

# METALEPTEA

THE NEWSLETTER OF THE



ORTHOPTERISTS' SOCIETY



# 13<sup>TH</sup>

## INTERNATIONAL CONGRESS OF ORTHOPTEROLOGY



**AGADIR,  
MOROCCO**  
**24 - 28 MARCH 2019**

# ABSTRACT BOOK 2019

[www.ico2019morocco.com](http://www.ico2019morocco.com)



## Dear Colleagues, collaborators and participants,

On behalf of the Organizing Committee and in my function as President of this Committee, I would like to express my sincere gratitude for your presence, your interest and involvement in this prestigious congress.

First of all, I would like to welcome everyone to our warm-hearted city of Agadir.

**The 13TH INTERNATIONAL CONGRESS OF ORTHOPTEROLOGY** is organized this year under the theme of "Challenges in front of Climatic and Environmental Changes" by the **IBN ZOHR University of Agadir, the National Center for Control of the Desert Locust and the Orthopterists' Society**.

This fruitful collaboration has allowed, for the first time in Africa and in Morocco, hosting of this prestigious event that brings together scientists from all over the world (22 nationalities).

Almost 200 scientists and researchers have enrolled to participate, and we have a rich and varied program with 5 keynote lectures, 3 workshops, 11 symposia and 5 oral sessions. This program shall allow us to enjoy about 220 communications with 73 oral presentations in symposia, 70 oral communications and 70 posters.

The organizing committee is very honoured to contribute to the spreading of the scientific knowledge produced by the many researchers present. We are confident that discussions will be fruitful.

We want to thank the **Orthopterists' Society** for the confidence placed in us to organize such an international event; the members of the Scientific Committee and the members of the Orthopterists' Society Board for their valuable help; the **Ibn Zohr University** represented by its **President Pr. Omar Halli** and the **Science Faculty** represented by its Dean **Pr. Ihya Ait Ichou** for their unshakable support; the **National Center for Control of the Desert Locust** represented by its director **Dr. Abdelghani Bouaichi** as well as its members for their active collaboration.

The success of this congress would not have been possible without the financial and moral backing of the **Commission for Desert Locust Control in the western region (CLCPRO : Commission de lutte contre le criquet pèlerin en Région Occidentale)**, its members and its Executive Secretary **Dr. Mohamed Lemine Hamouny**. CLCPRO, created under the hospice of **FAO**, promotes any action that can ensure a rational and sustainable management of the Desert locust in a preventive strategy in Western and Northern Africa. CLCPRO has always encouraged research and researchers working on Desert locust. May **CLCPRO** receive here the profound expression of our thanks.

We wish also to thank all the keynotes speakers, the symposium organizers and the chairmen of oral sessions. Their involvement is a key contribution to the success of the congress.

My gratitude goes also naturally to the members of the organizing committee that have involved themselves in this adventure for almost two years.

We cannot forget to thank our sponsors, the **Souss Massa Region, the City Council of Agadir, the Hassan II Academy, the Bel Hassan Foundation** as well as the companies **Elephant Vert and Micronair**.

We wish you rich scientific debates, pleasant meetings and happy evenings. The **Gala Dinner** as well as the **Locust Opera organized by Pr. Jeffrey Lockwood** and generously funded by **Dr. Koutaro Ould Maeno** and the **Orthopterists' Society** shall provide many opportunities for exchanges and entertainment on the side of the congress.

Wishing everyone an enjoyable and profitable conference,

**On behalf of the organizing committee,  
President, Pr L. M. Idrissi Hassani**





## Scientific Committee Members

- **Alexandre Latchininsky**, Food and Agriculture Organization of the United Nations. *alexandre.latchininsky@fao.org*
- **David Hunter**, Locust and Grasshopper Control, 125 William Webb Drive, McKellar ACT 2617 Australia. *davidmhunter100@gmail.com*
- Corinna S. Bazelet, Department of Conservation Ecology & Entomology, Stellenbosch University, Matieland, South Africa. *cbazelet@sun.ac.za*
- **Derek A. Woller**, USDA, APHIS, PPQ, CPHST-Phoenix Lab, AZ, USA. Derek.A.Woller@aphis.usda.gov
- **David C.F. Rentz**, 19 Butler Dr., Kuranda, Queensland, Australia. *orthop1@tpg.com.au*
- **Hojun Song**, Department of Entomology, Texas A&M University, College Station, TX, USA. *hsong@tamu.edu*
- **María Marta Cigliano**, División Entomología, Museo de La Plata, Universidad Nacional de la Plata, La Plata, Argentina. *cigliano@fcnym.unlp.edu.ar*
- **Michel Lecoq**, CIRAD, France. *mlecoq34@gmail.com*
- **Lahsen El Ghadraoui**, Université Sidi Mohamed ben Abdellah, Fès, Maroc. *Lahsen.elghadraoui@usmba.ac.ma*
- **Cyril Piou**, CIRAD, Centre de Biologie et de gestion des populations, Montpellier, France. *cyril.piou@cirad.fr*
- **Marie-Pierre Chapuis**, CIRAD, Centre de Biologie et de gestion des populations, Montpellier, France. *marie-pierre.chapuis@cirad.fr*
- **Axel Hochkirch**, Chair of the IUCN SSC, Trier University, Germany. *hochkirch@uni-trier.de*
- **Mohamed Abdallahi Ould Babah Ebbe**, INSAH/CILSS, Bamako, Mali. *maouldbabah@yahoo.fr*
- **Gerlind Lehman**, Humboldt University, Berlin, Germany. *gerlind.lehmann@biologie.hu-berlin.de*, *gerlind.lehmann@t-online.de*,
- **Karim Vahed**, University of Derby, UK. *k.vahed@derby.ac*
- **Zhang Long**, Agricultural University, Beijing, China. *locust@cau.edu.cn*;
- **Ioana C. Chintauan-Marquier**, Institut de Systématique Evolution Biodiversité (ISYEB), UMR 7205 CNRS/MNHN/UPMC/EPHE, Muséum National d'Histoire Naturelle, Sorbonne Universités, France.
- **Berthold Hedwig**, University of Cambridge, Department of Zoology, Downing Street, Cambridge, CB2 3EJ, United Kingdom. *bh202@cam.ac.uk*
- **Aicha Ait Alla**, Faculté des Sciences, Université Ibn Zohr Agadir. *a\_aitalla200@yahoo.fr*





# Officers of the Orthopterists' Society

orthoptera2019@uiz.ac.ma

**President:** Alexandre Latchininsky, Food and Agriculture Organization of the United Nations.  
*alexandre.latchininsky@fao.org*

---

**Incoming President:** David Hunter, Locust and Grasshopper Control, 125 William Webb Drive, McKellar ACT 2617 Australia. *davidmhunter100@gmail.com*

---

**President-Elect:** Axel Hochkirch, Trier University, Department of Biogeography, D-54286 Trier, Germany. *hochkirch@uni-trier.de*

---

**Executive Director:** Mohamed Abdallahi Ould Babah Ebbe, Institut du Sahel (INSAH), BP 1530 Bamako, *mohamedabdellahi.ebbe@cilss.int, maebbe@gmail.com*

---

**Treasurer:** Pamm Mihm, 2417 Fields South Drive, Champaign, IL 61822 USA.  
*p.mihm@regencyapartments.com*

---

**Managing Editor, JOR:** Corinna S. Bazelet, USDA-APHIS Raleigh, NC, USA.  
*corinna.bazelet@gmail.com*

---

**Editorial Assistant, JOR:** Nancy Morris, Department of Biology, University of Toronto at Mississauga, Mississauga, ON, Canada. *jor@utm.utoronto.ca*

---

**Webmaster, Orthopterists' Society Website:** Derek A. Woller, USDAAPHIS-PPQ-S&T-CPHST Phoenix Lab, AZ, USA. *asilid@gmail.com*

---

**Editor, Metaleptea:** Hojun Song, Department of Entomology, Texas A&M University, College Station, TX, USA. *hsong@tamu.edu*

---

**Associate Editor, Metaleptea:** Derek A. Woller, USDA-APHIS-PPQ-S&T-CPHST Phoenix Lab, AZ, USA. *asilid@gmail.com*

---

**Officer, Orthoptera Species File:** María Marta Cigliano, División Entomología, Museo de La Plata, Universidad Nacional de La Plata, Argentina. *cigliano@fcnym.unlp.edu.ar*

---

**Manager, The Ted Cohn Research Fund:** Michel Lecoq, CIRAD, France. *mlecoq34@gmail.com*

---



## PLENARY LECTURE 1

### DESERT LOCUST MANAGEMENT: A SUCCESS STORY

*Thami Ben Halima, Director of Agrotech Agadir .Past Director of CLCPRO/FAO*

The Desert Locust, *Schistocerca gregaria* (Forskål, 1775), is one of the main pests of humanity in reason of its invasions and of their serious economic, social and environmental consequences. During the invasions, swarms can invade, in the northern hemisphere, an area of 29 million km<sup>2</sup> extending from the Atlantic coast of Africa to the Indo-Pakistan border, across 65 African and Asian countries. The population dynamics of this pest alternate periods of remission, resurgence, recrudescence and invasion. Experience from the past invasions demonstrates that Desert Locust can only be properly managed if an effective preventive control strategy is implemented sustainably throughout the Desert Locust permanent habitat area (the remission area). All the countries with outbreak areas must, therefore, be able to implement this strategy in their respective territories: regular surveys in areas potentially favorable to multiplication and outbreaks, and rapid interventions on the first concentrations. Failure to implement this strategy will expose the 65 countries of the invasion area to disasters in the agricultural, food, economic, social, environmental and even political spheres. The curative control also requires the mobilization of enormous human and financial resources from the countries concerned and from the international donor community, and also requires the spraying of enormous quantities of chemical pesticides with disastrous consequences for human health and the environment. If during the past decades (before the 21st century) it was difficult to circumscribe and localize the areas likely to harbor the Desert Locust primitive outbreaks, the currently available knowledge on the bio-ecology and dynamics of the locust populations, the possibilities offered by new technologies (satellite imagery, GPS, and new technics to collect and transfer data), restructuring and institutional strengthening at national and regional levels, currently make it possible to conduct scientifically and effectively the preventive control strategy.

The implementation of this strategy, advocated by FAO since the 1960s, has become a reality in West and North-West Africa since 2006 thanks to the coordination of Desert Locust control activities by the FAO Commission for controlling the Desert Locust in the Western Region (CLCPRO), established in 2002, and the Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES) implemented in the same region since 2006 and coordinated by CLCPRO. This approach made it possible to control nine resurgences between 2007 and 2017 and thus avoided the development of locust crises similar to that of 2003/05. The appropriation of this preventive control strategy by all partners at the regional level (CLCPRO state members) and at the international level (FAO and donors) has made Desert Locust management in West and North West Africa an exemplary "success story".



## PLENARY LECTURE 2

# SPECIATION MECHANISMS OF EAST AFRICAN ORTHOPTERA

*Claudia Hemp, University of Wuerzburg, Germany*

---

Mountainous East Africa is known for its high degree of biodiversity and endemism, especially along the so-called Eastern Arc Mountains, stretching through Tanzania and southern Kenya. The Eastern Arcs were ranked under the ten most important hotspots for endemism. These mountain ranges harbor evergreen rainforests due to the westward winds that continuously bring moisture from the Indian Ocean.

Geologically young volcanoes adjacent to the northern branch of the Eastern Arc chain, such as Mount Kilimanjaro or Mount Meru, were thrown up in connection with the uplift of the rift valley system about 1–2Ma. Recent surveys focusing on the Orthoptera fauna show that these mountains also harbor a high biodiversity and a high degree of endemism in orthopteran insects.

Forest expansion during humid periods and retraction during dry periods are the best explanation for the patterns of geographical species distribution found on East African mountains. Vegetation corridors along rivers must have favored the dispersal of coastal taxa into the hinterland along the east African coast. During dry and warm periods taxa which became trapped in montane habitats successively adapted to the montane climate or went extinct. The special arrangement of mountain chains probably facilitated speciation. We suggest that climate fluctuations and orogenesis rather than a long-lasting and stable climate – in difference to the current scientific opinion – are most likely the reason for the high diversity found on the Eastern Arc Mountains and inland volcanoes. We also suggest that these speciation processes are limited to 1–2Ma and cannot be explained with the old geological age of the Eastern Arc chain.

Flightless and habitat-restricted Orthoptera serve as ideal model organisms to illuminate mechanisms of speciation.





## PLENARY LECTURE 3

# SPECIATION PHENOTYPES, GENOMICS, AND MECHANISMS OF DIVERSIFICATION IN THE ORTHOPTERA

*Kerry Shaw, Cornell University, NY, USA*

---

Orthoptera offer among the best systems with which to study the multitude of processes that cause speciation. What propelled the ancestral Orthopteroid into the many thousands of species we see in evidence today? This is a daunting question and an answer requires knowledge at many levels.

In this talk, I will ask a related but more tractable question: How do closely related species of Orthoptera differ? Detailing observations, along with speciation theory and evolutionary insights, we can systematically propose how new species arise in various groups, and then contrast and evaluate the mechanisms of speciation that have been famously debated in the Orthoptera.

## PLENARY LECTURE 4

# EVOLUTION OF SYSTEMS OF COMMUNICATION IN CRICKETS: A MULTIDISCIPLINARY EXPLORATION IN SPACE AND TIME

*Tony Robillard, Institut Systématique Evolution Biodiversité (ISYEB),  
Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, EPHE*

---

Adaptive radiations are major drivers of diversification which are triggered by novel ecological opportunities or opening of new niches due to innovations of variable traits, including key features of communication systems. For example, groups of animals that communicate using a particular type of signal that is not used by other species or not detected by predators may diversify more than species using a more occupied signal space, or with more attuned predators.

Most of our understanding of cricket communication derives from studies on field crickets (Gryllinae), in which males emit low-frequency calling signals (3-8 kHz) to attract females at long distances, and females find males by phonotaxis. However, crickets in the subfamily Eneopterinae use high-frequency signals (>12 kHz) to communicate, which may represent a key innovation for the adaptive radiation of this subfamily and the first step in the evolution of a new communication system in the tribe Lebinthini. In this tribe, females lack phonotaxis but reply to the male's high-frequency call by producing vibrations transmitted to the male through the plant substrate (ter Hofstede et al. 2015).

We currently investigate this new system of communication by a broad multidisciplinary approach to understand more precisely the interactions between males and females and the mechanisms involved in extant species. As for any adaptation, clues about past causes can be searched for through the study of the present state, but they can also be investigated by looking back at the spatiotemporal and past ecological context where the change occurred.

In this work, we combine calibrated molecular phylogenetic studies, biogeographical inferences of ancestral areas and modern phylogenetic comparative methods to investigate the "when" and the "where" of the origin of the new communication system in the tribe Lebinthini. We gathered data about morphology, bioacoustics, habitats and time of activity for a total of 14 traits in 42 species representing all the genera of the subfamily. For each trait, we estimated the ancestral states at each node of the calibrated phylogeny and established the context in which high-frequency calls arose based on information about past climates, vegetation and communities of predators and acoustic competitors. With such information, we review the different causes invoked to explain the evolution of high-frequency calls and the new system of communication.

Our results suggest that the high-frequency calls in the Eneopterinae have originated in Southeast Asia between late Paleocene and early Eocene (54-60 mya). Strikingly, this date coincides with the development of high-frequency communication in katydids. The diversification of bats also dates back to ca. 60 mya, suggesting that katydids and eneopterine crickets may have convergently evolved high-frequency communication while they faced a rising challenge of bat predation.



