natural calling behavior of females. These results are a promising first step in understanding what is feasible biologically for a vibrational control method.

THE ROLE OF SUBSTRATE-BORNE VIBRATIONS IN PAIR FORMATION AND MATING DISRUPTION OF THE LEAFHOPPER *EMPOASCA VITIS* (GÖTHE)

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The green leafhopper, *Empoasca vitis*, is a key pest of European vineyards and Asian tea plantations where the population level is often managed by means of pesticides. The recent policy of UE is driving towards the reduction of chemicals in favor of alternative methods for pest management. Therefore our work aimed at testing whether a mechanical mating disruption approach was applicable to *E. vitis* as well as it is to *Scaphoideus titanus*. Because substrate-borne vibrations have a key role in leafhopper reproductive strategy, we first studied the reproductive strategy of *E. vitis*, with particular focus on deciphering the mating communication. Vibrations have been recorded by means of a laser vibrometer, and behavioral observations of single individuals and pairs on a grapevine leaf were performed throughout a 24h period. To insight the occurrence of male rivalry behavior, bioassays of two males and one female have been performed. Playback tests were performed with an electro-magnetic shaker to disrupt the mating behavior of duetting pairs, using different signals: intraspecific rival signal, interspecific disruptive signals (*S. titanus* disturbance noise), a synthetic pure-tone (250 Hz), and white noise (0–1000 Hz).

Pair formation begins with the male's call which is made of 3 parts: a train of pulses, followed by a harmonic signal and sometimes by one or two pulses. The female reply with a broad-band signal and a duet is maintained until copulation occurs. A male can eavesdrop on an ongoing duet: it emits a broad-band pulse, as rival signal, which briefly interrupts the duet and gives him the chance to replace the other male. The play back of white noise into grapevine leaves was sufficient to significantly reduce the number of matings, while a lower effect was obtained with other tested playbacks. In conclusion, our work suggests that a mechanic mating disruption technique might be applied to *E. vitis*. However, future studies are needed to select more specific signals that are able to interrupt the mating behavior of the leafhopper and also to confirm the applicability of this method in the field.

STRUCTURAL DESIGN OF SIGNAL GENERATORS FOR MATING DISRUPTION BY VIBRATIONAL SIGNALS

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Mating disruption by vibrational signals is an emerging and promising technique for the protection of different kinds of plantations from parasitic insects. Signal generator devices, and their installation in the plantation are still in a prototype phase and they are far to be optimized. Taking the protection of vineyards from *Scaphoideus titanus* as case study, we present preliminary result based on classical structural mechanics coupled with numerical simulations showing the influence of the structural components of the vibrational system (e.g., position, dimension, materials, ground anchorages, etc.) to the efficient transmission of the signal to the plant.

We try to identify key design factors showing their implementation in simulation models of the system, also involving different size scales. The aim is to draw up new design protocols and guidelines for the realization of a new generation of optimized devices, to be manufacture at large scale and at low cost, and easily tenable and scalable to various plants and environmental conditions.

SOME UNSOLVED QUESTIONS ABOUT VIBRATIONAL COMMUNICATION IN HETEROPTERA

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In many groups of Heteroptera animals use in addition to the timbal or pendular abdominal vibrations, stridulatory signals, which can be detected in close range also by unaided human ears. The question is, why they combine these two vibrational mechanisms, which are producing vibrations in different frequency ranges. Since higher frequencies are better suited for airborne sound emissions and low frequency tremulation are more efficient as the substrate-borne signals one would assume that the stridulatory signals are primarily used for interspecific signalisation. The species of the fam. Cydnidae emit disturbance signals as pure stridulatory sounds in high frequency range 1 - 10 kHz. However, they use in premating behaviour combined signals with maxima in the low frequencies (usually 100-250 Hz) and higher frequencies (>1 kHz).

Could they use such signals for distance detection? Is this system useful in biotremulation just for the direct body to body transmission?

There are two (but not the only) other groups of bugs with combined vibratory mechanisms e.g. Reduviidae and Phymatidae. Stridulatory signals and structures in Reduviidae are well investigated but much less is known about the low frequency tremulation signals. The same is true for Phymatidae. The highly interesting mocking behaviour has been investigated some years ago, but we still do not know how they produce non stridulatory signals. Could the new video techniques help to solve such questions?

WHAT WE KNOW AND WHAT DO NOT KNOW ABOUT STINK BUG COMMUNICATION

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The aim of our contribution is to represent opened problems of stink bug communication with different languages. Strictly solitary living phytophagous Pentatominae represent in Brazil and worldwide economically important group of pests that success is among others based on efficient multimodal communication. Information exchange is mediated by chemical, mechanical and visual signals that use and efficiency in the field depend predominantly on communication distance and properties of the transmission medium. Substrate-borne communication, limited by plant's dimensions and architecture is accompanied at short distance by the use of the airborne component of vibrations produced by different mechanisms as well as by visual and contact chemical and mechanical signals.

