



**Ninth International Conference  
of the Orthopterists' Society**

*Integrative Biology in Orthopteran Research*

Canmore, Alberta, Canada

Aug 14-19, 2005

Presented by the Orthopterists' Society and

University of Lethbridge

University of  
**Lethbridge**







Art by Karen Brownlee; full description in final program

**Ninth International Conference of the Orthopterists' Society  
Canmore, Alberta, Canada, August 14-19, 2005**

**Program**

***Saturday August 13 - Sunday August 14***

Arrivals and transport from Calgary to Canmore.

(Contact [dan.transfer@gmail.com](mailto:dan.transfer@gmail.com) in advance for a ride from the Calgary International Airport to the Radisson Hotel and Conference Centre in Canmore)

***Sunday August 14***

1330 – 1900

Registration of participants (continues Monday).  
Refreshments.



Art by Karen Brownlee; full description in final program

**Monday August 15 – Registration open 0730 - 1400**

**OPENING CEREMONY**

(main plenary room, Lady Slipper- Orchid)

- 0820 Call to the meeting (Piper Andrew Watchman)
- 0830 Opening of the Conference, from the Orthopterists' Society;  
Michel Lecoq (Centre de coopération internationale en recherche  
agronomique pour le développement, CIRAD-Locust Ecology and  
Control Unit, France), President of the Orthopterists' Society
- 0835 Welcome, and Introduction to the Conference;  
Dan L. Johnson, Conference Chair
- 0845 Welcome from Bill Cade, President of the University of Lethbridge
- 0850 Welcome from the Radisson Hotel and Conference Centre,  
and Canmore
- 0900 In-coming President's Remarks: Michel Lecoq
- 0925 Welcome and Remarks from Executive Director Gregory Sword

- 0935 Nicholas D. Jago Memorial, presented by Andrew W. Harvey,  
FAO Locust & Sunn Pest Campaign Manager
- 1000 Thanks by Conference Chair
- 1000 – 1030 Coffee/Refreshment Break

## PLENARY LECTURES

- 1030 Call to order and Introduction of Plenary Speaker
- 1035 **Michel Lecoq, CIRAD-Locust Ecology and Control Unit,  
France**
- Integrated locust management in developing countries :  
From ecology to anthropology.**
- 1115 Introduction of Plenary Speaker
- 1120 **Stephen Simpson, Department of Zoology and Oxford  
University Museum of Natural History, UK**
- Phase change in locusts: from neurones to populations**
- 1200-1330 Lunch (provided in the Conference Centre,  
for registered participants)
- 1330 Reconvene for Plenary Symposia

All Plenary Symposia are in Lady Slipper- Orchid, the main meeting room of the conference. Poster sessions and the banquet will also be held in this room. Posters can be put up any time on Sunday or Monday, and remain on display until Friday. The attended Poster Session is Thursday 0930 – 1030, just before concurrent submitted papers.

**Plenary Symposium 1:**  
**Is Research a Sufficient Driver for Acridid Pest Control?**  
**Recent progress and key concerns in locust**  
**and grasshopper management.**

Co-chairs : Michel Lecoq, CIRAD-Locust Ecology and Control Unit, France, and Alexandre Latchininsky, Applied Acridology International, University of Wyoming, USA.

Introduction:

Orthopteroid insects are an essential component of the fauna of many ecosystems, in particular grasslands. Diverse and abundant, they play an important role in nutrient cycling and provide the food base for numerous animals, especially birds, mammals and reptiles. Although abiotic (weather) and biotic (natural enemies) factors keep their numbers under control most of the time, ever so often this regulatory mechanism fails, and a rapid build-up of population occurs. Such upsurge may lead to an outbreak of a local, regional or even transcontinental scale. If such an event happens, the orthopteroid pests (katydids and, much more frequently, the acridids) can destroy sufficient forage to cause human suffering, economic loss, or environmental damage. In such cases, the central dilemma of pest management is that we cannot avoid risks by failing to take action. Allowing a pest outbreak to proceed without intervention can be potentially harmful for humans and the environment.

However, there is no doubt that attempts to alter the course of an acridid pest outbreak have incumbent risks, too. Acridid control programs represent risks at an ecosystem level. Chemical insecticides may reduce biodiversity, degrade soil, air, water quality, and bioaccumulate in the food web. Introduced biological control agents may undermine the delicate integrity of co-evolved relationships within an ecosystem. Furthermore, there are potential hazards to human health. Finally, economic and socio-political impacts of large-scale acridid management programs are poorly understood.

The end of the 20<sup>th</sup> and the beginning of the 21<sup>st</sup> centuries were characterized by severe locust and grasshopper outbreaks in different geographical areas. Paradoxically, this upsurge of pest activities coincided with a marked decline of research centers in applied acridology throughout the world, which dramatically reduced our capacity to develop and implement safer, cheaper, and more efficient pest management practices. What challenges are we facing today in the domain of acridid pest control? What traditional and novel tools do we have in our arsenal? Is research a sufficient driver for making acridid pest management sustainable? These questions constitute the leitmotif of the current symposium on the state-of-the-art of the acridid pest management in the new millennium.

## Plenary Symposium 1 Presentations

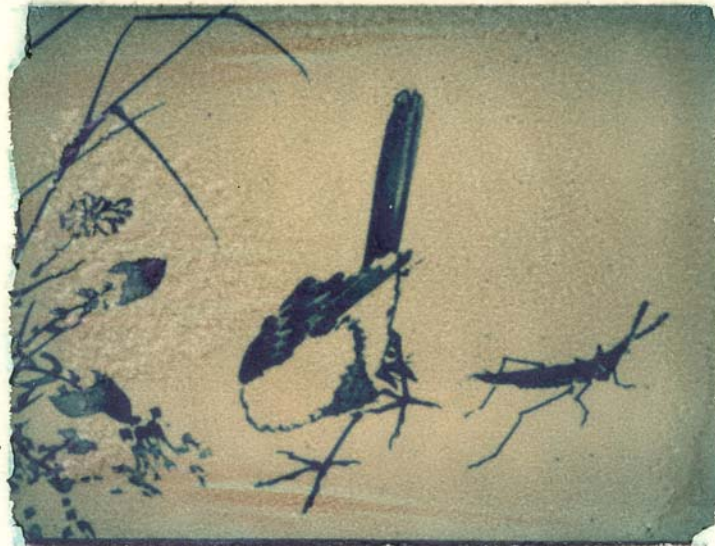
(each presented paper in Symposium 1 is 20 minutes in length,  
plus 5 minutes for summary, questions or discussion)

- 1330      **Jeffrey Lockwood**, University of Wyoming, USA.  
Aquinas and Acridids: Waging a just war against an insect enemy
- 1355      **Ralf Peveling**, University of Basel, Switzerland.  
We believe what we see – and vice versa:  
Evidence versus perception in locust control
- 1420      **David H. Branson**, USDA-Agricultural Research Service,  
Northern Plains Agricultural Research Lab, Sidney, MT, USA.  
Ecological research as a needed driver for preventative  
management of Acridids
- 1445      **Michael G. Sergeev**, Novosibirsk State University, Russia.  
Ecology and economy of the Italian locust outbreaks: Between the  
horns of dilemmas
- 1510      **Graham A. Matthews**, Imperial College, London, UK.  
The Pesticide Referee Group of FAO and its contribution to locust  
control
- 1535      Coffee/Refreshment Break (15 minutes)
- 1550      **David Hunter**, Australia.  
The use of *Metarhizium* in the integrated pest management of  
locusts and grasshoppers
- 1615      **Alexandre Latchininsky**, University of Wyoming, USA.  
Locust and grasshopper management in the countries of the  
former Soviet Union: New challenges
- 1640      Jean-François Duranton, CIRAD, and **Annie Monard**, FAO.  
Contribution to the bioecological study of two Peruvian locusts,  
*Schistocerca cf. interrita* Scudder, 1899 and *Schistocerca*  
*piceifrons peruviana* Lynch Arribalzaga, 1903 (Orthoptera:  
Cyrtacanthacridinae)

- 1705 Coffee/Refreshment Break (10 minutes)
- 1715 **M. A. Ould Babah**, M.L. Ould Ahmedou, M.E. Ould Jaevar, and S.A. Ould Mohamed, Centre national de lutte antiacridienne, BP 665, Nouakchott, Mauritania.  
Management of a major Desert Locust upsurge in Mauritania (2003–2004)
- 1740 **Dan L. Johnson**, University of Lethbridge, Alberta, Canada, Ray G. Poulin, L. Danielle Todd, University of Alberta, Priya Mir, and Brad Linderman Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada.  
Reconciling orthopteran pest management with environmental protection and conservation of biodiversity
- 1805 **V.E. Kambulin**, Institute for Plant Protection, Almaty, Kazakhstan.  
Italian locust in Kazakhstan: 145 years of warfare
- 1830 **Yeneneh T. Belayneh**, U.S. Agency for International Development, Washington, DC, USA.  
Acridid pest management in the developing world; can it be done?  
- A challenge to the rural populations, a dilemma to the international community
- 1900 **Reception** (Monday evening), Vic's Steakhouse & Bar, Radisson Hotel and Conference Centre; Hosted by the President of the University of Lethbridge







71 (28) Field + Blauschnepper, Zettigulic. © K. Brownlee 2003  
Sticky 10 Bamboo 5 holes

**Tuesday August 16**

Plenary Symposium 2:

**Hybrid Zones: Evolutionary Dead-end or Cradle of Innovation?**

Moderator : Daniel Howard (New Mexico State University)

(each presented paper in Symposium 2 is 25 minutes in length,  
plus 5 minutes for summary, questions or discussion)

- 0830      **Charles Ross**, New Mexico State University, USA.  
Mosaic hybrid zone structure and maintenance as moderators for  
introgression between the field crickets, *Gryllus firmus* and *G.*  
*pennsylvanicus*.
- 0900      **Klaus-Gerhard Heller**, Magdeburg, Germany.  
Hybrid zones and other consequences of contact between  
(sub)species in the genus *Poecilimon* (Orthoptera: Tettigonioidea:  
Phaneropteridae)
- 0930      **Jeremy Marshall**, University of Texas at Arlington, USA.  
Gametic isolation, reinforcement, and rapid speciation in an  
*Allonemobius* hybrid zone
- 1000      Coffee/Refreshment Break

- 1030      **Kerry L. Shaw**, Kyle Wagner, and Jennifer Jadin, University of Maryland.  
Testing hypotheses for bimodal hybrid zones with examples from simulated and real crickets
- 1100      **Daniel J. Howard**, New Mexico State University and Seth C. Britch, USDA-Agricultural Research Service, USA.  
Evolution in a cricket hybrid zone
- 1130      Discussion
- 1200-1330      Lunch (provided in the Conference Centre)

Plenary Symposium 3:

**Advances and Controversies in Phase Polyphenism Research**

Co-chairs: Gregory Sword, Stephen Simpson and Arnold De Loof

Introduction:

Phase polyphenism is a type of phenotypic plasticity expressed in a number of insect groups, but most commonly associated with locusts. Phase change often comprises a suite of physiological, behavioral and morphological phenotypic changes that are mediated by changes in local population density.

The biochemical, physiological and ecological mechanisms underlying the expression of phase change continue to be investigated using a variety of experimental approaches. This symposium serves to highlight ongoing research into the physiology, ecology and evolution of phase change. In particular, we hope to provide a forum to discuss recent advances in phase change research with special emphasis on current controversies and needs for future research.

Plenary Symposium 3 Presentations

(with the exception of the first paper, each presented paper in Symposium 3 is a total of 20 minutes in length, including questions or discussion)

- 1330      **Meir Paul Pener**, Hebrew University of Jerusalem, Israel.  
Volatile pheromones, contact pheromones, mechanical touching, and visual cues as signals in locust phase polyphenism: State of the art
- 1400      **Arnold De Loof**, Gert Simonet, Ilse Claeys, Roger Huybrechts and Jozef Vanden Broeck, Laboratory for Developmental Physiology, Genomics and Proteomics, Belgium.  
Molecular markers of phase transition in locusts

- 1420 **Stephen M. Rogers**, University of Cambridge, UK, and University of Oxford, UK, Thomas Matheson, University of Cambridge, UK, and University of Leicester, UK, Michael Anstey, University of Oxford, UK, and Stephen J. Simpson, University of Oxford, UK, and University of Sydney, Australia.  
Early induction of behavioural phase change in the Desert Locust
- 1440 **Tom Matheson**, University of Cambridge, UK, and University of Leicester, UK, Stephen M Rogers, University of Cambridge, UK, and Holger G. Krapp, University of Cambridge, UK.  
Changes in synaptic strength accompany phase change in locusts
- 1500 **Seiji Tanaka**, University of Wyoming, USA.  
Corazonin and phase polyphenism in locusts
- 1520-1540 Coffee/Refreshment Break
- 1540 **Ahmed Hassanali**, Magzoub Bashir, Peter Njagi and Sidiould Eli, International Centre of Insect Physiology & Ecology, Nairobi, Kenya. The role of semiochemicals in the desert locust gregarisation: its genesis, spread, and sustenance
- 1600 **Hans-Joerg Ferenz** and Karsten Seidelmann, Martin Luther University, Halle, Germany  
Locust volatiles - Pheromones for every purpose?
- 1620 **Karsten Seidelmann** and Hans-Joerg Ferenz, Martin Luther University, Halle, Germany.  
Unraveling the function of Phenylacetonitrile: Courtship inhibition or aggregation?
- 1640 **Emma Despland**, Concordia University, USA, and Stephen Simpson, University of Sydney, Australia  
Locust food choices reflect density-dependent anti-predator strategies
- 1700 **Hojun Song**, Ohio State University, Columbus, USA  
Phylogenetic perspectives on the evolution of locust phase polyphenism
- 1720 **Gregory A. Sword**, USDA/ARS, Sydney, MT, USA  
Genotype versus environment in locust swarm formation: How important is phase polyphenism?

Tuesday evening meetings.

All meeting locations, and additional meeting announcements, will be posted in the main hallway. The meeting rooms are together near the plenary room, Lady Slipper-Orchid. Watch for the signs.

1. Association for Applied Acridology International (AAAI). 1830 (6:30 p.m.).  
Contact: Alexandre Latchininsky
2. Special interest group: – *Schistocerca nitens* on Nihoa, Hawai'i . 2000 (8 p.m.). Contact: Dan Johnson, Jeff Lockwood, Alexandre Latchininsky or Stefan Jaronski
3. OSF2: Orthoptera Species File On-line. 1800 (6 p.m.). Dinner meeting.  
Contact: David Eades
4. You can arrange your own sub-group meeting by contacting Deanna (CNF@uleth.ca) or Dan (dan.johnson@uleth.ca), or leave a note at the hotel desk. Or just meet in Vic's!



Plague of locusts in Milan, July, 1556. Hans Weigel The Elder

**Wednesday August 17**

- 0800 No papers or presentations today. Meet in lobby of Conference Centre for start of **all-day field trip** to grassland and museum. Board buses in the parking lot.
- 0820 Depart Canmore on buses.
- 1000 (approximate time) Stop at grassland site for observations on local Orthoptera and habitat.
- 1230 Arrive Royal Tyrrell Museum (Paleontology). The entry fee is paid for those who signed up for the field trip.

Lunch on your own, in the Museum cafeteria

After lunch: tour the Museum on your own or in small groups.

- 1700 Assemble to board buses and depart Royal Tyrrell Museum. Return to Canmore, stopping on the way at a restaurant for evening meal (paid on your own).
- 2100 Arrive at Canmore. No other events are planned for Wednesday evening.



**Thursday August 18**

- 0830 Orthopterists' Society Business Meeting (1 hour)
- 0930 Poster session with poster authors present  
(1 hour; main plenary room, Lady Slipper- Orchid; please attend  
your posters and take questions)
- 1030 Attended poster session ends
- 1030-1100 Coffee/Refreshment Break
- Submitted symposium and submitted papers follow.

Note: Three concurrent session.  
Two concurrent sessions will be held in 35-seat rooms: Caribou and Wolverine.  
The Orthoptera Bioacoustics submitted symposium will be held in the large  
plenary room, combined "Lady Slipper – Orchid".

## Concurrent Presentations

Submitted symposium, and concurrent submitted papers.  
(Each submitted paper presentation will be 15 minutes in length,  
plus 5 minutes for summary, questions or discussion.)

1100 Submitted Symposium (main plenary room, Lady Slipper- Orchid)

### **Orthoptera Bioacoustics: Sound and Vibration**

Organized by: Fernando Montealegre-Z. and Glenn K. Morris, University of Toronto at Mississauga, Canada.

#### Introduction:

Acoustic communication has evolved importantly in many arthropods and usually mediates social or territorial behaviour. It is of particular importance in the lives of many Orthoptera. And due to their diversity of signals and receivers, orthopterans represent a large part of the most studied models among arthropods. In most species of Orthoptera, it is the male who makes sounds, which are used mainly by females for mate recognition.

A diversity of sound mechanisms occur in Orthoptera, almost all of them based on stridulation (the production of sound by rubbing together body parts). Basically the stridulatory mechanisms consist of files and scrapers localized on movable appendages. These stridulatory behaviours occur in many forms: femoro-abdominal, tergo-tergal, mandibular, labral, antennal, femoro-tegmina and tegmino-tegmina stridulation. In addition to stridulation some species use seismic communication as an alternative channel. In a similar way, receptor systems have evolved several times, with different morphologies and topologies. For example, tympanal organs can be found latero-dorsal in the abdomen of some Caelifera, but they occur basally on the tibia of several Ensifera.

Acoustic signals range from the audio range (50 - 20000 Hertz) to extreme ultrasonic channels (20000->100000 Hertz) and for many years, these signals their receptors and neural processing mechanisms have been a major focus of physiological and neurological research. Some species have economic importance and knowledge of their acoustic signaling has affected strategies of control. Acoustic signals have also been useful in studies of genetic and behavioural responses. Sound signals are species-specific, and bioacoustic analyses have helped to separate species that are difficult to distinguish by simple morphology. Such acoustic diversity can help to estimate species richness, and as many species are indicators of habitat quality, bioacoustic monitoring has proved to be useful for evaluation of habitat fragmentation.

This symposium is intended to present some of the most recent advances in bioacoustics of Orthoptera attained by experts in the field with the use of today's technology. Our meeting here today is an opportunity for discussions and dissemination of different points of view and ideas.

**Orthopteran Bioacoustics: adaptations for sound communication in crickets, grasshoppers and katydids**

- 1100        **Holger Braun**, University of Toronto at Mississauga, Canada; and Germany.  
“Little walking leaves” of Andean and Amazonian rainforests with remarkable calling songs (Tettigoniidae, Pterochrozini, *Typophyllum* spp.)
- 1120        **Filippo Buzzetti**, Università degli Studi di Padova, Italy, and Glenn K. Morris; University of Toronto at Mississauga, Canada. Bioacoustics of some Ecuadorean Ensifera.
- 1140        **Klaus-Gerhard Heller**, Magdeburg, Germany.  
Acoustic communication in the genus *Poecilimon* (Orthoptera: Tettigonioidae: Phaneropteridae)
- 1200-1330    Lunch (provided in the Conference Centre, for registered participants)
- 1330        **Peggy S. M. Hill**, University of Tulsa, Tulsa, OK, USA  
Singing from a constructed burrow: why vary the surface opening?
- 1350        **Fernando Montealegre-Z.**, University of Toronto at Mississauga, Canada. Physical constraints for the evolution of asymmetric wings in katydids
- 1410        **Dan Howard**, University of Tulsa, Tulsa, OK, USA.  
Morphology and calling song characteristics in *Gryllotalpa major*
- 1430        **Andrew C. Mason** and Glenn K. Morris; University of Toronto at Mississauga, Canada.  
Acoustic communication in the genus *Cyphoderris*
- 1450        **Daniel Otte** Academy of Natural Sciences of Philadelphia, USA.  
Old ideas you probably never heard about
- 1510-1540    Coffee/Refreshment break
- 1540        **Ken Prestwich**, College of the Holy Cross, Worcester, MA, USA  
Coarse and fine-scale views of calling energetics in crickets



- 1600        **Johannes Schul** and Sarah L. Bush. University of Missouri-Columbia, MO, USA.  
Co-evolution of sender and receiver: is genetic drift the driving force?
- 1620        **Klaus Riede**, Zoologisches Forschungsinstitut and Museum Alexander Koenig, Bonn, Germany.  
Automatised annotation of orthopteran songs: first results from analysing the DORSA sound repository
- 1640        **Glenn K. Morris**, University of Toronto at Mississauga, Canada.  
Acoustic behaviour of the bog katydid: *Metrioptera sphagnum* (Orthoptera, Tettigoniidae)
- 1700        Discussion and summary

**Concurrent Submitted Papers, section A (*watch for signs*)**

**Room: Caribou**

Each paper is 15 minutes in length plus 5 minutes for summary or questions.