## PLENARY LECTURE 5

# CHALLENGES ASSOCIATED WITH CLIMATE AND ENVIRONMENTAL CHANGE IN AFRICAN LOCUSTS AND GRASSHOPPERS

*Magzoub Bashir, University of Khartoum, Sudan*

---

Recent years have witnessed some discernable changes in the daily temperature and rainfall in the Sudan. This was evident in the main western and eastern breeding sites of the desert locust. A noticeable shift in the distribution and outbreaks of the species and other pestiferous species was evident. Compared to the 1988 major invasion of the desert locust there appears to be little evidence of invasions of gregarious populations hardly evident in the main breeding areas. This may be due to the low frequency of preferred desert plants particularly *Heliotropium* spp, *Crotalaria microphylla*, and *Zygophyllum simplex* in the east and *Schouwia* and cultivated millet in the west, which were previously shown to play an important role in the phase shift of solitary nymphs. Other locust species density and distribution also appear to be changing.

The migratory locust *Locusta migratoria* nymphs were seen marching with the desert locust nymphs in the eastern breeding areas. Its infestation extended to the main cultivated areas in the north and in the rain-fed schemes in central Sudan. Also, the tree locust *Anacridium melanorhodon* became prevalent in areas outside the acacia belt. The variegated locust *Zonocerus variegatus* also became a serious pest in the western regions of the country with denser populations and frequent outbreaks.

13<sup>TH</sup>

INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



# WORKSHOPS



## Workshop on OSF and TaxonWorks

# OSF AND TAXONWORKS: DEVELOPING A NEW INTEGRATIVE WEBSITE FOR ORTHOPTERA

María Marta Cigliano<sup>1,2</sup>

<sup>1</sup> Ecole Nationale Forestière d'Ingénieurs, Salé, Maroc

<sup>2</sup> Expert indépendant, Assanabile, Villa n°10, Route de Mehdyia, Salé, Maroc.

The Orthoptera Species File (OSF, <http://orthoptera.speciesfile.org/>) is the most up to date and complete taxonomic database of the world's Orthoptera (grasshoppers, locusts, katydids, crickets), both living and fossil. Nowadays, the classification of Orthoptera shown in OSF is being used worldwide as the general reference for the group. The field of cybertaxonomy represents the convergence of traditional taxonomic goals with new ones, powered by the full potential of cyberinfrastructure, digital technology, information science, and computer engineering. The potential of using OSF for integrating many of the most recent cybertaxonomic tools will be discussed. An introduction to TaxonWorks, the new platform that integrates the best features of Species File software with new ones will be presented. This new platform, constituted by a collection of open source tools and services that cover all aspects of the taxonomic workflow will help to maximize the efficiency of taxonomic work allowing the exchange of data among the orthopterists' community and helping to expand and enhance our knowledge of Orthoptera. The workshop will explore the use of TaxonWorks as it stands now, focusing on how to use the software

and discussing the possibilities of how to integrate its features to OSF. Currently, TaxonWorks is a workbench for individuals or small groups of collaborators that sits behind a login window, but it is nearing a stage where questions are beginning to arise as to how data within a workbench might be displayed to public users. Larger efforts will be devoted towards creating homepage, species pages, customizing them and populating them with OSF data. An integrative website of OSF that exposes the full richness of the data will be developed. Such a site that is rich and highly complex, takes a lot of time to code and maintain. How best to wrap this complexity, and maintain that wrapper for the longer term is a question that needs to be addressed by the broader community. This workshop will seek input from the orthopterists' community on this important issue discussing what should the new version of OSF supported by TaxonWorks minimally include? Or how can we improve the present version of OSF?

### **Key Words:**

OSF, TaxonWorks, cyber- taxonomy.



## Global Locust Initiative Workshop

# LOCUST AND GRASSHOPPER DATA MANAGEMENT IN THE INFORMATION AGE, A CASE STUDY OF THE ALRC ARCHIVES

*Rick Overson and Arianne Cease*

*Arizona State University, USA*

---

This workshop will engage grasshopper and locust researchers and practitioners to discuss how our community collects, cleans, stores, shares, accesses, and uses data over short, intermediate, and longer time scales. We will brainstorm and identify key successes, remaining obstacles, and ways forward, with regards to all aspects of data management. Relatedly, as a community, we will discuss a proposal to digitize the massive historical archives of the Anti-Locust Research Centre (ALRC). Edward Baker is championing this effort that will most likely be a 4–5 year project involving a team of people. The archives include a treasure trove of historical records, 16,000+ maps, many films which are highly flammable and sensitive, myriad field reports, and such gems as

Boris Uvarov's *Schistocerca gregaria* specimens! Before embarking on this endeavor, we want to ensure that this digitized resource will be broadly useful. As such, our community's input will be critical in envisioning its use and providing letters of support detailing how the digitization and broad access of the archives will benefit our community. Finally, after meditating on the case study of the ALRC archives, we will discuss how our community can elevate data collection now and in the future with regards to novel collection techniques, data cleaning and storage, leveraging the benefits of standardized data between institutions, and managing concerns with both data security and data sharing.



## Workshop CLCPRO Regional Research Plan

# REGIONAL RESEARCH PLAN OF THE FAO COMMISSION FOR CONTROLLING THE DESERT LOCUST IN THE WESTERN REGION (CLCPRO)

Mohamed Lemine Hamouny, CLCPRO Executive Secretary (FAO)<sup>1</sup>

<sup>1</sup> Secrétaire exécutif CLCPRO Alger/Algérie

The Commission for Controlling the Desert Locust in the Western Region (CLCPRO1), within the framework of the EMPRES2 programme of the Food and Agriculture Organization of the United Nations (FAO), has developed in 2009 a first regional research plan (2010-2013), based on a screening of research studies carried out in the western region (West and North-West Africa) during the last 50 years. In October 2015, research themes have been reprioritized by the stakeholders and the regional scientific community working on Desert Locust ecology and management and a second plan (2016-2019) prepared. Four main results are expected from this second research plan:

- 1) The early warning system is improved.
- 2) Alternative control techniques and environmentally friendly strategies are improved.
- 3) Environmental impacts of locust control are evaluated.

4) Socio-economic aspects related to Desert Locust are better understood.

This workshop will first present the details of the regional research plan, the actions supported by the CLCPRO since 2016 and the expected actions in a near future. The discussion with the audience will allow identifying how the scientific community working on Orthopterans could contribute to the implementation of CLCPRO's regional research plan and what is the best approach to interconnect with orthopterist researchers.

1- Commission of the Food and Agriculture Organization of the United Nations (FAO).

2- Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases.

### **Key Words:**

CLCPRO, Research Plan, desert locust.



INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



# LOCUST OPERA



## ORGANIZER JEFFREY ALAN LOCKWOOD

*Professor of Natural Sciences & Humanities,*

*University of Wyoming, Department of Philosophy (3392), 1000 E. University Ave., Laramie WY 82071*

*lockwood@uwyo.edu*

---

Locust" is a one hour chamber opera intended to bring orthopterology to the general public through the story of the Rocky Mountain locust, *Melanoplus spretus*. The opera is based on Jeffrey Lockwood's book, *Locust: The Devastating Rise and Mysterious Disappearance of the Insect that Shaped the American Frontier* (Basic Books, 2004), which Pulitzer Prize winning author Annie Proulx described as, "Gripping... fascinating...an entomological thriller."

The tale unfolds as an environmental murder mystery which is true to the science-as well as resonant with the imagination. This is an epic account of the Rocky Mountain locust, an iconic species that blackened the skies of North America in the 1800s with huge swarms, but suddenly disappeared forever at the turn of the twentieth century. In the operatic formulation, the ghost of the locust haunts a scientist until he can figure out how a creature that once numbered in the trillions survives only folklore.

With environmental crises emerging across the globe, scientists must find ways of sharing their knowledge with the public. And perhaps telling stories through music is one of the best ways to promote scientific literacy. The opera ends not only with the solution to a mysterious, century-old extinction but with powerful lessons for contemporary conservation.



INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



# SYMPOSIA



# SYMPOSIUM 1

## Orthoptera conservation

### Organizer: Axel Hochkirch

Trier University & IUCN SSC Grasshopper Specialist Group.  
hochkirch@uni-trier.de

1. **Simeon B. Borisov, Maya B. Ilieva, Georgi S. Popgeorgiev.** PRIORITY CONSERVATION AREAS FOR ORTHOPTERA IN BULGARIA
2. **Dragan P. Chobanov, Aneliya B. Bobeva, Simeon B. Borisov.** PHYLOGEOGRAPHY AND CONSERVATION STATUS OF BUSHCRICKETS WITHIN A COMPLEX ARCHIPELAGO-MAINLAND SYSTEM: TARGET GROUPS POECILIMON JONICUS AND P. HAMATUS SPECIES COMPLEXES
3. **Armin Landmann.** WILD RIVERS AND ELUSIVE GRASSHOPPERS: STATUS, THREATS AND CONSERVATION POSSIBILITIES OF SPECIALISED CAELIFERA ON DYNAMIC RIVERBANKS OF THE ALPS
4. **M. Celeste Scattolini, Andrés Lira-Noriega, María M. Cigliano.** DIVERSITY, DISTRIBUTION AND CONSERVATION STATUS OF THE SOUTH AMERICAN DICHROPLINES (ORTHOPTERA: ACRIDIDAE)
5. **Ricardo Mariño-Pérez.** PYRGOMORPHIDAE CONSERVATION IN THE WORLD
6. **Karim Vahed, Rose Poston-Saynor.** PITFALL TRAP SURVEYS OF THE THREE MAIN POPULATIONS OF THE SCALY CRICKET, PSEUDOMOGOPLISTES VICENTAE, IN THE U.K
7. **Baudewijn Odé, Axel Hochkirch.** EUROPEAN RED LIST OF GRASSHOPPERS: LEADS FOR CONSERVATION
8. **Axel Hochkirch.** DEVELOPING CONSERVATION STRATEGIES FOR THREATENED ORTHOPTERA
9. **Linda Bröder, Laurent Tatin, Axel Hochkirch.** UNRAVELLING THE THREATS TO THE CRAU PLAIN GRASSHOPPER (PRIONOTROPIS RHODANICA)
10. **Anja Danielczak, Axel Hochkirch.** BIOACOUSTIC MONITORING AND MICROHABITAT PREFERENCES OF THE ADRIATIC MARBLED BUSH CRICKET ZEUNERIANA MARMORATA



## Orthoptera Conservation

# PRIORITY CONSERVATION AREAS FOR ORTHOPTERA IN BULGARIA

Simeon B. Borisov<sup>1</sup>, Maya B. Ilieva<sup>2</sup>, Georgi S. Popgeorgiev<sup>3</sup>

<sup>1</sup> Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria; borissovsb@gmail.com

<sup>2</sup> Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences, Wrocław, Poland

<sup>3</sup> National Museum of Natural History, Bulgarian Academy of Sciences, Sofia, Bulgaria

Bulgaria occupies ca. 111 000 km<sup>2</sup> in the eastern part of the Balkans. Its territory covers some of the most diverse areas for orthopterans in Europe as shown in the European Red List of Grasshoppers, Crickets and Bush-crickets (Hochkirch et al. 2016). Though comparatively intensively studied in the second half of the XXth Century, in the past 15 years many new findings have been published concerning the taxonomy and faunistics of Bulgarian Orthoptera. In the present study we summarize all published and new records, including a few taxonomic changes, to compile a complete updated list of orthopterans in this country. All species listed have been assessed according to the application standards of the IUCN Red List Criteria at Regional Level. Then we selected species of regional importance,

including (1) endemic species, (2) species with fragmented or restricted area of distribution in this country, and (3) threatened species, to map their distribution. Different resources and tools based on Geographic information system (GIS) were used to map the distribution of each species, rasterize the polygons and value the raster layer according to the threatened category of the respective species. Spatial evaluation was performed (1) for the number of taxa and (2) for accumulated value of threatened categories to outline territories of special importance for Orthoptera conservation in Bulgaria.

### **Key Words:**

Balkans, Orthoptera conservation, Bulgaria, priority areas.



## Orthoptera Conservation

# PHYLOGEOGRAPHY AND CONSERVATION STATUS OF BUSHCRICKETS WITHIN A COMPLEX ARCHIPELAGO-MAINLAND SYSTEM: TARGET GROUPS *POECILIMON JONICUS* AND *P. HAMATUS* SPECIES COMPLEXES

Dragan P. Chobanov<sup>1</sup>, Aneliya B. Bobeva<sup>1</sup>, Simeon B. Borisov<sup>1</sup>

<sup>1</sup> Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria;  
dchobanov@gmail.com

The stepwise disintegration of the land mass of the Aegean tectonic plate, which started during Middle Miocene, was a prerequisite for isolation and allopatric speciation of many terrestrial animals. The following repeating periods of isolation and contact between populations formed the current diversity in that region. Major tectonic event is the formation of a deep marine barrier – the mid-Aegean Trench (12-9 MYA), which outlined the future speciation of all terrestrial fauna in the region. Flightless species of the genus *Poecilimon* are prone to isolation resulting in high levels of endemism in the Mediterranean region.

Our study concentrates on two species complexes of orthopterans spread on both sides of the mid-Aegean Trench. The related species groups *Poecilimon jonicus* and *Poecilimon inflatus* consist of seven taxa at the Balkan mainland and 10 taxa at the SW Anatolia-Crete area. The species group *Poecilimon hamatus* (subgenus *Hamatopoecilimon*) includes six closely related species distributed on several Aegean islands

and in Western Anatolia. In our study we perform phylogenetic analyses based on mitochondrial and nuclear markers and estimate lineage divergence times. Genetic distances, divergence estimates and field observations were used as a basis for discussion on the conservation status of the studied taxa and groups.

**Acknowledgements:** This study was supported by the National Science Fund (MES) of Bulgaria – project DN11/14-18.12.2017 to Dragan Chobanov. The material was collected with the support by The Theodore J. Cohn Research Fund (OSF), Deutsche Gesellschaft für Orthopterologie (grants to Simeon Borisov), and The Scientific and Technological Research Council of Turkey (TÜBİTAK) (postdoctoral research grant to Dragan Chobanov).

### Key Words:

*Poecilimon*, Phylogeography, Conservation, Diversity, Balkans, Anatolia.

## Orthoptera Conservation

# WILD RIVERS AND ELUSIVE GRASSHOPPERS: STATUS, THREATS AND CONSERVATION POSSIBILITIES OF SPECIALISED CAELIFERA ON DYNAMIC RIVERBANKS OF THE ALPS

Armin Landmann<sup>1</sup>

<sup>1</sup> Institute of Zoology, University of Innsbruck, Innsbruck, Austria; armin.landmann@uibk.ac.at

According to the WWF European Alpine Program 2014 the pan-Alpine river network consists of more than 10.500 river units with a total length of about 57.000 km. However, one third of rivers with catchments over 500 km<sup>2</sup> must be classified as heavily modified or even as artificial water bodies or are at least in a bad to poor ecological status, and only less than 5 % or less than 500 km of the river network length of these larger rivers have been assessed to still show a high ecological status by the WWF. In particular, stretches of braided floodplains (Fig. 1) with high seasonal and year to year hydrological and morphological dynamics, once keystone ecosystems of the Alps, are now among the most endangered systems even on a global scale. The banks of such rivers are dominated by extensive gravel fields with sparse vegetation and are inhabited by a large number of highly specialised, mainly semiaquatic or hygrophilous plants and animals.