Understanding of communication demands holistic approach to evaluate the relevance of different mechanisms running the complex process. Despite of broad knowledge on the vibratory song repertoire described in more than 36 pentatomine species, basic data on signal production mechanisms, transmission through plants as well as on morphology and function of sensory and neuronal system obtained by research on a few model species, we still need responses to many important questions. How do mates meet in the field without the use of chemical signals? What triggers male spontaneous emission of the vibratory calling song and why in certain species this emission does not trigger any obvious female response? Why emission of minute long sequences of short, low amplitude and readily repeated pulses in mates in copula? Has the tergal plate any timbale-like role in production of vibratory signals? Is species recognition a step-by-step process with signals running through different transmission channels? How and where in the brain is the yes-or-no decision accepted by processing of experience and multimodal information coming from different sensory inputs? Is communication through a narrow frequency window an advantage?

MATING BEHAVIOUR OF *PSAMMOTETTIX ALIENUS* DAHLBOM (HEMIPTERA: CICADELLIDAE)

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The wheat dwarf disease caused by the Wheat dwarf virus (WDV) is considered one of the most important diseases in cereals and *Psammotettix* leafhoppers are known to be exclusively responsible for plant-to-plant transmission of WDV. Here we investigated the reproductive behaviour of the main vector *P. alineus* (Dahlbom 1850). Leafhoppers were collected at various locations including cereal fields, grasslands and meadows in France and Slovenia. The sanitary status of the collected individuals was determined and individuals carrying WDV were included in the study in order to test the impact of the viruliferous status of leafhoppers on signalling and mating behaviour.

Results of the present study showed that as in other Cicadellidae, mating behaviour in P*. alienus* is stereotyped and associated with the emission of species- and sex-specific vibrational signals. However, our results revealed important differences with other leafhopper species so far studied in detail. The unique features of vibrational communication in *P. alienus* are: (1) that the pair formation is initiated by either gender; (2) the same general, simple structure of male and female calling song and (3) progression from a patterned to a loosely coordinated duet. Furthermore, the viruliferous status of insects may have an effect on the emitted signals, but our current results did not reveal a significant effect of virus on leafhopper performance in mating behaviour. Although current results are not conclusive, they show that it is worthwhile testing in more detail whether reproductive behaviour in *P. alienus* is influenced by the virus. We have also recorded putative masking signals but future studies should reveal whether coordinated duet in this species is vulnerable to disruption.

This study will hopefully contribute to sustainable management strategies as the current protection strategy against the leafhopper vectors is based on area-wide use of pesticide treatments.

SUBSTRATE-BORNE VIBRATIONAL CALLS OF MALE *AACANTHOCNEMA DOBSONI* (HEMIPTERA: TRIOZIDAE) VARY WITH BODY SIZE AND AGE BUT FEMALES ARE INDIFFERENT

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During sexual selection, members of the opposite sex utilize a variety of signal modalities to acquire information about potential mates. As a prerequisite, signal modalities must exhibit intra-specific variation and correlate to desirable traits such as body size and age that reflect the signallers fitness. Anecdotal accounts suggest that female psyllids are choosy and utilize substrate-borne vibrations (SBVs) to choose between males. We used laser vibrometry and playback experiments to study the mating and calling behaviours of a psyllid (*Aacanthocnema dobsoni* (Hemiptera: Triozidae)). Specifically, we quantified call parameters and asked whether they vary intra-specifically and correlate to male body size and age. We also tested whether female responsiveness is influenced by body size and age of calling males. Calls are sex-specific; male calls are more complex and comprise of long- and short-syllables while female calls are simple, comprising of only short syllables. Temporal and spectral male call parameters differ significantly from those of female calls, however, the structure of female syllables is similar to that of male short-syllables. Calls of both sexes exhibited a high level of intra-specific variation. Larger males produced calls with lower dominant frequency and older males produced calls with higher intensity and pulse rate. We used playbacks to test female responsiveness to calls recorded from males of contrasting sizes and ages. Surprisingly, female responsiveness was neither influenced by body size nor age of the calling males. Interestingly, while males call and search continuously, females, once mated neither call no respond to male calls. Nevertheless, males continuously attempt and often succeed to mate with unresponsive females.

These results demonstrate that *A. dobsoni* utilizes SBVs for mate attraction but not for pre-copulatory sexual selection. Given the polyandrous nature of females, sexual selection in this species is most likely achieved via post-copulatory mechanisms such as sperm competition and cryptic female choices.

POSTERS /

FLASH TALKS

SPECIAL FLASH TALK (5TH JULY)

SABIOD PROJECT: BIOACOUSTICS AND ECOACOUSTICS FOR RESEARCH, MONITORING AND CONSERVATION OF TERRESTRIAL HABITATS

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The SABIOD (Scaled Acoustic Biodiversity) project (http://sabiod.org), granted by CNRS and University of Toulon (F), is aimed at exploring the use of Bioacoustics and ecoacoustics as emerging tools in biodiversity science and biodiversity conservation: From the recognition and monitoring of individual species through to soundscape analysis and description, these disciplines provide new insights and approaches for science, conservation, and education.

Ecoacoustics is a recently defined interdisciplinary science, derived from bioacoustics and ecology, that investigates natural and anthropogenic sounds and their relationship with the environment over a wide range of study scales, both spatial and temporal, at individual, community and population level. Ecoacoustics operates in all types of terrestrial and aquatic (freshwater and marine) ecosystems extending the scope of acoustics and bioacoustics and providing tools for the monitoring and the management of the environment.