- 1100        Alex Franc<sup>1</sup>, Tsitohaina Andriamaroahina<sup>2</sup>, Yann Legros<sup>3</sup>, and Jean-François Duranton<sup>1</sup> CIRAD, Montpellier, France ; <sup>2</sup> Centre National Antiacridien, Tuléar, Madagascar ; <sup>3</sup> Institut National Géographique, Paris, France.  
Using remote sensing to improve the evaluation of the Malagasy migratory locust risk *Locusta migratoria capito* (Saussure, 1884), Orthoptera: Acrididae
- 1120        Arnold van Huis<sup>1</sup>, Keith Cressman<sup>2</sup>, and Joyce I. Magor<sup>3</sup>  
<sup>1</sup> Wageningen University, the Netherlands, <sup>2</sup> Desert Locust Information Service, FAO, Rome. <sup>3</sup> Natural Resources Institute, Chatham Maritime, UK.  
Preventing desert locust plagues: Optimizing management interventions
- 1140        Alexandre V. Latchininsky and Scott P. Schell, University of Wyoming. Optimized parameters for rangeland grasshopper treatments using ultra-low insecticide coverages and kairomonal attractants.
- 1200-1330    Lunch (provided in the Conference Centre, for registered participants)

- 1330 Peter A. Spurgin, Australian Plague Locust Commission, Canberra, Australia. Applied Operational Research: Use of fipronil to control infestations of Australian plague locust, *Chortoicetes terminifera* (Walker), in rangeland areas
- 1350 Michael J. Samways, University of Stellenbosch, South Africa. Response of Orthoptera assemblages to changing land mosaics in southern Africa
- 1410 Tim B. Graham, Southwest Biological Science Center, Moab, Utah. Grasshopper communities in native and non-native grasslands on the Colorado Plateau: Differences in density and species composition
- 1430 Marie-Pierre Chapuis<sup>1</sup>, Arnaud Augé-Sabatier<sup>1</sup>, Arnaud Estoup<sup>1</sup>, Antoine Foucart<sup>3</sup>, Michel Lecoq<sup>3</sup>, and Yannis Michalakis<sup>2</sup>, <sup>1</sup>INRA, France, <sup>2</sup>Centre d'Etudes sur le Polymorphisme des Microorganismes, UMR CNRS-IRD, Montpellier, France, <sup>3</sup>Centre de coopération internationale en recherche agronomique pour le développement, Montferrier/Lez, France.  
Genetic determinism of gregarization in the migratory locust *Locusta migratoria*
- 1450 Sharon R. Hill and Ian Orchard, University of Toronto at Mississauga, Canada. FMRFamide-related peptides in *Locusta migratoria*: association and involvement in the digestive system.
- 1510-1540 Coffee/Refreshment break
- 1540 Marguerite A. Rizk<sup>1</sup>, G.Z.Taha<sup>2</sup>, A.M.El-Gammal<sup>2</sup> and M.F.Harb<sup>2</sup>  
<sup>1</sup>Agricultural Research Center, Fayoum, Egypt, <sup>2</sup>Agric. Res. Center, Dokki, Egypt. Studies on some biological actions of the weed *Anagallis arvensis* L. in relation to its digestive capacity in *Schistocerca gregaria* (forsk.)
- 1600 Spare; or Discussion and summary

**Concurrent Submitted Papers, Section B (*watch for signs*)**  
**Room: Wolverine**

Each paper is 15 minutes in length plus 5 minutes for summary or questions.

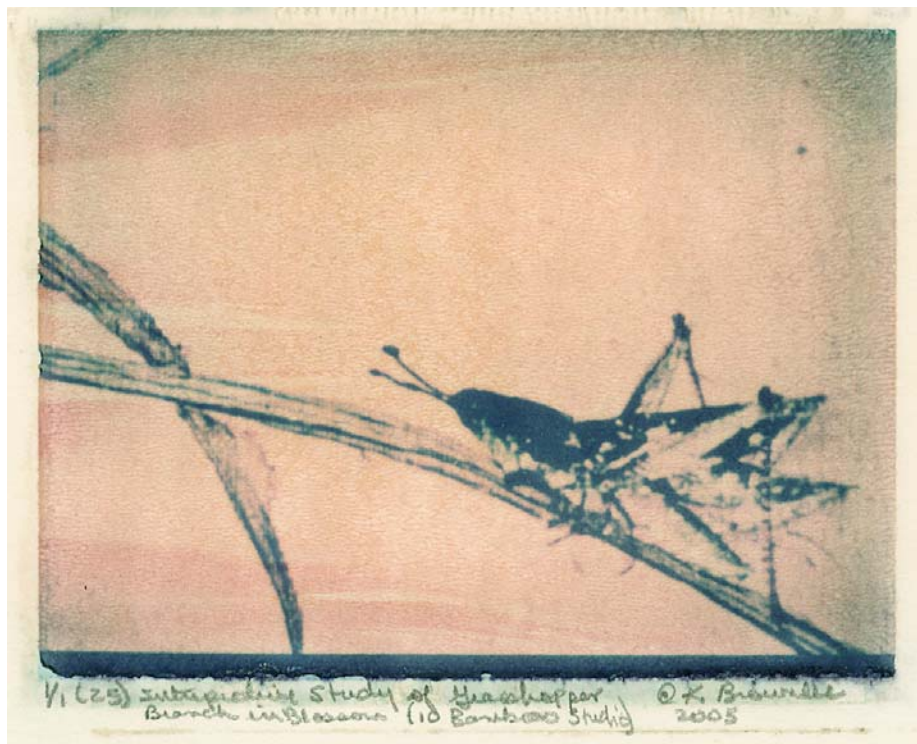
- 1100 Janice Edgerly-Rooks and C.N. McCreedy. Santa Clara University, CA, USA. Exploring a silken empire: A review of behaviour and diversity in females of the little known orthopteroid order *Embioptera*
- 1120 Thomas M. McCarthy<sup>1</sup>, John Keyes<sup>2</sup>, and William H. Cade<sup>2</sup>. <sup>1</sup>Utica College, Utica New York, <sup>2</sup>University of Lethbridge, Lethbridge, Canada. Male calling and phonotactic behaviors in the field cricket, *Gryllus texensis*
- 1140 David B. Weissman<sup>1</sup> and David C. Lightfoot<sup>2</sup>, <sup>1</sup>California Academy of Sciences, San Francisco, USA, <sup>2</sup>University of New Mexico, USA. The significance of cytology in *Trimerotropis* (Orthoptera: Oedipodinae) grasshopper taxonomy
- 1200-1330 Lunch (provided in the Conference Centre, for registered participants)
- 1330 Darryl T. Gwynne Department of Biology, University of Toronto in Mississauga, Canada. Reproductive biology of New Zealand weta (Ensifera: Anostostomatidae)
- 1350 Daniel E. Perez-Gelabert and Daniel Otte, U. S. National Museum of Natural History, Smithsonian Institution, Washington, DC, USA, and Academy of Natural Sciences, Philadelphia, USA. Crickets of the Caribbean: 15% of the World Species.
- 1410 David C. Eades Illinois Natural History Survey, Champaign, Illinois, USA, Progress Report on the Orthoptera Species File (Version 2)
- 1430 Theodore J. Cohn, University of Michigan, 1108 Geddes Ave., Ann Arbor, MI. Bringing Taxonomic Data presentation into the 20th if not the 21st Century
- 1450 Ali Akbar Keyhanian and M. Ghazavi, Plant Pests and Diseases Research Institute, Tehran, Iran. Biology and seasonal occurrence of katydids, Decticinae (Tettigoniidae: Decticinae), in Iran

1510-1540 Coffee/Refreshment break

1540 Spare. Or if not used, will serve for discussion of:  
Barcoding Orthoptera: summary of recent activity and background in collaboration with the Barcoding of Life NSERC Network. (Dan Johnson, University of Lethbridge)

1600 Spare, or Discussion and summary

1900 **Banquet in Lady Slipper-Orchid,**  
followed by presentation of awards.



**Friday Aug 19**

Plenary Symposium 5:

**Sexual Selection and Reproductive Behaviour**

Moderators: Darryl Gwynne (before break), University of Toronto, and  
Bill Cade (after break), University of Lethbridge

- 0830            Opening remarks
- 0840            **David Gray**, California State University, USA.  
Song, sex, and species of *Gryllus* field crickets
- 0905            **William Brown**, SUNY Fredonia, USA.  
Motivation to fight over females and aggressive songs in crickets
- 0930            **Clint Kelly**, University of Toronto, Canada.  
Sexual selection and sexual dimorphism in tree weta
- 0955            **Ken Fedorka**, University of Georgia, USA.  
Sexual conflict and immune suppression in ground crickets.
- 1020            Break
- 1035            **Karim Vahed**, University of Derby, UK.  
A negative correlation between the degree of polyandry and  
sperm numbers, across taxa, in bush crickets (Tettigoniidae)
- 1100            **Patrik Nosil**, Simon Fraser University, Canada.  
Natural selection drives the evolution of sexual isolation between  
populations of *Timema* walking-stick insects
- 1125            **Tamra Mendelson**, LeHigh University, USA.  
Rapid speciation in Hawaiian crickets linked to sexual behaviour
- End             1150
- 1200-1330      Lunch (provided in the Conference Centre,  
for registered participants)
- 1330            Gather near front of Conference Centre for transportation to the  
site of the Montane field trip. Nets and guidebooks will be  
available.

The art displayed during the Ninth International Conference of the Orthopterists' Society was generously created for us by Karen Brownlee.

The various studies are comprised of both Polaroid emulsion and image transfers. The technique involves using Polaroid film to photograph transparencies. The photograph is then manipulated by varying the exposure time, cropping the original to focus on the orthoptera, and transferring the emulsion and/or the image onto fine art paper. In some cases hand coloring was added, especially to the image transfers. Each image is considered to be an original, and is matted to museum standards. This process is a relatively new form of artistic expression.

The interpretive studies were specially prepared for the conference and were derived from: "The Mustard Seed Manual of Painting" (Nanking XVII century) and "The Ten Bamboo Studio, A Chinese Masterpiece" (first published in 1619).

Karen's mages were included in the program, and as gifts. One of the images is available as a conference t-shirt.

Biography: "Karen is a full-time practising artist, residing in Lethbridge, Alberta, Canada. Her visual arts practice includes studio and plein air painting, with a focus on rural Alberta, including the grain elevators, as well as Alberta landscape flora and fauna. She has a deep love of the natural world and has painted on location on the eastern slopes of the Rockies, including Waterton International Peace Park and World Heritage site, for twenty-five years. Karen welcomes inquiries regarding commissions, the use of her paintings as book covers, and other creative and publishing opportunities and consortiums."

Karen's book of original watercolour paintings of rural Alberta will be published in September, 2005.

<http://people.uleth.ca/~karen.brownlee>

[karen.brownlee@uleth.ca](mailto:karen.brownlee@uleth.ca)

# Abstracts

Note: this is a draft set of abstracts. The final corrected abstracts and program will be printed as a special issue of *Metaleptea*.

## **The Orthoptera of a sub-mediterranean zone of the Trentino region (Northeast Italy)**

Barbara Agabiti<sup>1</sup> and Cristina Salvadori<sup>2</sup>

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The aim of our work was to study the Orthoptera fauna of an esalpic area located in the southern part of the Adige Valley of the Trentino region (northeast Italy), which is characterized by a sub-Mediterranean climate. A checklist of the species of Orthoptera collected during two years of sampling (2003 – 2004) and the results of a statistical analysis of the data are reported. In order to determine the environmental factors that better characterize the distribution of Orthoptera on the studied territory, we carried out a statistical investigation of the variables of altitude, slope, and type of environment. The collected data was analysed using the CANOCO 4.0 software (Cajo J.F. Ter Braak, 1998). Another software, Biodiv 5.1 (Baev and Penev, 1993), was used to create biodiversity indexes and for cluster analysis. Findings of particular bio-geographical and eco-fauna interest are the presence of species, such as *Antaxius difformis*, *Chopardius p. pedestris*, *Chorthopodisma cobellii*, and *Glyptobothrus alticola*, usually endemic to the north-eastern Alpine arch; *Pseudoprumna baldensis* orophilic species endemic to the M. Baldo region (South Trentino); *Aiolopus s. strepens*, typical to the ecotone xeric zone; *Barbitistes vicetinus*, endemic species of Veneto region (North-east Italy); *Stethophyma grossum*, *Arcyptera f. fusca* and *Oedipoda germanica*, considered threatened species; and *Xiphidion discolor*, *Calliptamus siciliae*, and *Psophus stridulus*, species typical to the arid dry grasslands.

Keywords: Orthoptera, ecology, biodiversity, Trentino, Italy.

## **Odorant-binding proteins and chemosensory proteins in the locust**

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Two major families of soluble proteins are expressed in chemosensilla of insects and seem to be involved in the perception of volatile and contact stimuli, odorant-binding proteins (OBPs), and chemosensory proteins (CSPs). Both are small polypeptides (120-140 residues for OBPs and 100-120 for CSPs) and are mainly folded in  $\alpha$ -helical domains.

Both OBP and CSPs have been reported in the locust. Cloning has revealed the presence of two closely related genes encoding OBPs in *Locusta migratoria*, while there is still no report on OBP in *Schistocerca gregaria*. The ORF encoded a mature OBP of 130 residues, followed by two stop codons and a non-translated region of 200 bases (accession number in GenBank: AF542076). The deduced protein sequence showed low similarity to a number of insect OBPs from different orders. Concerning the expression of OBP and the sub-class of CSPs in locust, we observed that OBP is strictly antenna-specific.

By contrast, at least twenty genes have been described for CSPs in *L. migratoria* and eight genes encoding CSP in *S. gregaria*. At the same time, a great diversity has been observed at the protein level. Based on their similarities at the amino acid level, these sequences for CSPs can be segregated into three sub-classes: CSP-I, CSP-II and CSP-III. Members of the same sub-class can differ by only a few or up to 50% of their amino acid residues. The percentage of identical amino acids among three sub-classes ranged from 20 to 60%.

Using polyclonal antibodies, we have also monitored the expression of three CSP sub-classes in locusts. The result showed that CSP-I is ubiquitous in both *L. migratoria* and *S. gregaria*. Cloning of CSP-II were available in *L. migratoria*, named CSP-Lmig-II, which has also been monitored in *S. gregaria* by Western Blot with antiserum against recombinant CSP-Lmig-II. CSP-III expresses specifically in *S. gregaria*.

### **Orthoptera Acridoidea of “El Cielo” Biosphere Reserve, Northern Mexico**

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El Cielo Biosphere Reserve is located along an offset of the Sierra Madre Oriental mountain range in northern Mexico. Located between parallels 22°55', 23°25'N, and 23°03'S and meridians 99°95' and 99°26'W, the reserve – a 350,000 acre site – constitutes the largest and most important protected area of northeastern Mexico. The State of Tamaulipas established El Cielo Biosphere Reserve on July 13, 1985. In 1986, the United Nations designated the area as a World Heritage site. With elevation ranging from 600 to 7,600 feet, the reserve encompasses four different ecosystems (tropical jungle, cloud forest, pine-oak forest, and chaparral), all of them comprising a remarkable and unique mixture of flora and fauna not found elsewhere in the world. Research work on fauna biodiversity of the reserve includes birds (> 255 resident species and 175 migratory species), amphibia (21 species), reptiles (60 species), bats (40 species), and wild felines (6 species), amongst others. However, few studies have been conducted to study the entomological diversity; this is the first effort to study the Orthoptera of "El Cielo." Specimens were collected during summer and fall of 2002 – 2003 using an entomological net. Collection sites were 50X50m at low (600-2,600 Ft.), median (>2600 -4,900), and high elevations (>4,900 Ft.); collection time was no less than 2 hours per site and at least six collection trips were carried out to the area. During the above period around 600 specimens were collected, representing in order of abundance the subfamilies Cyrtacanthacridinae, Melanopliinae, Gomphocerinae, Romaleinae, Oedipodinae, Ommatolampinae, and Acridinae. A total of 29 species are reported, with the subfamily Melanopliinae showing the greatest biodiversity (16 species), followed by Cyrtacanthacridinae (4 species) and Gomphocerinae (4 species). The most common species are as follows: *Schistocerca nitens*, *Schistocerca pallens*, *S. piceifrons piceifrons*, *S. albolineata*, *Melanoplus differentialis*, *Perixerus spp.* *Phaulotettix compressus*, *Phaulotetti spp.*, *Taenipoda tamaulipensis*, *T. auricornis*, and *Chromacris colorata*.



## **Integrated management of the Central American locust (*Schistocerca piceifrons piceifrons*, Walker) in México**

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A technical cooperation programme was started in 2001 in collaboration with the Plant Protection Program in one of Mexico's southern states, Tamaulipas. The purpose of the collaboration was to assist in campaign management and control activities against the Central American Locust (*Schistocerca piceifrons piceifrons* Walker). Until very recently, chemical products and control techniques used against this pest in northern Mexico were obsolete and inefficient. A major objective was to introduce and validate appropriate technology, as well as alternative products for locust control in this region. As a result of this cooperation, we have available, at present, environmentally safer alternatives, i.e., the biopesticide *Metarhizium anisopliae* var. *acridum* and phenil-pyrazol fipronil (Regent 200 S.C); the latter product is used at very low doses (2-5 g.a.i/ha) and has a persistence of 8 to 20 days, which allows barrier spraying. In this way application costs and environmental impact – a result of products used previously such as Methyl Parathion – are decreased considerably. In the case of *Metarhizium*, doses of 25 g spores/ha are recommended to control 1st through 5th instar nymphs, or 50 g spores/ha to control 6-7th instar nymphs or young adults; it is not recommended to use *Metarhizium* to control adults more than 2-3 weeks old or swarms. Both, fipronil or *Metarhizium* may be applied as conventional or ULV; for ULV applications it is recommended to mix product with 1-2 litres crude soy oil or citrolina/ha. Fipronil may be applied as blanket or barrier spraying (untreated swaths of 60-80 m wide). For nymph control, 2 g. a.i./ha are recommended as conventional spraying (30 litres of water + 1% molasses/ha) or as ULV (in crude soy oil 2 litres/ha); for control of swarms 5 g.a.i/ha are recommended as blanket, conventional, or ULV spraying. Barrier spraying was possible due to fipronil persistence under field conditions; this locust control technique was used in México for the first time; results obtained were excellent since only 20 – 40 % of infested areas treated measured substantial or secondary environmental impact. In addition operation costs were reduced to US\$3.70 vs. US\$18.00/ha with the previous use of Methyl Parathion. The above results have allowed the implementation of an Integrated Control Strategy against the Central American locust in northern Mexico.

## ***Mantis religiosa*: Dynamics of population, coloration and territoriality**

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**Abstract.** A population of mantids (*Mantis religiosa*, Linnaeus, 1758) was studied in natural conditions, between August and October 2003 in a submontane habitat near Vicenza in Italy. The population was observed and studied with the mark and recapture method. Different dynamics between males and females probably linked to sexual cannibalism were recorded. In particular the estimated population of adult males decreased faster than that of females and in the end of the season only females were present. The seasonal occurrence of the two main colour patterns (green and brown) of *Mantis religiosa* was studied and an increasing of green specimens percentage was observed from Summer to Autumn. The green and the brown colours can occur in different instars of one individual but in addition a partial change in colour from brown to green have been observed in adult specimens kept in laboratory conditions in late season. Data

concerning home range dimension, mobility and habitat preferences are also presented. A marked preference for *Rubus ulmifolius* bushes has been outlined in comparison with the other kinds of vegetations.

### **Mating behaviour and sexual cannibalism in *Mantis religiosa***

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**Abstract.** The mating behaviour of 13 males and 14 females mantids of the species *Mantis religiosa* (Linnaeus, 1758) was studied in laboratory conditions between September and October 2003. The following data were recorded: frequency of cannibalism (attested on 45.45% on a total of 22 encounters), male copulating success when cannibalized (20%), males cannibalization during the first encounter (70%), male mating success with more than one female (46.15%), number of females that mated more than once (64.29%), total number of females successfully fecundated (78.57%), number of females that maintained the same attitude in the following mating (from cannibal to cannibal and from non-cannibal to non-cannibal) (62.50%), number of females that devoured the male during the first (60%) or following encounters (40%), total number of females that produced at least one ootheca (72.7%), number, size and weight of oothecae produced by cannibal (0.75, 3.44 cm<sup>3</sup>, 0.331 g) and non-cannibal (1.30, 4.50 cm<sup>3</sup>, 0.396 g) females, average duration of a mating without cannibalism (3.35 hours), average duration of male approach (5.2 hours), presence of intraspecific sounds during approaches and matings (not present).

### **Acridid pest management in the developing world: A challenge to the rural population, a dilemma to the international community**

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Acridid pests – locusts and grasshoppers – pose continued threats to the rural communities in developing countries. The threat is evermore prominent in sub-Saharan Africa where the human and physical resources to combat these pests are meager to none. This has significantly undermined the livelihoods and economic basis of the affected communities in the harboring nations. Over the past fifteen years or so, numerous large-scale invasions, upsurges, and/or a plague of the desert locust, *Schistocerca gregaria* (Forsk.) at times mixed with the migratory locusts, *Locusta migratoria migratorioides* (Reiche and Fauremaire), as well as the Senegalese Grasshopper, *Oedaleus senegalensis* (Krauss), among others, have occurred in the Sahel and/or the Red Sea region, in northwest Africa along the Indo-Pakistan outbreak regions. Efforts to control these pests have largely been supported by the international community despite the dilemma that continuously haunts them. Nevertheless, without their assistance, most frontline countries in the Sahel are virtually handicapped to stand up to the challenge. Large-scale control interventions always rely on application of enormous quantities of synthetic chemical pesticides. The 2003-2004 upsurges and the 1986-89 plague combined required treating more than 25 million ha (> 62 million acres), nearly the same number of liters of pesticides. At the current estimated cost of control, that may have cost in the upwards of \$500. Given the magnitude of the

spray operations that took place, the associated environmental cost and economic burdens are also immense. This paper attempts to present an overview of the challenges, impacts, and implications of the current approach and discusses perceived benefits to the rural communities in affected countries. It tries to capture lessons learned and experiences gained from previous and recent past campaigns, formulate suggestions and conclusions and offer recommendations for future directions.

Key words: Acridid pests, *Schistocerca gregaria*, invasions, upsurges, Sahel

## **New genera and the real status of Taxiarchus Brunner in Proscopiidae (Orthoptera: Eumastacoidea)**

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Among the genera of proscopiids, there is none with such a complicated history as the genus *Taxiarchus Brunner von Wattenwyl 1890*, described on the basis of *T. superbus*. In its original description, based on characteristics of its external morphology, a conspicuous tuberculate carina on the mesothorax is mentioned and present in all of this species. In 1906, Rehn described *T. paraensis*. Hebard (1924) classified *Taxiarchus* under *Proscopia Klug 1820*. This classification was accepted by Liana (1972) and listed by Carbonell (1977). Jago (1989) revalidates *Taxiarchus*, with its species *superbus* and *paraensis*, and transfers to it *Proscopia latirostris Brunner 1890* and *P. sajax Scudder 1869*. This classification is based mainly on characteristics of the phallic complex. From our examination of the spermathecae, the phallic complex, and the external characteristics, we agree with Jago on the identity of this ensemble of species as being different from those in the genus *Proscopia*. However, we find that the type-species *Proscopia, P. gigantea*, is based on a female whose spermatheca shares all the important characteristics of the species of the genus *Taxiarchus*. Thus *Taxiarchus* can be considered synonymous with *Proscopia*, and all of its species must be placed in the latter genus. The rest of the species included in *Proscopia*, which indeed do not belong in *Taxiarchus* have been classified mostly on the basis of characteristics of their spermathecae and phallic complex and are placed under two new generic names. This study includes keys for males and females of the three genera involved.