However, due to the high small-scale variability in soil structures, micro-topography and micro-climates these dynamic habitats traditionally have also been refuges for xerophilic and geophilic grasshoppers. In particular, four camouflaged species, namely *Tetrix tuerki*, *Epacromius tergestinus ponticus*, *Bryodemella tuberculata* and *Chorthippus pullus* in the Alps are more or less exclusively bound to such dynamic habitats along wild rivers. All these species thus are listed in higher threat categories of the Red Lists of the countries which have part in the Alpine Arc, and even are regarded as "Regionally Extinct" in several states.

What is more, all four species overall still show decreasing population trends in the Alps and most regional populations are severely fragment-

ed and isolated now and continue to decline due to habitat deteriorations caused by ongoing river regulation programs, hydropower use or gravel-mining.

Conservation measures therefore are urgently needed in order to preserve the last remaining alpine populations of these species. The talk first gives a short overview about the current population and threat status of the species in the Alpine Arc and about conservation activities which have been implemented so far. In particular an actual river-restoration program funded by the EU-LIFE scheme (Dynamic River System LIFE Lech 2016–2021) at the Lech River (Tyrol, Austria, s. Fig. 1) is presented. Amongst others, riverbank grasshoppers have been selected there as target and flagship species, and the local distribution, population status and habitat requirements of three species which still occur at the Lech river are monitored.



Figure 1. The Lech River in the Northern Limestone Alps of the Tyrol (Austria) in part is one of the last preserved braided river systems of the Alps. (A. Vorauer, WWF).

**Key Words:** Alpine braided rivers, gravel bank grasshoppers, Conservation measures, Austria



## Orthoptera Conservation

# DIVERSITY, DISTRIBUTION AND CONSERVATION STATUS OF THE SOUTH AMERICAN DICHROPLINES (ORTHOPTERA: ACRIDIDAE)

*M. Celeste Scattolini*<sup>1,2</sup>, *Andrés Lira-Noriega*<sup>3</sup>, *María M. Cigliano*<sup>1,2</sup>

<sup>1</sup> Centro de Estudios Parasitológicos y de Vectores, CEPAVE, CONICET-CCT La Plata, Argentina; celestescattolini@yahoo.com.ar

<sup>2</sup> Museo de La Plata, División Entomología; FCNyM-UNLP, La Plata, Argentina

<sup>3</sup> Catedrático CONACyT, Instituto de Ecología, A.C., Red de Estudios Moleculares Avanzados, Veracruz, Xalapa, Mexico

The South American tribe Dichroplini presents 163 species, belonging to 28 genera. The group inhabits open biomes encompassing very different geomorphological areas of South America and are particularly diverse in the Seasonally Dry Tropical Forests (SDTFs). The tribe exhibits the greatest diversification of South American melanoplinae, being the dominant group both in number of species and individuals in most grassland communities. Two main diversification centers occurring in the Northern Andes (Colombia and Venezuela) and the Parano-Platense basin had been proposed for the tribe.

The main objective of this work is to explore the diversification patterns of the species and genera of the Dichroplini tribe and to contrast various hypotheses proposed to explain the spatial variations in speciation rates with the patterns of diversification in the tribe.

The diversity patterns of the species and genera were analysed considering the richness, range size and niche breadth. The results suggest that the diversification centers of the Dichroplini tribe would coincide with those mentioned for the group (Northern Andes and Parano-Platense basin), adding a third evolutionary center in the Central Andes region. The Andes

are characterized by brachypterous species, with reduced niche breadths and ranges, with a high degree of endemisms and high regional richness. The evolutionary center of the Parano-Platense basin presents the greatest diversification of the tribe, finding the greatest richness in the Paranaense Atlantic Forest and Humid Chaco of the Seasonally Dry Tropical Forests (SDTF) and in the Araucaria Forest of Tropical Rain Forest, characterized by brachypterous and macropterous species with variable distribution ranges. Also, Red List assessments of 41 out of 163 (25 % of the species) species were elaborated to aid in determining spatial priorities regarding the conservation of Dichroplini.

This work highlights the value of South American open biomes as areas of high endemism and key regions to understand biogeographic patterns. Such ecosystems urge for research and conservation efforts. Spatial prioritization proposals incorporating biotic elements and conservation biogeographical analyses should be seen as a top research priority to safeguard the evolutionary significance of these biodiversity hotspots.

**Key Words:** Red List, open biomes, macroecology, diversification.

## Orthoptera Conservation

# PYRGOMORPHIDAE CONSERVATION IN THE WORLD

Ricardo Mariño-Pérez

Department of Entomology, Texas A&M University, College Station, USA; pselliopus@yahoo.com.mx

Currently there are only two species of *Pyrgo* morphidae with assessment information in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, both from Europe. The first one is *Pyrgomorphula serbica*, commonly known as the Serbian Stick Grasshopper. It was assessed as Critically Endangered because its extent of occurrence is only 16 km<sup>2</sup> in Serbia, and there are only five subpopulations with a continuing decline of mature individuals. The second species is *Pyrgomorpha cypria* (Cyprian Stick Grasshopper). Its assessment is of Least Concern due to its widespread across the island of Cyprus (14,000 km<sup>2</sup>). Its populations are considered stable.

As an example for Asia, it has been recommended to conserve *Aularches miliaris* in south India due to its local rarity, despite the fact it is very abundant and even reported as a minor agricultural pest in other parts of India. An Australian case is the Leichhardt's grasshopper, *Petasida ephippigera*, which is endemic to wet-dry tropics of Northern Australia. It is used for advertising Kakady and Keep River Nationals Parks. However, there are no management strategies for this emblematic pyrgomorph. It was described in 1845 and until 1971 it was known from only five specimens. Even it is known as Aljurr, children of the lightning man among the aboriginal dreaming stories. Due to its coloration, distribution and cultural importance, it is a good candidate to conduct an IUCN assessment and use it as a flagship species for conservation in Australia. Regarding African examples, five species found in Somalia are potentially endangered due to their narrow distributions.

*Paraphymateus roffeyi* (Fig. 1) is known for only four or five specimens from three localities in central Somalia. *Megalopyrga monochroma* is known from

the unique female holotype. *Parorthacris somalica* is known from male material only from the type locality. *Vittisphena somalica* is known only from its type locality. *Xiphipyrgus tunstalli* has been collected only in two localities. These few records could be due to the lack of recent collecting trips or due to political reasons. Nevertheless, in Kenya, which has been better explored, there is a single male specimen known for *Marsabitacris citronota* from Mount Marsabit. Two species endemic to Socotra Island (part of Yemen but African in nature) are endangered due to current political issues (*Physemophorus sokotranus* and *Xenephias sokotranus*). Finally, an example concerning New World Pyrgomorphidae is *Piscacris affinis*, known from a single hill in Southwestern Mexico

There are several other worldwide examples of pyrgomorphs known from a single or very few specimens and locality(ies). This could be due to lack of collecting or a very restricted distribution.

As part of my PhD project, I reviewed the distribution of the 487 recognized species in 149 genera. This knowledge will allow a better understanding for conservation actions and it will be the starting point of Red List assessments for the IUCN.



Figure 1. *Paraphymateus roffeyi* female, Somalia.

**Key Words:** Gaudy Grasshoppers, Pyrgomorphidae, Conservation

## Orthoptera Conservation

# PITFALL TRAP SURVEYS OF THE THREE MAIN POPULATIONS OF THE SCALY CRICKET, PSEUDOMOGOPLISTES VICENTAE, IN THE U.K.)

Karim Vahed<sup>1</sup>, Rose Poston-Saynor<sup>2</sup>

<sup>1</sup> University of Derby, Derby, U.K.; k.vahed@derby.ac.

<sup>2</sup> University of Derby, Derby, U.K

The Scaly cricket, or Atlantic beach cricket (Fig. 1), is classified as “Vulnerable” globally. In the U.K., it is known to occur in only 3 populations, where it lives in coastal shingle. An unusually severe storm surge hit the U.K. in winter 2013/14, inundating parts of the known scaly cricket habitat. The aims of the present study were to establish new base-line data for future monitoring of the U.K.’s Scaly cricket populations and to compare the relative size (in terms of numbers caught per pitfall trap) and extent of each population prior to, and following, the storm surges of 2013/14.

All three populations (Chesil beach, Branscombe and Marloes Sands) were surveyed in summer 2016. Baited pitfall traps (with dried cat biscuits) were left overnight. This was combined with 15 min hand searches at the Marloes site. At each site, traps were placed at the same grid locations as in previous surveys.

At Branscombe (Fig. 2) and at Chesil, the number of scaly crickets per trap was significantly lower than in the pre-2013 surveys (i.e. before the storm surge). At Marloes, both the number per trap and number in timed searches were not significantly different than in the pre-2013 survey. However, loss of shingle habitat and a decline in scaly crickets was evident in the western half of the beach. Caution is needed in interpreting these results because they only represent separate snap-shots in time of populations that may naturally fluctuate from year to year. This study does, however, highlight the need for on-going monitoring of these populations.



Figure 1. A Scaly cricket nymph in its natural habitat at Chesil beach (Photo by Alex Hyde).

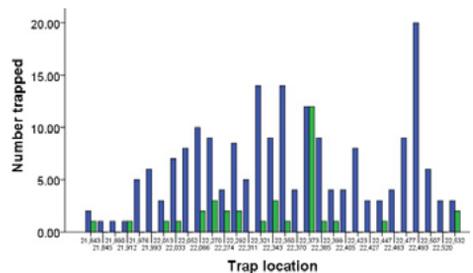


Figure 2. Number of crickets per trap at Branscombe in 2010 (blue; data from Laney & Shute, pers. com.) and in the present survey (green). The traps run west to east along the beach.

**Key Words:** Scaly cricket, Atlantic beach, cricket, Mogoplistidae, Conservation, Monitoring.

## Orthoptera Conservation

# EUROPEAN RED LIST OF GRASSHOPPERS: LEADS FOR CONSERVATION

Baudewijn Odé<sup>1</sup>, Axel Hochkirch<sup>2</sup>

<sup>1</sup> De Bongerd 29, 6584 DG Molenhoek, The Netherlands; baudewijnode@gmail.com

<sup>2</sup> Universität Trier, Department of Biogeography, D-54286 Trier, Germany; hochkirch@uni-trier.de

Conservation starts with an analysis of the status of a species. The IUCN Red List status based upon the best available information has proven to be an effective way to assess the extinction risk of species. Until recently this has been especially been done for local faunas or island endemics.

In 2016, a Red List assessment of all European grasshoppers (including crickets and bush-crickets) has been published, comprising all native 1082 species. A global Red List assessment has been done for 793 endemic species of Europe; the other species have been assessed at a regional level.

In Europe, taxonomy, distribution and ecology of Orthoptera is relatively well-known. The comprised dataset helps to identify the major conservation issues with species: which species are really threatened with extinction and what causes their decline. But also, which threats are predominant and in what regions do threats pose a significant pressure on native populations.

Threatened species are especially present in Southern Europe, highly coinciding with biodiversity hotspots for Orthoptera. Major threats are considered livestock grazing, arable farming, wildfires, urbanization and touristic development. Although climate change has been considered a threat for only 87 species, declines of species usually occur in response to a combination of factors.

The information gathered in the European Red List helps to set priorities for conservation measures. Preferably this is done both at a level of European, national or regional legislation, e.g. protecting species and their habitats, but also at local levels in nature reserves, protecting the species' habitat

from overgrazing, abandonment or other land use changes.

Seven species have been assessed as Possibly Extinct. This categorization usually elicits more faunistic research, which already resulted in the rediscovery of one of the species.

The European Red List also exposes that some 107 species lack information to properly assess the extinction risk. Listing those species stimulates researchers to raise more knowledge. Faunistic researchers should put more effort to survey the distribution of species through open databases but should also try to collect data on population sizes. Taxonomists should be stimulated to enhance their publications to be able to assess the Red List status of a species.

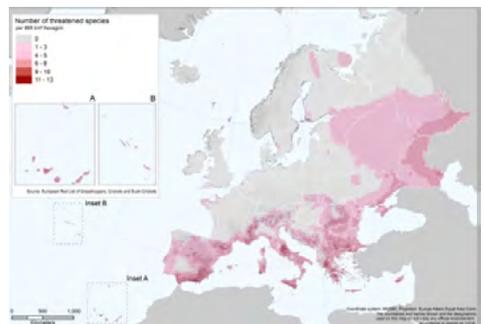


Figure 1. Distribution of threatened species in Europe.

**Key Words:** Conservation, Red List, Threats, Endemism, Measures, Monitoring, Data Deficient.

## Orthoptera Conservation

# DEVELOPING CONSERVATION STRATEGIES FOR THREATENED ORTHOPTERA

Axel Hochkirch

Trier University, Department of Biogeography, D-54286 Trier, Germany; hochkirch@uni-trier.de

In the light of dramatic insect declines that have been documented all over our planet, it is crucial to develop strategies to stop the ongoing loss of biodiversity. When dealing with the conservation of individual species, it is crucial to first gain some insight into the conservation status of the species, particularly its distribution, habitat, population trend and threats. IUCN Red List assessments are an important tool to evaluate the conservation status of species. However, in many cases the published information on the status of a species is far from adequate. For many species, only the information on the type locality exists. Therefore, virtually all conservation projects for Orthoptera first require some initial research to get more precise data on the distribution, habitat requirements and ongoing threats.

The IUCN SSC (Species Survival Commission) follows a strategic plan with 43 Key Species Results organized in an Assess-Plan-Act cycle. This means that assessments are done to improve the understanding of biodiversity and its threats, these assessments feed into planning, which facilitates the identification of the best conservation strategies to conserve biodiversity and these plans provide the necessary information to act to improve the status of biodiversity. When dealing with Orthoptera, it is evident that this Assess-Plan-Act cycle needs to be amended by a "Study"-Part. This means that we first need to perform research to be able to provide better assessments and that any conservation action needs to be monitored to improve our conservation plans.

The IUCN Guidelines for Species Conservation Planning provides valuable recommendations

how to plan conservation action for threatened species. The IUCN SSC Grasshopper Specialist Group has used this approach twice so far, to develop conservation strategies for two threatened Orthoptera species: The Crau Plain Grasshopper (*Prionotropis rhodanica*) and the Adriatic Marbled Bush-Cricket (*Zeuneriana marmorata*). Even these plans contain a relatively high number of research targets as comprehensive data on both species is lacking.

For the Crau Plain Grasshopper the conservation strategy has been implemented since 2014. First results suggest that intensive grazing might be a key threat to this species. Furthermore, innovative methods are being applied to optimize the monitoring, using detection dogs. For the Adriatic Marbled Bush-Cricket, two national conservation action plans have been developed for each of its countries of occurrence, i.e. Italy and Slovenia. Initial research has resulted in the rediscovery of two more populations of this species in the Venice region.

Strategic conservation planning follows a process of intensive stakeholder consultation during a joint workshop. Experience from the past workshop shows that there is strong support for Orthoptera conservation among stakeholders, including the regional administrations. However, the implementation of any new strategy is critically depending on the existence of a dedicated champion on the ground.

**Key Words:** conservation, threats, strategic planning, conservation action.



## Orthoptera Conservation

# UNRAVELLING THE THREATS TO THE CRAU PLAIN GRASSHOPPER (*PRIONOTROPIS RHODANICA*)

Linda Bröder<sup>1</sup>, Laurent Tatin<sup>2</sup>, Axel Hochkirch<sup>1</sup>

<sup>1</sup> Department of Biogeography, Trier University, 54296 Trier, Germany; linda.broeder@mailbox.org

<sup>2</sup> Conservatoire d'espaces naturels de Provence-Alpes-Côte d'Azur, 13310 Saint-Martin-de-Crau, France

For species conservation, it is essential to have a clear understanding of the main threats and the parameters affecting survival. But in some cases the threats are not obvious and it is difficult to identify complex threat structures. Consequently, reasons for population declines are unknown for some species.