Current research trends and technologies, including scaled unsupervised coding of bird and whales songs developed within SABIOD will be presented.

A UNIVERSAL PLATFORM FOR IN VIVO FUNCTIONAL NEUROIMAGING IN INSECTS

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Multiphoton laser scanning microscopy is a powerful method to study morphology and function of the living brain in small animals. We present our customized in vivo imaging platform, which, in the case of insects, grants access to the full brain providing at the same time a spatial resolution of single neurons. In addition, the temporal bandwidth reaches from real time studies e.g. of neuronal plasticity over hours to frame rates of 500 Hz, ideal to resolve neuronal coding dynamics.

While we concentrated our research so far mostly on the olfactory pathway following signal processing of odour stimuli, the apparatus can be flexibly used to trace neuronal responses to any kind of stimuli including vibrations.

CAN WE MAKE AN ARTIFICIAL LEAFHOPPER FEMALE?

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We designed a proof of concept autonomous system capable of recognizing a male advertisement call of *Aphrodes bicincta* "Dragonja" (Hemiptera: Cicadellidae) and generating a female response in real time. This currently non-described leafhopper species was chosen due to a complex duet structure with strict timing requirements where female response needs to appear in short 45-175 ms intervals between repeating elements in male call in order to trigger the male searching behavior.

The device is a low cost microcontroller system which gathers the signals from the laser vibrometer, performs vibrational signal recognition using a digital signal processing algorithm and generates female responses via the vibrational exciter. The problem addressed by the algorithm is similar to the isolated word recognition in human speech, which comprises a feature extraction and the classification stage. The feature extraction part of the algorithm is based on linear-predictive cepst ral coefficients (LPCC) where the spectral envelope of the input signal is modelled using an all pole filter. The classifier was realized using a biological neural network model called the multilayer perceptron (MLP). To avoid feeding noise based feature vectors into the classifier a bandwidth limited call activity detector was designed.

Behavioral tests of such a system on adult males of *A. bicincta* "Dragonja" under laboratory conditions have shown good results in terms of discerning and detecting the species-specific male calls from the background noise. The system also attracted males to the source of the female reply.

The autonomous system will be used for further study of leafhopper behavior in a species where manual playbacks are not possible due to the duet structure By re-learning the classifier we have the possibility to extend our system to other species with a similar frequency-temporal vibrational signal structure.

COMPARATIVE NEUROANATOMY OF THE SCOLOPIDIAL ACCESSORY ORGAN, A PUTATIVE RECEPTOR FOR LOW FREQUENCY VIBRATIONS IN ORTHOPTEROID INSECTS

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Highly sensitive vibroceptors are found in the legs of insect and consist of scolopidial sensilla. Among different sensory organs, the Nebenorgan or accessory organ has been identified in cockroaches, heelwalkers and weta. It is a small organ with maximally 15 sensilla, located next to the larger subgenual organ, and sometimes recognised as a part of it. In cockroaches, neurophysiological studies suggest it responds to low frequency vibrations (up to 700 Hz, with main sensitivity below 200 Hz).

The structure and innervation of the subgenual organ complex in Ensifera has been studied recently in a comparative approach. By use of axonal tracing with cobalt ion solution, the sensilla and nerve fibers in the legs can be revealed. The accessory organ was (re-) described as part of the subgenual sensory complex in bushcrickets (Tettigoniidae), cave crickets (Rhaphidophoridae) or splay-footed crickets (Schizodactylidae). Notably, the accessory organ occurs in lineages rela ted to Tettigoniidae, but has not been reported in crickets.

The scolopidial sensilla usually have rather small somata and are located closely under the cuticle. Though the characterisation of sensory physiology is so far limited, neuroanatomical data are consistent with a function in detecting low-frequency vibration transferred by the leg cuticle. Comparative studies show that the accessory organ is common in many taxa relying on signals transferred as substrate vibrations for intraspecific communication or mate detection. Since several sensory organs occur in the subgenual organ complex, the relevance of these different organs for vibrational physiology and behaviour remains to be established.

VIBRATION-SENSITIVITY OF THE STICK INSECT *SIPYLOIDEA SIPYLUS* IN DIFFERENT STIMULATORY PARADIGMS

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In insects, the subgenual organ in the proximal tibia is considered the most sensitive vibration receiver in the leg. In stick insects, the subgenual is well developed, containing about 40 scolopidial sensilla. This subgenual organ is accompanied by a so-called distal organ with about 20 linearly arranged sensilla.

We studied the physiological responses of these organs to sinoidal vibration stimuli delivered by a mini-shaker in the species *Sipyloidea siyplus*. Compound action potentials from subgenual and distal organ were recorded from the main leg nerve in the femur. Different stimulatory regimes were tested which varied the direction of stimulus delivery: the leg was displaced in horizontal or vertical direction. In addition, recordings were taken after ablation of a small scolopidial organ, the distal tibial organ or tibio-tarsal organ, by heat or by cutting of the sensory nerve. The recorded activity should represent exclusively neuronal responses from th e subgenual and distal organ. In each series of experiments, vibrational stimuli were applied for different frequencies ranging from 50 – 5000 Hz, each frequency with increasing stimulus amplitudes, to determine the sensory thresholds.