## **Nuevos géneros y status real de Taxiarchus Brunner en Proscopiidae (Orthoptera, Eumastacoidea).**

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Entre los proscopidos, ninguno ha tenido una vida tan controversial como el género *Taxiarchus Brunner von Wattenwyl*. En la descripción original base a caracteres de morfología externa, el autor remarca una carena tuberculada que se encuentra en el mesotórax, propia de todos los *Taxiarchus*. Fue descrito en base a una sola especie, *T. superbus*. Posteriormente, Rehn, 1906 describió otra, *T. paraensis*. Hebard (1924) sinonimizó *Taxiarchus* a *Proscopia*. Esta sinonimia fue listada por Carbonell en su catálogo (1977) y aparentemente por Liana (1972) también. Jago (1989) valida nuevamente el género y agrega dos nuevas combinaciones: *T. latirostris* (Brunner) y *T. sajax* (Scudder) y reinstala *T. paraensis*, sinonimizado bajo *Proscopia scabra* por Rehn. Esta reinstalación se hizo en base e estudios del complejo fálico, sin estudiar las espermatecas, las

cuales son características. Basados en el estudio de éste órgano conjuntamente con el complejo fálico y caracteres morfológicos externos, concordamos con Jago en la identidad de éste conjunto de especies, muy diferentes hasta lo que ahora es Proscopia. Sin embargo, Proscopia gigantea, especie tipo del género, comparte los caracteres de genitalia femenina (el holotipo es una hembra) del conjunto de especies anterior. También presenta la muy característica carena lobulada del mesotórax. Por lo tanto por el principio de precedencia, todas las especies pertenecientes al género Taxiarchus, se vuelven Proscopia. El resto de las especies de Proscopia se distribuyen en dos nuevos géneros basándonos en la genitalia masculina y en la espermateca. Este estudio se completa con claves para machos y hembras de los géneros involucrados.

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### **Impact of Malathion and Deltamethrin (ULV formulation) on honey bees, *Apis mellifera* L., in semi-natural conditions**

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The current study has been undertaken under semi-field conditions in order to evaluate the impact of Malathion and Deltamethrin in ULV formulation on honey bees, *Apis mellifera* L., according to the CEB method n° 129. The lethal and repulsive effects induced by these insecticides, widely used in locust control, have been assessed as direct application during the peak of foraging activity and as indirect treatment during the absence of foraging bees. Malathion, applied during the peak of foraging activity at the registered dose rate in locust control of 960 g a.i./ha, has exhibited a high risk against the honey bees. The lethal effects of Malathion applied in the presence of foraging bees has been characterised by a substantial mortality per day of treatment, 15 times higher than the average mortality due to captivity established three days before treatment. The average mortality recorded three days after treatment is approximately 8.5 times higher than the average mortality exhibited three days before treatment. The repulsive rate calculated on the basis of the variation in average densities of foraging bees between treated and untreated zone, three days after compared to three days before treatments is approximately 87 %. Applied during the absence of foraging activity, the lethal effects of Malathion has decreased approximately to 55 % compared to those induced when applied during the presence of foraging bees.

In contrast, Deltamethrin, applied at the recommended dose rate in locust control of 12.5 g a.i./ha, has showed evidence of relatively minor risk against the honeybees compared to Malathion. The average mortality induced by Deltamethrin during the attendance of the foraging bees represented only 22 and 15 % of the mortality induced by Malathion in the same conditions, a day and three days after treatment respectively. This ratio is set only to 5.6% the day of treatment when the Deltamethrin is applied during the absence of the foraging bees. This relatively risk-free effect of Deltamethrin is due to its short residual toxicity vis-à-vis the honey bees compared to Malathion.

## **Ecological research as a needed driver for preventative management of acridids.**

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Thirty-five years ago, Sir Boris Uvarov proposed that regulating acridid population dynamics through the deliberate modification of key ecological factors could lead to the gradual replacement of direct chemical control. Due to the historical emphasis on outbreak suppression and intervention, relatively little is known about prevention of acridid outbreaks. Habitat management practices such as burning or livestock grazing could be important tools in preventative grasshopper management. Foraging by livestock can reduce food availability for grasshoppers through competition or indirectly via changes in plant community composition. In addition, both grazing and trampling affect the structure and microclimate of the grasshopper habitat. A limited study has shown that a rotational grazing practice resulted in significantly reduced grasshopper densities compared to a season-long grazing practice. In western North America, grassland fires appear capable of having positive or negative effects on grasshopper population densities, with the timing and intensity of fires playing important roles. A better understanding of how ecological mechanisms underlying grasshopper population dynamics operate is needed.

Understanding these ecological mechanisms will facilitate the development of ecologically based management strategies that can prevent or reduce the severity of outbreaks through the manipulation of critical ecological interactions.

## **“Little walking leaves” of Andean and Amazonian rainforests with remarkable calling songs (Tettigoniidae, Pterochrozini, *Typophyllum* spp.)**

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The Pterochrozines have perfected crypticity. Species of the genus *Typophyllum* resemble six-legged leaves in various stages of decay. Many microscopic details – including transparent windows imitating wormholes, artificial moss, and small factitious fungi cultures – enhance this leaf mimicry. The mating behaviour of *Typophyllum* spp. is equally remarkable: Prior to copulation, the tiny male spends several days riding atop the wings of the female who is twice her mate's size. No less unusual are the calling songs of these “little walking leaves”: These sounds are almost pure sine waves at the lower boundary of the ultrasonic portion of the spectrum (~ 20 kHz). The very narrow spectrum of the carrier frequency is somewhat wider in species found in lower vegetation of habitats above the tree line. The stridulatory apparatus shows several morphological peculiarities to which features of the musical songs may be linked (e.g., microstructure of the file, enhanced subalar airspace, left-wing damping). This type of calling song may have been selected to increase the transmission range of these sparsely distributed forest-dwelling tettigoniids (by concentrating all the energy on a very narrow frequency band), to indicate male fitness (rather unlikely), or to thwart localisation by mammalian predators. Species living at lower elevations, where foliage-gleaning bats also occur, display very low calling activity.

## **Male aggression in house crickets: size, motivation and the information content of aggressive songs.**

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House crickets are a model system for both studies of animal aggression and bioacoustics, yet we know very little about the function of their distinctive aggressive songs and factors, other than body size, that determine the intensity and outcome of aggressive contests. We studied the information content of aggressive songs to test their ability to inform opponents about fighting ability and motivation. We show that songs produced by individual males are highly repeatable and contain information about body size, condition (size standardized body mass), and the outcome of previous contests (dominance). All of these factors related to fighting ability. In contrast, we found no components of song that signal motivation to fight. Although males with restricted access to mates were significantly more aggressive and won fights more often, their songs did not reflect the asymmetry in motivation to fight. We discuss possible reasons for the absence of signals of motivation during animal contests.

### "Bioacoustics of some Ecuadorean Ensifera"

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The bioacoustics of some Ecuadorean Ensifera is illustrated. The calling song of male *Syntechna angulata* Hebard, 1924 and the warning song of female *Diophanes salvifolius* (Lichtenstein, 1796) are described. Songs of male *Gryllus assimilis* (Fabricius, 1775) and other unidentified Phaneropterinae and Pseudophyllinae are shown.

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### Illustrated checklist of Acridomorph (Orthoptera) species from Argentina and Uruguay

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A digital checklist of Acridomorph (Orthoptera) species from Argentina and Uruguay has been elaborated. This reference list was originally compiled by the senior author from information he obtained throughout his scientific career. Names of genera, species, and subspecies have been listed. For each species, the following information is given: synonyms, geographic distribution, main host plant species, economic importance according to the categories defined in *The Locust and Grasshopper Agricultural Manual* (COPR, 1982), some selected observations, and the most relevant bibliographical references. With the exception of Eumastacoidea, the species are illustrated with photographs of male and female specimens and the species' habitat, if images were available. When images of living specimens were not available, photographs of specimens

from museum collections were included. The information on the geographical distribution of the species was obtained by the authors from their field work records and from the available scientific literature. The species can be searched by alphabetical order, geographical distribution, and their position in the classification of Acridomorph. A digital checklist is included in a CD ROM. Macromedia Flash MX and Adobe Photoshop programs were used for its development. The CD runs on both Microsoft Windows and Macintosh OS. A demonstration of the CD "Tucuras" will be given at the attended poster session.

### **Genetic determinism of gregarization in the migratory locust *Locusta migratoria***

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The density-dependent transition between the solitary and gregarious phases, called gregarization, is a defining feature of the migratory locust, *Locusta migratoria*, being central to the biology of the species and to its significance as a serious pest. Nine geographical taxa of *L. migratoria* with different propensities to display outbreaks were described and considered as subspecies. Among these subspecies, swarming and the expression of gregarization are highly correlated. Differences in the propensity to gregarization between subspecies may reflect differences in their environments, some being rarely and others cyclically favourable to increases in population density (e.g. palearctic zone vs. intertropical zone, respectively). On the other hand, it is still unknown whether the gregarization associated with outbreaks has a genetic determinism. This question was addressed by analysing the magnitude of behavioural and morphometrical gregarization under environmental control in two populations characterized by contrasted patterns of outbreak events. In France, only uncommon and low intensity outbreaks have been reported. This area (*L. m. cinerascens*) is hence considered as a non-outbreaking area. In Madagascar, frequent and intense outbreak events have been recorded over the last century. Madagascar (*L. m. capito*) is thus considered as a frequently outbreaking area. Our results show that Malagasy population expressed significantly more pronounced gregarization relative to French population. Because both populations were raised in a common environment during our experiment, it is highly likely that a genetically based adaptive process is responsible for the gregarization differences between subspecies. More specifically the high propensity for gregarization of the Malagasy population may have evolved due to selection for maintaining phase plasticity. The lower propensity for gregarization of the French population may rather be an experimentally induced re-expression of the ancestral gregarious character, which evolved by genetic drift since selection for this trait was relaxed (atavism).

## **Bringing Taxonomic Data presentation into the 20th if not the 21st Century**

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### **Abstract**

The indispensable role that taxonomy plays in biology is being undermined by old and very imperfect methods of data presentation which give the impression of a backward and uninteresting science. Old-style paragraphic descriptions, diagnoses, keys, tables of measurements, scattered figures, and plates with poorly organized and merely numbered figures can be greatly but quite easily improved to make them more suitable for the reader to use for identification and comparison, and far more appropriate for testing hypotheses of relationship. A major advance would be to taulatae descriptions using different type styles indicating autapomorphic, synapomorphic, and plesiomorphic conditions. Simple modification of such tables could adapt them for identification and diagnosis, as well as for demonstrating relationships. Small figures can be included with little extra work. Character conditions in these data matrices could be easily coded for interactive computer identification programs now readily available, and for computer generated phylogenies. Figures should be at least clustered for easier comparison rather than being placed with each species treatment. Plates of figures can be greatly improved merely by labeling each figure with the species name, placing figures for any one structure together, and using arrows or lines to indicate diagnostic characters as in field guides. Data in tables of measurements could be rearranged so that they would be more readily analyzed statistically, rather than having to be laboriously retyped. Illustrations of old and better techniques will be given

## **A Molecular Phylogenetic Analysis of The Relationship between Selected North American and Eurasian Gomphocerine Grasshoppers**

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The Gomphocerinae, the second most speciose subfamily of Acrididae are distributed world-wide and present on all continents except Australia and Madagascar. Often called the “tooth-legged” grasshoppers, they possess a row of stridulatory pegs on the inner surface of the hind femur distinguishing the subfamily Gomphocerinae from its sister subfamily, the Acridinae. Although there has been considerable speculation on the internal organization of the Gomphocerinae, to date there has not been a large-scale molecular analysis performed on the subfamily. This study aims to examine suggested tribal affiliations and test biogeographic hypotheses concerning connections between the Eurasian and North American Gomphocerinae. Portions of four mitochondrial genes were sequenced and phylogenetically analyzed using weighted and unweighted maximum parsimony, Bayesian inference and maximum likelihood methods. Our data agrees with previous hypotheses that there were multiple periods of movement of gomphocerines between the two northern continents. The first division likely occurred during the sundering of the Laurasian continent, with the second division occurring approximately 35 million years ago during a migration event across the Bering land bridge. A very close link between species of *Aeropedellus* and *Chorthippus* would suggest another incursion to North America occurring about a million years ago.



## Molecular markers of phase transition in locusts

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The transition from the solitary to the gregarious phase state involves drastic changes in morphometrics, behaviour, reproduction, etc. Our laboratory is searching for primordial hormonal factors causally linked to phase transition. It has long been known that JH promotes the solitary phase state, but that it is not the primary inducer. The discovery that corazonin promotes the typical dark cuticular body color in both *Locusta* and *Schistocerca* incited us to search for other phase related effects of this neuropeptide. Indeed, it changes some aspects of behaviour towards values typical for the gregarious phase state; it also influences morphometrics and pigment migration in the eyes. However, some other physiological and behavioural changes are not influenced by corazonin, indicating that there must be additional primordial controlling factors/hormones. Differential display technology was used to compare gene expression in brains of solitary and gregarious locusts. Apart from a number of genes present in both phases but showing differential expression, one marker gene, exclusively expressed in brains of gregarious locusts and not in solitarious ones was identified. Our lab identified four novel neuroparsins and one insulin-related peptide *Schistocerca*, and analysed the presence of the corresponding mRNAs in various tissues and in function of phase transition. Finally, five pacifastin precursor transcripts, encoding 13 homologous peptides, have been identified in *Schistocerca*. Studies using HPLC in combination with mass spectrometry showed phase-dependent pacifastin peptide profiles in *corpora cardiaca* and hemolymph extracts. In addition, pacifastin precursor mRNA levels were shown to differ very drastically between isolated- and crowd-reared locusts.

## Locust food choices reflect density-dependent anti-predator strategies

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The two phase states of the desert locust represent cryptic and aposematic anti-predator strategies. Indeed, locusts that have fed on toxic plants are protected against predators if they exhibit the bright black-and-yellow colouration of gregarious locusts, but less so if they are green. We tested whether solitary and gregarious locusts respond differently to hyoscyamine, the plant alkaloid that confers this protection. We did not detect any physiological cost to consuming hyoscyamine. Solitary locusts were deterred by this compound. Indeed, solitary locusts avoid predator detection through crypsis and would not benefit greatly from consuming toxic plants. By contrast, gregarious-phase locusts readily fed on the alkaloid that protects them against predators. Changes in food selection thus provide a mechanism for inducible antipredator defence mediated by toxic gut contents. Surprisingly, solitary insects that had begun the transition to the gregarious phase (i.e. that had been crowded) accepted and even seemed to prefer food containing the alkaloid. Computer simulations show that, when solitary locusts are crowded, crypsis ceases to be effective as an anti-predator strategy, and chemical defence becomes essential as conspicuousness increases with local density. Under these conditions, switching to the gregarious warning colouration becomes advantageous.

## Dual morphologies and behavior in bladder grasshopper males: A family wide trend in phenotypic plasticity?

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Bladder grasshoppers (Orthoptera: Pneumoridae) are a unique group of nocturnal, specialized herbivores endemic to the coastal regions of South Africa. In the majority of species, adult males are characterized by an inflated abdomen, which aids in the production of a long-distance acoustic signal. Female response to this call leads to reciprocal duetting and pair formation. Dirsh (1965) describes three genera in which adult males lack the inflated abdomen. We have since documented the existence of a male dimorphism (alternate males) in three taxa, and suggest (i) that genera with uninflated males may be the result of taxonomic splitting, (ii) that male dimorphism is a naturally occurring phenomenon, which (iii) occurs across the entire family Pneumoridae. Using morphological, geographic, and biome data, we describe the phenotypic characteristics of the uninflated/alternate and primary male forms in 12 pneumorid species. We then characterize the behavioral responses of the two morphs to conspecific male and female signals in one species (*Bullacris membracioides*). Results show that across multiple species, alternate males share similar morphological and geographic attributes, whereas primary inflated males follow a separate trajectory. An identical trend is evident between uninflated males and the primary inflated males of putative conspecifics. Behavioral studies indicate that alternate males are unintended receivers who effectively exploit the signal dynamic for conspecific location. The evolutionary impact of this satellite tactic may be significant, potentially affecting other aspects of the biology of the family, such as sexual selection, the communication system, and speciation history.

## **Rethinking organization and governance for surveillance and risk management of desert locust outbreaks**

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Experience acquired over the last 40 years in preventive control of the Desert Locust as well as the lessons learnt from the two last invasions that started in 1987 and 2003 reveals the complexity of problems in this fight. We advocate a thorough consideration of the organisational dimensions of the struggle to control this invasive biological aggressor.

The objective of our work is to promote efficiency by questioning the management of risks relating to this pest, taking into account the social, organisational, and cultural rationalities in which collective action is located. Until now biological, ecological, and economic rationalities have ruled the cognitive framework for risk management and control.

Analysis of the modes of structuring and analysis of the governance over systems of multi-level stakeholders who carry through and organise collective action for effective survey and control is thus essential to re-thinking and re-designing an efficient management system as well as integrating sustainable objectives. Better knowledge will promote understanding of the causes of malfunctions and inconsistencies in current management settings.

A preventive management plan that fits a long term sustainable perspective will engage a pragmatic approach that integrates an analysis of the various logics at work as well as the routines and specific actions organised through control systems. The biophysical and ecological mechanisms are also taken into account. Finally, this perspective necessitates the opening of a new field of study into locust control that would answer issues raised about Desert Locust management and include conceptual, methodological and operational perspectives.

**Contribution to the bioecological study of two Peruvian locusts, *Schistocerca cf. interrita* Scudder, 1899 and *Schistocerca piceifrons peruviana* Lynch Arribalzaga, 1903 (Orthoptera: Cyrtacanthacridinae)**

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During several years (1997-2003), the departments of Lambayeque and Cajamarca suffered from a plague due to *Schistocerca cf. interrita* Scudder 1899 while recurrent infestations of *Schistocerca piceifrons peruviana* Lynch Arribalzaga, 1903 were persisting in the central-south of the country. Following a request from the Peruvian Government, an "Assistance programme for locust control in Peru" (FAO Project TCP/PER/0065) was carried out and funded by FAO own resources (200-2003). An HQ staff member and consultants were fielded in the outbreak areas of the Peruvian locusts. These missions allowed the supervision of the national staff from SENASA (National Plant Protection and Animal Health Service of the Ministry of Agriculture) involved in the locust control, bio-ecological observations and synthesis of the available data. Based on a better knowledge of the bio-ecology of the concerned locusts, the assessment of the situation resulted in an operational strategy for survey and preventive control of the Peruvian locusts. A comparison of the bio-ecology and the biogeography of the two main locust pests present in Peru is presented by the authors.

**Progress Report on the Orthoptera Species File (Version 2)**

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The basic functionality of the Orthoptera Species File (OSF) as a resource for taxonomists has been completed. Data from the Zoological Record has been entered through 2003. Programming is complete and ready for entry of interactive keys (both dichotomous and matrix-based). Four sample keys have been entered. Specimen level data can be entered together with a history of identifications. The next significant extension will deal with the history of combinations as a species moves from genus to genus. An endowment has been established to support continuing work.

Internet website publishing is increasingly used as an alternative to traditional publication. Advantages include reduced cost, improved accessibility, and the ability to customize the presentation of information for individual users. In the Orthopterists' Society we can benefit from cooperation between OSF and the Journal of Orthoptera Research (JOR). Updating OSF for articles when accepted by JOR would accelerate the entry of data into OSF and call attention to some kinds of errors at a time when they can still be fixed before publication.

OSF data has been exported to major biological Internet sites (ITIS, Species 2000, NCBI for GenBank), which makes OSF the most widely used source of information about the classification of Orthoptera. The membership of the Orthopterists' Society should consider some issues. Does the Society want a role in choosing among alternate higher-level classifications to be shown by OSF? The present system leaves decisions to a single person, which may not be desirable.

## **Exploring a silken empire: A review of behaviour and diversity in females of the little known orthopteroid order *Embioptera***

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Embiids, the sister-group of stick insects, display unique traits including tarsal silk glands; wingless, nymph-like females; and winged males that live only briefly after reaching adulthood. Embiids are also characterized by primitive social behaviour: subsociality and coloniality. They are exceptional insects in that they spin silk in all stages of life. Living in tight silk tunnels has constrained their body form and as such they are remarkably homogeneous throughout their range. In fact, due to their uniformity, embiid taxonomists often cannot differentiate adult females even at the family level. Thus, male morphology has dominated all systematic efforts to date. The lack of published information on females is formidable and unfortunate given that they express interesting and complex behaviours that play a significant role in defining the order. Our current focus is to discover traits of female life history and behaviour that vary across the order. This paper presents recent findings from the laboratory and field on diversity in spinning and how the variable reliance on silk as a building material relates to colonial behaviour of females. An analysis of life history traits of females will also be presented. Distinct life syndromes are detectable in an ordination analysis (non-metric multi-dimensional scaling) of 10 species of embiids. The variation is subtle, but that is to be expected for insects whose lives are confined by silk tunnels no matter where in the world they spin.

## **A PCR assay for the specific detection of the acridid pathogen *Metarhizium anisopliae* var. *acridum***

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*Metarhizium anisopliae* var. *acridum*, an entomopathogenic fungus indigenous to the tropics, is registered as a mycopesticide for acridid control in Africa and Australia and is a potential alternative to chemical insecticides for grasshopper control in Canada. Prior to registration as a pesticide, an organism must be shown to be safe for non-target entities and capable of being monitored in the environment. Traditionally, identification of *M. anisopliae* var. *acridum* infection in grasshoppers and locusts has relied upon development of fungal growth in infected cadavers, with confirmation by culture, bioassay, and microscopy. A PCR-based method for the detection of *M. anisopliae* var. *acridum* was developed. Sequence data from the distinct ITS rDNA regions facilitated the design of PCR primers that were used in PCR-based diagnostic assays for the detection of fungal DNA. The amplified sequence was 420 bp in length and specific to *M. anisopliae* var. *acridum*. Isolates of *M. anisopliae* var. *anisopliae*, including native strains and *M. flavoviride* Gams and Rozsypal produced no PCR product with these primers. Other fungal entomopathogens, plant pathogens, mycopathogens, and soil saprophytes were also not detected by the pathogen-specific primers. The assay was effective for the detection of *M. anisopliae* var. *acridum* DNA in infected grasshoppers.

## **Mortality of non-target arthropods after chemical control of Desert Locust - a rapid assessment method**

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Since October 2003, the beginning of the upsurge of Desert Locust *Schistocerca gregaria* (Forskål) 12.9 million ha have been treated. (FAO, 2005). The objectives of the study were to test a rapid assessment method for monitoring direct effects of chemical insecticides on non-target arthropods (NTAs) and to compare affected NTA communities by the use of a diversity index.