The Crau Plain Grasshopper, *Prionotropis rhodanica*, is an example for a species in which the population declined strongly during the last two decades and where the reasons for the decline were largely unknown. The species is classified as Critically Endangered and endemic for the Crau steppe, a small Mediterranean stone steppe in southern France.

In 2014, an IUCN conservation strategy was developed, which includes several hypotheses on

potential threats and precise research objectives. Hereupon a broad range of field studies (microhabitat study, release-recapture experiment, camera trap experiment) has been implemented in order to survey potential reasons for the population decline. Our presentation will give an overview about how we unravelled the interaction of the ecological habitat requirements of the Crau Plain Grasshopper and the factors sheep grazing and predation by insectivorous birds.

**Key Words:** Conservation strategy, Threat analysis, Microhabitat structure, Livestock grazing, Predation pressure, Camera traps, Mark-release-recapture



## Orthoptera Conservation

# BIOACOUSTIC MONITORING AND MICROHABITAT PREFERENCES OF THE ADRIATIC MARBLED BUSH-CRICKET ZEUNERIANA MARMORATA

Anja Danielczak<sup>1</sup>, Axel Hochkirch<sup>2</sup>

<sup>1</sup> Trier University, Department of Biogeography, 54286 Trier, Germany; s6andani@uni-trier.de

<sup>2</sup> Trier University, Department of Biogeography, 54286 Trier, Germany; hochkirch@uni-trier.de

The Adriatic Marbled Bush-cricket-Zeunerianamarmorata, is an Endangered bush-cricket species, that was already thought to be extinct, until its rediscovery near Monfalcone (Italy) in 1996. Meanwhile it is known from the Slovenian marshes south of Ljubljana and a few wetland areas along the Adriatic coast of Italy. This species is facing a couple of threats like habitat conversion into cornfields, spread of invasive plant species, drainage for agricultural land use and the rising of sea level. In 2016 two national conservation action plans were developed including goals for conservation management, research and awareness raising.

The purpose of this study is the implementation of monitoring and research actions suggested in the conservation strategy. *Z. marmorata* is

hiding in dense vegetation and therefore difficult to find, but during suitable weather conditions, males seem to sing continuously. Hence, a bioacoustic monitoring was performed to study its distribution in Italy and Slovenia and to gather data on population sizes. Furthermore, data on microhabitat structure was collected to infer the effects of current grassland management on *Z. marmorata* and to make recommendations on the most suitable grassland management for this species. Results of the first year of data collection on distribution and effects of grazing and mowing regime on the species will be presented.

**Key Words:** Orthoptera, Conservation, management, *Zeuneriana marmorata*, Distribution



## SYMPOSIUM 2

### Forecasting Locust Risks

#### Organizer: Cyril PIOUS

CIRAD, UMR CBGP, 755 avenue du campus Agropolis,  
CS30016, 34988 Montferrier sur Lez - Cedex, France.  
Cyril.piou@cirad.fr

1. **Ted Deveson, G. Robert George.** APPROACHES TO USEFUL FORECASTS OF LOCUST EVENTS
2. **Keith Cressman.** DESERT LOCUST FORECASTING: ART OR SCIENCE?
3. **Robert A. Cheke, Xia Wang, Stephen Young, Jamie A. Tratalos, Sanyi Tang, Keith Cressman** WHAT ARE THE ULTIMATE CAUSES OF DESERT LOCUST OUTBREAKS?
4. **Mohammed F. Smiej, Mohammed Layelmam, Abderrahman Atillah, Cyril Piou, Saïd Ghaout** FORECASTS OF DESERT LOCUST PRESENCE IN MOROCCO COUPLING REMOTE SENSING IMAGERY AND FIELD SURVEYS
5. **Cyril Piou, Pierre-Emmanuel Gay, Ahmed Salem Benahi, Mohamed Abdallahi Ould Babah Ebbe, Jamal Chihrane, Saïd Ghaout, Sory Cisse, Fakaba Diakite, Mohammed Lazar, Keith Cressman, Olivier Merlin, Maria-José Escorihuela.** SOIL MOISTURE ESTIMATES FROM SATELLITE IMAGERY TO IMPROVE DESERT LOCUST FORECASTS
6. **Eduardo Trumper, David Hunter, Cyril Piou, Héctor Medina.** STUDIES TO IMPROVE THE FORECASTING OF THE SOUTH AMERICAN LOCUST, SCHISTOCERCA CANCELLATA IN ARGENTINA
7. **Jørgen Aagaard Axelsen, Idrissa Halidou Maiga.** SIMULATION STUDIES OF THE SENEGALESE GRASSHOPPER ECOSYSTEM I

## Forecasting locust risks

# APPROACHES TO USEFUL FORECASTS OF LOCUST EVENTS

Ted Deveson<sup>1</sup>, G. Robert George<sup>2</sup>

<sup>1</sup> Australian Plague Locust Commission, Department of Agriculture and Water Resources, Canberra, Australia; ted.deveson@agriculture.gov.au

<sup>2</sup> University of New South Wales, Sydney, Australia

The goal for predicting locust outbreaks is a forecast of high value and reasonable accuracy. The longer the lead time to a forecast event the higher value it has to users, because it allows a response plan or possible agricultural decisions relevant to the risk. The trade-off is lower certainty and often lower accuracy. Forecasts contain information on timing, location and scale of events, as well as duration and migrations. Accuracy can be measured against these elements and should include expressions of probability or uncertainty.

Many methods of predicting transitions between population states, particularly increases or declines, have been developed. A broad range of environmental, control and sociological measures relevant to locust recruitment success have been utilised. The scope and technical complexity of environmental data sources, as well as statistical treatments of relevance has continued to broaden in this century.

Timescales of forecasts range from weeks, seasons, interannual and now interdecadal, as suites of models of future climate extend to the end of this century. The base information flow in operational forecasting practice is prior population level and stage. As habitat productivity is often the primary driver of successful recruitment, measures of climate and environmental conditions are used to remotely model population outcomes. Where long-term values of locust

abundance are available, the matching of population fluctuations with historical climate data is often used to establish relationships with potential predictive value.

We review the development of modelling approaches and their associated technologies used to assist Australian locust forecasting. We present the results of modeling the seasonal extent of *Chortoicetes terminifera* swarming using lagged rainfall data and meteorological forecasting indices, based on the El Niño Southern Oscillation of tropical Pacific Ocean temperatures. The goal was to build and test simple models to predict the geographical extent of swarms at 90-270 day lead time. Seasonal models were developed in a generalised additive model (GAM) framework. Models that included lagged locust extent performed better than those using only meteorological data.

The performance and limitations of the models relative to twenty-first century outbreaks are discussed. Establishing any fundamental meteorological relationships with locust extent could provide background to extending spatially explicit range dynamics models that make use of outputs from numerical weather prediction systems with equivalent lead times.

**Key Words:** *Chortoicetes terminifera*, locust forecasting, seasonal extents, population modelling.

## Forecasting locust risks

# DESERT LOCUST FORECASTING: ART OR SCIENCE?

*Keith Cressman*

*UN Food and Agriculture Organization, Rome, Italy; keith.cressman@fao.org*

---

The Desert Locust (*Schistocerca gregaria* Forskål 1775) is the most damaging of migratory pests in Africa and Asia. The Food and Agriculture Organization of the United Nations (UN FAO) operates a global early warning system as part of the preventive control strategy to reduce the duration, intensity and frequency of locust plagues and to protect livelihoods and food security in some of the world's poorest countries. A key component of this system is the accurate forecasting of the location, time and scale of locust presence, breeding, gregarization and migration. A number of techniques, tools and products are utilized to provide sub national-level forecasts to affected countries and the international community up to six weeks in advance.

Despite significant advances in remote sensing, communications and other technologies, formidable challenges associated with climate change, incomplete monitoring, insecurity and sustainability impact the early warning system. As a result, Desert Locust forecasting can be considered as much art as it is science. This presentation provides an overview of Desert Locust forecasting while illustrating some major successes and highlighting areas that require additional efforts and collaboration.

**Key Words:** migratory pest, Desert Locust, early warning, forecasting, remote sensing, FAO

## Forecasting locust risks

# WHAT ARE THE ULTIMATE CAUSES OF DESERT LOCUST OUTBREAKS?

Robert A. Cheke<sup>1</sup>, Xia Wang<sup>2</sup>, Stephen Young<sup>1</sup>, Jamie A. Tratalos<sup>3</sup>, Sanyi Tang<sup>2</sup>, Keith Cressman<sup>4</sup>

<sup>1</sup> Natural Resources Institute, University of Greenwich at Medway, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK; r.a.cheke@greenwich.ac.uk

<sup>2</sup> School of Mathematics and Information Science, Shaanxi Normal University, Xi'an, 710119, P.R.China

<sup>3</sup> Centre for Veterinary Epidemiology and Risk Analysis, School of Veterinary Medicine, University College, Belfield, Dublin 4, Republic of Ireland

<sup>4</sup> Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy

The proximate, short term, causes of outbreaks of locusts, including the Desert Locust *Schistocerca gregaria*, are combinations of the timings, geographical distributions and amounts of rainfall and associated vegetation growth. However, what controls these drivers, and the degree to which they are cyclic, is poorly understood. Various hypotheses, such as that sunspot activity plays a major role, have been advanced by entomologists since 1883 to account for long term patterns in locust numbers but statistical analyses have not offered strong evidence for any causal links. In this study we employed new mathematical methods to demonstrate causality between time series. We will present results of applying such techniques to the analysis of the FAO data on numbers of territories infested with swarms of the desert locust from 1866 to 2015. Most of our analyses were conducted on the "inferred series" which adjusts for poor reporting during 1866 to 1925. Spectral analysis revealed a significant peak, with a periodicity of 13 years and a 7.5 year harmonic. For further analyses, we converted the raw inferred time series data for the 1930 to 2015 period, when data are thought to be consistently reliable, from numbers per territory to numbers per 1 degree grid square, and separated them into regions (Western, North Central, South Central and Eastern). For these truncated series, the peaks, although still present, were not statistically significant for either the whole series or regional subsets of the data. To examine whether there were any links between oceanic circulation systems and / or sunspots and desert Locusts we separated the various data sets into low (LF) and high frequency (HF) components by Kalman filtering.

We then sought evidence of causal links by testing with Multispatial Convergent Cross Mapping methods (Clark et al. 2015, *Ecology* 96: 1174–1181). Statistically significant evidence was found that both the LF sunspots and the LF Southern Oscillation index (SOI) had causal links with the LF inferred locust series. In addition, the LF North Atlantic Oscillation index (NAO) was causally linked with the LF gridded data, with the NAO for December-March being most influential on the latter. Also, the raw sunspots data were causally linked with the total for the LF gridded data and for the LF of all of the four regions.

The well-known approximately 11 year periodicity in the sunspots series was confirmed. This, taken together with a 1 to 4 year lag between the onset of suitable environmental conditions and the time needed for locust phase changes to accrue and build up to a plague suggest that the sunspot cycles are driving the locust dynamics. The details of how solar activity affects weather patterns and exactly how these in turn influence the locust dynamics remain unclear. Given evidence for cyclicity in sunspot activity and a delay in a similar response in the insect dynamics, it is possible that with further research a method of forecasting long term trends in desert locust outbreaks may become feasible as a supplement to current short term methods.

**Key Words:** Desert Locust, Spectral Analysis, Kalman Filter, Multispatial Convergent Cross Mapping, Sunspots, Oceanic Circulation Systems, Forecast.



## Forecasting locust risks

# FORECASTS OF DESERT LOCUST PRESENCE IN MOROCCO COUPLING REMOTE SENSING IMAGERY AND FIELD SURVEYS

Mohammed F. Smiej<sup>1</sup>, Mohammed Layelmam<sup>2</sup>, Abderrahman Atillah<sup>1</sup>, Cyril Piou<sup>3,4,5</sup>, Saïd Ghaout<sup>4</sup>

<sup>1</sup> Centre Royal de Télédétection Spatiale, Rabat, Morocco; smiej@crts.gov.ma

<sup>2</sup> Institut Agronomique et Vétérinaire Hassan II, Rabat, Morocco

<sup>3</sup> CIRAD, UMR CBGP, Montpellier, France

<sup>4</sup> Centre National de Lutte Anti-acridienne, Agadir, Morocco

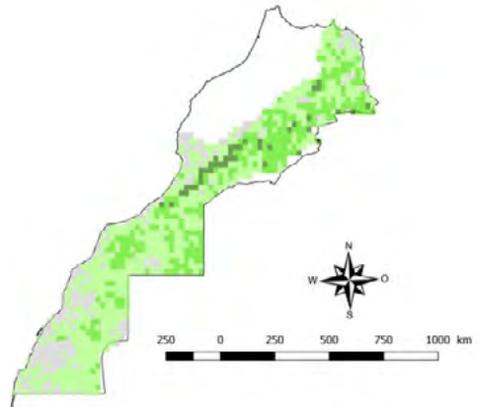
<sup>5</sup> University Ibn Zohr, Agadir, Morocco

With the objective of improving preventive management of desert locust, an operational system was developed to help in the planning of field surveys in Morocco. This operational system produce regularly some presence probability maps of solitarious or transiens desert locust. The spatial resolution is 25km over the Moroccan territory and the temporal horizon of the forecasts are 40 days.

The forecasts are based on statistical models coupling historical data of field surveys with several layers of remote sensing imagery. These images are proxy of environmental variables important for desert locust: temperature, rainfall and vegetation availability. The statistical coupling was realised with random forest models. These models were assessed with a splitting of the data to evaluate the forecast errors and validate the approach. An automatic process was also developed to transform new remote sensing imagery into probability maps in order to operationalize the system.

As the system has been running for over 3 years, another level of evaluation can be presented: the correspondence between the forecasts of probability of locust presence and

the actual observations of field survey teams of the national anti-locust centre of Morocco since 2015.



**Figure 1.** Example of probability map of the operational system with levels of green indicating probability of presence of desert locust (gray=0; dark green =1)

**Key Words:** *Schistocerca gregaria*, random forest models, forecasting tool, remote sensing

## Forecasting locust risks

# SOIL MOISTURE ESTIMATES FROM SATELLITE IMAGERY TO IMPROVE DESERT LOCUST FORECASTS

Cyril Piou<sup>1,2,3</sup>, Pierre-Emmanuel Gay<sup>1</sup>, Ahmed Salem Benahi<sup>4</sup>, Mohamed Abdallahi Ould Babah Ebbe<sup>4,5</sup>, Jamal Chihrane<sup>2</sup>, Saïd Ghaout<sup>2</sup>, Sory Cisse<sup>6</sup>, Fakaba Diakite<sup>6</sup>, Mohammed Lazar<sup>7</sup>, Keith Cressman<sup>8</sup>, Olivier Merlin<sup>9</sup>, Maria-José Escorihuela<sup>10</sup>

<sup>1</sup> CIRAD, UMR CBGP, Montpellier, France;  
cyril.piou@cirad.fr

<sup>2</sup> Centre National de Lutte Antiacridienne, Agadir,  
Morocco

<sup>3</sup> University Ibn Zohr, Agadir, Morocco

<sup>4</sup> Centre National de Lutte Antiacridienne, Nouakchott,  
Mauritania

<sup>5</sup> Institut du Sahel/CILSS, Bamako, Mali

<sup>6</sup> Centre National de Lutte contre le Criquet pèlerin,  
Bamako Mali

<sup>7</sup> Institut National de la Protection des Végétaux, Alger

<sup>8</sup> Food and Agriculture Organization of the United  
Nations, Rome, Italy

<sup>9</sup> CESBIO, Univ Toulouse, IRD, UPS, CNRS, CNES,  
Toulouse, France

<sup>10</sup> isardSAT, Barcelona, Spain

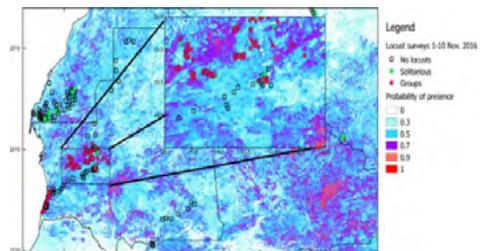
Desert locust is still a major threat to agriculture in an extensive area from Western Africa to India. The preventive management of Desert locust relies on surveying its potential habitats to find outbreaks as early as possible and control the gregarizing populations. Despite being a major ecological driver of Desert locust populations, soil moisture is missing in the current imagery toolkit for preventive management. The SMELLS project funded by the European Space Agency proposed to develop a product of 1km resolution estimates of soil moisture in 4 countries of Western and Northern Africa to test the potential help of soil moisture in Desert locust preventive management.