The resulting sensory thresholds are lower (more sensitive) to vertical leg movements than to horizontal leg movements. In the ablation experiments of the distal tibial organ/ tibio-tarsal organ, the sensory threshold were not changed significantly, a finding that supports the subgenual organ as the most sensitive vibration receptor in the tibia. Since the direction of stimulation affects the overall sensitivity recorded, this should be taken into consideration for electrophysiological experiments on behaviourally relevant vibration signals in insects in general.

PHYSIOLOGY OF THE FEMORAL CHORDOTONAL ORGAN OF *DROSOPHILA MELANOGASTER*

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The physiology of femoral chordotonal organ (fCO) of adult *Drosophila* is investigated. The fCO develops during pupal stage and consist of different subparts of the organ. For this study, recording from the leg nerve of the frontleg were performed. The frontleg was attached to a minishaker and either frequency-modulated or amplitude modulated stimuli were applied.

The frequency-modulated stimuli contained frequencies from 1Hz to 4000Hz in an ascending and descending order. Interestingly, the ascending order was reacted to more strongly than to frequencies in the descending part. Furthermore, the response variation was larger in the ascending part. Best reactions were found in the range below 600Hz with additional peaks at about 100Hz, 1800Hz, and 3500Hz. The amplitude-modulated stimuli had a ramp-shaped envelop and carrier frequencies from 10Hz to 4000Hz with 4s duration each.

Again the first part, the ascending amplitudes were stronger responded to than the descending amplitudes. From the reactions threshold curves have been extracted. The investigation of the physiology of the proprio- and vibration receptive femoral chordotonal organ of adult *Drosophila* opens the field for analyzing mechanisms of mechanotransduction by using mutant lines.

MECHANOSENSORY ORGANS IN THE LEGS OF MANTIS (HIERODULA MEMBRANACEA)

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The complex tibial organs of the legs of mantid *Hierodula membranacea* were anatomically and physiologically investigated. Two main questions were the base of the study. 1. Do mantids have a complex sensory tibial organ and how does it compare to the organs in orthopterans? 2. What are the specializations in the organ in respect to the different functions and type of legs?

The mantid *H. membranacea* possesses an organ complex with a subgenual organ (SGO) in all three leg pairs. This general structure of the SGO compares well to that of other insects, like Orthoptera and Blattodea. It is a fan-shaped organ, with a typical sensory projection in the corresponding ganglia. Within the organ complex a distal organ can be distinguished, which might be homolog to distal organs in other taxa. The vibration sensitivity is best in low frequency range (200-1000Hz) with no marked peaked frequency.

The foreleg of mantids is specialized for prey capture and has substrate contact only during climbing. The mid- and hindlegs are used for normal walking and have substrate contact during resting. Thus, substrate vibrations should be mainly perceived via the mid- and hindlegs. This functional difference is reflected in the SGO. The number of sensory cells in the foreleg SGO is lower than in the mid- and hindleg (27 versus 50 or 46 cells). The foreleg seems to be less vibration sensitive than the other legs, especially in the higher frequency range. In summary, the mechanosensory systems of the legs seem to correlate to the leg morphology and function.

GOOD OR BAD VIBRATIONS: IMPACTS OF MAN-MADE VIBRATION UPON MARINE INVERTEBRATES

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Anthropogenic activities directly contacting the seabed, such as drilling and pile driving, produce a significant vibration likely to impact benthic invertebrates near the activity. Vibration is also likely to be used by marine species in a similar way to terrestrial organisms, for the detection of biotic and abiotic cues, yet the significance of this and the sensitivities to vibration are undocumented for many marine species. Exposure to additional vibration may elicit behavioural or physiological change, or even physical damage at high amplitudes or particular frequencies, although this is poorly studied within underwater noise research. Here the available peer-reviewed information is summarised regarding the sensitivities and responses of marine invertebrates to substrate-borne vibration. This includes information related to vibrations produced by those construction activities directly impacting the seabed, such as pile driving.

The review indicates that these species are able to detect vibration and respond to anthropogenically-produced vibrations, although the short and long-term implications of this are not known. As such it is vital that the sensitivities of these species are further understood, given that noise and energy-generating human impacts upon the marine environment are only likely to increase.

VIBRATION AND ACOUSTIC SONGS IN THE *ACANTHOSCELIDES OBTECTUS* (COLEOPTERA: BRUCHIDAE)

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Many Bruchidae species are widely used as model species. However, as far as we know, acoustic communication has never been studied in detail in this group. One of the few examples is the study on acoustic behaviour of the *Callosobruchus maculatus* larvae feeding in cowpeas.

The aim of our study was to investigate various aspects in Bruchidae acoustic communication as an example *Acanthoscelides obtectus*. The vibrational signals were recorded with a GZP-311 monophonic piezoelectric cartridge. Acoustic songs record with microphone (type 4191, 1/2 inch; Bruel &Kjær, Nærum, Denmark). The temporal parameters and power spectra of the songs were analysed with TURBOLAB 4.0 (Bressner Technology, Germany). Two types of signal emission were registered in *A. obtectus*: abdomen tremulations and wing vibrations. Both the calling and courtship signals have been registered for male beetles (n= 58); in females (n= 18) we have registered three types of signals: a response call that follows a male's calling signal, male courtship song and female calling song. Some signals include acoustic and vibration component.