During September 2004, seven semi-arid environments in Tahoua and South Tamesna regions in Niger that had been treated with organophosphate insecticides were monitored. Within a 1/4 ha-square in each treated area, two persons searched for dead NTAs for 30 min. Hurlbert's (1971) diversity index, which gives the probability of an interspecific encounter (PIE), was calculated.

1,487 freshly dead NTAs, representing 81 species were found. The beetles found in greatest numbers were the tenebrionids *Diodontes porctaus* and *Zophosis quadrilineata*, the scarabids *Metacatharsius ferrugineus*, *Onthophagus gazella* and *Podalgus cuniculus*, and the curculionid *Anamereus fuscus*. *Decapotoma affinis* was the most affected blister beetle (Meloidae) and there were numerous dead ants, in terms of both numbers and species (e.g. *Monomorium spp.*, *Camponotus spp.*). The PIE average diversity value range was 66-89%, with the highest diversity of dead NTAs in a millet field, 48 hrs after an aerial application of chlorpyrifos (ULV, 240 g a.i./l, 1 l/ha, 200 ha, as reported). The method was found efficient with visible effects of insecticide impact in the field.

FAO, 2005. Desert Locust Bulletin. July, 2005. No. 322.  
(<http://www.fao.org/ag/locusts/en/info/info/index.html>)

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52: 577-585.

## **Investigations on the long-horned grasshoppers (Orthoptera: Tettigoniinae, Phaneropterinae) in the Karaj-Damavand region of Iran**

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During investigations in 2001 and 2004, ten species of the subfamily Tettigoniinae were identified, as follows: *Tettigonia viridissima* L., *Tettigonia caudata caudata* (Charp.), *Platycleis (Platycleis) escalerae iranica* Rme., *Platycleis (Platycleis) intermedia*, *mesopotamica* Rme., *Decticus annalisae* Rme., *Decticus albifrons* ( F.), *Decticus verrucivorus* (L.), *Medecticus assimilis* (Fieb.), *Paradrymadusa siazovi* Uv., and *Uvarovistia Zebra* Uv.

Taxonomical characteristics for identification – which were based on shape and size of male genitalia (titilators), ovipositor, and cerci – were measured and drawn for comparison and criticism.

Between 2001 and 2004, six species of katydid, (subfamily *Phaneropterinae*) were collected from the Karaj–Damavand district of Iran and identified (the first records of the species not yet mentioned from this district are shown by an asterisk): \**Isophya caspica caspica* Rme, \**Leptophyes iranica* Rme, \**Leptophyes trivittata* B.-Bienko, *Phaneroptera falcata* Poda, *Polysarcus elbursianus* Uv., \**Polysarcus denticauda* (Charp).

Taxonomical characteristics such as shape, size, and colour of the pronotum, tegmina, antenna, fore, mid and hind femora, genitalia of males, ovipositor, and cerci were measured and drawn for comparison and criticism.

### **Sexual conflict and immune suppression in ground crickets**

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The opportunity for sexual conflict occurs when male and female reproductive fitness optima do not overlap, and may be subdivided into two types including intralocus conflict (epistatic interaction between a gene and the sex-specific genetic background) and interlocus conflict (antagonistic interaction between two genes within a genome). Here, we provide evidence that both types of sexual conflict occur in the striped ground cricket, *Allonemobius socius*. First, we show that females who mate with high quality males produce high quality sons, but low quality daughters (intralocus conflict). Second, we highlight a potential antagonistic interaction between the male ejaculate and the female immune system (interlocus conflict). These data suggest that many “stereotypical” sexual selection systems (i.e. those typified by pre-copulatory female choice and male competition), such as crickets, might also be rife with sexual conflict.

### **Locust volatiles: Pheromones for every purpose?**

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A number of volatiles associated with desert locusts have been identified. It has been suggested that they are involved in control of development and behaviour of locusts, in particular in phase transition. However, more recent studies show that important aspects of locust life can - at least predominantly - be induced and/or regulated by other factors. The induction of phase changes in desert locusts can be explained to be principally the result of repeated mechanical stimuli of the outer surface of the hind femora. Such stimuli are caused by high population density resulting from very successful reproduction and when vegetation starts to dry out. Also, the presence of an aggregation pheromone system appears to be questionable since the main component phenylacetonitrile has been identified as a repellent. This repellent, specific for the gregarious phase, supports mating males in defending their females from rivals. Although aggregated oviposition is observed in the field, this may primarily be the result of a perfect sensorial system for soil humidity rather than of an attractant. These and more examples suggest a critical reconsideration of the function and relevance of some of the described locust semiochemicals. Recent progress and perspectives in locust pheromone research will be summarized and discussed in this presentation.

**Red locust phases in Madagascar (*Nomadacris septemfasciata* Serville, Orthoptera, Cyrtacanthacridinae).**

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Little is known about phase polymorphism of the red locust, *Nomadacris septemfasciata* (Audinet-Serville, 1838) in Madagascar despite its economic importance. Gregarious forms of this locust had never been recorded until now on the island, only solitary and *transiens* forms. The worsening of outbreaks provided an opportunity to study phase polymorphism under experimental and field conditions. Morphometric changes were noted when hoppers and adults were caged at different densities. Changes in different parameters (size, pronotum shape, and E/F ratio) were recorded under crowded conditions. These criteria were then used to analyze adults collected in different areas from amongst populations of various densities (from less than 1000 adults/ha to more than 25000/ha). In the past, gregarious red locusts were likely classified as *transiens* locusts. The results of the present study revealed that true gregarious populations do exist in Madagascar. The phase transformation threshold density was determined: adults living in low density populations, i.e. less than 5000/ha, showed solitary traits; whereas beyond this density the locusts were either *transiens* or even highly gregarious. Gregarious populations were observed in the northern part of the island, where serious outbreaks recently occurred after deforestation and the creation of new favorable biotopes. True gregarious populations were also observed in the south, a common outbreak area where, in the past, it was assumed that ecological conditions were not suitable for complete phase transformation to occur.



## **Using remote sensing to improve the evaluation of the Malagasy migratory locust risk *Locusta migratoria capito* (Saussure, 1884), Orthoptera: Acrididae**

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In 1974, the definition of the optimal rainfall range (ORR: 50 to 125 mm monthly) for the Malagasy migratory locust formed the basis for the first locust forecasting system. This implied that the risk of gregarization and of the consequent appearance of invasions would become very high if the optimal rainfall range occurred for three consecutive months. After the 1997 – 2000 locust invasion, this tool used to monitor the locust risk had to be updated and improved. As every locust habitat reacts differently to the rainfall, the areas at risk can be defined and organized more accurately by crossing rainfall zones with a qualitative map of the locust habitat.

Remote sensing made it possible to characterize the habitats of the Malagasy migratory locust. The selected image, *Landsat 7* n°160.077 on August 21, 1999, centred on the Mahafaly Plateau and shows great diversity: it represents the majority of the habitat types within the outbreak area. The habitats were determined by combining a visual interpretation with a supervised analysis (with IDRISI® software) for each of the 5 eco-regions delimited by photo-interpretation. After verification in the field, 22 habitats were described according to plant cover and hygrotrophy. The attractiveness of the habitats for the migratory locust in its solitary phase was arranged in hierarchical order according to 5 rainfall ranges.

The spatiotemporal data relative to the habitat types and the rainfall is managed by a GIS that constitutes an operational result while permitting the real-time assessment and localisation of the locust risk.

## **Amélioration de l'outil d'évaluation des risques acridiens du criquet migrateur malgache grâce à la télédétection**

**Alex Franc<sup>1</sup>, Tsitohaina Andriamaroahina<sup>2</sup>, Yann Legros<sup>3</sup>, and Jean-François Duranton<sup>1</sup>**

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En 1974, la définition de la plage optimale pluviométrique (POP : 50 à 125 mm mensuel) du criquet migrateur malgache a servi de base au premier réseau d'avertissement acridien. Dans son aire grégarigène, le risque de grégarisation et le départ des invasions deviennent très élevés dans un polygone concerné par la POP plus de 3 mois consécutifs. Après l'invasion de 1997-2000, cet outil de suivi du risque acridien devait être actualisé et affiné.

Puisque chaque biotope acridien réagit différemment selon la pluviométrie, les polygones de risque peuvent être précisés et hiérarchisés en croisant la pluviométrie avec une carte qualitative des biotopes acridiens.

La télédétection a permis de caractériser les biotopes du criquet migrateur malgache. L'image choisie (cliché Landsat 7 n° 160.077 du 21.08.1999) centrée sur le plateau Mahafaly est très diversifiée : la majorité des types de biotopes de l'aire grégarigène y sont représentés.

Les biotopes sont obtenus en associant une interprétation visuelle et une analyse supervisée (logiciel IDRISI®) pour chacune des 5 écorégions, délimitées par photo-interprétation. Après vérification sur le terrain, 22 biotopes sont décrits en fonction du couvert végétal et de l'hygrotophie.

L'attrait de chaque biotope pour le criquet migrateur solitaire a été hiérarchisé en fonction de la pluviométrie, et aboutit à une zonation des surfaces offertes selon 5 plages pluviométriques mensuelles. Les données spatio-temporelles relatives aux potentialités des biotopes et aux plages pluviométriques sont gérées par un SIG. Il constitue un résultat opérationnel permettant d'évaluer et de localiser les risques acridiens en temps réel.

## **A Molecular Phylogenetic Analysis of Relationships Among Selected Oedipodinae Grasshoppers**

**M. K. Fries and W. Chapco**

A molecular phylogenetic analysis of selected North American, Eurasian and African band-winged grasshoppers, the Oedipodinae, was performed to determine relationships among taxa within and among continents with the view to shedding some light on the subfamily's origin. Portions of four mitochondrial genes (COI, COII, cytb and ND5), totalling 2254 bases, were sequenced in 26 species, and analyzed using parsimony and Bayesian methods. Both approaches recovered topologies in which 13 Eurasian/African taxa are paraphyletic to 8 or 9 (depending on method) North American species. Methods differed in the branching order of the placement of two genera (external to the above), one North American and one Eurasian. Biogeographic implications of these results are discussed.

## **Comparison of Orthoptera communities in Salt Creek, Canyonlands National Park: Fluctuations over time in open-, closed-, and no-road parts of the canyon**

**Tim B. Graham and Kelly N. Wilson**

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Salt Creek, Canyonlands National Park is an interrupted stream with more aquatic and mesic riparian habitat than any canyon in the park except the Green and Colorado Rivers. Salt Creek was used by vehicles for at least 50 years; in 1998, 14 km of roadway was closed by a federal judge, providing an opportunity to track recovery of the riparian ecosystems after decades of vehicle disturbance. We began to describe and compare invertebrate communities in the open-, closed-, and no-road segments of the caZon in 2000. Here we report on the Orthoptera from one site in each segment, sampled in June and September 2000-2003, to determine whether there were consistent patterns among the Orthoptera related to either disturbance history or the intensifying drought that occurred during the study. It was hypothesized that over the years the closed road site would more closely resemble the no road site. Results show that the closed road

site more closely resembles the open road site. Abundance of *Gryllus* species showed the greatest differences between caZon segments; other taxa show trends as well, but total numbers are small. Differences between the no-road samples and open- and closed-road samples are due at least in part to inherent differences in the character of the caZon upstream (no-road) and downstream (open- and closed-road). Lack of difference between open- and closed-road sites may be due to slow recovery because of drought conditions experienced during the years of sample collection.

### **Grasshopper communities in native and non-native grasslands on the Colorado Plateau: Differences in density and species composition**

**Tim B. Graham**

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Grazing, fire and other disturbances have altered ecosystems across the western United States. Millions of hectares of native perennial grassland are now dominated by introduced annual grasses. Shifts from native to exotic and perennial to annual grasses affect ecosystem processes and community dynamics. The change from native to non-native grasses affects quality, quantity, and timing of available food for grasshoppers and other herbivores, which may affect grasshopper community structure, increasing pressure on native perennial grasses. The objective of this study was to examine grasshopper community composition in native and exotic grasslands on the Colorado Plateau. In June and July of 1997 and 1998, I conducted surveys of grasshopper density and community composition in native perennial, and non-native annual or perennial grasslands. June 1997 surveys showed a clear pattern of higher total grasshopper densities in exotic grasslands. July 1997 densities were more similar between native and exotic grasslands, probably because cheatgrass has senesced by then. Patterns were less distinct in 1998. Grasshopper community structure between exotic annual-dominated and native perennial-dominated grasslands differed primarily in relative abundances of species rather than species composition. Grasshopper communities in crested wheatgrass (*Agropyron cristatum*), an introduced perennial grass, however, were extremely simple, but with the highest densities. How these differences in grasshopper species composition and density could affect plant community structure by affecting vigor and/or recruitment of native grasses will be discussed.

### **Song, sex, and species of *Gryllus* field crickets.**

**David A. Gray**

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The diagnosis and naming of Ensiferan species often relies heavily on properties of the male calling song. The extent to which species boundaries will accurately reflect song boundaries depends upon male-female behavioral interactions. Here I present data from a series of experiments assessing behavioral divergence and mating behavior in two species of field crickets, *Gryllus rubens* and *Gryllus texensis*. The behavioral data suggest that pre-mating isolation via the calling song is probably strong, whereas pre-mating isolation via close-range courtship interactions is probably weak. Molecular genetic data are then used to compare species distinctness in mitochondrial DNA, and suggest plausible routes of speciation in these cricket species.

## **Reproductive biology of New Zealand weta (Ensifera: Anostostomatidae)**

**Darryl T. Gwynne**

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The Gondwanaland family Anostostomatidae are represented in New Zealand by giant weta (*Deinacrida*), tree weta (*Hemideina*), tusked weta (two genera), and ground weta (*Hemiandrus*). These orthopterans have been well studied with respect to conservation biology and ecology (several giants and one tusked weta are endangered), but we lack knowledge on their reproductive biology. I will review recent work from my laboratory that has revealed a remarkable diversity of mating and parental behaviours.

## **Biomass production in acridids**

**Parimal Haldar, Hena Anand, & Sarasi Das**

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Acridids are known to have a high nutritional value (Julieta et. al., 1997), high reproductive potential (Haldar et. al., 1999), rapid life cycle, and high growth rate. So for utilizing Acridids as an alternative protein supplement for poultry and fishmeal, and establishing Acridid farms, the knowledge of total biomass production is of immense importance.

It was observed that a total of 0.05 kg (0.02 kg male biomass + 0.03 kg female biomass), 1.75 kg (0.36 + 1.39), 33.77 kg (14.93+ 18.84), and 711.43 kg (152.85+ 558.58) from a single gravid female individual of *Hieroglyphus banian* (Fabricius), *Acrida exaltata* (Walker), *Spathosternum prasiniferum prasiniferum* (Walker), and *Oxya fuscovittata* (Marschall) respectively could be produced by culturing these species for one year in optimum environmental conditions in the laboratory.

Estimation of energy content revealed that *H. banian* has 6.808 kcal of energy per gram of dry tissue; a total of 136.16 kcal (6.808 kcal/gm x 20 gm) of energy would be obtained a year from only one female. Similarly *A. exaltata* has 4.959 kcal/gm of energy; a total of 3520.89 kcal (4.959 x 710) can be obtained. From *S. pr. prasiniferum* 5.500kcal/gm energy would produce 60720 kcal (5.5 x 11040) of energy per year, and from *O. fuscovittata* having 4.657 kcal/ gm energy, a total of 1109902.8 kcal (4.657 x 238330) of energy would be obtained during same period.

Thus among the four Acridid species, *O. fuscovittata* yields the highest amount of biomass and energy and would be the most preferable species for future Acridid farming.

## **The role of semiochemicals in the desert locust gregarisation: Its genesis, spread, and sustainance**

**Ahmed Hassanali, Magzoub Bashir, Peter Njagi, and Sidiould Eli**

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Locust gregarisation is a density-driven process that is mediated by both primer and releaser signals. Much of the earlier locust research and literature confused the functions of these two sets of signals. One set is associated with gradual physiological transition from *solitaria* to the *gregaria* (also manifested in behavioural, biochemical/pheromonal and morphological changes) and with synchronous development and maturation of individuals in the population. The other is associated with immediate release of behavioural responses from recipient members. The primer or releaser roles of semiochemicals in locust phase dynamics include (i) termination of reproductive diapause in solitary individuals before the onset of seasonal rains; (ii) preference for oviposition near specific desert plants, which are also preferred for feeding by solitary nymphs that emerge; (iii) resulting phase-transition of nymphs that experience crowding (mediated by a contact pheromone in addition to mechanostimulus?); (iv) cohesive behaviour mediated by distinct stage-specific pheromone blends; (v) recruitment of solitary individuals into nuclei of gregarising groups; (vi) synchronization of maturation of adults (due to primer effects of the cohesion pheromones); (vii) cross-phase mating preferences, which serve as another mechanism for recruiting *solitaria* into a gregarising population; (viii) communal oviposition by gregarising females that also recruits solitary counterparts; and (ix) maternal transfer of gregarious traits resulting from primer effect of oviposition pheromone. Pheromone-emitting gregarising groups then act as nuclei for recruiting their solitary counterparts, and this provides a 'snow-ball' effect for the spread of gregarious characters across a population. It is proposed that the basic dynamics of the process resembles the evolution of a chemical explosion and may be treated as involving a series of equilibria, from reproductively inactive *solitaria* to a gregarious population. Such a kinetic model may provide a conceptual framework for further field studies in locust primary breeding areas and in the development of a predictive gregarisation model.

## **Acoustic communication in the genus *Poecilimon* (Orthoptera: Tettigoniidea: Phaneropteridae)**

**Klaus-Gerhard Heller**

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The genus *Poecilimon* is one of the most acoustically diverse groups of bush-crickets, not only for the pattern of the calling songs, but also for the behavior of the females. In this paper, two aspects of this variety are treated. (A) While in most species the females respond acoustically to the male song, they have lost this ability independently several times. I will present data on the accompanying changes in male song and in the risks for singing males. Due to an increased duty cycle, the singing animals can be easily located by acoustically orienting parasites and predators. (B) In some species songs are observed with a frequency much lower than expected from body size. *Poecilimon tschorochensis* produces an unusually low frequency song by means of its enlarged tegmina; in *P. inflatus* a Helmholtz-like resonator is most likely involved.

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## **Hybrid zones and other consequences of contact between (sub)species in the genus *Poecilimon* (Orthoptera: Tettigonioidea: Phaneropteridae)**

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The genus *Poecilimon* is the second largest genus of bush-crickets. All of its far more than 100 species are unable to fly and occur in the Balkans, Anatolia, and the Caucasus. Many species have a restricted range, and members of one group of related species often occur allopatrically. However, contact zones have been observed for some of these groups. In the *Poecilimon propinquus* group, contacts between several species are known. Sometimes mosaic distributions were observed; sometimes over a distance of some ten meters, one species is completely replaced by another, typically at an ecological boundary such as a valley-slope transition. No hybrid zones were found, although at the level of mitochondrial DNA, hybridization can be documented. A different situation is found in the *Poecilimon sanctipauli* group. On the island of Lesbos, two subspecies of *Poecilimon mytilenensis* are found, connected by a broad hybrid zone with clinal transition as the key characteristic. In neighbouring Anatolia, the species *Poecilimon lodosi* seems to be a hybrid species between *Poecilimon sanctipauli* and *P. pulcher* that occur sympatrically in most other parts of their range.

## **Singing from a constructed burrow: why vary the surface opening?**

**Peggy S. M. Hill**

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The 76 known species of molecrickets in the Family Gryllotalpidae are characterized by their mole-like digging forelimbs. Most of them also sing from constructed burrows in the soil. Few of their songs have been characterized, however, and fewer still of the burrows have been described. Our laboratory team has been studying the prairie molecricket, *Gryllotalpa major* Saussure, at White Oak Prairie in Oklahoma, USA since 1993. We have documented a variation in burrow opening shapes that has not been indicated in descriptions of this or other molecricket species. We have identified six distinct shapes that are seen in most years. Frequencies range from 0 to 0.62 for representation in a year, with the "slit" shape first described by Thomas Walker and Dennis Figg being the most common during seven of the eight years in our records. Since the surface opening of the burrow acts as the system "radiator", we hypothesized that variation in the shape would account for at least some of the measured variation documented in the songs produced by the White Oak population of males. We looked for patterns in the variation of dominant frequency of calling songs and maximum amplitude of calls when the shape of burrow openings in which the calls were produced varied. We played a series of pure tones and a standard *G. major* song through a sample of burrows in 2004 to determine if the output from standardized sounds varied with variation in the burrows, including the surface openings.

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## Sound production in *Mantis religiosa* (Mantodea: Mantidae): Description of the stridulatory structures and acoustic signal

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The orthopteroid insect *Mantis religiosa* performs a defensive display during close-range encounters with predators. In adults of this species, the defensive display includes both visual and acoustic components, the latter associated with abdomino-alary stridulation. In the present study, stridulatory modifications of the abdomen and hindwings, and acoustic properties of the defensive sounds of *M. religiosa* are described for the first time. Adult *M. religiosa* bear stridulatory teeth and denticles on the longitudinal veins of the hindwings and abdominal pleura, respectively. The down-pulse is the loudest portion of a sound emission and has an average duration of 195 ms and relatively impulsive onset. Time intervals between consecutive syllables (each composed of an up-pulse and a down-pulse) are not constant. Defensive stridulation in *M. religiosa* is non-resonant broadband (~2.4-16.8 kHz at 6 dB down relative to the intensity of the highest amplitude frequency) and of relatively low intensity (~68-70 dB re 20x10<sup>-6</sup> Pa at a distance of 3 cm dorsal to the hindwings). A weak ultrasonic component is sometimes present in the spectra of these mantids. The modal peak frequency range (interval 2 kHz in width) is 10-12 kHz (mean ~ 7.4 kHz); however, the spectral energy distribution of *M. religiosa* is highly variable. Acoustic parameters which differ between the sexes may be related to the sexual size dimorphism of this species. The acoustic signal of *M. religiosa* is discussed with reference to adaptation for effective signal transmission and its plausible role in predator deterrence.

## **FMRFamide-related peptides in *Locusta migratoria*: association and involvement in the digestive system.**

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Locusts threaten the sustainable food production in regions that can least afford crop devastation. Investigating peptides that modify locust feeding physiology and behaviour may lead to more effective pest control. FMRFamide-related peptides (FaRPs) constitute a super-family of modulatory peptides terminating in Arg-Phe-NH<sub>2</sub> that have been shown to modulate insect feeding physiology.