We used statistical analyses coupling locust presence/absence observations from field surveys with the soil moisture product to evaluate how soil moisture dynamics may influence the development of locust populations. Further analyses aimed in comparing the potential help of soil moisture in preventive management compared to vegetation index, rainfall estimates and soil temperature. Finally, a forecasting model was established with a random-forest approach using both vegetation index and soil moisture.

We observed that a soil moisture dynamics of increase above 9% for 20 days followed by a decrease of soil moisture may increase the chance to observe locusts 70 days later. The gain in early warning timing compared to using imagery from

vegetation was estimated to be three weeks. We demonstrated that the errors of the forecasting model may be reduced by the combination of structural and dynamical indicators of soil moisture and vegetation index. However, the forecasts of locust presence were not perfect and there were plenty of room for improvements.

Nevertheless, we recommend the use of maps of soil moisture estimates in the planning of survey campaign of Desert locust as the gain in timing is substantial compared to vegetation index products.



**Figure 1.** Example of forecasting map of locust presence based on soil moisture over 3 months before November 2016 with observations of locusts during the first decade of that month.

**Key Words:** *Schistocerca gregaria*, satellite imagery, SMOS mission, preventive management, NDVI



## Forecasting locust risks

# STUDIES TO IMPROVE THE FORECASTING OF THE SOUTH AMERICAN LOCUST, *SCHISTOCERCA CANCELLATA* IN ARGENTINA

Eduardo Trumper<sup>1</sup>, David Hunter<sup>2</sup>, Cyril Piou<sup>3</sup>, Héctor Medina<sup>4</sup>

<sup>1</sup> INTA, EEA Manfredi, Ruta Nacional 9, Km636, 5988 Manfredi, República Argentina. [trumper.eduardo@inta.gob.ar](mailto:trumper.eduardo@inta.gob.ar)

<sup>2</sup> Locust and Grasshopper Control, 125 William Webb Drive, McKellar, Canberra, Australia.

<sup>3</sup> CIRAD, UMR CBGP, Montpellier, France.

<sup>4</sup> SENASA, Programa Nacional de Langostas y Tucuras, CABA, República Argentina

The south american locust (sal), *schistocerca cancellata*, was in plague proportions in 48 of the 58 years from 1897 to 1954, but following the introduction of a program of preventive management, there were no plagues for 60 years. Preventive management relies on regular monitoring of locust infestations in northwest Argentina (nwa) with treatment of any bands and swarms detected. However, many swarms “suddenly” appeared in Santiago del Estero province in nwa in July 2015, and populations then increased further to reach plague proportions. We aimed to analyse the factors leading to the initial outbreak of swarms and their further increase through two complementary approaches: 1) a chronological analysis relating population dynamics to rainfall and 2) a correlation analysis looking at reproduction events and vegetation dynamics. Both were conducted using a sal monitoring data base running from 2013 to 2018.

Previous studies during the 1980's found a correlation between outbreaks and rains from winter/early spring through summer in nwa allowing three generations in a season. It was hypothesized that rainfall provided green herbaceous vegetation for adult maturation and survival of nymphs, and soil moisture for egg survival and hatching. Our analyses show that during the 2014-15 seasons, only two generations were possible in catamarca, and the few bands found there were treated. However, even though three generations were possible in at least four other provinces in nwa, except for la rioja, they had either limited surveys or none at all. These provinces could have been the source of breeding that led to the July 2015 swarms. Three

generations were also possible in many areas during both 2015-16 and 2016-17 seasons—resulting in further sal population increase. During the summer of 2016-17, most locusts migrated to Bolivia and Paraguay and had the third generation there. During June 2017, these swarms invaded Argentina in plague proportions and even though a number of swarms were treated, widespread oviposition was reported. While the large 2017 outbreak of the sal was eventually reduced, early infestations were not detected which may be avoided in the future by having a system in place to detect conditions particularly favourable for locusts. Modis satellite imagery was used to analyse vegetation conditions in the permanent breeding and recession regions of nwa. based on a logistic regression approach, the presence/absence of reproduction events was correlated to point ndvi measures with and without a range of time lags with respect to monitoring dates, the minimum and maximum historical ndvi, and the ndvi difference between date of reproduction events and minimum historical ndvi. The most promising models were identified with aic and auc statistics. These models reported a potential increase of reproduction success in areas with high historical ndvi variation, which is a signature of semi-desert areas, and recent increase in ndvi at a scale of 2 months, which supports the hypothesis of outbreaks being related to rainfall. These results could be the basis of an improved early warning system for sal preventive management.

**Key Words:** South American locust, upsurge, forecast, ndvi, rainfall.



## Forecasting locust risks

# SIMULATION STUDIES OF THE SENEGALESE GRASSHOPPER ECOSYSTEM INTERACTIONS: THE ECOSYSTEM MODEL AND THE OPTIMIZATION OF GRASSHOPPER CONTROL

Jørgen Aagaard Axelsen<sup>1</sup>, Idrissa Halidou Maiga<sup>2</sup>

<sup>1</sup> Institut for Bioscience - Plante- og insektøkologi, Silkeborg, Denmark; jaa@bios.au.dk

<sup>2</sup> AGRHYMET Regional Centre, Niamey, Niger

The Senegalese Grasshopper (*Oedaleus senegalensis* Krauss, 1877) (SG) is a well-known pest on millet in the Sahel countries, and most spray campaigns are aimed at this particular species. This pest breeds in the rainy season throughout the Sahel and can have three generations per year developing at different geographic latitudes. The first generation can cause serious damage on millet seedlings forcing farmers to plant repeatedly until they run out of seed. When adult, these grasshoppers move northwards, where their offspring cause only little damage to the growing crops because they prefer to stay in the grassland. The most serious damage is caused when the third generation of grasshoppers, which to a large extent develops in the grasslands north of the millet belt, migrates back southwards in large swarms, damaging the ripening millet ears. A model that can simulate the ecosystem dynamics of the SG in the Sahel is presented. It includes the migration of the SG by simulating the population dynamics and migration in a number of locations on a S-N transect. The model ecosystem in each location is millet, a natural Sahelian grass representing the grassland vegetation, the SG, a less important grasshopper, *Acrotylus blondeli*, two species of egg pod predators and 24 species of birds preying on grasshoppers. The model requires input on grasshopper densities and has been created for integrated with a grasshopper monitoring program. Furthermore, the model is rain driven and uses real weather measurements as input, and it is able to include the impact of grasshopper control measures such as treatments with chemical pesticides and the biopesticide Green Muscle®. The model has a wide variety of

possible applications and may be used for both scientific and practical purposes. The scientific purposes might be concerned with the relative roles of the natural egg pod predators and the many grasshopper consuming bird species and the ecological balance of a pest species that is under extensive natural control. The practical purposes might be to simulate the impact of various control strategies on both the millet yield and the environment, and it can be used to make projections of where on the south – north migration route it is most profitable to carry out control operations.

The model was used to evaluate the impact of grasshopper control campaigns in 2004. Results showed that the largest impact on the “cumulated transect grasshopper days” was obtained by the spraying carried out at the southernmost location of the transect. Sensitivity analysis of some of the input parameters that had been estimated during the calibration process or might vary from year to year were performed, and it was found to be sensitive to changes in the relative start densities in the two southernmost locations. Integrated with a monitoring program the model can be a central element in a decision support system on grasshopper control. It can also be modified to simulate other pests. A similar model on fruit fly damage in mango plantations has been integrated in a decision support system and implemented in ten countries in the West African Fruit Fly Surveillance project financed through ECOWAS.

**Key Words:** control campaigns, ecosystem model, metabolic pool, pest management, population dynamics, simulation model.



## SYMPOSIUM 3

### Orthopteran Physiology

#### Organizer: Amir Ayali

School of Zoology, Tel Aviv University, Tel Aviv, Israel  
ayali@tauex.tau.ac.il

1. **Uwe Homberg, Frederick Zittrell, Uta Pegel, Keram Pfeiffer, Basil el Jundi, Stanley Heinze.** THE CENTRAL COMPLEX-AN INTERNAL SKY COMPASS IN THE LOCUST BRAIN
2. **Amir Ayali, Stav Talal, Eran Gefen.** LOCUSTS AND GRASSHOPPERS AS MODELS IN THE STUDY OF RESPIRATION AND DISCONTINUOUS GAS EXCHANGE
3. **Stephen Rogers.** MECHANISMS OF BEHAVIOURAL PHASE CHANGE IN THE AUSTRALIAN PLAGUE LOCUST, CHORTOICETES TERMINIFERA
4. **Paul A. Stevenson, Jan Rillich.** NEUROTRANSMITTERS AND THE DECISION TO FIGHT OR FLEE - NOVEL INSIGHTS ON AGGRESSION FROM CRICKETS
5. **Jozef Vanden Broeck.** RECENT ADVANCES IN THE STUDY OF NEUROPEPTIDES AND THEIR RECEPTORS IN LOCUST PHYSIOLOGY



## Orthopteran Physiology

# THE CENTRAL COMPLEX-AN INTERNAL SKY COMPASS IN THE LOCUST BRAIN

Uwe Homberg<sup>1</sup>, Frederick Zittrell<sup>1</sup>, Uta Pegel<sup>1</sup>, Keram Pfeiffer<sup>1,2</sup>, Basil el Jundi<sup>1,2</sup>, Stanley Heinze<sup>1,3</sup>

<sup>1</sup> Faculty of Biology and Center for Mind, Brain and Behavior (CMBB), University of Marburg, Marburg, Germany; homberg@biologie.uni-marburg.de

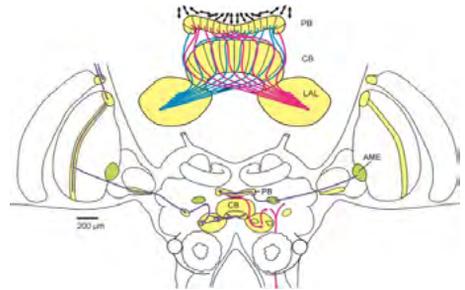
<sup>2</sup> Behavioral Physiology and Sociobiology, Biocenter, University of Würzburg, Würzburg, Germany

<sup>3</sup> Lund Vision Group, Department of Biology, Lund University, Sweden

Desert locusts, like many other insect species, are able to use celestial cues, like the position of the sun or the polarization pattern of the blue sky, for spatial orientation (Kennedy 1945, *Trans R Entomol Soc Lond* 95:247) and likely make use of this capacity during their seasonal migrations (Homberg 2015, *Front Behav Neurosci* 9:346). Sky polarization is detected by insects through a highly specialized dorsal eye region, the dorsal rim area. Desert locusts, *Schistocerca gregaria*, have a particularly prominent dorsal rim area. In laboratory experiments, tethered flying locusts show polarotactic yaw torque responses mediated by photoreceptors of the dorsal rim area (Mappes and Homberg, 2004, *J Comp Physiol A* 190:61), confirming the role of this eye region in the detection of the plane of polarized light. Tracer injections into the eye and several underlying brain areas revealed that polarization vision pathways from the dorsal rim areas converge in the central complex, a group of neuropils, including the protocerebral bridge (PB) and the central body (CB), spanning the brain midline (Homberg et al., 2003 *J Comp Neurol* 462:415).

Neurons of the central complex are highly sensitive to the oscillation plane of polarized light presented from dorsal directions. Columnar neurons of the central complex topographically represent heading directions of the animal based on preferred polarization angle (Heinze and Homberg 2007, *Science* 315:995). Receptive field analyses showed that neurons collect polarization angle information from the entire sky in patterns matching particular sun positions. In addition to polarization sensitivity, all neurons of the sky compass network also encode the azimuthal

direction of unpolarized light spots likely representing the sun (Pegel et al. 2018, *J Exp Biol* 221). Outputs from the central complex target descending pathways via the lateral accessory lobes (LAL) suited to control navigational directions of the animal. Input from the accessory medulla (AME), the presumed circadian clock of the locust, to the PB might serve for time compensation during long-range migrations. The system of sky compass coding in the locust appears to fulfill a function equivalent to mammalian head direction cells, which likewise code for orientation of the animal in space.



**Polarization vision pathways in the brain of the desert locust.** Upper panel: topographic representation of preferred polarization angles (double arrows) in columns of the protocerebral bridge (PB) and central body (CB). Lower panel: polarization vision pathways (blue, left) to the CB, presumed pathway for time compensation (blue, right), and outputs for motor control (red arrows) via the lateral accessory lobes (LAL).

**Key Words:** Spatial orientation, Sky compass, Dorsal rim area, Central complex, Polarization vision, *Schistocerca gregaria*



## Orthopteran Physiology

# LOCUSTS AND GRASSHOPPERS AS MODELS IN THE STUDY OF RESPIRATION AND DISCONTINUOUS GAS EXCHANGE

Amir Ayali<sup>1</sup>, Stav Talal<sup>1</sup>, Eran Gefen<sup>2</sup>

<sup>1</sup> School of Zoology, Tel Aviv University, Tel Aviv, Israel; ayali@post.tau.ac.il

<sup>2</sup> Department of Biology, University of Haifa-Oranim, Israel

Insects exchange respiratory gases through an extensive network of tracheae that open to the surface of the body through segmental spiracles. Monitoring CO<sub>2</sub> release at rest or at low metabolic rates reveals, in some insects, a discontinuous gas exchange (DGE) pattern, consisting of short periods of spiracular gas flow, separated by long periods characterized by closure of the spiracular openings. In actively ventilating insects, such as locust and grasshoppers, respiration involves, in addition to spiracular activity, abdominal pumping movements.

In order to better understand the complexity of insect respiratory motor activity and its neural control, we simultaneously monitored CO<sub>2</sub> emission, activity of the closer muscles of thoracic and abdominal spiracles, and the abdominal ventilatory muscles' motor patterns in fully intact desert locusts demonstrating DGE. We found that during the burst of CO<sub>2</sub> emission, the spiracles opened and closed rapidly rather than remained continuously open. This activity was strongly correlated with rhythmic abdominal ventilation activity. Abdominal spiracles were

found to open out-of-phase of the thoracic ones and in-phase with the ventilation muscles activity, thus facilitating a unidirectional flow of air through the body.