We show that all of the registered acoustic signals in *A.obtectus* beetles contain both stable (pulse duration, pulse period: CV=5-10%) and variable (duration of series of pulses, phrase duration: CV=38-50%) signal elements. The frequency parameters exhibit low variation in all of the registered signals (CV=5-12%). Interesting that, the dominant frequency of all registered signal types is similar (1100-1178 Hz). It has been previously shown that frequency characteristics and fine temporal structure (e.g. pulse period) are generally more stable, while gross-temporal properties (e.g. series of pulses) are much more variable. Our data are consistent with this hypothesis.

VIBROACOUSTIC COMMUNICATION IN *CREMATOGASTER SCUTELLARIS* ANT

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Communication is a crucial feature for ant colonies, which are usually formed by thousands of interacting workers. Although chemical signals remain the main modality of intracolony communication, several ant species can exchange information also through substrate-borne vibrations. In many ant species vibrational signals are produced by stridulation, by rubbing the file (or pars stridens), located on the upper anterior surface of the first gastral segment, against a scraper (or plectrum), located on the upper part of the postpetiole segments. Stridulation occurs in many different behavioural contexts that vary according to the species, their social organization and the environment.

We studied the stridulatory behaviour in *Crematogaster scutellaris*, which is a dominant tree-nesting myrmicine ant widely distributed throughout the Mediterranean basin, in different behavioural situations, such as routine daily activity inside the nest, food retrieval by workers and a smulated predator attack (i. e. a single individual was immobilized with a rubber band). Recordings were carried out using a laser vibrometer, and the signals emitted by three different castes (queens, workers and males) were analysed and compared. Playback tests were performed with an electro-magnetic shaker, to investigate the ability of vibroacoustic signals to trigger a response in conspecifics. All castes were able to produce long sequences of signals formed by disyllabic chirps. The signal is distinctive of each caste, considering temporal (e.g. the number of bursts, chirps and gap duration) and spectral parameters. Worker signal has higher dominant frequency (above 1000 Hz) and lower intensity compared to reproductive individual signal (dominant frequency below 600 Hz). The function of these signals probably changes according to the context: whenever an individual was trapped, stridulation occurred, thus suggesting a deterrent function, but workers stridulated also when a drop of honey was offered to them to recruit nest mates. On the contrary, no vibrational signals were ever recorded during normal nest activity.

CONTEXT DEPENDING DIRECTIONAL VIBRATION SENSING IN *ATTA SEXDENS*

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Communication in social insects is mediated primarily by chemical signals, but vibrational signals are also frequently used, especially to recruit nest mates. Foraging workers of the leaf-cutting ant *Atta sexdens* stridulate while cutting leaf fragments. Workers respond to the vibrations transmitted through the plant by orientating towards the source of vibration. Workers also stridulate when they are buried by a cave-in of the nest. A stridulating ant attracts other workers which subsequently start to dig. Recently we demonstrated that *A. sexdens* is able to localize sources of vibrations through time-of-arrival differences between legs down to 0.1 ms. Here we show that this tropotactic orientation of *A. sexdens* foragers interacts with chemical communication signals. The presence of citral, a compound of their alarm pheromone, modulates the ants' directional response to vibrational stimuli significantly.

The ants seem to pay less attention to directional cues leading them to profitable food sources when they are confronted with an alarm signal and a recruitment signal at the same time.

FEEL THE WOMEN`S VIBES: CUES USED FOR DIRECTIONAL VIBRATION SENSING IN *NEZARA VIRIDULA*

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Several behavioral studies demonstrate the ability of insects to localize the source of vibrations. Especially mate location behavior in *Nezara viridula* is very well studied. The female resides on the plant stem without moving and produces rhythmic repetitions of her calling song. A male located on the same plant, answers with calling and courtship songs and searches for the female. When encountering branching points, the male stops and straddles its legs across the fork to compare the vibrations in the two branches. Measurements of vibrational signals on plants show significantly different amplitudes and arrival times of the signal between the two different branches. It has been shown, that differences in amplitude are sufficient to cause different neuronal responses in legs positioned on the two branches. Experiments on natural plants however, do not allow the examination of whether male *N. viridula* use amplitude or time of arrival differences to find the female.

We therefore, chose an artificial t-maze set-up that enabled us to examine both parameters independently. Two bridges could be vibrated independently allowing us to vibrate the legs of the left and the right body side with time delays and amplitude differences. In our set-up searching males' legs straddled the two bridges forming the t-maze and proceeded to walk after detecting playback of the female calling song. After passing the bridge, males had to choose one side. We performed experiments with amplitude differences, time of arrival differences and combinations of both.

Here we show that time-of-arrival differences of the vibrational signals are used for tropotactic orientation in *N. viridula*. The time delays detected by males are in the same range as the time delays detected by termites and scorpions. Furthermore, our experiments reveal that amplitude differences and combinations of amplitude and time-of-arrival differences are used as directional cues.