We investigated possible roles for FaRPs in the digestive system of African migratory locust, *Locusta migratoria*. FMRFamide-like immunoreactive (FLI) processes are associated with all regions of the gut including stomatogastric ganglia, processes extending over all gut regions, putative foregut proprioceptive multipolar cells and midgut endocrine-like cells. In an attempt to identify which FaRPs are associated with the gut, we used RP-HPLC and tandem MALDI-TOF mass spectrometry to sequence FLI peptides. Two FaRPs were sequenced: the myosuppressin SchistoFLRFamide (PDVDHVFLRFamide) and a novel extended RFamide (LWENLRFamide). Further characterization of SchistoFLRFamide identified a partial transcript sequence. The phylogenetic analysis of insect myosuppressin sequences collected from the literature and databases reveals conserved gene and prepropeptide structures.

FMRFamide-like immunoreactivity associated with the gut is affected by the feeding state of the locust. Starvation and nutritional content of the diet, specifically the protein to carbohydrate ratio, affects the total FLI material and the number of FLI endocrine-like cells associated with the gut. FaRPs are also shown to affect feeding physiology. Three FaRPs are shown to modulate the activity of carbohydrases in the locust midgut *in vitro* dependent on the feeding state, the duration of peptide application and the peptide concentration.

## **Morphology and calling song characteristics in *Gryllotalpa major*.**

**Dan Howard**

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The prairie mole cricket (*Gryllotalpa major* Saussure) is a native of the tallgrass prairie ecosystem of the south central United States. Largest of the North American cricket species, its populations have dwindled with the reduced availability of suitable grassland habitat. Populations are known to occupy relict prairie sites in Oklahoma, Kansas and Missouri. Prairie mole cricket populations were surveyed at The Nature Conservancy's Tallgrass Prairie Preserve in north central Oklahoma in the spring of 2005, using the male cricket's acoustic call as a discrete presence indicator. Ninety-five acoustic burrows occupied by calling males were located, with taped recordings of fifty-five of these males obtained. Morphology measurements were procured for eight of these recorded males. Morphology data obtained specified each individual's mass, length and pronotal width. Using SIGNAL software, taped recordings for these eight males were then digitized, with analysis characterizing each male's call for the following variables: syllables per chirp, chirp duration, inter-chirp interval, duty cycle, maximum amplitude, dominant frequency and



chirp rate. A statistical analysis of call song and morphology characteristics was conducted to examine the relationship between these variables. This data is being used in the construction of a geospatial model for *Gryllotalpa major* reproductive aggregations.

### **Evolution in a Cricket Hybrid Zone**

**Daniel J. Howard and Seth C. Britch**

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**Abstract:** Long-term study of the *Allonemobius fasciatus*—*A. socius* hybrid zone in eastern North America has identified two patterns: (1) the southern cricket, *A. socius* is expanding northward in the interior of the continent, and (2) parental types retain their identity in the hybrid zone. A GIS analysis of climate patterns across three transects through the zone, one coastal and two interior, indicate that all transects are experiencing progressively warmer winters, but only the interior transects are experiencing drier falls and winters. The combination of a warmer climate and a decrease in precipitation may explain the northward movement of the hybrid zone. Zone movement and the consequent ephemerality of contact between populations of the two species may hinder evolution in the *A. fasciatus*—*A. socius* hybrid zone.

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### **Mycopesticides as part of integrated pest management of locusts and grasshoppers**

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Since 2000, the mycoinsecticide *Metarhizium anisopliae* var. *acridum* has been produced commercially (as Green Guard®) and used operationally in Australia: nearly 50,000ha of locust and grasshopper infestations were treated between February 2004 and February 2005. Research, though important, was not sufficient to lead to operational use; the critical factor was the formation of the Locust and Grasshopper BioControl Committee that consisted of research providers, end users, and a commercial partner who pooled its financial resources to rapidly advance the development of a commercial product. At each stage of R&D, and continuing today, there is a close liaison between researchers and end users so that all end users can have the product they want, formulated as they want, and that controls locusts or grasshoppers effectively in their situations.

In Australia, one use of *Metarhizium* is where chemical pesticides cannot or should not be used: on organic properties in locust source areas in the interior that produce organic beef for export, and in environmentally sensitive areas such as near waterways, or where there are rare and

endangered species. However, an increasingly important use is by individual landholders who want to limit the amount of chemicals used on their products because of a perceived higher price received for such products. This latter use is potentially very large but is limited by two characteristics of *Metarhizium*: its slower action and its higher price than chemicals. The slower action is not a major problem when *Metarhizium* is used in *preventive* control programs conducted early in outbreaks or when locusts are small (young nymphs). Locusts are treated early when they are causing minimal damage and most will have died long before they reach the very damaging adult swarm stage. The higher price is a consequence of the narrow host range; *Metarhizium anisopliae* var *acridum* is specific to locusts and grasshoppers, so the research, development and registration costs have to be divided amongst products for one or two target pests instead of the dozens of target pests available for chemicals.

Yet the greatest problem for *Metarhizium* is the sporadic nature of locust and grasshopper outbreaks meaning there is only an intermittent need for the product in a given region. An intermittent need means even higher prices and a lack of availability when it is needed, particularly as part of preventive control programs. If *Metarhizium* is ordered when an outbreak begins or is noticed, by the time it is produced and delivered months later, the outbreak will be well underway and with locusts, the target pests may even have moved to another country by then! The markets for chemicals used in acridid control are global and there must be similar global markets for mycopesticides. To ensure guarantee of supply and timely delivery at a reasonable price, an isolate must be produced nearly continuously and used in a number of regions. There may be markets for several isolates in the world, and the isolates chosen must be amenable to high yield high quality commercial production. Some isolates have a low yield during production, and low yield combined with inconsistent quality when production has been switched from the laboratory to commercial scales, can result in a high cost product that gives inconsistent results in the field, leading to scepticism among potential users. Regulatory authorities that insist on the use of local isolates will inadvertently ensure the continued exclusive use of chemicals in their regions because the local isolates will be sporadically available and priced so high that they will rarely be used.

There are, however, some countries that have substantial locust and grasshopper control every year. To ensure food security for its large population, China engages in *preventive* control of locusts and grasshoppers where 300,000 to 1,000,000 ha are treated per year, mainly in pastures before they reach crops. The oriental migratory locust and some grasshopper species are common near water so a biological agent (*Nosema*) is used currently, even though it only gives 40-60% control. In trials in 4 Chinese provinces over the past 3 years, Green Guard® applied at low to moderate doses (25-50 g/ha), caused 76-97% mortality of migratory locusts in 8-11, and in one case, 14 days. Substantial increases in the area treated are planned in cooperation with researchers and end users (provincial authorities) in China. A number of countries in Asia, Latin America and Africa have treated locust infestations with local or exotic *Metarhizium*, usually with high mortality though at times mortality has been low because of inconsistent quality. In North America, laboratory tests have shown *Metarhizium* to cause high mortality against a variety of grasshoppers. The results of these studies will be discussed with a view to determining the next steps required to move the use of *Metarhizium* from trials to large scale operational use as has already occurred in Australia.

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## **Molecular and morphological analysis of the red-legged grasshopper within relic and restored prairies in Wisconsin, USA.**

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The Wisconsin Department of Natural Resources and other non-government organizations have invested heavily in prairie restoration over the past decade. Little effort has been made to evaluate the populations of insect species that inhabit these projects. Seventy-two individual red-legged grasshoppers, *Melanoplus femurrubrum* (DeGeer), from 7 populations (3 relic and 4 restored grasslands) were studied to observe differences at the molecular and morphological levels. Molecular analyses were performed by PCR amplifying and sequencing the mitochondrial genes *cytochrome oxidase* subunit I (COI) and *cytochrome b*. Most specimens from both relic and restored grasslands displayed a high degree of sequence similarity (>97% homology). Interestingly, four males collected from relic populations showed significant variation in these mitochondrial genes (<96% sequence homology). Morphometric analysis, including fifteen separate measurements, and data were analyzed using a General Linear Model (GLM). We observed significant differences ( $P < 0.05$ ) in 10 of the fifteen measurements. A Tukey post-ANOVA analysis revealed significant differences between gender and geographic distance separating sampling sites. These results indicate the presence of unique and possibly ancient grasshopper populations living in the prairie relics. These data may be used to improve the management of relic and restored grasslands.

## **Conocephalinae of the Indo-Australian Region (Orthoptera: Tettigoniidae)**

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With regard to the invertebrate-fauna, the Indo-Australian Region still largely belongs to the white stains on earth. However, by investment of former generations, extensive material of some invertebrate groups may exist in museum-collections that is scientifically still unstudied. The Conocephalinae (Tettigoniidae) are an example for this. In Dutch, German, Indonesian, U.S. American and other collections, more than 3000 unstudied specimens in over 500 species could so far be located. A great part of the specimens comes from historical collections (e.g. the German "Kaiserin-Augustafluss-Expedition" 1912–1913 to the Sepik river in New Guinea), collected before modern man and industries started to affect the natural habitats. They are thus of great value for biodiversity assessments and tracing of faunal changes in the future. In a forthcoming project those specimens form the base for a systematic-taxonomic monograph of the Conocephalinae of the area from Sulawesi and the Philippines to the Solomon Islands. A phylogenetic analysis of the genera and species shall be included as well as biogeographical studies and comparison of the Conocephalinae fauna east and west of the Wallace line (the latter studied by Ingrisch 1998). All specimen-data and other important results shall be digitized, documented with images on the internet and linked to systematic authority files and geographic map servers. Some first proposals for a re-arrangement of taxa are presented.

## **Reconciling orthopteran pest management with environmental protection and conservation of biodiversity**

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The high density of individuals often associated with pest species also make these species significant contributors to ecosystem dynamics, therefore, pest management systems must be considered beyond a set of integrated methods for reducing pest activity and resulting damage. Varying levels of insect pest populations and activity add significant perturbations to a system and may provide highly beneficial ecosystem services and as such pest control actions have the unintended potential to disrupt ecosystem services and threaten biodiversity. We examined the role of orthopteran food items to Burrowing Owls, an endangered species of the Canadian grasslands. Burrowing Owls are generalists that will eat most prey small enough for them to catch (e.g. mice, voles, songbirds, frogs, beetles, grasshoppers). What makes Burrowing Owls a model organism for this type of study is that they tend to fledge a number of young proportional to the amount of food they can provide their offspring. This suggests that an abundance of prey species can be beneficial to Burrowing Owl populations and that pest management actions, or the effects of weather, that reduce the abundance of prey could be detrimental to Burrowing Owl populations. We monitored orthopteran populations and communities in detail, in regions in which Burrowing Owl behaviour, reproductive success and populations were carefully monitored. We determined the nutritional quality of grasshoppers and katydids, using GC analysis of fatty acids, protein determination and bomb calorimetric assessment of caloric content. We determined the biomass and ease of capture of spring species, to make a timetable of availability. Grasshoppers became important to Burrowing Owl diets at the time when the demand for food was at its highest (i.e., the young owls were approaching adult size but were still dependent on their parents for food). From analysis and models we conclude that burrowing owls are likely to benefit greatly from the presence of an abundant supply of grasshoppers.

## **Egg development in the brown locust**

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The brown locust, *Locustana pardalina* (Walker) (Orthoptera: Acrididae), is found in the semi-arid regions of the central Karoo, South Africa. Diapause and quiescent eggs contribute to brown locust survival under arid conditions, preventing immediate hatching and allowing build-up of eggs in the soil. The drought resistant eggs can survive a reduction of up to 60% in moisture content. Non-diapause eggs may enter and leave quiescence repeatedly. There are two major stages in egg development, namely anatrepsis and catatrepsis. Anatrepsis is the development prior to rotation of the embryo. Here the serosal strand connects the head of the embryo to enlarged serosal cells, hydropyle cells responsible for water absorption. Diapause eggs remain in anatrepsis. Catatrepsis begins when the embryo turns, breaking the serosal strand. Once catatrepsis begins, the development process is usually completed irrespective of environmental conditions. This project looks at effects of hydration on the metabolic rate and hydropyle structure during the development of normal diapause and quiescent eggs. Eggs were obtained from adult locusts collected in the Karoo and bred in the laboratory. Metabolic rate was measured using the LI-CO 6262 analyzer detecting CO<sub>2</sub> only. Embryonic development and changes in hydropyle structure were examined using light microscopy. Hydrated non-diapause eggs steadily increased in mass until hatching occurred after 10 days of incubation. Their metabolic rate increased steadily from day 0. Hydropyle cells increased in size during hydration and became vacuolated. Diapause eggs absorbed little water and maintained a low constant metabolic rate as did quiescent eggs in the catatreptic stage.

## **Variation in resource quality and opportunity for sexual selection on weaponry in a sexually dimorphic insect**

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In many animal species, males do not seek females directly but instead locate and defend sites that contain spatially- or temporally-limited resources essential to female survival and reproduction. Resident males that successfully repel conspecific rivals can mate with sexually receptive females attracted to these resources. Sexual selection theory hypothesizes that increasing resource value increases harem size and thus increases the opportunity ( $I_{\text{mates}}$ ) for and strength of sexual selection on traits crucial to males in combat for control of female harems. I experimentally tested this hypothesis in the field using the Wellington tree weta, *Hemideina crassidens* (Orthoptera: Tettigoniidae: Anostomatidae), a sexually dimorphic insect in which males use their enlarged mandibles as weapons to control adult females housed in galleries within trees. By manipulating gallery size I show that, compared with smaller galleries, larger galleries house larger harems and promote longer tenure by males. As predicted, variation in gallery size is an important determinant of  $I_{\text{mates}}$  but, contrary to expectation, greater opportunity existed in small galleries compared with large galleries. Also, my study strongly suggests that, as predicted, male weapon and body size are targets of selection and are under positive directional selection with larger males having longer tenure in galleries as well as having larger harems. Furthermore, selection of weaponry and body size appears to be stronger for male tree weta in larger, rather than smaller, galleries.

## **Biology and seasonal occurrence of katydids, Decticinae (Tettigoniidae: Decticinae), in Iran**

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Field studies were conducted on the seasonal incidence of katydids (Decticinae) in Iran in relation to the biological characteristics, population, and weather parameters between 1992 and 1993 in the Tarom altitudes, Iran. Our studies reveal interesting insights about the lifecycle of these katydids.

The initial occurrence of katydids is usually noticed during the last week of March, when the greatest proportion of first nymphal instar is seen on and inside the cushion-shaped bushes under which eggs are laid in the soil. The adults appear after completing five nymphal instars in early June. A population increase of this insect is striking in some years, as bands of mobile nymphs or adults attack the cultivated lands, rangelands, and orchards adjacent to their natural habitats. After mating in the second week of June, females begin to lay at end of June. Oviposition is gradual, and each female lays up to 66 eggs. The insect passes the fall and winter in the form of diapausing eggs. The whole nymphal period lasts 40 to 61 days, depending on weather conditions. Adults can be found up to early August. This katydid has one generation a year. The population fluctuation of insect has also been studied during the above mentioned years, and the peak of each developmental stage has been determined. Maximum and minimum temperature and relative humidity were positively correlated with pest incidence. Sunshine amounts showed no significant positive correlation with the pest incidence.

## Guide to the grasshoppers of Wisconsin

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Grasshoppers (Orthoptera: Acrididae) have been collected on a scientific basis in Wisconsin since 1881. Based on over 2800 collection records, the Wisconsin grasshopper (Orthoptera: Acrididae) fauna includes 69 confirmed species from 6 subfamilies. The most abundant subfamilies are the Melanoplinae with 25 species and the Oedipodinae with 22 species. All species are native and none are endemic to Wisconsin. This field guide greatly expands North American distribution records for many species. This guide also provides the first comprehensive treatment of Wisconsin acridids and includes keys for identifying species, maps of known species distributions, descriptions of habitats occupied, and comments on taxonomy, life history, and ecology of the individual species. Of the 69 recognized species, we found that 31 species had been collected at less than 20 locations or had not been collected during the last 25 years. These species were given the designation *special concern* on the Wisconsin Natural Heritage Working List of the Wisconsin Department of Natural Resources and will be given special attention to further assess conservation status.

The Lake Huron Locust, *Trimerotropis huroni*, is also federally listed as an endangered species by the United States Fish and Wildlife Service. Another fifteen species, while not yet collected in Wisconsin, are recognized here as potentially present in the state and have been included in the taxonomic keys. As a comprehensive field guide to the grasshoppers, this book represents a new resource for anyone interested in the acridid fauna of the upper Midwestern United States.

## Optimized parameters for rangeland grasshopper treatments using ultra-low insecticide coverages and kairomonal attractants

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Reduced Agent and Area Treatments (RAATs) is a strategy of integrated pest management (IPM) for rangeland grasshoppers in which the rate of insecticide is reduced from traditional levels and untreated swaths (refuges) are alternated with treated swaths. Ground application of RAATs with a sprayer mounted on a heavy-duty all-terrain vehicle (ATV) was implemented on replicated 8-ha plots of short-grass prairie in SE Wyoming (USA). The insecticide used was an insect growth regulator diflubenzuron (Dimilin<sup>®</sup> 2L) at a dose rate of 18 g of a.i. per ha. Pre-treatment grasshopper densities ranged from 17.5 to 33.5 individuals per square m. Grasshopper communities were dominated by second and third instar nymphs of *Aulocara ellioti*, *Ageneotettix deorum* and *Melanoplus spp.* Insecticide was applied in 6-m swaths as 50, 33 and 20% coverage. Fifty percent coverage yielded 83% of corrected mortality 21 d after application. Thirty-three percent coverage resulted in 78% of corrected mortality, while twenty percent coverage yielded 62% of corrected mortality 21 d post-treatment. Taking into account the costs of the insecticide and labor, the 33% coverage appeared to generate the best compromise for sufficient control and acceptable cost of the operation.

In order to enhance the insecticide formulation, two different rates of kairomonal attractants (mineral and vegetable oils) were added to Dimilin<sup>®</sup> 2L. The Dimilin<sup>®</sup> 2L was applied at a dose rate of 18 g of a.i. per ha in a 33% coverage, for all replicated treatments. The adjuvant combinations included 1) 584 ml/ha of C.O.C., and 2) 146 ml/ha of C.O.C and 438 ml/ha of canola oil. Without adjuvants (with only water added), Dimilin<sup>®</sup> 2L yielded 69% control 21 d post-treatment. Adding C.O.C increased the control to 83%, and the combination of canola oil and C.O.C resulted in 89% control, 21 d after application. Surfactant and kairomonal properties of adjuvants can enhance the effectiveness of Dimilin<sup>®</sup> 2L and ensure the adequate protection from pest grasshoppers.

## Plenary scientific presentation

### Integrated locust management in developing countries: from ecology to anthropology

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In many developing countries, especially in Africa, locusts remain a major threat for food security and social stability, particularly for many rural populations who depend on crops grown in high climatic risk areas. Preventive strategies, developed through continuous advances in locust ecology, proved effective, and led to a dramatic decrease in the outbreak frequency and duration over the last 40 years. Nevertheless, during recent desert locust outbreaks, the current organization to manage emergency situations was revealed to be insufficient with respect to the affected countries and to the international community of donors whose funds are mobilized too slowly during a crisis. The shortage of knowledge on the locust problem has long been an impediment to rational implementation of control operations. This is no longer the case. The main problems are now of an organizational nature. The lack of insight into the rationale and strategies of the many different stakeholders concerned about locusts seems to be a major factor responsible for crisis management dysfunction and for reducing the effectiveness of control operations. Favourable conditions must be created to develop truly sustainable preventive control strategies through the implementation of natural risk management plans for locust outbreaks. Studies on these outbreaks should be based on the biological and ecological mechanisms considered to date and also be broadened to include economic, social, organisational and cultural mechanisms that have been largely overlooked in the past. A new paradigm is required that is focused on the ecology of the locust, but which also takes human imperatives and new concepts, such as risk management systems, stakeholder strategies, and governance into serious consideration.

Key words: locust, *Schistocerca gregaria*, invasions, risk management systems, stakeholder strategies, governance

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## Preliminary taxonomic analysis of the tribe Tetrataeniini (Acrididae, Leptysminae)

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The tribe Tetrataeniini (Amedegnato, 1974) has been recently revised by Roberts & Carbonell in 1980 and includes at present 10 genera and 32 species and 17 subspecies. Basically, this group of neotropical semi-aquatic grasshoppers may be recognized by a short, cup-shaped male sub genital plate; they usually have an upturned arm of the cercus (never narrowly hook-shaped) and the epiphallus is more strongly developed with weakly sclerotized ancorae. The lophi are well defined upturned lobes with their upper or distal portion heavily pigmented in black. For this study, specimens of 12 institutions and from field trips in Uruguay, Brazil and Paraguay were studied. A preliminary new classification for this group and maps of distribution, based in the data from the literature and from the material deposited in collections, are provided here. Also, 6 new species of this group are here described.

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## Does photoperiod influence the number of juvenile instars of *Cornops aquaticum* (Bruner, 1906) (Orthoptera: Acrididae) from the Brazilian Pantanal?

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The semi-aquatic grasshopper *Cornops aquaticum* is host specific on *Eichhornia* spp. from Mexico to Argentina. Published data indicate, that juvenile instars (5-7) apparently mirror the photoperiod and temperature pulses of different climatic conditions in the respective geographical regions.

For this reason, stage numbers in 335 nymphs, hatching on *E. azurea* in the northern Pantanal, were monitored in climatic chambers at Cuiabá University under different photoperiodic conditions (8, 12, 16, 24 hs and without light) at 25 °C and under natural conditions (control).

A total of 103 individuals grew into adults and both sexes presented 5 and 6 instars (only one female with 7 instars at 8 hs light/day). No statistical significant difference (ANOVA,  $p \leq 0.05$ ) was found between photoperiod and instar numbers. However, females had significantly more instar stages (six). Best development (= low mortality, adult stage attained by most individuals) occurred at 12 hs of light/day. Mortality was higher at short periods of light (<12 hs/day). The first instar generally showed the highest mortality. Development was faster at periods with more than 12 hs of light/day.

Results are in contrast to those for populations obtained on *E. crassipes* in Central Amazonia and South Africa. Life-history and genetic studies in Latin America are currently testing whether the varying number of juvenile instars represents a phenotypic plasticity of a single genotype or an adaptation that is genetically fixed, due to an evolutionary relationship of the host with its host-plant.