Bursts of abdominal constrictor muscles were tightly coupled to increased activity of the thoracic spiracle closure muscle also during the long periods of spiracle closure, facilitating efficient mixing of the tracheal gas content.

In order to further investigate the control of ventilatory pattern generation by concentrations of respiratory gases, we recorded the motor output of in-vitro isolated thoracic ganglia. We kept the main tracheae intact and perfused them with various mixtures of CO<sub>2</sub> and O<sub>2</sub>. CO<sub>2</sub> levels were found to strongly modulate the fictive ventilatory activity. This modulation was, however, affected by O<sub>2</sub> concentrations. Our findings indicate central sensing of both respiratory gases and interactions in their effects on the respiratory output from the CNS.

**Key Words:** Ventilation, spiracles, central patten generation, motor pattern coupling, modulation



## Orthopteran Physiology

# MECHANISMS OF BEHAVIOURAL PHASE CHANGE IN THE AUSTRALIAN PLAGUE LOCUST, *CHORTOICETES TERMINIFERA*

Stephen Rogers

Department of Zoology, University of Cambridge, United Kingdom; smr34@cam.ac.uk

The Australian plague locust, *Chortoicetes terminifera*, like other locusts can transform between solitary and gregarious phases, developing different behavioural and physiological strategies to cope with altered lifestyles and environments. Behavioural change is mediated by changes in population density as in other locust species but the time course and mechanisms driving the transformation are little understood. Laboratory colonies of *C. terminifera* were reared either in complete isolation from other locusts or in cages containing several hundred locusts. Final larval instar solitary-reared locusts were crowded by being placed in high-population density locust cages for periods between 1-72 h, and crowd-reared locusts were isolated for similar periods. Behaviour was observed at different time intervals using an arena-based assay that measured overall activity and attraction / repulsion to other locusts.

The locusts were then flash frozen and amounts of biogenic amines in the brain and thoracic nerve cord measured using High Pressure Liquid

Chromatography (HPLC). Both gregarisation and solitarisation followed similar time-courses in this species.

There was an initial period of rapid behavioural change lasting a few hours which took the locusts to an intermediate state, followed by a longer period of slower change lasting 2-3 days after which the locusts behaviourally fully resembled those of the opposite phase.

Amounts of octopamine increased during gregarisation and tracked the entire process, whereas dopamine tracked the initial stage only. Biogenic amine titres however, did not closely track the process of behavioural solitarisation. Even after three days of isolation, after which behaviour had become fully solitary, amounts of all biogenic amines were still higher than in solitary-reared locusts.

**Key Words:** Phase-change, behavioural assay, biogenic amine, solitary, gregarious, octopamine, dopamine.

## Orthopteran Physiology

# NEUROTRANSMITTERS AND THE DECISION TO FIGHT OR FLEE - NOVEL INSIGHTS ON AGGRESSION FROM CRICKETS

*Paul A. Stevenson, Jan Rillich*

*University of Leipzig, Institute for Biology, Talstr. 33, 04103 Leipzig, Germany; stevenson@rz.uni-leipzig.de*

Aggression between individuals of the same species serves to secure limited resources, but the costs involved can quickly outweigh the potential rewards. Hence, for aggression to be evolutionary adaptive, animals must somehow decide when best to flee, rather than fight. How it's done, is arguably best understood in adult male crickets (*Gryllus bimaculatus*). Our work has revealed that these insects implement the decision by simply modulating the behavioural threshold to flee. This threshold is raised by potentially rewarding, or at least non-aversive, experiences (resource possession, winning, physical exertion, male contact), as a direct result of the concomitant activation of the octopamine system. Hence in effect, the animal becomes less prone to flee on contacting an adversary and will accordingly persist longer in fighting. The amine octopamine can thus be regarded as the motivational component of aggression. Conversely, the threshold to flee is lowered by nitric oxide, which is released in response to aversive stimuli experienced during fighting: primarily the opponent's offensive agonistic actions. Hence, the gaseous neuromodulator nitric oxide acts in effect to increase the tendency to flee in response to an opponent's momentary aggressive actions. Crickets will then actually

retreat, the moment when the sum of their opponent's offensive actions accumulated during fighting exceeds the threshold to flee. Due to the action of nitric oxide, the resultant loser has a low threshold to flee, and hence appears to be non-aggressive, since it tends to retreat on even slightest contact with a conspecific male. This state of depressed aggressiveness in losers is maintained by interaction of nitric oxide with serotonin, and usually last 3 hours, but can for last days after multiple defeats due to the continued action of serotonin acting via type 2 like receptors. Both octopamine and dopamine can restore aggression in losers, whereby dopamine, but not octopamine, is actually necessary for natural recovery after defeat. Our current work is now showing how social experience, and in particular, multiple defeat, can have life-long consequences for a cricket's total behavioural profile, i.e. its "personality" to use the currently en vogue term.

Our work is supported by the German Research Council (DFG grants STE 714/4-1, STE 714/5-1; RI 2728/2-1).

**Key Words:** Social behaviour, decision making, agonistic behaviour, nitric oxide, serotonin, octopamine, dopamine.



## Orthopteran Physiology

# RECENT ADVANCES IN THE STUDY OF NEUROPEPTIDES AND THEIR RECEPTORS IN LOCUST PHYSIOLOGY

Jozef Vanden Broeck

Molecular Developmental Physiology and Signal Transduction lab, Division of Animal Physiology and Neurobiology, Department of Biology, KU Leuven, Belgium; [jozef.vandenbroeck@kuleuven.be](mailto:jozef.vandenbroeck@kuleuven.be)

Despite their huge biodiversity, some fundamental characteristics are shared by all animals. Insects, like other metazoans, are heterotrophs, implicating the basic need for the intake of food. Subsequently, their metabolism, growth, postembryonic development and reproduction will depend on this nutritional and energetic input. Therefore, it is crucial that they can rely on physiological mechanisms controlling and integrating these essential processes. Nutrient-sensing, hormonal and neuronal signalling systems are playing an important role in this complex regulation.

In this presentation, we will consider a few neuropeptide-mediated signalling pathways that are implicated in the regulation of developmental-physiological processes in insects. In particular, we will discuss recent data obtained in the locusts, *Schistocerca gregaria* and *Locusta migratoria*, which are swarming pest species that irregularly devastate the agricultural production in large areas of the world. In a physiological and neurobiological context, they have proven to be interesting experimental research organisms. We also evaluated the potential of peptido-mimetic analogues to interfere with neuropeptide receptor signalling, as well as

downstream physiological processes. Moreover, RNA interference constitutes a highly efficient and robust method to silence the expression of peptide precursors and/or receptors in several insect species, including locusts.

We have identified several insect neuropeptide precursors and receptors and will report on our recent physiological and molecular biological studies that further illustrate the important role of neuropeptides and their receptors in locusts. The general aim of our work is to contribute to a better understanding of the regulation of postembryonic processes, as well as of the functional interactions between different regulatory pathways in an integrative -organismal/systemic - physiological context.

**Acknowledgements:** We gratefully acknowledge the EU (Horizon-2020 project nEUROSTRESSPEP), the Research Foundation of Flanders (FWO-Flanders), the Interuniversity Attraction Poles program (Belgian Science Policy Grant IAP P7/40) and the Special Research Fund of KU Leuven (C14/15/050) for financial support.

**Key Words:** Phase-change, behavioural assay, biogenic amine, solitary, gregarious, octopamine, dopamine.



## SYMPOSIUM 4

### Sexual selection in the Orthoptera

#### Organizers: Gerlind Lehmann<sup>1</sup> and Karim Vahed<sup>2</sup>

<sup>1</sup> Humboldt University Berlin, Department of Biology, Invalidenstrasse 43 10115 Berlin, Germany  
gerlind.lehmann@biologie.hu-berlin.de, gerlind.lehmann@t-online.de, www.guclehmann.de

<sup>2</sup> University of Derby, Department of Biosciences, Kedleston Road, Derby DE22 1GB E-mail:k.vahed@derby.ac.uk

1. **Marianna Anichini, Fran Rebrina, Klaus Reinhold, Gerlind U.C. Lehmann.** EFFECT OF IMMEDIATE NEIGHBOURS AND MALE BODY CONDITION ON SIGNALLING STRATEGIES IN THE BUSHCRICKET *POECILIMON VELUCHIANUS*
2. **Nathan W. Bailey.** SEXUAL SELECTION AFTER SIGNAL LOSS: BEHAVIOUR AND GENOMICS OF ADAPTIVE SONG LOSS IN FIELD CRICKETS
3. **Susan M. Bertram, Sarah J. Harrison.** THE INFLUENCE OF DIETARY NUTRIENT BALANCE ON FEMALE SEXUAL RESPONSIVENESS AND MATE PREFERENCES
4. **Darron A. Cullen, Gregory A. Sword, Stephen J. Simpson, Jozef Vanden Broeck.** CAROTENE-BASED SEXUAL SIGNALLING IN LOCUSTS
5. **Klaus-Gerhard Heller, Claudia Hemp.** WHAT'S THE MAIN DRIVING FORCE FOR SONG EVOLUTION IN THE GENUS *EURYCORYPHA* (TETTIGONIOIDEA, PHANEROPTERINAE)?
6. **Clint D. Kelly.** SEXUAL SELECTION AND PHENOTYPIC DIVERSITY WITHIN AND BETWEEN THE SEXES IN THE WELLINGTON TREE WETA
7. **Gerlind U.C. Lehmann.** BUSHCRICKET GENITALIA AND FEMALE CHOICE (ORTHOPTERA: ENSIFERA: TETTIGONIIDAE)
8. **Edith Julieta Sarmiento-Ponce, Berthold Hedwig.** LIFETIME STUDY IN CRICKETS REVEALS NO CHANGE OF FEMALE CHOOSINESS
9. **Johannes Strauß.** WHAT DETERMINES THE NUMBER OF AUDITORY SENSILLA IN THE TYMPANAL HEARING ORGANS IN TETTIGONIIDAE?



## Sexual selection in the Orthoptera

# EFFECT OF IMMEDIATE NEIGHBOURS AND MALE BODY CONDITION ON SIGNALLING STRATEGIES IN THE BUSHCRICKET *POECILIMON VELUCHIANUS*

Marianna Anichini<sup>1</sup>, Fran Rebrina<sup>2</sup>, Klaus Reinhold<sup>3</sup>, Gerlind U.C. Lehmann<sup>1</sup><sup>2</sup>

<sup>1</sup> Humboldt University Berlin, Department of Biology, 10115 Berlin, Germany; [mary.anichini@gmail.com](mailto:mary.anichini@gmail.com), [marianna.anichini@student.hu-berlin.de](mailto:marianna.anichini@student.hu-berlin.de)

<sup>2</sup> Bijenička cesta 182, 10000 Zagreb, Croatia

<sup>3</sup> Universität Bielefeld, Faculty of Biology, 33615 Bielefeld, Germany

In many acoustic communicating species chorusing evolved. Signalling males act as both senders and receivers. Acoustic cues are used to respond to neighbouring competing males and to attract choosing females. In a chorus, changes of social composition might determinate variations of competition pressures and signalling effort. To maintain an effective communication and deal with social heterogeneity, individuals may alter their acoustic production. Although plasticity of traits can be advantageous for signallers, intrinsic and extrinsic factors might affect its expression. As plasticity produces fitness costs, variations between males in adjustment of their acoustic traits to social environmental changes are expected. To explore this possibility, we used the Phaneropterinae bushcricket *Poecilimon veluchianus* as model organism.

We investigated the acoustic responses of heavy and light males in competition against rivals of different type and number. We predicted that males alter the magnitude of acoustic response only depending on the social environment. Heavier focal males should show a plastic response with greater magnitude than light males.

We found an interaction effect between both, male condition in terms of body mass and social external factors.

Only heavy males showed significant plasticity in their signalling behaviour depending on type and number of rivals. When competing against two heavy rivals, they signalled with low effort, shorter verses and reduced number of syllables, in comparison to facing any other constellation of rivals. Moreover, when contesting against light rivals, heavy focal males signalled more when rivalling with two individuals than only one competitor.

Our findings describe how males with diverse body condition are differentially affected by social environment. Plasticity of males' signal features were higher than expected and may depend on the integration of different cues of surrounding environment and on the current body reserves. We suggest that signalling strategies are not just depending on condition but adapted to fit somehow an intermediate optimum. A prospect to the implication for a chorus of many males has to be discussed.

**Key Words:** Acoustic communication, body mass, male competition, signal plasticity, Tettigoniidae.

## Sexual selection in the Orthoptera

# SEXUAL SELECTION AFTER SIGNAL LOSS: BEHAVIOUR AND GENOMICS OF ADAPTIVE SONG LOSS IN FIELD CRICKETS

Nathan W. Bailey

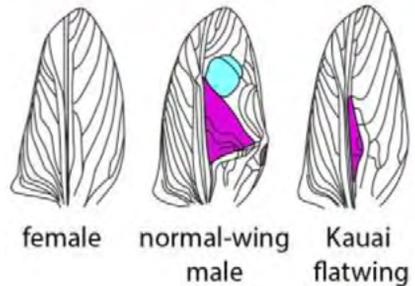
School of Biology, University of St Andrews, St Andrews, Fife KY16 9TH, United Kingdom;  
nwb3@gst-andrews.ac.uk

Conspicuous sexual signals are a common feature of singing insects, but they can attract undesirable attention from eavesdropping predators. How do organisms respond to natural selection on sexually-selected signals, when these signals are so central to reproduction?

I will discuss research addressing this question in populations of the Hawaiian cricket *Teleogryllus oceanicus*. Recently, a silent male morph – flatwing – emerged and spread rapidly under pressure from deadly, acoustically-orienting parasitoid flies, *Ormia ochracea*. The flatwing phenotype is caused by Mendelian mutations that eliminate sound-producing structures on male wings.

Flatwing males are protected from the fly and spread very rapidly. In one population on Kauai, they have almost entirely supplanted normal, singing males. How has flatwing, with its clearly detrimental consequences for sexual advertisement, courtship, and intrasexual competition, spread so quickly?

I will present behavioural and genomic data from *T. oceanicus* to evaluate the idea that sexually selected traits, such as insect song, represent a large target for evolutionary adaptation under natural selection. Genomic invasion by adaptive mutations such as flatwing is only the first step towards rapid evolutionary adaptation. The genome must cope with negative consequences of this disruption, and individual organisms must cope with the massive social change that accompanies sexually-selected signal loss. How does this happen?



**Figure 1.** Hawaiian *Teleogryllus oceanicus* forewings (adapted from Pascoal et al. 2014). Females (left) do not have sound-producing structures on their wings, but normal-wing males do (middle, shaded structures). Flatwing males (right) have feminised wings with severely reduced or erased sound-producing venation, causing them to be silent. How did flatwing mutations invade the genome and spread so quickly, when sexually-selected male song is so essential to the mate recognition system of this species?