REDUCING THE NOISE: UNCOVERING THE MORPHOLOGICAL AND BEHAVIOURAL EVOLUTION OF HEMIPTERAN VIBRATIONAL SIGNALS

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Heteroptera (Insecta: Hemiptera), known as True Bugs, represent one of the most successful insect radiations, occupying virtually every terrestrial and freshwater habitat. Vibrational and acoustic signaling in Heteroptera and their relatives has expanded more than any other insect order, used in communication, courtship, defence and prey acquisition. The mechanisms generating these signals include tymbal buckling, abdominal tremulation, percussion and stridulation. Attempting to uncover key patterns in Heteropteran biotremology, we critically revise what is known in this field and highlight areas of future study. Using state-of-the art technology such as synchrotron microtomography (μCT), we try to answer fundamental questions on the developmental origin, evolution and morphology of Hemipteran vibrational organs. The results of our morphological analysis suggest that tremulatory organs in the abdomen evolved at least thrice in Hemiptera, in contrast with some recent theories (Tymbalia concept). Based on our literature review and original observations, vibrational signals serve as evolutionary precursors (exaptations) for acoustic communication, in agreement with studies in other insects and vertebrates. Moreover, acoustic organs frequently originate partly or entirely from vibrational ones. The selective pressures triggering the evolution of acoustic signals and their adaptive advantage are poorly known, but seem to vary among examined taxa. Heteropteran vibrational communication converges in many points with that of their sister group, the Auchenorrhyncha. However, the latter are characterized by more specialized vibratory behaviours, while chemical communication is reduced or absent. In contrast, most Heteroptera have greatly expanded their chemical repertoire and rely on multimodal signals to stimulate the receiver by as many communication channels as possible.

VIBRATORY COMMUNICATION AND REPRODUCTIVE ISOLATION IN TWO SYMPATRIC STINK BUG SPECIES (HEMIPTERA: PENTATOMIDAE: PENTATOMINAE)

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In phytophagous stink bugs communication is related to mating behavior that among others includes location and recognition of the partner during calling and courting. Specificity of temporal and frequency parameters of vibratory signals contributes to species reproductive isolation. *Chinavia impicticornis* and *C. ubica* are two green Neotropical stink bugs that live and mate on the same host plants. We tested the hypothesis that differences in temporal and spectral characteristics of both species vibratory signals enable their recognition to that extent that it interrupts further interspecific communication and copulation.

We monitored both species mating behaviour and recorded with laser vibrometers their vibratory signals on non-resonant loudspeaker membranes and on plants. The level of interspecific vibratory communication was tested also by play-back experiments. Reproductive behavior and vibratory communication show similar patterns in both *Chinavia* species. Differences observed in temporal and spectral characteristics of female and male signals enable species discrimination. Insects that respond to heterospecific vibratory signals do not step forward to behaviors leading to copulation.

Results suggest that species isolation takes place in both investigated *Chinavia* species at an early stage of mating behavior reducing reproductive interference and the probability of heterospecific mating.

WHY DOES MOTHER BURROWER BUG SHAKE HER EGG MASS? MATERNAL HATCHING REGULATION MITIGATES THE RISK OF FUTURE CANNIBALISM

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Parents in some social egg-laying species provide special care for embryos at hatching. Subsocial burrower bug, *Adomerus rotundus* (Heteroptera: Cydnidae) exhibits maternal care, such as defense against predation and providing food. We found that *A. rotundus* mothers shaken their body rhythmically and produced a physical vibration, while maintaining the egg-guarding posture, i.e. holding the egg mass under the thorax, between the forelegs and midlegs. The occurrences of this behaviour apparently had a peak, coinciding with the time when most embryos synchronously started to emerge from their shells. On the other hand, the brood, which was isolated from the mother, hatched asynchronously. We experimentally exposed mature egg masses to an artificial vibration and monitored the hatching pattern, and then, synchronous hatching was induced.

These results suggest that *A. rotundus* mothers promote synchronous hatching using physical vibration. Such sophisticate d hatching care is readily expected to have the adaptive function of supporting the young offspring. We expected that synchronous hatching might prevent cannibalism among siblings. The occurrences of nymphal cannibalism in hatched asynchronously groups were significantly higher than in hatched synchronously groups. We frequently observed that earlier-hatched nymphs ate later-hatched nymphs and that earlier-hatched nymphs also faced risk of predation by later-hatched nymphs at molting in hatched asynchronously groups. We conclude that *A. rotundus* mothers actively regulate synchronous hatching by physical vibration for mitigating the risk of “future” sibling cannibalism.

SUBSTRATE-BORNE VIBRATIONAL COMMUNICATION IN THE VECTORS OF APPLE PROLIFERATION *CACOPSYLLA PICTA* AND *C. MELANONEURA* (HOMOPTERA: PSYLLIDAE)

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Apple Proliferation (AP) is a disease known in many fruit-growing European regions and represents one of the most severe problems in apple orchards. The etiological agent of this disease is a phytoplasma named '*Candidatus* Phytoplasma mali'. So far, two psyllid species, *Cacopsylla picta* (Förster) and *C. melanoneura* (Förster) have been identified as the vectors of AP phytoplasma. The populations of these two species are ordinarily controlled with chemicals by means of multiple treatments during springtime. It is known that some psyllids use substrate-borne vibrations in sexual communication. Here, we report the first laser vibrometer recordings of vibrational signals of the two vectors emitted during courtship. Usually, females of *C. picta* initiated communication on the host plant by emitting trains of vibrational pulses, followed by a duet consisting of male call and female reply, the latter again as a pulse train. We did not obtain sufficient data to describe the signaling sequence of *C. melanoneura*, but we managed to record several male calls. The signals appear to be species- and gender-specific; however, they are not a prerequisite for courtship – some pairs mated without any vibrational signal emission. Moreover, as already seen in other psyllid species, a scanning electron microscopy investigation showed the presence of stridulatory mechanism on thorax and wings of both species. This corresponds to rapid wing movements observed during signaling that is synchronous with signal emission. Manipulation of animal behavior with vibrations in the field can be used as an alternative pest control method to reduce pesticide use. Our preliminary results provide new information about the biology of both species and could suggest an innovative approach for an environmentally friendly integrated management strategy.