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## Use of stomodeal cuticular structures in taxonomy I.-subfamily Melanoplinae.

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Taxonomic relevance of stomodeal cuticular structures has been determined at levels of order, suborder, and family (Judd, 1941, 1958; Muralirangan & Anantakrishnan, 1974; Bentos-Pereira & Lorier, 1992, 1995). It has been suggested that proventricular structures are powerful diagnostic characters (?characteristics) in acridid subfamilies (Bentos-Pereira & Lorier, 1995). In the present study, stomodeal structures are used in the subfamily Melanoplinae (Orthoptera, Acrididae), attempting to contribute to the taxonomic understanding of the group. Stomodea were treated in 10% solution of KOH and mounted in polyvinyl alcohol media. Sixteen stomodeal characters were listed, as well as mandibular types, according to Isely (1944). Euclidean distance and Bray-Curtis index similarity matrix were calculated; cluster analysis conducted, and complete linkage and group average algorithms used. Species were separated into seven groups. However, *Neopedies* sp., *Dichroplus robustulus*, and *D. pratensis* showed variable associations. Most of the groups had members with different mandibular types. Four groups (1,4,5,7) contained species assigned to tribe Dichroplini, while the other three (2,3,6) contained species from different tribes or unassigned to any tribe. Species of *Dichroplus* did not group together. Taxonomic status of this genus remains uncertain (Ronderos & Cigliano, 1990; Cigliano & Otte, 2003). Species from group 1 belong to paranense-pampean group (Dichroplini). However *Scotussa*, considered to belong in the same group, was left out. Ecological strategies of this genus could explain this exclusion. While the results of this study are preliminary, they confirm some of the taxonomic relationships inside Melanoplinae. Further and more detailed selection of characters may improve their usefulness for clarifying taxonomic problems.

## Gametic Isolation, Reinforcement, and Rapid Speciation in an *Allonemobius* Hybrid Zone

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Hybrid zones have yielded many insights into the evolution of reproductive isolation, including the simple result of identifying that there are in fact two species. Such identification is often trivial except in the case of rapid or incipient speciation where sharp clines in allele frequencies are often the first evidence of speciation. This was the case in the *Allonemobius socius* complex as a new species (*A. sp. nov. Tex*) and hybrid zone was initially identified based on sharp transitions in allozyme markers. Since this finding some four years ago, we have used multiple molecular markers to not only confirm our original finding but also develop phylogenies and assess rates of speciation. Overall, we have found that this new species is sister to *A. socius* and that the entire *A. fasciatus*, *A. socius*, *A. sp. nov. Tex* complex has diverged within the last 3,000-30,000 years. More detailed studies of the *A. socius/A. sp. nov. Tex* system has revealed that post-mating, pre-zygotic gametic isolating barriers are the primary mechanisms of reproductive isolation with no evidence of hybrid inviability or sterility. Finally, unlike the *A. fasciatus/A. socius* hybrid zone, reinforcement of male choosiness occurs in sympatry.

## Acoustic communication in the genus *Cyphoderris*?

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The genus *Cyphoderris* are relict Ensifera, closely related to crickets and katydids but placed in their own family, the Haglidae. The calling songs of *Cyphoderris* spp. are very similar in physical structure, consisting of a succession of chirps with each chirp composed of a variable number of evenly spaced, sound pulses. The pulses are cricket-like in that they are pure-tone, but they have higher carrier frequencies (12-15 kHz). Two species, *C. buckelli* and *C. monstrosa*, live in subalpine forests of northwest North America with overlapping ranges. In some areas, males of both species call within earshot of one another. They differ in preferred calling sites, with *C. monstrosa* males singing from the trunks of mature trees at heights of 2m or more, and *C. buckelli* males remaining within 1m of the forest floor and signing from understory shrubs. The songs of the two species differ in frequency (*C. monstrosa* – 12 k song).

## Changes in synaptic strength accompanying phase change in locusts

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Solitarious and gregarious locusts (*Schistocerca gregaria*) live in different visual environments and respond differently to visual stimuli. We have previously shown that an identified visual interneurone, the descending contralateral movement detector (DCMD) responds differently in the two phases (Matheson *et al.* (2004) *J. Neurophysiol.* 91: 1-12). The neurone's response to an approaching object habituates more strongly in solitarious than gregarious locusts.

We now show that the strength of an output synapse made by DCMD onto a postsynaptic target, the fast extensor tibiae motor neurone (FETi), also differs between the phases. The amplitude of an excitatory postsynaptic potential evoked in FETi by a single DCMD spike is  $0.41 \pm 0.18$  mV (mean  $\pm$  SD) in solitarious but  $0.19 \pm 0.08$  mV in gregarious locusts. The mean half width is 6 ms in both phases.

DCMD responds to an approaching object with a burst of spikes that increases to a peak rate of 200-300 spikes  $s^{-1}$  near the time of expected collision. The maximum amplitude of depolarisation of FETi during such stimuli was indistinguishable in solitarious and gregarious locusts, despite the different synaptic strengths in the two phases ( $1.72 \pm 0.52$  mV versus  $1.64 \pm 0.66$  mV respectively). The time at which this peak of depolarisation occurred in FETi differed significantly between phases although the time of maximum DCMD firing was similar. The transmission of visual information to the motor system in locusts is thus tuned differently depending on phase state. This should influence how individuals respond to both conspecifics and predators.

## **The Pesticide Referee Group of FAO and its contribution to Locust Control**

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At the time of the major outbreak of desert locust in the late 1980s, FAO convened a meeting to discuss control operations in view of the worldwide ban on the use of dieldrin, hitherto regarded as the most important insecticide to control locusts. One of the outcomes of the meeting was to set up an independent advisory body, the Pesticide Referee Group (PRG), to examine the scientific data obtained from laboratory and field trials submitted to FAO. The PRG was expected to make recommendations on which insecticides were effective and the dosage that should be used either as a barrier treatment or for full-cover applications. The remit of the PRG was subsequently extended to consider environmental data and indicate the possible risk that the effective insecticides pose to various categories of non-target fauna.

The aim of the recommendations has been to give locust affected countries a choice of suitable insecticides, to avoid the previous problems of maintaining stocks of only one insecticide, and to allow flexibility in relation to possible environmental impact. The need for ULV formulations, with specifications that include appropriate volatility and viscosity requirements, is stressed for operational reasons. Stocks of these formulations can be reformulated for use against other pests to avoid long-term storage or obsolescence. Attention has been given to new alternatives including insect growth regulators and the bio-pesticide *Metarhizium anisopliae* var *acridum*. The PRG has requested feedback on operational use of insecticides, including these new products, so the list can be refined and extended.

### **Crickets of Lubbock County, Texas**

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Located in the high plains of West Texas, Lubbock County has a semi-arid climate where its flora and fauna of the former grassland are affected by agriculture and urbanization. This work reports on the cricket fauna of Lubbock County. Specimens that were examined included crickets from the Museum of Texas Tech University collection as well as additional crickets sampled from Lubbock County, with an emphasis on prairie dog town localities.

## **Male calling and phonotactic behaviors in the field cricket, *Gryllus texensis***

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Examining behavioral responses to acoustic cues is essential for understanding mating systems in many orthopteran systems. While considerable attention has focused on the responses of female crickets to the songs of conspecific males, relatively few studies have examined how males respond to songs from other males. This could be an important factor influencing male reproductive success in systems with male-male competition and alternative male mating strategies. We monitored the calling characteristics and phonotactic responses of Texas field crickets, *Gryllus texensis*. Song stimuli elicited positive phonotactic responses from males, but males were less likely to respond and had weaker responses than females. We found no relationship between a male's calling behavior and phonotactic response. Both calling frequency and phonotaxis varied with male body size, with large males calling earlier and having stronger phonotactic responses than small males. Interestingly, the phonotactic responses of adult males did not vary significantly with age. Preliminary data suggest that previous exposure to females may also be an important factor influencing male behaviors.

## **Challenges for locust control in Australia**

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### **Abstract**

The focus of this paper is to examine the challenges that currently exist in Australia for safe, effective and efficient locust control and those that are likely to emerge in the future. The Australian operational environment for locust control has changed significantly in the past 10-15 years. There is now an emphasis on accountability in terms of environmental, trade and human and occupational health risks. There is also an ongoing requirement to demonstrate the effectiveness and economic benefits of locust control. The Australian Plague Locust Commission (APLC) has successfully adapted to these challenges with no significant diminution in its control capability. The integration of adequately funded research and control functions is seen as one of the APLC's strengths in responding and adapting to these changes and also in the development and evolution of a preventive locust control strategy. Further significant change in the operational environment is certain and will necessitate ongoing adaptation. Similar, if not identical, challenges are also likely to be faced by locust control authorities in other countries.

## **Rapid speciation linked to sexual behavior in Hawaiian crickets (Gryllidae: *Laupala*)**

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*Laupala* is a genus of flightless, forest-dwelling crickets undergoing explosive speciation. Thirty-eight species comprise the genus, and all are endemic to the Hawaiian Islands, suggesting speciation has occurred within the upper age of the archipelago, or 5 million years. To estimate more precisely the rate of speciation requires a well-resolved phylogeny; however, these are difficult to obtain for recent species radiations in which little genetic variation have accumulated among species. Here, we used AFLPs (amplified fragment length polymorphisms), a genetic technique particularly suited to resolving relationships among closely related species, to estimate a fully resolved phylogenetic tree of *Laupala*. Our results reveal extremely rapid allopatric speciation, with one lineage in the genus diverging at a rate of 4.17 species per million years. This represents the highest reported rate of speciation in arthropods and is exceeded only by that of the rapidly speciating African cichlid fish. Because *Laupala* species differ primarily in secondary sexual traits, these results provide empirical support for the hypothesis that sexual selection drives rapid speciation.

## **Physical constraints for the evolution of asymmetric wings in katydids**

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Male crickets and katydids of many species call to attract distant females using songs dominated by a single sound frequency. Such pure-tone carriers are commonly in the audio (both cricket and katydid spp.) or low ultrasonic frequency range (only katydid spp.). In these animals, rubbing the forewings together results in sound production; one wing bears a file of teeth ventrally and the other a scraper. Scraper-tooth contacts create oscillations in adjacent forewing structures (wing veins and cells) that radiate sound and the resultant sound may be resonant or non-resonant. Crickets stridulate using a resonant (tonal) mechanism whereby each file tooth controls scraper advance in a manner analogous to a clock escapement: the right and left forewings oscillate in phase, radiating one wave for each contacted file tooth. Most species of crickets stridulate at low frequencies in the range of 2-8 kHz. Resonance is common in crickets, which use bilaterally symmetric forewings. Katydid have asymmetric forewings; the file-bearing wing is robust and acoustically damped. Katydid generate either musical or broadband sounds and use a broader range of frequencies (from 600 Hz up to ~130 kHz) than crickets. Since katydids produce sound at higher frequencies (short wavelengths), precise phasing of the two wings is more critical. Based on a comparative analysis across tettigonids using pure tones, we concluded that the constraints on the phase relation of the forewings might have influenced the evolution of asymmetric wings in katydids. Thus katydids make pure-tone ultrasonic sounds and phase-matching of the forewings is not critical.

## **Contraints physiques relatifs à l'évolution des ailes asymétriques dans les katydids**

Plusieurs espèces de criquets et katydids mâles attirent leurs femelles par des appels dominés par des sons de fréquences simples. Cette sorte de transporteur à tons purs sont habituellement en audio (les espèces de criquets et katydids) ou à une basse fréquence ultrasonore (seulement l'espèce des katydids). Dans ces animaux, le frottement de leurs ailes

antérieures entraîne la production de son; une des ailes est composée ventralement d'une rangée de dents et l'autre d'un racloir. Les contacts entre dent et racloir produisent des oscillations dans les structures adjacentes des ailes antérieures (les ailes, les veines et les cellules). Ces oscillations irradient du son, celui-ci pouvant être résonant ou non. Les criquets strident en utilisant un mécanisme résonant (tonal), où chaque dent dans la rangée contrôle l'avancement du racloir, dans une manière analogue à l'échappement d'une horloge: les ailes antérieures droite et gauche oscillent en phase, irradiant une onde pour chaque contact fait avec une dent dans la rangée. La plupart des espèces de criquets strident à des fréquences entre 2 et 8 kHz. La résonance est commune parmi les criquets qui utilisent des ailes antérieures bilatéralement symétriques. Les katydids ont des ailes antérieures asymétriques; l'aile avec la rangée de dents étant robuste et acoustiquement atténuée. Les katydids produisent soit des sons musicaux ou des sons à large bande et ils utilisent un plus grand nombre de fréquences (de 600Hz jusqu'à ~130kHz) que les criquets. Étant donné que les katydids produisent des sons à des fréquences plus élevées (petites ondes), la mise en phase des deux ailes est encore plus cruciale. Suite à une analyse comparative avec des tettigoniids qui utilisent des tons purs, on a conclu, qu'il se peut que les contraintes sur la relation de phase des ailes antérieures, ont influencé l'évolution des ailes asymétriques de les katydids. Donc, les katydids produisent des sons ultrasonores à tons purs et le correspondage de phase n'est pas crucial.

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**Acoustic behaviour of the bog katydid, *Metrioptera sphagnum* (Orthoptera: Tettigoniidae)**

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The call of this acoustic insect alternates between two distinctive spectra, produced by non-resonant and resonant stridulatory mechanisms. High-audio spectra are generated distad on the file (audio mode) and are followed without song pause, by trains of short pure-tone ultrasonic pulses over the basal file region (ultrasonic mode). The males occupy spruce and tamarack trees in sphagnum bogs attracting females and singing both day and night. They defend these sites acoustically against male conspecifics, at times escalating to approach and fighting. Characteristic song changes occur in these aggressive contexts and similarly in response to human disturbance. Playback experiments designed to simulate acoustic encroachment, elicit song change in males on their singing territory: those that slow their mode change rate – those for which their rate before playback is less than their rate during playback – significantly increase ( $P = 0.006$ ) their mode change rates when playback ends.

## **Divergent selection and gene flow interact to affect the magnitude of sexual isolation between walking-stick populations**

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The process of speciation has received renewed attention, but few studies have elucidated the mechanisms either driving or constraining the evolution of reproductive isolation. In theory, reinforcing selection for increased mating discrimination where interbreeding produces hybrid offspring with low fitness and adaptation to different environments can both promote speciation. Conversely, high levels of homogenizing gene flow can counteract selection. We demonstrate the joint effects of reinforcement, ecological adaptation, and gene flow on progress towards speciation in the wild. Pairs of *Timema cristinae* walking-stick populations adapted to different host-plant species show greater sexual isolation than similar-aged pairs of populations using the same host. Among pairs adapted to different hosts, the magnitude of sexual isolation is greatest when migration rates between populations are high enough to allow reinforcement, but low enough to prevent gene flow from eroding adaptive divergence in mate choice. Overall, sexual isolation is strongest under the combined effects of reinforcement and adaptation to alternate hosts. Sexual isolation is caused, at least in part, by divergence between populations in pheromones. Collectively, our results shed light onto both the processes and the traits involved in the evolution of divergent mate preferences during the early stages of speciation.

### **Old ideas you probably never heard about**

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In science many search for new information with scant attention to investigations of the past. Systematics and good comparative biology may be better sciences in this regard because their due process requires access to all earlier relevant work. In long-forgotten literature of the origin and evolution of signals among grasshoppers and crickets there is much to surprise those operating in the present.

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## Management of a major Desert Locust upsurge in Mauritania (2003–2004)

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From 2003 to 2004, a major Desert Locust, *Schistocerca gregaria* (FORSK. 1775) upsurge developed at an alarming pace in the central part of the western region. Populations grew rapidly within the country, due to favourable breeding conditions. The upsurge triggered a large, tough and dynamic control campaign extending over a vast area, with treatments conducted over 2.7 million hectare in the Sahel, about half of them in Mauritania. To understand and manage a campaign of such tremendous dimension in a country covering more than one million square kilometres, the *Centre de lutte antiacridienne* (CLAA) activated a control mechanism inspired by experiences made during previous Desert Locust control campaigns (1987–88, 1993–94).

The mechanism relies on the concerted action of a well selected, multidisciplinary team. Full sovereignty in decision-making with respect to all terrestrial and aerial control operations is an important element of the system. The roles of and the relationships among the different components are well-defined, and an organisational basis is provided to accommodate and coordinate a range of activities related to the management and coordination of terrestrial and aerial control operations. Apart from control, these activities comprise environmental monitoring, locust data management (data bank linked with a Geographical Information System, GIS), the use of Differential Global Positioning Systems (DGPS) in control execution as well as the involvement of other groups such as the National armed Forces and selected Non-governmental Organisations (NGOs).

After the campaign, an audit was held. About 80 stakeholders, including representatives from the public and main partner organisations, participated in the audit. The audit revealed an overall positive opinion of the public and most stakeholders towards the control mechanism practiced. However, the delayed provision of financial resources and the insufficient involvement of the local population were perceived as disadvantages of the current system.

## **Le dispositif de gestion d'une recrudescence majeure du Criquet pèlerin en Mauritanie (cas 2003-2004)**

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Une intense recrudescence du Criquet pèlerin *Schistocerca gregaria* (FORSK.1775) s'est développée de façon rapide à l'intérieur de la région occidentale, sans apport de populations acridiennes allochtones, entre fin 2003 et 2004. Cette situation a généré une très grande, rude et dynamique campagne antiacridienne qui a permis de traiter, entre autres, 2,7 millions d'ha au Sahel, dont la moitié en Mauritanie. Pour concevoir et gérer de telles campagnes dans un pays aussi vaste, avec une superficie de plus d'un million de km<sup>2</sup>, un mécanisme organisationnel inspiré de l'expérience en gestion des campagnes de lutte passées (1987-88, 1993-94) a été mis en place au sein du Centre de lutte antiacridienne (CLAA) de la Mauritanie.

Ce mécanisme s'est appuyé sur une équipe multidisciplinaire restreinte ayant l'autonomie de décision et l'entière autorité sur les dispositifs terrestres et aériens, des rôles et relations inter et intra- composantes bien définis, et disposant de mesures organisationnelles adaptées et d'un plan d'action couvrant plusieurs volets dont notamment la stratégie de gestion et de coordination des interventions terrestres et aériennes et leur impact environnemental, l'introduction de nouvelles technologies (SIG, Bases de données, DGPS) et l'implication d'autres acteurs tels que l'armée nationale et quelques ONGS .

L'évaluation publique de ce mécanisme à travers un atelier bilan national post campagne associant les 80 acteurs principaux, y compris la société civile et les partenaires, a démontré que, bien que cette organisation ait donné des résultats globalement performants, le retard dans la mobilisation des ressources financières nécessaires ainsi que la faiblesse d'implication des populations locales ont constitué des entraves majeures.

### **Development of the desert locust outbreak in Mauritania: Case of 2003/2004**

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Mauritania is known as a permanent habitat of the desert locust *Schistocerca gregaria* (FORSK. 1775). Between 1993 and 2004, two outbreaks and one upsurge occurred. The outbreak that started in 2003 exceeded all historical accounts. Rather than depending on swarms from the Central Region, it developed from concentrations of indigenous populations, leading to an upsurge, and later, to an outbreak.

This unexpected development was triggered by abundant rainfall in the summer in Sahelian countries, particularly Niger, Mali, and Mauritania after years of drought. Rains contributed to locust breeding and concentrations, changing locust behaviour from solitary to gregarious. A combination of an unusually heavy rainfall in October 2003 in central and northern Mauritania with continuing drought in the south contributed to locust gregarization. This rapid development of

locust upsurge in Mauritania was caused by ecological conditions, particularly vegetation and soil moisture. In northern Mali, 80% of vegetation had dried out by the end of October, and the soil was dry. At the same time, this type of vegetation was lush and green in central Mauritania and soil was wet. This complementarity between the two habitats led to a rapid increase of locust populations in central Mauritania in November and December 2003 due to influx of groups from Mali. As a result, the first large swarm was observed in December 2003. Successful locust breeding continued in Mauritania in January and March 2004, and at least three generations were produced between August 2003 and March 2004, contributing to a build-up of an outbreak.

## **Volatile pheromones, contact pheromones, mechanical touching and visual cues as signals in locust phase polyphenism; state of the art**

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Locusts exhibit density-dependent continuous phase polyphenism. They appear in the gregarious and solitary phases with intermediate (transiens) forms. Increased population density (crowding) induces gregarious phase characteristics. Signals related to locust phases were studied in several laboratories. Volatile emissions from gregarious nymphs and their feces may act as aggregation or 'cohesion' pheromones, though they may not shift the more sedentary solitary behavior to the more active gregarious behavior. However, combined volatile and visual stimuli may induce such a shift. It was claimed that gregarious behavior is induced by cuticular hydrocarbons, presumably acting as contact pheromones. However, more recent findings indicate that mechanical touching ('tickling'), especially of the hind femora, has a major role in induction of gregarious behavior. The volatile emissions of gregarious adults of the Desert Locust, *Schistocerca gregaria*, differ from those of conspecific nymphs. Phenylacetonitrile, produced only by sexually mature gregarious males in this species is a major component of adult volatiles. Phenylacetonitrile was claimed to serve as an adult aggregation pheromone, but recent findings show that it acts as a rival male repelling pheromone. Although change of the behavior is the first overt outcome of an increased density, the cues inducing gregarious behavior are not necessarily identical to putative other cues that may induce more delayed phase changes, such as coloration, or morphometrics.

## **Crickets of the Caribbean: 15% of the World Species**

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### **Abstract**

A summary of our taxonomic research on the West Indian cricket fauna is presented, giving data on new species and total number of species described per island. Over 400 new species are described (multiplying the known species from the area by four) and elevating the total number to over 550 species. This makes the crickets of the Caribbean about 15% of the cricket species in the planet. Nine subfamilies of crickets are represented, being the Podoscirtinae and the Phalangopsinae the most diverse.