**Key Words:** acoustic signalling, behaviour, evolution, gryllid, genomics, parasitoid.



## Sexual selection in the Orthoptera

# THE INFLUENCE OF DIETARY NUTRIENT BALANCE ON FEMALE SEXUAL RESPONSIVENESS AND MATE PREFERENCES

Susan M. Bertram<sup>1</sup>, Sarah J. Harrison<sup>2</sup>

<sup>1</sup> Carleton University, Ottawa, Canada; Sue.Bertram@carleton.ca

<sup>2</sup> Carleton University, Ottawa, Canada

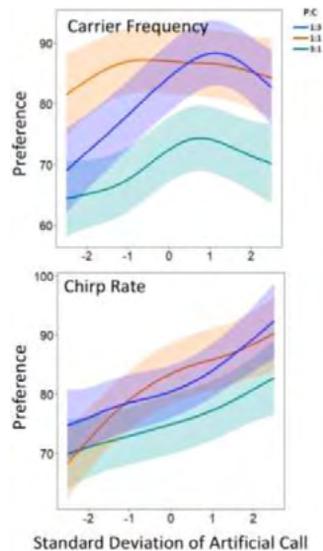
In sexually reproducing species, females generally prefer to mate with males displaying more elaborate sexual ornaments or higher effort mate attraction signals, which has important consequences for the evolution of male sexual traits. However, females also show a great deal of intraspecific variation in their mate choice decisions. This variation may be due to female condition, as mate searching and assessment activities are costly, such that only high condition females should be able to express strong mate preferences. Female fecundity may also influence variation in mate preferences, as only females with reproductive capabilities stand to benefit from being choosy. While previous research has demonstrated that nutritional stress influences female sexual responsiveness and mate preferences in a variety of taxa, research on this topic has traditionally suffered from a lack of nutritionally explicit methodologies.

We raised female *Gryllus veletis* field crickets on one of six unique diets differing in protein, carbohydrate and phosphorus composition, and after reaching adulthood, measured their sexual responsiveness and preference functions for artificial male acoustic mate attraction signals using a series of no-choice phonotaxis trials in an open-arena apparatus. Additionally, we examined how female body size and fecundity alter female mate preferences, as these traits themselves are influenced by dietary nutrient balance.

Females that consumed high-protein diets during development were larger as adults, and these larger females were subsequently more sexually responsive and had steeper preference functions for male acoustic signals, suggesting that female mate preferences may depend on resources accumulated during development. In contrast, females that consumed high-carbohydrate diets as adults were also more sexually responsive to artificial male acoustic signals, suggesting that females' willingness to search for mates and copulate may be constrained by carbohydrate-

derived energy stores (Fig. 1).

Neither dietary phosphorus nor fecundity significantly influenced female responsiveness or preference functions. Together, these findings support theoretical predictions that female mate preferences are condition dependent and suggest that dietary nutrient balance during both developmental and adult life stages may have important consequences for the strength and direction of sexual selection on male acoustic mate attraction signals.



**Figure 1.** Average preference functions with standard error bands within each diet treatment (protein: carbohydrate ratio) by call treatment (chirp rate and carrier frequency), fitted with Pfunc.

**Key Words:** Nutrient availability, Development, Carbohydrates, Proteins, Preference functions, Condition dependence.



## Sexual selection in the Orthoptera

### CAROTENE-BASED SEXUAL SIGNALLING IN LOCUSTS

Darron A. Cullen<sup>1,2</sup>, Gregory A. Sword<sup>3</sup>, Stephen J. Simpson<sup>4</sup>, Jozef Vanden Broeck<sup>1</sup>

<sup>1</sup> Zoological Institute, KU Leuven, Leuven, Belgium; darron.cullen@kuleuven.be (presenting author)

<sup>2</sup> Department of Zoology, University of Cambridge, Cambridge, UK

<sup>3</sup> Department of Entomology, Texas A&M University, College Station, TX, USA

<sup>4</sup> Charles Perkins Centre and School of Life Sciences, University of Sydney, Sydney, Australia

Locusts are grasshoppers that are famous for exhibiting a suite of strong phenotypic plasticities, which can give rise to extreme differences in form and behaviour depending on local population density. A particularly striking plastic trait in several locust species, and in some other grasshoppers, is a strong yellowing that occurs only in mature gregarious males; it does not happen in gregarious females, or in any locusts reared at low densities (or on their own). This colour is caused by the gregarious male-specific expression of a  $\beta$ -carotene binding Yellow Protein (YP), which binds dietary carotene into the cuticle.

Despite being a physiological curiosity for many decades, the adaptive significance of male-specific yellowing has remained a mystery. I have recently discovered an important function for this trait in the Desert Locust, *Schistocerca gregaria*. I used RNA interference (RNAi) of YP to create non-yellow mature males. Behavioural assays containing a mix of control (yellow) and YP-RNAi (non-yellow) males showed that YP-RNAi males were significantly more likely to be sexually mounted by other males. Yellow colouration therefore appears to act as a male-male signal, preventing mistaken sexual identity during swarming. Examples of such easily manipulated visual signals are rare, as are carotene-binding proteins with a known sequence, making this an intriguing system through which to investigate the evolution of animal signals at multiple levels of analysis; mechanism, development and epigenetics, function and phylogeny.

I will present preliminary data from functional binding assays of recombinant YP with its  $\beta$ -carotene ligand, in combination with a range of other factors that might affect YP-carotene binding. At the developmental and epigenetic

level, I will outline ongoing and planned experiments designed to unravel the regulatory mechanism(s) that limit YP expression to gregarious males, despite the fact that females also carry the gene. I will also discuss ongoing work at the functional level, investigating the potential multimodality of yellowing alongside olfactory and auditory signals. I will outline plans to investigate other potential functions of male-specific yellowing, as well as some comparative experiments of YP-based signalling in other species of locust. Finally, I will present my ongoing phylogenetic work, which aims to determine when YP-based signalling first arose, and whether it has always served the same adaptive function throughout its history.



**Figure 1.** Male-male mounting in *S. gregaria*. Note the attempted copulation of the YP-RNAi (non-yellow) male by the yellow control male.

**Key Words:** Phenotypic plasticity, sexual signalling, homosexual behaviour, male-male mounting, mistaken identity, density-dependent signalling, carotenoid-based signalling.



## Sexual selection in the Orthoptera

# WHAT'S THE MAIN DRIVING FORCE FOR SONG EVOLUTION IN THE GENUS EURYCORYPHA (TETTIGONIOIDEA, PHANEROPTERINAE)?

Klaus-Gerhard Heller<sup>1</sup>, Claudia Hemp<sup>2</sup>

<sup>1</sup> Free zoologist, Magdeburg, Germany; heller.volleth@t-online.de

<sup>2</sup> Biodiversity and Climate Research Centre (BiK-F), Frankfurt, Germany

Acoustic communication plays a central role in the mating system of many Ensifera, mainly of crickets and bush-crickets (Tettigoniodea). Guided by the male acoustical signals females find phonotactically their mates. The process of recognition and tracking of the long lasting and rhythmical sounds has been intensively studied on behavioural and neurophysiological level. Simplified, the syllable repetition rate and chirp repetition rate are most important for song recognition. However, most species of the tettigonioid subfamily Phaneropterinae use a bi-directional communication system: the male sings and the female responds acoustically. So it makes no sense for the male to use stereotyped, long-lasting signals. The female does not need them for phonotaxis. On the other side, if the female has started a duet, the male must be very careful that rivals do not exploit the information about the location of the female.

Under these premises it is easily understandable the male songs in Phaneropterines have another basic structure than that of e.g., of gryllids and conocephalines. For long-winged phaneropterines, the vast majority of the species in this huge group, however, quite few information are available about song structures and song evolution. Most of the sparse data refer to genera poor in species number.

Here we present a study of the songs and duets in the genus *Eurycorypha* in East Africa. The genus is known from all regions of tropical Africa with at present 52 species and it is remarkable because of its ant-like nymphs. However, its diversity may still be heavily underestimated since in Tanzania alone 18 species are known (Hemp 2017 Zootaxa 4358: 471–93) many of which occur sympatrically in various combinations. For example, on the geologically young volcano

Kilimanjaro, 7 *Eurycorypha* species were counted. We have recorded the male calling songs of 16 species and the duets of 8 of them. Concerning carrier frequency, male and female signals are in a range of 10 to 22 kHz with broad banded and narrow banded species. In amplitude modulation, the male songs are quite divers. The echemes (=chirp) have mostly 4 to 6 syllables, but the numbers range from 2 to about 400 (one species). Many species use several types of echemes with differing syllable repetition rates (SRR; range 5–50 Hz), alternating singly or in groups. Even within these echemes the SSR can increase or decrease. In addition, different echemes types can be presented with different intensities. In the song of some species also isolated syllables are observed with special amplitude modulation or fixed interval to an echeme. The latency of the female response is with 100 to 400 ms distinctly larger than in the well-studied short-winged Barbitistini. The function of various song components and the reason the extremely high song diversity will be discussed.



*Eurycorypha varia*

**Key Words:** Male calling song, female response, duet, female latency, East Africa, Tanzania.



## Sexual selection in the Orthoptera

# SEXUAL SELECTION AND PHENOTYPIC DIVERSITY WITHIN AND BETWEEN THE SEXES IN THE WELLINGTON TREE WETA

*Clint D. Kelly*

*Canada Research Chair in Behavioural Ecology, Département des Sciences biologiques, Université du Québec à Montréal, Montréal, Canada; kelly.clint@uqam.ca*

---

Sexual selection is arguably nature's most powerful evolutionary process in that it overcomes natural selection in males and females to produce incredible phenotypic diversity within and between the sexes and across taxa in remarkably short periods. There are few better examples in nature of intense sexual selection shaping male morphology and behaviour than the Wellington tree weta (*Hemideina crassidens*). The Wellington tree weta exhibits strong sexual dimorphism with males possessing tremendously enlarged jaws relative to females. This species also exhibits extraordinary variation among males in phenotype, a hallmark of alternative mating strategies.

My research seeks to identify the proximate and ultimate causes of this tremendous phenotypic variation with specific attention given to how the observed phenotypic variation is maintained in the wild, how the environment mediates sexual selection on male phenotype, and how investment in sexually-selected traits trades-off against other fitness-related traits like immunity.

**Key Words:** alternative mating strategies, sperm competition, immune response, weaponry, polymorphism, sexua dimorphism.



## Sexual selection in the Orthoptera

# BUSHCRICKET GENITALIA AND FEMALE CHOICE (ORTHOPTERA: ENSIFERA: TETTIGONIIDAE)

Gerlind U.C. Lehmann

Humboldt University Berlin, Institute of Biology, AG Evolutionary Ecology, Berlin, Germany;  
gerlind.lehmann@biologie.hu-berlin.de

Male genital organs are among the fastest evolving morphological structures. In several bushcricket species, males bear sclerotized genital appendices called titillators. For a long time, it was assumed that titillators are used as hooks and males fixate themselves at the females during copulation in all species. However, functional investigations were hindered by the fact that the male's genitalia are inserted into the female during mating and therefore invisible to the outside. During the last years we established the Tettigoniidae *Metriopectera roeselii* as a test species for the evolutionary consequences of bushcricket genitalia. We investigated the function of titillators with different methods, using  $\mu$ CT, in-vivo X-ray cineradiography, neurophysiology as well as behavioural experiments to clarify the function and usage of the titillators by the males. In contrast to previous assumptions, we could show that the males do not fixate themselves with their titillators. In contrast, in-vivo X-ray videos demonstrate that titillators tap softly on the surface of the females' subgenital plate. Such action can clearly be interpreted as stimulation for copulatory courtship. Behavioural tests showed that females discriminate against males' with artificially shortened or even ablated titillators. Females struggled against those males to free themselves out of the mating position. Males bearing asymmetric manipulated titillators caused the strongest struggling response. The female struggling behaviour could be suppressed if the females were sensory blinded by the application of anaesthetics or glue. Once females don't sense the asymmetry of their mates any more, they don't try to escape from copulations. Additionally, we identified neurons

in the female's abdomen sensing the rhythmical movement of the male titillators. The conclusive evidence for *Metriopectera roeselii* is that titillators stimulate the females and are therefore used for copulatory courtship. They play also a role to ensure the spermatophore transfer, which failed in a high percentage if titillators are ablated.

The evolutionary question was whether titillator function is similar between species or if sexual selection has taken different routes in different species. Therefore, we extended our studies to investigate titillator function in other bushcricket species. We selected two additional Tettigoniidae species and one Phaneropterinae, in which titillators have independently evolved. The behavioural tests with titillator manipulated males yielded species-specific results. In Pholidoptera *littoralis* for example we found strong evidence that these genitalia devices are used to hook and fixate the males in the soft tissue of the female genital chamber. Shortened titillators resulted in failed matings and unsuccessful spermatophore transfer.

In conclusion, titillators serve different functions in various bushcrickets species. Using a unifying explanation falls therefore short. Sexual selection by female choice, postgame effects as sperm competition and sexual conflict over matings seem to be key drivers for species-specific functions of internal genitalia in bushcrickets.

**Key Words:** Sexual selection, mating, genitalia, titillators, X-ray synchrotron videos, neurophysiology, Tettigoniidae.

## Sexual selection in the Orthoptera

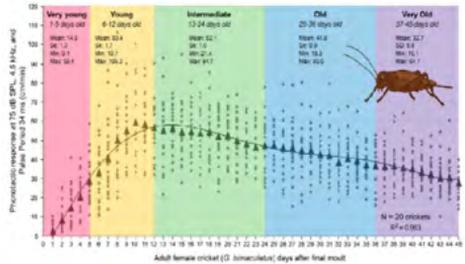
# LIFETIME STUDY IN CRICKETS REVEALS NO CHANGE OF FEMALE CHOOSINESS

Edith Julieta Sarmiento-Ponce 1, Berthold Hedwig

University of Cambridge, Department of Zoology, Downing Street, Cambridge, CB2 3EJ, United Kingdom

The female mate choice plays a major role in the fitness of individuals throughout their lifetime and relates to their ability to survive to reproductive age, to find a mate, and to produce offspring. In crickets, the female choosiness hypothesis postulates that young females tend to be more selective of male calling song patterns and spend more time looking for high-quality males relative to older individuals. However, there is no information about the phonotactic response of an insect over its complete adulthood, or how choosiness may be affected with age, if at all. Here, I explored the influence of age on female choice in the field cricket *Gryllus bimaculatus*. I analysed the auditory behaviour of females throughout their entire adulthood by using a trackball system to measure the phonotactic response to three acoustic parameters: sound intensity, carrier frequency, and the temporal pattern of the test song. Females aged between 7 to 24 days post-final moult event, their age will be referred simply as “d”, showed the strongest phonotactic response at a sound intensity of 70-80 dB SPL, a frequency range from 4.0-5.5 kHz, and song pattern with a pulse period of 34-42 ms. Based on the resulting phonotactic response curve, I devised a classification into five age categories. Very young adults (d1-d5) had a statistically significant lower phonotactic response in all acoustic parameters relative to all other age categories ( $P < 0.001$ ). Young (d6-d12) and intermediate (d13-d24) females performed the strongest phonotactic response. By contrast, old (d25-d36) and very old (d37-d45) females showed a gradual decrease in the strength of their phonotactic response. Despite these differences, all age groups demonstrated a strong preference for male calling songs with a pulse period of 26-50 ms, sound intensity of 75 dB SPL, and a frequency of 4.5 kHz. These results indicate

that song pattern selectiveness in females of *G. bimaculatus* does not change throughout their adulthood, although age does have an important effect on the strength of the phonotactic response that is low in very young and old individuals. Our findings in *G. bimaculatus* contradict the main prediction of the female choosiness hypothesis observed in other cricket species and instead suggest that with age there is a decrease in the phonotactic response, rather than a loss of calling song selectivity.



**Figure 1.** Overall best phonotactic response over the adulthood of female *G. bimaculatus* considering an attractive male calling song acoustic parameters obtained in the results (i.e. 75 dB SPL, 4.5 kHz, and pulse period of 34 ms). Age groups divided in five categories: 1. Very young: 0-5 days after final moult; 2. Young: 6-12 days after final moult; 3. Intermediate: 13-24 days after final moult; 4. Old: 25-36 days after final moult; and 5. Very old: 37-45 days after final moult.