SPECIAL SESSIONS

SPECIAL TALK : CETACEANS

MARINE MAMMALS ACOUSTICS AND TOOLS FOR BIOACOUSTIC AND ECOACOUSTIC RESEARCH

Gianni PAVAN

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In the last 20 years the development of bioacoustic research in the marine environment has been mostly driven by the scientists' concern about the impact of anthropogenic noise on marine mammals and other marine creatures. Bioacoustics and ecoacoustics are emerging tools in biodiversity science and biodiversity conservation: from the recognition and monitoring of individual species through to soundscape analysis and description, they provide new insights and approaches for science, conservation, and education.

Ecoacoustics is a recently defined interdisciplinary science, derived from bioacoustics and ecology, that investigates natural and anthropogenic sounds and their relationship with the environment over a wide range of study scales, both spatial and temporal, at individual, community and population level. Ecoacoustics operates in all types of terrestrial and aquatic (freshwater and marine) ecosystems extending the scope of acoustics and bioacoustics and providing tools for the monitoring and the management of the environment. Current research trends will be presented with the support of sound samples.

DRUMMER AWARDS 2016, RENÉ-GUY, MARIE-CLAIRE BUSNEL AND GLENN K. MORRIS

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Although the importance of vibrational signals for inter- and intraspecific communication in animals, especially insects, such e.g., Hemiptera and Orthoptera, had been recognized at least since the middle of the 20th century, research on vibrational communication has received far less attention than the study of auditory communication by the scientific community. For a long time, vibrational communication was believed to be rare or subordinate to auditory systems. It is only within the last two decades that the ubiquity of vibrational signals among animals, invertebrates as well as vertebrates, and even plants, has become generally accepted.

In order to honour milestone achievements in the study of vibrational communication and to further draw attention to this field of research, the Insect Drummer Award was created in 2011. Here we give a brief overview of the contributions of previous laureates, and present laudations for the recipients of the Insect Drummer Awards 2016, René-Guy and Marie-Claire Busnel and Glenn K. Morris.

ULTRASONIC COMMUNICATION IN FROGS

Peter M. NARINS

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Among the vertebrates, only microchiropteran bats, cetaceans (whales and porpoises) and some rodents are known to produce and detect ultrasounds (US) for the purpose of communication and/or echolocation, suggesting that this capacity may be restricted to mammals.

In this talk, I shall present the first evidence of US communication in an amphibian - the concave-eared torrent frog, *Amolops tormotus* (Ranidae) from Huangshan Hot Springs, China. Males of *A. tormotus* produce diverse bird-like melodic calls with pronounced frequency modulations that often contain spectral energy in the US range. This extraordinary upward extension into the ultrasonic range of both the harmonic content of the advertisement calls and the frog's hearing sensitivity is likely to have coevolved in response to the intense, predominately low-frequency ambient noise from local streams.

A second, distantly related frog species, *Huia cavitympanum*, inhabits vegetation along swiftly running streams in Sarawak, Malaysian Borneo. Males of this species produce high-pitched calls with prominent ultrasonic components. In fact, some calls are completely in the ultrasonic range! Because amphibians are a distinct evolutionary lineage from microchiropterans and cetaceans, US perception in these animals represents a novel example of independent evolution.

ARACHNID ORCHESTRA. JAM SESSIONS BY TOMÁS SARACENO

Tomas SARACENO & Roland MÜHLETHALER

Studio Tomas Saraceno Hauptstrasse 11/12, 10317 Germany

Arachnid Orchestra. Jam Sessions is the pioneering and visionary project by artist Tomás Saraceno. It brings his long-term research on spider webs into the realm of sound and was commissioned by curator Ute Meta Bauer for Saraceno's first solo show in Southeast Asia at the NTU Centre for Contemporary Art in Singapore (2015).

Situated at the intersection between art, architecture and science, the artist turns spider webs into musical instruments embodying the incredible structural properties of the spider's silk, but also the spider's sophisticated mode of communication through vibrations. Arachnid Orchestra. Jam Sessions was developed in collaboration between arachnologists, musicians, sound engineers and other experts of different universities and fields of knowledge, with whom Saraceno succeeded to amplify the spiders' vibrational communication system and web plucking—not perceivable to human ears—into acoustic rhythms. The exhibition space was turned into an interactive sound and visual installation, a process-driven laboratory for experimentation that pushes the boundaries of interspecies communication. Various musicians and sonic artists based in Singapore were invited to respond to the spiders' vibrational communication in three live performances (jam sessions), creating a collective and immersive interspecies musical composition.