## **We believe what we see – and vice versa: Evidence versus perception in locust control**

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Sustainable development has been defined in 1987 by the *World Commission on Environment and Development* as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability has since become a guiding principle and basis for action in all fields of agriculture, including pest management. The principle is stipulated in the *Declaration on Environment and Development* (1992) which calls for “pesticides that are target-specific and readily degrade into harmless constituent parts after use”, as well as in the *Plan of Implementation of the World Summit on Sustainable Development* (2002) which calls for “environmentally sound [programmes and] effective and efficient ... pest control”. How do these obligations translate into the reality of locust control? This paper addresses this question from three perspectives: *capacity*, *understanding*, and *willingness* (Gallopín, 2002). It concludes that substantial progress has been made over the last decade in improving the technological *capacity* for more target-specific control (application technology, biological control, barrier treatment). However, despite all evidence, these innovations are often perceived with suspicion by locust control practitioners. The paper identifies a lack of confidence in the efficacy of some of the new technologies as a major constraint to their adoption. Improving the *understanding* of these technologies is key to overcoming this constraint. This may require believing what one does not see immediately. Only then may decision makers be *willing* to include new and more environmentally sound technologies into their control portfolios – and progress towards sustainable locust control.

## **Eumastacidae from Colombia I.- A new genera and specie of Eumastacinae (Orthoptera, Eumastacoidea).**

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A new species of Eumastacid grasshopper is described, and we propose a new genus to accommodate it. It lives in a mixed zone between the Orinoquia and the Andean border. We assign it provisionally to the subfamily Eumastacinae, but its endophallic plate shows some resemblances to the Pseudomastacinae. This kind of problem turns the taxonomic work into a challenge that requires a further study on the Colombian fauna.

## **Regional relationships between climate, soil moisture, and grasshopper populations in Alberta, and implications for future grasshopper population prediction.**

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Crop damage by grasshoppers is a challenge to farming in the Canadian prairies, where outbreaks can damage millions of dollars worth of crops and forage in a single growing season. These potentially crippling losses have resulted in annual survey-based forecasts. Current methods of prediction use air temperature and precipitation as explanatory factors, to adjust expected populations given the population the previous year. Soil moisture status may also be an important variable controlling timing and density of grasshoppers in predictive models, given that grasshoppers spend a significant portion of their life cycle in the soil (at oviposition, as overwintering embryos, and during hatching the following spring). The objectives of this study were twofold: a) to investigate soil moisture as a potential predictor of changes in grasshopper populations; and b) to determine whether or not relationships between grasshopper populations, weather and soil moisture exist at the regional scale, which would facilitate the inclusion of weather forecasts and observations in annual predictions. We adapted an iterative chi-squared technique which identified the timing of weather and soil moisture effects on grasshopper population dynamics. Our results indicate that fall and spring soil moisture conditions have some predictive capacity, showing strong associations to grasshopper abundance. We also identified regional relationships between temperature, soil moisture and grasshopper populations. These relationships appear far stronger for resulting low grasshopper populations, suggesting that population declines are easier to predict than outbreaks. Cool, wet weather in the spring and warm, dry weather in the fall and early winter are strongly associated with resulting low populations.

## **Course and fine scale views of calling energetics in crickets**

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Some theories of mate choice posit that receivers use features of signals to estimate the signaler's energy expenditure and thereby to assess the signalers' condition. In acoustic communication this assumption rests on there being a close relationship between the sounds an animal produces and the energy it expends. This assumption has generally not been tested rigorously.

In ensiferans there is a good relationship between expended energy and "calling effort." Calling effort is an aggregate measure determined by pulse duration, period, pulse pattern, and by total calling bout duration. All of these are directly related to the actions of stridulatory muscles and thus to energy consumption. What is less clear is the relationship between a call's amplitude and energy expenditure. On a course scale, amplitude must be proportional to stridulatory muscle mass. However, a number of energy transmission/transformation events occur between the production of ATP and the radiation of sound. These fine scale transformations determine a trait termed the *efficiency of sound production*.

I will discuss the extent that intraspecific variation in calling energetics in three species of trilling crickets (*Scapteriscus borellii* and *vicinus*, *Anurogryllus arboreus*) is ascribable to differences in calling effort, size, and sound production efficiency. It is likely that there are relationships between size and call amplitude and between differences in calling bout duration and total energy

expenditure. However, differences may be confounded by constraints acting on females and by environmental conditions. Caution should be used when postulating their usefulness as revealing indicators.

### **Automatised annotation of orthopteran songs: First results from analysing the DORSA sound repository**

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Orthoptera songs are widely used for the description and diagnosis of "new" species. For several species, acoustic communication has been studied in detail, revealing neural mechanisms of sound production and phonotaxis. Most of the corresponding sound recordings are in analogue format (tapes). They are widely scattered among institutions, and only a small fraction is accessible as organised collection (phonothek).

More than 5,000 orthoptera sound recordings, representing approximately 1,000 species have been digitised and databased within the DORSA project (Digital Orthoptera Specimen Access – [www.dorsa.de](http://www.dorsa.de)). This sound data repository is now accessible on-line through the SYSTAX database. Together with images and collection data of voucher specimens, the DORSA serves as a "Virtual Museum," summarizing distributed collections and phonotheks from several German researchers and institutions. A subset of 215 songs was used to develop automatic sound recognition tools by using neural networks in combination with acoustic feature extraction, programmed using the MATLAB sound tool box. After having been trained with 215 song tracks from 137 individuals, the network can reliably classify all 30 cricket species.

The same feature extraction tools were then used to determine carrier frequency and pulse repetition rate for all 5,000 song files and are available in the DORSA database. Plotting pulse repetition rate against carrier frequency revealed species-specific clusters for crickets (*Grylloidea*), but revealed an inhomogeneous picture for katydids (*Tettigonioidea*). Nevertheless, the annotated database can now serve as a "look-up table" which can be rapidly queried for important song parameters, thereby identifying subsets of potentially similar songs

### **Annotation automatisée de chants d'Orthoptères: premiers résultats après avoir analysé le dépôt d'archive du son DORSA**

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Les chants d'Orthoptères sont beaucoup utilisés pour décrire et déterminer des "nouvelles" espèces. Pour plusieurs espèces la communication acoustique a été étudiée en détail, montrant des mécanismes neuronales sous-jacents de reproduction du son et de phono taxis. La plupart des enregistrements du son concordants sont d'un format comparable (cassettes), ils sont dispersés parmi des institutions, et seulement une petite partie est accessible comme collection structurée (phonothèque).

Plus de 5.000 enregistrements du son d'Orthoptères, (représentant environ 1.000 espèces), sont digitales et à base de données à l'intérieur du projet DORSA (Digital Orthoptera Specimen Access – [www.dorsa.de](http://www.dorsa.de)). Ce dépôt d'archives de données du son est maintenant accessible on-line à l'aide de la base de données SYSTAX. Ensemble avec des illustrations et des données de collection des preuves spécimens, le DORSA a le but de servir comme "Musée virtuel", regroupant des collections et phonothèques distribuées de plusieurs chercheurs et institutions allemands. Un sous-ensemble de 215 chants a servi à développer des instruments de

reconnaissance de son automatique, en utilisant un réseau neuronal en combinaison avec une extraction des paramètres acoustiques, programmée à se servir d'utiliser de son MATLAB. Après avoir été formé par 215 pistes de chants venant de 137 individus, le réseau peut classer les 30 espèces de grillons de façon convaincante. Les mêmes instruments d'extraction de paramètres sont alors utilisés pour déterminer la fréquence porteuse et les taux de répétition des impulsions pour tous les 5.000 fichiers de chants, disponible dans la base de données DORSA.

L'enregistrement des taux de répétition des impulsions opposés à la fréquence porteuse révèlent les glomérules d'espèces spécifiques pour les grillons (Grylloidea), d'un autre côté il révèle une image non homogène quant aux sauterelles (Tettigonioidea). Néanmoins, la base de données annotée peut maintenant servir d'ouvrage de référence ("look up table") qui peut être rapidement consulté pour des paramètres de chants importants, tout en identifiant des sous-ensembles de chants se ressemblant probablement, une fois que des nouveaux enregistrements de sons sont disponibles.

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### **Studies on some biological actions of the weed *Anagallis arvensis* L. in relation to its digestive capacity in *Schistocerca gregaria* (forsk.)**

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*Anagallis Arvensis* L. is an annual winter weed found in fields and gardens. Its biological actions on *Schistocerca gregaria* (Forsk.) as fresh diet and extracts with different solvents were investigated.

Permanent feeding of the 1<sup>st</sup>, 2<sup>nd</sup>, 4<sup>th</sup> and 5<sup>th</sup> instar nymphs of *S. gregaria* on the fresh plant resulted in prolongation in their nymphal duration. Mortality percentages during these instars were; 80.0, 16.7, 60.0 and 75.0 for each instar, respectively. These percentages ranged from 100 to 30 for the residual effects of its fine powder extracts.

The density of the cell type as well as the importance value (I.V.) in the faeces of the treated 1<sup>st</sup> and 2<sup>nd</sup> instar nymphs indicated that the toxic action of *A. arvensis* depends upon the digestive capacity of *S. gregaria* to the plant cells.

**Key words:** *Anagallis Arvensis* L., *Schistocerca Gregaria* (forsk.), Mortality digestive, important value, powder extracts, plant cells, biological actions.



## Early induction of behavioural phase change in the Desert Locust

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Repeated mechanosensory stimulation of the hind femora of a solitary locust produces complete behavioural gregarization within 2 – 4h. Tactile stimulation alone, however, fails to elicit gregarization if the hind leg is fully restrained. Restricted movement at the coxal joints (approximately 20°) with the hind femora close to the body allows gregarization to occur when the femur is stroked in otherwise restrained locusts, but gregarization fails if the femur has a similar range of movement held out from the body. Patterned electrical stimulation of metathoracic nerve 5B, which serves the hind leg, induces full behavioural gregarization even in fully restrained animals. These experiments imply that there is a proprioceptive component to this gregarizing stimulus. Solitary and gregarious locusts differ in the amounts of many neurochemicals in their central nervous systems, which change progressively over the course of phase-change. Only 5-hydroxytryptamine (5-HT), however, undergoes a dramatic change over the initial 4h of behavioural gregarization. 5-HT increases 2 – 4 fold in the thoracic ganglia, the region receiving gregarizing stimuli from the hind legs. A detailed analysis of individual locusts that were either crowded with other locusts or had metathoracic nerve 5B electrically stimulated revealed that amount of 5-HT increased exponentially with degree of behavioural gregarization, before subsiding to pre-stimulus levels once locusts had fully gregarized. We suggest that mechanical stimulation of leg mechanoreceptors in solitary locusts leads to an elevation of 5-HT in the thoracic ganglia, which is an important early component of the suite of neuronal and biochemical changes that underlie phase change.



## Mosaic hybrid zone structure and maintenance as moderators for introgression between the field crickets, *Gryllus firmus* and *G. pennsylvanicus*

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Hybrid zones may serve as arenas for the evolution of barriers to gene exchange while still allowing the exchange of favorable alleles between species. Differential introgression of linkage groups indicate favored, neutral, and not-favored genomic regions with respect to intrinsic (epistatic interactions, linkage to specific genes) and extrinsic (environmental selection, behavior, ecological interactions) environments. Additionally, the ability of alleles to introgress will depend on hybrid zone structure (opportunity for individuals to interact) and maintenance (criteria for favorable traits). I investigated the structure and maintenance of a mosaic hybrid zone between two North American field crickets, *Gryllus firmus* and *G. pennsylvanicus*, to understand the arena in which hybridization and introgression is occurring, and to understand those extrinsic traits that potentially facilitate or retard introgression. Because this mosaic hybrid zone is presumably structured by soil habitat, characteristics associated with crickets, soil interactions should influence both the structure and maintenance of the hybrid zone. While both species show tight associations with soil characteristics at all spatial scales, neither over-wintering egg viability in different soils nor oviposition preference for different soils fully explain the maintenance of this hybrid zone. As a result, cricket traits associated with soil variation may not prevent exchange of genetic information between these two species.

The ultrastructure of hydropyle cells in dehydrated and rehydrated quiescent eggs of the South African brown locust

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Water regulation in drought-resistant eggs of the brown locust *Locustana pardalina* (Walk.) may be mediated by specialised serosal cells in the hydropyle region. The characteristics of hydropyle cells in quiescent eggs were examined at intervals during desiccation at 15-22% RH, and again after rehydration. Embryos were pre-catareptic and any pre-existing diapause condition had terminated.

The most noticeable changes occurred during the first 48 hours of desiccation: egg water contents decreased, as did the sizes of cells and nuclei. Deformable cell and nuclear membranes accommodated size changes. Active uptake of water was evident in rehydrated cells: surface microvilli increased in length; endoplasmic reticulum and mitochondrial integrity improved; and cytoplasmic vacuoles increased in size. Vacuole contents empty into the space facing the developing embryo, possibly via scattered basal infoldings. Autophagy was evident in cells from all treatments.

Hydropyle cells may also produce and secrete a water-soluble proteinaceous substance as protection against excessive water loss. Neither dehydrated and rehydrated cells showed structural evidence of RNA transcription, or protein synthesis and secretion, but there were electron dense vesicles at the apical boundaries as well as dense intrusions between the cell surface and the inner edge of the cuticle. Desiccation damage was observed in both dehydrated and rehydrated cells, but did not appear to affect cell functioning as embryos from rehydrated eggs developed to hatching. The results seem to indicate that hydropyle cells may not incur protection mechanisms against desiccation damage, but that limited repair is undertaken upon rehydration.

**Response of Orthoptera assemblages to changing land mosaics in southern Africa**

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Southern Africa has not had any major glaciations for over 200 million years, although its climate has changed considerably during that time. These climate changes and topography have been among the main drivers for vicariance and speciation, resulting in an estimated 40% species endemism.

During nearer geological time, high populations of mammalian herbivores have had a major impact on the land surface through trampling as well as browsing and grazing. Inevitably, this has had a major impact on orthopterans. Recent research has shown how resilient or, alternatively, how sensitive orthopteran populations are to various changing and oscillating land impacts, including that of rain, fire, and domestic livestock. No orthoptera species in southern Africa appears to be threatened with extinction, but the synergistic impact of various abiotic and biotic factors has a major impact on their population levels. Overall, across much of southern Africa, orthoptera assemblages are excellent indicators of land use and condition.

## **The Robert Pfadt grasshopper collection: A half century in the making**

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Acridids and other orthoptera collected during Emeritus Professor Robert E. Pfadt's long and distinguished career at the University of Wyoming have been curated and inventoried. Over 11,500 specimens are in the collection, with 221 species currently identified. The oldest specimen is from 1903 while the newest is from 2003. There are specimens from Afghanistan, Inner Mongolia, Libya, and many other countries but the vast majority are from the western United States. Our goal is to protect and expand the collection and provide access to this valuable resource to researchers.

## **Co-evolution of sender and receiver: Is genetic drift the driving force?**

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Recent studies of communication systems in closely related insect or anuran species indicate that sender and receiver are not necessarily as tightly linked as generally expected. Rather, signals and signal recognition mechanisms might evolve in a more independent fashion. This phenomenon, termed "non-parallel co-evolution of sender and receiver" is seemingly not explained by current models of character evolution in communication systems (Schul & Bush, 2002, *Proc. Roy. Soc B* 269: 1847-1852). Here we propose a scenario to explain this phenomenon, based on a comparative study of male calls and female call recognition mechanisms in groups of katydids (Genus *Neoconocephalus*) with known phylogeny.

In *N. robustus*, call and call recognition are in the ancestral state. In *N. bivocatus* and *N. retusus*, the temporal call pattern is in a derived state, and this derived temporal pattern probably evolved independently in the two species. Call recognition in female *N. bivocatus* differs from the ancestral state, and relies on the new call pattern. In contrast, in *N. retusus* call recognition is in the ancestral state and does not attend to the derived call pattern of the males.

We suggest that genetic drift rather than selection is the driving force, and that males are leading the process. Males introduce a new call trait without any fitness consequences by exploiting the extended range of female call recognition. Changes of female call recognizers occur subsequently.

## **Unraveling the function of phenylacetonitrile: Courtship inhibition or aggregation?**

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Phenylacetonitrile (PAN, synonym: benzylcyanide) is the major component of the odor bouquet of mature gregarious males of the desert locust (*Schistocerca gregaria*). Solitary males do not release this substance; therefore, PAN was assumed to play an important role in aggregation and swarm formation of the desert locust. However, the release pattern of the pheromone is difficult to understand in light of the proposed function in aggregation: Only mature males release the substance, although immature animals also form swarms. The release of PAN depends on the presence of other mature males. Females and immature males are not able to trigger the pheromone emission. Moreover, in olfactometer experiments the substance was found to have a soft-repellent effect to older nymphs as well as immature and mature individuals of either sex. These results suggest a function of PAN in the reproductive behavior of locusts. Arena experiments demonstrated a function of PAN as courtship inhibiting pheromone. The pheromone is used by mature males for chemically enhanced mate guarding at high population densities with extended sexual competition. Also the production sites of PAN in wings and hind legs support this function. However, at very low concentrations, we observed a certain "indecision" of the locusts in our olfactometer studies, pointing at a possible information content of PAN that swarm fellows are around. Whether a visual orientation is initiated by PAN resulting in a significant contribution to swarm cohesion remains to be investigated.

## **Ecology and economy of the Italian locust outbreaks: Between the horns of dilemmas**

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The Italian locust (*Calliptamus italicus* L.) is a common species in the dry steppes, semi-deserts, and deserts of Central and Southwestern Asia and also in the Mediterranean Region. It is the most significant pest in these areas. During the 20<sup>th</sup> century, heavy outbreaks occurred in several decades (1921-1930, 1931-1940, 1991-2000). The situation became especially serious at the end of last century. In 2000 more than 16,600,000 ha were infested and more than 10,000,000 ha were treated with different insecticides from organophosphates to IGRs. During this outbreak, some serious ecological and economical dilemmas were outlined. Several of them are old and some are new for the former USSR countries. An analysis of these dilemmas shows that we should move common management approaches to early warning systems. Such systems should be based on long-term dynamic patterns of the spatial and temporal population structures of the species across a range of scales from the general to the local and on long-term economical estimations of ecosystem/population functions. These studies were supported by the Russian Foundation for Basic Research (grant 03-04-48633) and the Siberian Branch of the Russian Academy of Sciences (grants 49 and 91).

## **Testing hypotheses for bimodal hybrid zones with examples from simulated and real crickets**

**Kerry L. Shaw, Kyle Wagner and Jennifer Jadin**

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Bimodal hybrid zones are characterized by rare hybrids and abundant parental forms, whereas in unimodal hybrid zones, intermediate forms are abundant. Jiggins and Mallet (2000; TREE 15:250-255) have argued that pre-mating barriers to reproduction between hybridizing populations or species are necessary for the existence of a bimodal hybrid zone, but that a bimodal hybrid zone will collapse into a unimodal zone without some post-zygotic selection against hybrids. Furthermore, exogenous selection (selection against hybrids due to the external environment rather than genomic/developmental incompatibilities) is hypothesized to be the primary factor in hybrid zone stability.

The Hawaiian cricket genus *Laupala* is an intriguing system with which to examine these ideas because closely related species 1) frequently live in sympatry, 2) have similar lifestyles, and 3) apparently hybridize frequently, although intermediates are rare. In this study, we model the evolution of this group with a computer simulation, *cricketsim*, by manipulating genetic and evolutionary parameters as well as parameters affecting the simulated environment and its crickets. The individual-based simulator creates a lattice (cellular) world in which male and female “crickets” interact by moving, signaling/responding, and mating. One or more populations of crickets evolve over simulation time as each individual cricket interacts with others during its lifetime, possibly creating new offspring through successful mating. We discuss simulations designed to test hypotheses about bimodal hybrid zones using information from the *Laupala* system as input.

## **Heat shock, thermotolerance, and biogenic amines in the African migratory locust**

**Kelly L. Shoemaker, Gary A.B. Armstrong, and R. Meldrum Robertson**

Department of Biology, Queen’s University, Kingston ON, Canada.

Exposure to a sublethal temperature stress results in the development of subsequent thermotolerance, in which survival is protected at normally lethal temperature extremes. We have demonstrated this thermotolerance in the African migratory locust. Moreover, behaviour continues during these temperature extremes, indicating that the underlying neural circuitry has been protected. The mechanisms by which neural function is modified following a heat stress is the focus of our work. Using the rhythmic ventilatory motor rhythm as our model system, we have shown that a heat shock results in the ability to ventilate at higher temperatures than normal, ventilate longer at sustained high temperatures, and recover faster following circuit failure. These protective effects can be mimicked by the injection of the biogenic amine octopamine into the animal, and can be blocked by injections of the octopamine-receptor antagonist, epinastine. These results strongly suggest the involvement of octopamine in the development of thermotolerance. We are currently using HPLC to quantify levels of octopamine in the metathoracic ganglion, where the ventilatory circuit is housed, to examine whether levels fluctuate during a heat shock. Additionally, we have recently initiated new studies to assay muscle, fat body, and nervous tissues for changing levels of mRNA and protein for heat shock protein 70 (HSP70), which has been associated with the heat shock response and thermotolerance in many model systems.

## Plenary lecture:

### Phase change in locusts: from neurones to populations

Stephen J. Simpson  
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In the early 1990s my group embarked upon a study of behavioural phase change in the desert locust. Behaviour is the most labile of the suite of characters that comprises phase change and provides positive feedbacks that drive the process at a population level. My contention was that a quantitative description of the dynamics of behavioural phase change offered the most effective route into understanding the underlying physiological and molecular mechanisms, and also provided the basis for developing individual-based models with which to explore the population-level consequences, ecological correlates and evolutionary bases of phase change. In my talk I will provide an overview of our research programme, highlighting key advances and attempting to justify my original contention about the need for a behavioural analysis of phase change.

In the solitary phase, locusts avoid each other, but actively aggregate when gregarious. The first stage was to produce a simple, robust and sensitive assay for measuring the behavioural phase-state of individual locusts, using logistic regression as a means of encapsulating the multiple behavioural elements involved. The assay was used to show that individuals change behavioural phase rapidly (in a matter of hours), and also that behavioural state is transmitted across generations epigenetically, with females gregarising their developing offspring to an extent which reflects both maternal and paternal experience of crowding. In a decisive series of experiments the behaviourally gregarising cues from other locusts were identified. The interactive effects of olfactory, visual, contact chemical and mechanical stimuli were teased apart. The most powerfully gregarising stimulus was shown to be physical contact among locusts. Remarkably, mechanosensory inputs from the hind femur are key, a finding that opened the possibility to study phase change as a model system for neuronal plasticity.

We discovered that the maternal influence on hatchling behavioural phase state is by a water-soluble chemical agent emanating from the female reproductive accessory glands and introduced into the foam that surrounds the eggs when they are laid. The female has a memory of when she was last crowded, which is reflected in the extent to which she adds the gregarising compound to her eggs at oviposition.