For the 1st International Symposium on Biotremology in Italy (July 2016) we are showing excerpts of Arachnid Orchestra to the scientific audience to present the achievements of Saraceno's line of inquiry as well as to discuss his hypotheses of play and creativity that ask for a more complex understanding of human and non-human cohabitation.

BUGS, A WALRUS AND DOOR TRENTO, LIVE

Boštjan PEROVŠEK

The composition based on the original song “Bugs, a walrus and a door start dancing” (30 minutes, 8 channel version, 1986), uses sound material created by bugs, a walrus and a door at the Vodnik Homestead in Ljubljana before it was oiled. Prof. Matija Gogala “equipped” me with an array of magnetic tapes with different tunes. These tapes consisted of approx. 80 hours of material, from which I took roughly 20 different length samples - ranging from a few seconds to half a minute.

Once they were classified and listened to, the sounds of the walrus and the door were added. I classified this piece of music as a bioacoustic piece, although it could easily be considered electroacoustic. However, since I want to remain consistent to the original idea, I insist on this definition. The composition is not called bioacoustic due to the fashionable bio trends, but rather because it is founded on sound materials obtained from scientists who investigate animal sounds. This scientific discipline is called bioacoustics. The credits go to the included voluntary live performance (by the members of the experimental music group SAETA) and involuntary performers (animals) – a result of being consistent in defining the project’s starting points and the music itself. The short stereo version of the composition, which can be found on the CD “Boštjan Perovšek – Touchings”, and on the vinyl LP “Bio, Industrial Acoustica (green)” was also included in the Ars Acoustica 1995-1996 Listening Proposals program within the frame of the European Broadcasting Union.

The composition “Bugs, a walrus and door Trento, live” is a special version based on the 30 minute original version. It can be realized as a 15 - 20 minutes long quadrophonic or stereo version, in which original samples are mixed in a new way and in new combinations. This version also includes a new soloist: a bug “*Legnotus limbosus*”.

AUTHENTIC RESEARCH IN THE CLASSROOM: TRANSFORMING YOUR COURSE INTO A COURSE-BASED RESEARCH EXPERIENCE (CURE) FOR UNDERGRADUATES

Carrie HALL & Daniel HOWARD

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Active learning strategies such as using 1) primary literature as a learning tool, 2) guided inquiry learning curricula, and 3) early participation in undergraduate research have been shown to improve content learning, student confidence and identity as scientists, and retention and persistence in science degrees. By re-designing traditional lecture and laboratory courses into active learning courses framed around empirically validated teaching practices including course-based research, faculty can transform their own courses into research courses in which undergraduate students experience the process of science in an authentic way.

By adopting these practices, faculty benefit from increased research productivity (data production and publication rate), connection active integration of teaching and research agendas, increased enjoyment and satisfaction of teaching, and a broadened research interest. During this workshop, junior and senior faculty who are interested in transforming their traditional courses into research-based courses will 1) learn about research in active learning methodology, 2) discover the various methods of course-based research implementation, 3) examine the curricula of their own course(s) and evaluate the feasibility of transforming the course, and 4) work collaboratively to develop a course-based research teaching module framed around questions in biotremology. Participants are asked to bring a copy of a syllabus for a course that they would be interested in transforming into a course-based research model.

ENGINEERING, MECHANICS AND INFORMATICS MEET ENTOMOLOGY: COMMUNICATION, INTERFERENCE AND DISRUPTION BY VIBRATIONAL SIGNALS

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In this workshop we want to explore the possibility of introducing an engineering and informatics approach for the optimization of systems aimed at interfering/interacting with insects, both for laboratorial scale experiments and field practical applications. Different factors in both temporal and spectral patterns of the signals, and that are related to specific features of the insect/plant system (e.g. trellis, physiology, phenology etc) are crucial in determining a positive behavioural response in the animal. This means to obtain an effective conditioning of the individual decisions that can vary from simple duetting with them to attracting or even disrupting their mating behaviour. We will discuss how mechanical engineers and informaticians should approach this topic and then integrate it into the entomological problems.

The workshop is open to expertise in the following fields:

- Bioacoustics
- Solid mechanics (vibrations)
- Computational mechanics, computer aided engineering
- Information and communications technology
- Interactive systems
- Digital signal processing

MAKING A WORLDWIDE AND ROBUST NETWORK IN BIOTREMOLOGY

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To promote the development of the emerging community of biotremologists we need a robust network that not only facilitates scientific communication, but helps us to claim and bundle resources for research, training and outreach. The workshop will be a platform for proposing and discussion of ideas and possible, as well as existing, efforts in fund-raising. The goal is to coordinate all such efforts and define concrete steps (and persons responsible) to be taken in the near future.

First things to discuss specifically are:

– concept and community input (advice and material) for an outreach and training website for vibrational communication studies funded by NSF(US) at the Cocroft Lab;

– discussing an application for a NSF(US) “Research Coordination Network” grant;

– discussing an application for a matching European program (COST actions) to build a worldwide network for training, method development, data exchange, and generally broaden the base for our community.

Further ideas are very welcome, and can be communicated to the workshop organizers as well as presented during the workshop.

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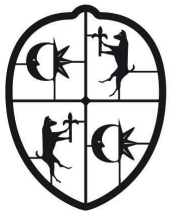

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