We investigated in laboratory and field experiments and individual-based computer models the relationship between individual behaviour, population responses, and the spatial distribution and chemical quality of resources within the local environment. Whether a local population of solitary locust will gregarise, and hence potentially seed larger scale outbreaks, was shown to depend critically on the fine-scale distribution and quality of resources. A consequence of forming aggregations is that local populations of locusts become susceptible to predation and disease. Newly gregarised locusts feed selectively on poisonous plants, thus conferring anti-predator protection during the vulnerable, early stages of group formation and also show elevated immune responses, which establishes the desert locust as a casebook example of 'density-dependent prophylaxis'. Fundamental insights into population processes such as these have not been available from previous higher-level analyses, and have shown why information about the structure and quality of food resources at fine spatial scales must become a central component in monitoring and control strategies. They also provide some of the most compelling examples of the power of individual-based approaches in ecology.

## Sensory systems in family *Pneumoridae*: How does life history affect sensory arrays?

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The number and distribution of sensory receptors on orthopteran antennae are often a direct reflection of the environmental conditions that the organism experiences. Previous work has demonstrated that the degree of sensory stimulation present in early development influences the density and complexity of the sensory receptor array in later instars. Many orthopteran receptors respond strongly to food plant odors and are likely involved in host plant location or selection. Structurally similar receptors in other insect taxa have been shown to detect sexual cues such as pheromones. By examining differences in intersexual and interspecific receptor patterns, it may be possible to determine the general life-history traits that most strongly influence the development of sensory arrays in a natural setting and that may be of potential relevance for speciation. This study focuses on bladder grasshoppers (Orthoptera: Pneumoridae), a family of South African endemics, with several species containing a dual male strategy and varying degrees of host specialization. Two congeners were selected for characterization: *Bullacris unicolor* and *B. membracioides*. The former is the more widely distributed species, with a wider variety of known host plants. In addition, *B. membracioides* has a confirmed alternate male strategy, with inflated and uninflated males displaying markedly different morphologies and life-history strategies. Intraspecific analyses of receptor densities indicate male biased sensory systems in both species, with alternate males possessing a hybrid array with characteristics of both genders. The interspecific analyses revealed higher densities in *B. membracioides*, which runs contrary to predictions based on dietary breadth.

## **Phylogenetic perspectives on the evolution of the locust phase polyphenism**

**Hojun Song**

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Since the discovery of locust phase *polyphenism*, many distantly related acridid species have been identified as valid locust species. There are more than 15 known locust species, belonging to at least six subfamilies of Acrididae. This indicates that the phase polyphenism has evolved multiple times in the grasshopper lineage, but no attempt has been made to understand its evolution from the phylogenetic perspectives. For example, it is not clear how different or similar phase characteristics are among the locust species or why they are different. I adopt a cladistic view and argue that behavioral and ecological characteristics evolve by descent with modification, similar to morphological characteristics. Therefore, a phylogenetic relationship among locust species can reveal the pattern of phase evolution. In this study, I present a comprehensive morphological phylogeny of the subfamily Cyrtacanthacridinae, which contains some of the most well known locust species such as *Schistocerca*, *Nomadacris*, and *Anacridium*. Because phase polyphenism is a complex syndrome consisting of numerous behavioral, physiological, and morphological characteristics, I treat it as a composite characteristic and reduce it down to smaller components. I argue that certain components of phase polyphenism, though highly plastic and labile, are under phylogenetic constraints, rather than under strictly adaptive pressure. I also present a novel insight into the biogeography of Cyrtacanthacridinae in light of the phylogeny.

## **Applied Operational Research: Use of fipronil to control infestations of Australian plague locust, *Chortoicetes terminifera* (Walker), in rangeland areas**

**Peter A Spurgin**

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The Australian plague locust, *Chortoicetes terminifera* (Walker), is an important pest of agriculture in Australia. Outbreaks frequently begin in remote rangeland areas followed by long-range migrations of adults into agricultural districts. The Australian Plague locust Commission (APLC) attempts to limit the size and extent of these migrations by following a strategy of early intervention to control major infestations of nymphs as soon as possible following detection and before they develop into highly mobile adult swarms. Until recently, this involved spraying target areas from aircraft using blanket treatments of fenitrothion ULV, an organophosphorus pesticide. While effective, this method of control is time consuming, expensive operationally and has potential risks for non-target species especially if large areas (>10 km<sup>2</sup>) are sprayed.

Following the Australian registration of fipronil, a phenyl pyrazole pesticide with high activity and persistence at very low dosages, the APLC commenced testing this pesticide as an alternative to fenitrothion, to treat large areas of nymphs rapidly with greater efficiency. Aerial treatments with the ULV formulation of fipronil (registered as Adonis 3UL), combined with Differential GPS technology, permitted spray runs to be accurately spaced up to 500 m apart (instead of the 50 or 100 m normally used with blanket treatments) with mean area doses of < 1 g a.i./ha. During the 2003-04 outbreak and subsequent 2004-05 plague in eastern Australia, this technique was used by the APLC to effectively rapidly treat 202 targets covering ca. 289,000 ha. Use of the wide spacing application technique was a key factor in the success of the recent control campaigns and also has significant cost benefits when compared to blanket treatments.



## **Genotype versus environment in locust swarm formation: How important is phase polyphenism?**

**Gregory A. Sword**

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The locust genus *Schistocerca* (Acrididae: Cyrtacanthacridinae) provides an excellent model system for a comparative phylogenetic analysis of the ecological versus genetic factors that lead to locust swarm formation. In contrast to evidence from morphological data, mtDNA sequence data suggests that all of the New World Cyrtacanthacridinae species (*Schistocerca* & *Halmenus*) are the result of a single east to west transatlantic colonization event by an ancestral form of the Old World desert locust, *S. gregaria*. Resolving this discrepancy between molecular and morphological data will be a necessary precursor to a phylogenetic analysis of swarm formation in this genus. Given a robust phylogeny, identification of critical locust traits involved in swarm formation will be central to disentangling the effects of genotype versus the environment in swarm formation. The expression of phase polyphenism correlates with locust swarm formation, but the precise relationship between these two phenomena remains unclear. During outbreaks, juvenile locusts often form migratory bands, and the formation of these mobile groups has been attributed to the expression of phase polyphenism. However, recent evidence from another migratory band-forming Orthopteran, the Mormon cricket, *Anabrus simplex* (Tettigoniidae), suggests that the expression of phase polyphenism is not required for migratory band formation. Furthermore, other locusts such as the Australian Plague locust, *Chortoicetes terminifera* (Acrididae: Oedipodinae), also form migratory bands and flying swarms, but are not thought to express phase polyphenism. These observations do not rule out a causal role for phase polyphenism in *Schistocerca* swarm formation, but do suggest that it is not a prerequisite.

## **Host plant-associated genetic differentiation in the snakeweed grasshopper, *Hesperotettix viridis* (Acrididae: Melanoplinae)**

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Studies of herbivorous insects have played a major role in understanding how ecological divergence can facilitate genetic differentiation. In contrast with the majority of herbivorous insects, grasshoppers as a group are largely polyphagous. Due to the relative lack of intimate grasshopper-plant associations, grasshopper-plant systems have not played a large part in the study of host-associated genetic differentiation. The oligophagous grasshopper *Hesperotettix viridis* (Thomas) is endemic to North America and feeds on composites (Asteraceae) within the tribe Astercae. Previous work has shown both preference and performance differences between *H. viridis* individuals feeding on either *Solidago mollis* or *Gutierrezia sarothrae*. We examined the genetic relationships among 38 *H. viridis* individuals feeding on these plants, both in sympatry and allopatry using 222 AFLP markers. Neighbor-joining analysis resulted in two distinct host-associated clades with 71% bootstrap support for host-associated monophyly. Analyses of molecular variation (AMOVA) revealed significant genetic structuring with host plant accounting for 20% of the total genetic variance while locality accounted for 0%. Significant genetic differentiation was detected between *S. mollis*-feeders and *G. sarothrae*-feeders, even when the two were present in sympatry. These results suggest that *H. viridis* as a species is comprised of at least two distinct host plant-associated lineages.

## Using radiotelemetry to analyze Mormon cricket migration

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Outbreaks of insect pests are common and can have devastating effects on natural and agricultural ecosystems. Little is known about the causes of these outbreaks, not to mention the causes of *en masse* migrations during outbreaks. Our work has focused on flightless Mormon crickets (*Anabrus simplex* (Tettigoniidae)), a katydid species that forms large, mobile groups (migratory bands) during outbreak periods. We utilized radiotelemetry, a valuable tool for understanding animal movement patterns, to quantify movements of individual Mormon crickets under natural conditions. To date, we have tested hypotheses about: (1) movement differences between insects in outbreak and non-outbreak populations; (2) wind direction as a cue determining band movement direction; and (3) the role of social interactions in migratory band formation and movement. Our results indicate that Mormon crickets in outbreak populations exhibit collective movement patterns and travel much further than those in non-outbreak populations. Wind direction plays little if any role in determining the direction of migratory band movement. Social effects have a major effect on both the distance and direction traveled by band members. In addition, we have shown that migratory band membership benefits individual insects by greatly reducing their probability of being killed by predators. This suggests that migratory band formation has evolved as an anti-predator strategy that confers substantial protection to insects within the group.

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## Corazonin and phase polyphenism in locusts

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Locusts exhibit various morphological changes in response to crowding. Body color is one of the most conspicuous changes. As a hormonal factor inducing dark color, a neuropeptide present in the brain and corpora cardiaca was suggested for *Locusta migratoria* and *Schistocerca gregaria* using an albino bioassay, and it was recently isolated as [His7]-corazonin. In this paper, I will summarize the functions of [His7]-corazonin and discuss the possible involvement of this neuropeptide in the control of phase-related morphological changes in locusts.

This peptide induces not only black patterns typical for crowded nymphs but also other colors commonly observed in locust nymphs at low density. Recently we examined the role of [His7]-corazonin in the control of other morphological changes induced by crowding. As a result, it was discovered that the peptide caused changes in morphometric ratios (F/C and E/F: F=hind femur length; C=maximum head width; E=elytron length) towards the values typical for gregarious adults when injected into isolated-reared individuals of *L. migratoria* and *S. gregaria* during the nymphal stage. Injection of the peptide into isolated-reared nymphs was also found to influence the development of antennal sensilla in both species: the total number of sensilla on some antennal segments, which has been known to be smaller in gregarious vs. solitary adults, was reduced significantly after injection and became similar to that for crowd-reared adults, while the number of these sensilla for oil-injected individuals remained unchanged. The results may suggest that [His7]-corazonin plays a role in the control of phase-related morphological changes.

### **A NEGATIVE ASSOCIATION BETWEEN THE DEGREE OF POLYANDRY AND SPERM NUMBER, ACROSS TAXA, IN BUSHCRICKETS (ORTHOPTERA: TETTIGONIIDAE).**

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Recent models of sperm expenditure across species predict that while sperm numbers should increase as the average number of competing ejaculates rises from one (no sperm competition) to two, they should *decrease* for all sperm competition intensities greater than two. The aim of this study was to test the predictions of this model using Tettigoniids. The intensity of sperm competition (= degree of polyandry) was estimated for fourteen species of European tettigoniids by counting the number of spermatodoses within the spermathecae of field caught females towards the end of the season. Data for four further species were taken from the literature, together with data on sperm counts per ejaculate, male body mass and spermatophylax mass for all eighteen species. The mean degree of polyandry per species ranged from two to thirty-eight. Analysis of the data using both generic regression and comparative analysis by independent contrasts indicates that both relative sperm number (with male body mass controlled for) and relative spermatophylax mass decrease as the degree of polyandry increases. This appears to be the first comparative study to demonstrate a decrease in sperm number with increasing sperm competition intensity.

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## Evolution of acoustic behavior and diversification within the Jerusalem crickets (Orthoptera Stenopelmatidae)

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Jerusalem crickets (Orthoptera Stenopelmatidae) are one of the most conspicuous and awe inspiring insect families found throughout western North and Central America. Stenopelmatids are reportedly the insects most often brought to entomologists for identification. Despite this public notoriety, they have received surprisingly little taxonomic attention. For example, in the genus *Stenopelmatus*, only 16 species have been described from North America. Recent work on the acoustic mating calls (produced by abdominal drumming) has revealed substantial cryptic diversity within *Stenopelmatus*, with as many as 70-80 morphological-song species determined to date. Here we examine the evolutionary pattern of acoustic signaling within the context of a molecular phylogeny for the North American stenopelmatids. Over the past 30 years, live specimens were collected from throughout North and Central America. Individuals were raised to adulthood, their calling songs were recorded and karyotypes were determined from male specimens. DNA was extracted from 112 recorded individuals representing 66 song species in the genera *Stenopelmatus* and *Ammopelmatus* and from 2 individuals from the genus *Stenopelmatopterus* (collected from Central America) which were used as an outgroup. Approximately 1200 bases of the mitochondrial DNA Cytochrome Oxidase I (CO I) gene was amplified from each. A molecular phylogeny was generated using maximum likelihood and Bayesian search methods. Mating song characteristics were then mapped onto the resulting phylogenetic hypothesis. Each song species for which multiple haplotypes were amplified forms a highly supported monophyletic clade. Moreover, the mtDNA phylogeny is highly concordant with major song characteristics and geographic regions. Species producing single drums group in a well supported monophyletic clade as do those producing a trilled drum in northern California and those with a sexually dimorphic drum found in southern California and northern Baja California. A male karyotype of  $2N=25$  is most common, and based on a CO I phylogeny, we find at least 5 independent fusion events leading to loss of chromosomes ( $2N=23$ ,  $2N=19$ ) and potentially 1 fission event ( $2N=19$  to  $2N=21$ ) scattered throughout the gene tree. Representatives of *Ammopelmatus*, a genus described as sand dune specialists, do not appear to form a monophyletic group and are instead scattered within the single drum clade of *Stenopelmatus*. Finally, a specimen representing a new species collected from Nuevo Leon, Mexico, falls outside and basal to *Stenopelmatus*. Although this species does not have wings (as in *Stenopelmatopterus*), it exhibits behavior found in other members of the latter genus and unknown in any *Stenopelmatus* species. Overall, our results suggest that both shifts in calling song and geographic barriers have had an important role in the diversification of this group.

## **Potential of Soil as a Limiting Environmental Factor in the Distribution of a Polyphagous Montane Grasshopper Species**

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*Melanoplus alpinus*, a montane/alpine grasshopper species found in the central and northern Rocky Mountains, has a disjunct distribution with highly divergent mtDNA lineages structured among meadows and drainages within mountain ranges. Previous analyses showed that genetic differentiation is not distance driven, so habitat factors may account for genetic structuring and diversity within the species. In this study, three mtDNA lineages were analyzed for their association with ecological variables, including soil texture and dominant plant coverage. Chi-square analysis revealed mtDNA lineage predominance in particular soil textures, indicating the potential of soil to function as a limiting environmental factor in the distribution of lineages within this species. Genotype-habitat associations did not extend beyond soil, however.

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## **Preventing desert locust plagues: Optimizing management interventions**

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Solitarious and gregarious desert locusts migrate to breed where winter, spring, and summer rains fall. Unlike other African locust species, there are no permanent outbreak areas where control would be able to prevent plagues. In some years, seasonal rains support population growth and gregarization for two or three generations, resulting in local outbreaks on a limited scale. Less frequently, rains are widespread, frequent, heavy, and long lasting and then outbreaks may occur simultaneously within a large area over successive seasons. At this stage only a small proportion of the locusts are aggregated into treatable targets and so spraying them fails to stop the upsurge sequence. Spraying the entire infested zone would arguably be both financially and environmentally unacceptable. However, with each successive season of good rains and successful breeding more of the population becomes gregarious and thus sprayable. Eventually, unless the rains fail, the upsurge populations become fully gregarious. Although the number of locusts continues to rise, the infested area diminishes. Upsurge populations continue to grow to plague levels unless checked by drought, migration to hostile habitats, or effective control. Since 1968, large-scale control and poor rains coincided with the upsurge stage; no plague followed, and the upsurge collapsed. The efficacy of treating early outbreaks and the optimum stage for interventions are disputed. Research on recession population dynamics and control campaign evaluations are strongly recommended. Without a better understanding of the factors involved in initiating and preventing plagues, there will remain doubt about the effectiveness of control operations.

## The significance of cytology in *Trimerotropis* (Orthoptera: Oedipodinae) grasshopper taxonomy

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*Trimerotropis* is an unusual grasshopper genus comprised of two chromosomal sections: Section A species all have 23 rod shaped chromosomes in the male (XO sex determination) because the centromere is always terminal in position. Section B species have either 21 or 23 chromosomes and, by definition, have some (metacentric) autosomes with the centromere not terminal in position. The X chromosome is always metacentric (except in 1 species).

Examples will be given showing how these chromosomal characters can be used as markers to answer several questions: What are species distributions? What are species affinities? Could a morphologically intermediate individual, represent a hybrid? Are 2 populations of the same "species" with different chromosomal numbers just different "races" or actually different species?

We now make some predictions (which we will test within the year using mitochondrial and nuclear DNA analysis) based upon cytological evidence alone. We believe that because chromosomal characters are "endophenotypic" and probably very evolutionarily conservative, they may reflect phylogeny better than morphological "exophenotypic" characters. We thus predict that all Section B species are more closely related to each other than they are to any Section A species. "*Microtis*" *helferi* belongs in Section B *Trimerotropis*. Section B *Trimerotropis* and all *Circotettix* species are more closely related to each other than to any Section A *Trimerotropis*. The New World trimerotropines (*Trimerotropis* and *Circotettix*) are not closely related to the Old World Bryodemini. North American *T pallidipennis* is more closely related to other US species in the *pallidipennis* group (*saxatilis*, *schaefferi*, *salina*, *diversellus*) than it is to South American *T pallidipennis*.

## Assessing the status of endangered or threatened orthopteroid insects (Insecta) from Taiwan

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This paper deals with four species of insects from Taiwan whose habitats are of conservation concern. Two species, *Megacrania tsudai* Shiraki 1933 and *Phyllophora kotoshoensis* Shiraki 1930 are already officially listed as vulnerable and rare species in Taiwan. Two more species, *Hexacentrus fuscipes* Matsumura et Shiraki 1908 and *Taiwanemobius formosanus* Yang et Chang 1996 are not yet listed, but are both threatened by the destruction of their coastal habitats. The distribution, population sizes, ecology, life histories, conservation status, and threats are outlined for each of these species. The author assesses the possible categories that, according to the data compiled in this study, for both 1996 and 2000 standards of IUCN/SSC. It would be useful to evaluate the conservation policy of orthopteroid insects at national and regional levels.

## **Chemosensory organs of *Locusta migratoria*: Ultrastructure and expression of odorant-binding and chemosensory proteins**

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The fine structure of different types of chemosensilla on antennae and labial palp in *Locusta migratoria* was investigated in detail by light microscopy, scanning, and transmission electron microscopy. There are four types of chemosensilla on antennae: namely, sensilla basiconica, sensilla trichodea, sensilla coeloconica, and sensilla chaetica. The single-walled s. basiconica and s. trichodea and the double-walled s. coeloconica are all perforated with wall pores and suggested to be olfactory sensilla. Sensilla chaetica have a single terminal pore with the typical morphology of contact chemosensilla. The sensory dome on the tip of labial palp carries only two chemosensilla types, s. basiconica and s. chaetica, of which the spatial map has been made. S. basiconica have similar structure to the counterparts on antennae. S. chaetica show morphological features of contact chemosensilla and can be further subdivided into three subtypes, according to the number (6, 7 or 10) of neurons.

An immunocytochemistry experiment was carried out using antisera against odorant-binding (OBP) and chemosensory (CSP) proteins from locusts. It reveals that OBP is present in the sensillum lymph of sensilla trichodea and s. basiconica, both in antennae and labial palp. The outer sensillum lymph of chaetic sensilla and the subcuticular space between the epidermis and the cuticle of the antennae were labeled with anti-SgreCSP-I, *Lmig*CSP-II and *Sgre*CSP-III. However, anti-*Lmig*CSP-II did not label (?identify) any types of palpal sensilla. The outer sensillum lymph of all three subtypes of terminal s. chaetica on labial palp was specifically labeled with anti-SgreCSP-I in various densities.

**Key Words:** labial palp, antenna, chemosensilla, odorant-bind proteins, chemosensory proteins, immunocytochemical localization

## **Development of odorant-binding and chemosensory proteins in *Locusta migratoria* (Orthoptera: Acrididae)**

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Locusts can distinguish various chemical compounds, both volatile odorants and contact stimuli, with sensilla of their chemosensory organs. The chemosensilla contain lymph soluble proteins, belonging to two major families, odorant-binding proteins and chemosensory proteins. OBPs and CSPs are small polypeptides, of 120-130 and 100-110 amino acids, respectively, but completely unrelated in their amino acid sequences. Both types of proteins reversibly bind pheromones and general odorants, and are considered to be involved in chemical signal transduction. Since OBPs and CSPs are associated with perception of chemical stimuli, therefore it would be expressed in certain developmental stages of insects. We are trying to detect the expression stages of OBPs or CSPs in locusts.

The development of odorant-binding and chemosensory proteins in locust, *Locusta migratoria*, was detected using SDS-PAGE, western blotting analysis and immunocytochemistry with antisera against *Sgre*CSP-I, *Lmig*CSP-II and *Lmig*OBP. The SDS-PAGE and western blotting analysis indicated that both CSP-I and CSP-II distribute broadly in different parts of body, such as

antennae, labrum, labium, palps, tarsi, wings, ovipositor, but OBP was only detected specifically in the antennae. On western blotting analysis, CSP-I, CSP-II and OBP were demonstrated in all developmental stages after hatching. CSP-I and CSP-II were expressed more in nymphs than in adults. With anti-*Lmig*OBP antiserum, two bands appeared about 15kDa from 1st to 4th-instar nymphs, whereas in 5th-instar and adult there was one more band at 30kDa. Only CSP-II was expressed in embryo. CSP-I was not detected in locust embryos using western blotting. The results of more sensitive immunocytochemical experiments, however, showed that OBP is expressed in sensillum lymph of sensilla basiconica on embryo antenna, and the two subclasses of CSPs do not present in embryo antenna, but in other chemosensory organs according to the results of western blotting.

Key Words: *Locusta migratoria*, odorant-binding protein, chemosensory proteins, development, immunochemistry, western blotting

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