**Key Words:** Insect communication, phonotaxis, female choice, insect aging, individual variation.



## Sexual selection in the Orthoptera

# WHAT DETERMINES THE NUMBER OF AUDITORY SENSILLA IN THE TYMPANAL HEARING ORGANS IN TETTIGONIIDAE?

Johannes Strauß

1 Justus-Liebig-University Giessen, Institute for Animal Physiology, AG Integrative Sensory Physiology; Giessen, Germany; johannes.strauss@physzool.bio.uni-giessen.de

Tettigoniidae (bushcrickets or katydids) have elaborate tympanal hearing organs in the tibia of their forelegs, which consist of the tympanal membranes, an acoustic trachea, and the auditory organ. This auditory organ is termed the crista acustica, and its scolopidial sensilla respond to different best frequencies, shifting from low- to high-frequency tuning from proximal to distal.

Previous neuroanatomical studies have established that the number of auditory sensilla in the tettigoniid crista acustica is species-specific, and sensillum numbers between 15 – 115 sensory neurons are documented. However, the factors causing the differences between species have been difficult to identify. This is in part due to several evolutionary factors that could affect the function of hearing simultaneously, including natural and sexual selection, physical constraints, as well as genetic drift. The adaptations resulting from can be studied by sampling several species from taxa with an established phylogeny and well-studied acoustic behaviour and comparing their hearing organs for differences and similarities.

A comparative neuroanatomical study investigating the number of auditory sensilla used different species from the genus *Poecilimon*. In this model clade for acoustic signalling and behaviour, the species vary not only in the temporal structure of their calls but also in their communication systems and calling behaviour.

Usually in *Poecilimon*, males and females produce acoustic duets in a bidirectional

communication system (male call - female response). Since the female response sounds

are shorter in duration and less loud than the male calls, the selection is on ears in males for higher sensitivity. In some species, the female response is abolished, resulting in a unidirectional communication system (male call only). Here, higher selection pressure is on sensitivity in female ears to locate males.

In most species including the outgroup species, the auditory organs are well developed, with sensillum numbers of ~30 sensory neurons. Importantly, among species with a simplified communication system, the crista acustica showed a significantly lower number of auditory sensilla. In the ear of a parthenogenetic species, the lowest number of auditory sensilla was found. These findings indicate the importance of sexual selection for elaborate hearing organs mediated by the communication system.

These results are compared with other evolutionary simplifications in tettigoniid signalling systems e. g. by changing vibrational signals as main signalling modality. Such comparative analysis can emphasise the strong influence of sexual selection as well as natural selection on the number of auditory sensilla.

**Key Words:** Auditory organ, Tettigoniidae, neuroanatomy, tympanum, crista acustica, evolution, functional morphology.



## SYMPOSIUM 5

# Evolution, diversification and biogeography of Orthoptera

**Organizer: Hojun Song,**

Texas A&M University, USA.  
hsong@tamu.edu

1. **Vanessa Couldridge, Mikhaila Gordon, Rekha Sathyan.** EVOLUTION AND DIVERSIFICATION OF BLADDER GRASSHOPPERS (ORTHOPTERA, PNEUMOROIDEA)
2. **Hojun Song, Olivier Bethoux, Seungwan Shin, Sabrina Simon, Shanlin Liu, Guanliang Meng, 1KITE Orthoptera.** PHYLOGENOMIC ANALYSIS OF ORTHOPTERA SHEDS NEW LIGHT ON THE EVOLUTION OF ACOUSTIC COMMUNICATION
3. **M. Celeste Scattolini, Viviana A. Confalonieri, María M. Cigliano.** DIVERSIFICATION PATTERNS IN SCOTUSSAE (ORTHOPTERA: ACRIDIDAE) GENUS GROUP
4. **Johannes Strauß.** DIVERSITY OF THE SUBGENUAL ORGAN COMPLEX IN ENSIFERA: USING COMPARATIVE NEUROANATOMY IN SEARCH FOR A GROUND PATTERN
5. **Ben H. Warren, Sylvain Hugel, Laure Desutter-Grandcolas.** LONG-LEGGED CRICKET PHYLOGENY (ORTHOPTERA, GRYLLOIDEA, PHALANGOPSIDAE): DELIMITING NEW MODEL GROUPS FOR EVOLUTIONARY STUDIES
6. **Lu Yang, Nitin Achari, Ricardo Mariño-Pérez, Riddhi Deshmukh, Krushnamegh Kunte, Hojun Song, Peter Andolfatto.** CARDENOLIDE INSENSITIVITY EVOLUTION IN PYRGOMORPHIDAE



## Evolution, diversification and biogeography of Orthoptera

# EVOLUTION AND DIVERSIFICATION OF BLADDER GRASSHOPPERS (ORTHOPTERA, PNEUMOROIDEA)

Vanessa Couldridge<sup>1</sup>, Mikhaila Gordon<sup>2</sup>, Rekha Sathyan<sup>2</sup>

<sup>1</sup> University of the Western Cape, Bellville, South Africa; [vcouldridge@uwc.ac.za](mailto:vcouldridge@uwc.ac.za)

<sup>2</sup> University of the Western Cape, Bellville, South Africa

The Pneumoroidea are a relatively small group of orthopteran insects, yet they are intriguing due to their unusual anatomical and behavioural adaptations that position them amongst the most highly specialised acoustic signalling insects in the world. Males produce extremely loud advertisement calls at night by scraping their hind legs against their inflated abdomens. Females respond to searching males with a much softer call, enabling males to track them acoustically. Pneumorids are found mostly in southern Africa, with their distribution also extending into East Africa. However, the majority of species are endemic to South Africa. Despite this somewhat limited geographic distribution of the family, they are ecologically diverse, inhabiting areas ranging from deserts to forests. Several anatomical and behavioural characteristics are correlated with habitat type. For example, species inhabiting forests are generally larger in body size and produce more complex calls.

In order to gain insights into the evolution and diversification of this group, we examined morphological, acoustic and genetic variation, both within and between species, and also related this to ecological factors.

Results indicate that there is extensive geographic variation within a species, both phenotypic and genotypic. While sexual selection is likely to be a

major driving force behind the diversification of geographically separated populations, ecological selective pressures have also played a role. Variation in local climatic conditions correlates with observed population divergence. In addition, community composition causes populations to alter their signal characteristics and signalling behaviour. Co-existing pneumorid species alter their call features as well as their signal timing to avoid potential overlap. Thus, populations inhabiting different geographic areas, with different suites of co-existing species, demonstrate differing levels of signal divergence. Variation in predatory bat activity has also been shown to drive divergence on a geographic scale by influencing diel signalling patterns.

To examine variation between species, mitochondrial and nuclear genetic markers were used to construct a phylogenetic tree for the family, using specimens collected in the field throughout South Africa. Preliminary analyses indicate that species diversification is correlated with major habitat shifts, and also that the current taxonomic classification for this group needs to be revised.

**Key Words:** Acoustic signals, Ecology, Geographic variation, Phylogenetics, South Africa.

## Evolution, diversification and biogeography of Orthoptera

# PHYLOGENOMIC ANALYSIS OF ORTHOPTERA SHEDS NEW LIGHT ON THE EVOLUTION OF ACOUSTIC COMMUNICATION

Hojun Song<sup>1</sup>, Olivier Bethoux<sup>2</sup>, Seungwan Shin<sup>3</sup>, Sabrina Simon<sup>4</sup>, Shanlin Liu<sup>5</sup>, Guanliang Meng<sup>5</sup>, 1KITE Orthoptera<sup>6</sup>

<sup>1</sup> Department of Entomology, Texas A&M University, College Station, TX, USA.

<sup>2</sup> Muséum National d'Histoire Naturelle, Centre de Recherche sur la Paléontologie, Paris, France.

<sup>3</sup> Department of Biological Sciences, University of Memphis, Memphis, TN, USA.

<sup>4</sup> Biosystematics Group, Wageningen University, Netherlands.

<sup>5</sup> Beijing Genomic Institute-Shenzhen, China.

<sup>6</sup> 1K Insect Transcriptome Evolution Consortium.

The ability to process auditory signals is the first step for evolving acoustic communication, and the insect order Orthoptera represents the earliest lineage to evolve hearing, long before the evolution of frogs, songbirds, and mammals. Orthopterans are also the first to evolve the ability to produce audible sound for sexual communication. Crickets, katydids, mole crickets, grigs, bladder grasshoppers, pampagids, and some acridid grasshoppers are known to communicate acoustically, and received much attention from researchers interested in bioacoustics and biophysics. Over the years, there have been several hypotheses regarding the evolution of hearing and sound producing organs, often focusing on the suborder Ensifera, but because of the lack of robust phylogeny, there is currently no consensus on how many times tympana and stridulatory organs could have evolved in Orthoptera. In this presentation, we present a large-scale phylogenomic analysis of Orthoptera based on transcriptome and mitochondrial genome data and conduct

ancestral character reconstruction to infer how different types of tympana and different stridulatory organs have evolved in Orthoptera. We show that tibial tympana evolved twice in Ensifera, and abdominal tympana evolved three times in Caelifera. Tegminal stridulation evolved twice in Ensifera, and different modes of stridulation evolved several times throughout the evolutionary history of Orthoptera. We also show that there is a correlated pattern in the evolution of tibial tympana and tegminal stridulation, while in Caelifera, most species with abdominal tympana lack the ability to produce sound. We discuss about the implication of this finding in terms of our current understanding on the evolution of acoustic communication. We discuss strengths and weaknesses of the current phylogenomic approach and outline a future plan for advancing orthopteran phylogenetics.

**Key Words:** Phylogenomics, tympana, stridulatory organ, ancestral character reconstruction.



## Evolution, diversification and biogeography of Orthoptera

### DIVERSIFICATION PATTERNS IN SCOTUSSAE (ORTHOPTERA: ACRIDIDAE) GENUS GROUP

M. Celeste Scattolini<sup>1,2</sup>, Viviana A. Confalonieri<sup>3</sup>, María M. Cigliano<sup>1,2</sup>

<sup>1</sup> Centro de Estudios Parasitológicos y de Vectores, CEPAVE, CONICET-CCT La Plata, Argentina; celestescattolini@yahoo.com.ar

<sup>2</sup> Museo de La Plata, División Entomología; FCNyM-UNLP, La Plata, Argentina

<sup>3</sup> Departamento de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires (EGE-FCEN-UBA) and IEGEBA (UBA-CONICET), Ciudad Autónoma de Buenos Aires, Argentina

The Scotussae genus group is a diverse clade that inhabits open biomes of Brazil, Bolivia, Paraguay, Uruguay and Argentina, occurring mainly in the Chacoan and Parana dominions of South America. This clade of brachypterous and macropterous species is characterized by the variation in the ovipositor morphology and by complex chromosomal rearrangements. The aim of this study is to apply an integrative biogeographic approach to study the diversification of the group, analysing simultaneously three sources of evidence: diversification time, phylogenetic relations and geographic evolution.

Fifty specimens of the Dichoplini tribe were analysed representing all the genera of the Scotussae group and 4 species selected as outgroup. A total evidence phylogenetic analysis was performed considering three genetic regions (COI, ND2, H3) combined with morphological evidence. Niche similarity tests and the degree of niche overlap were estimated among the species. Ecological niche models were generated assessing the realized ecological niche and the potential distribution. Phylogenetic signal between the phylogenetic relatedness and the niche overlap, the geographic and the environmental distances

were analysed. The phylogenetic signal in the environmental variables and the ancestral range were also evaluated.

Our findings suggest that ecology would have played a major role in the diversification of the Scotussae group, since phylogenetic relationships have a greater association with

environmental variables than with geographical distances. Within the group, two main clades (Brachypterous / Macropterous) with different diversification patterns were recovered. The diversification of the Scotussae genus group would have occurred during the Pliocene in the Seasonally Dry Tropical Forests (SDTF) open vegetation biome. The geo-historical events that occurred during the last glacial-interglacial cycles in the SDTF could have played a predominant role in the allopatric speciation that might have suffered the Brachypterous clade. On the other hand, it is considered that the main diversification event within the Macropterous clade could have been sympatric speciation, finding evidence of ecological speciation and cytogenetic barriers.

**Key Words:** Biogeography; BioGeoBears; Phylogenetic Signal, Ecological Niche Modeling.

## Evolution, diversification and biogeography of Orthoptera

# DIVERSITY OF THE SUBGENUAL ORGAN COMPLEX IN ENSIFERA: USING COMPARATIVE NEUROANATOMY IN SEARCH FOR A GROUND PATTERN

Johannes Strauß

Justus-Liebig-University Giessen, Institute for Animal Physiology, AG Integrative Sensory Physiology; Giessen, Germany; johannes.strauss@physzool.bio.uni-giessen.de

Ensifera are studied in detail for their tympanal hearing organs, located in the forelegs of e. g. crickets and tettigoniids. The auditory sensilla are generally placed next to an important vibration receptor organ, the subgenual organ. Since further mechanosensory organs can occur close to these organs, they are together referred to as subgenual organ complex.

This mechanosensory complex mediates important stimulus modalities for Orthoptera (airborne sound and substrate-borne vibration), and the evolutionary origin and modifications of sensory organs can be investigated in taxa with different signalling mechanisms. So far, the subgenual organ complex in Orthoptera is best studied for the sensory organs associated with tympanal membranes in crickets, bushcrickets, and tree weta. Several of the Ensifera lacking tympanal organs employ substrate-borne vibrational signals produced by abdominal drumming, tremulation, or leg tapping on the substrate. While the subgenual organ is expected to be generally present across Orthoptera, the additional sensory organs have been addressed for comparative neuroanatomy only recently.

This comparative approach revealed that several atympanate ensiferan taxa have sensilla homologous to the auditory sensilla of tettigoniids and weta (the crista acustica) (representatives of Stenopelmatidae, Gryllacrididae, Schizodactylidae, atympanate

Anostomatidae: *Hemiandrus*). These groups also have subgenual organs, prominent intermediate organs, and accessory organs, in sum revealing a sophisticated subgenual organ complex with up to four sensory organs.

A crista acustica is not found in all atympanate taxa, as it is lacking in representatives of the cave crickets (Rhaphidophoridae) which have a "simple" subgenual organ complex.

A further scolopidial organ is the accessory organ, consisting of few sensilla (5 – 15) which has been found in tettigonioids as well as cockroaches. This organ has not been described in crickets, and it is also lacking in locusts and stick insects. Such neuroanatomical data give the basis to discuss the evolutionary origins of tympanal auditory organs and vibration receptor organs.

They show that the subgenual organ complex consists of several (two to four) scolopidial organs, even in atympanate taxa. However, a ground pattern is more difficult to infer for the tympanal organs with a crista acustica, and for accessory organs, due to their scattered distribution within Ensifera. Further investigations allow to address the possibility of repeated origins of sensory organs or the repeated evolutionary reductions.

**Key Words:** tympanal organ, neuroanatomy, subgenual organ, evolution, vibration detection, accessory organ.



## Evolution, diversification and biogeography of Orthoptera

# LONG-LEGGED PHYLOGENY (ORTHOPTERA, GRYLLOIDEA, PHALANGOPSIDAE): DELIMITING NEW MODEL GROUPS FOR EVOLUTIONARY STUDIES

Ben H. Warren<sup>1</sup>, Sylvain Hugel<sup>2</sup>, Laure Desutter-Grandcolas<sup>1\*</sup>

<sup>1</sup> Institut de Systématique, Evolution et Biodiversité (ISYEB), Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, EPHE, 57 rue Cuvier, CP 50, 75231 Paris cedex 05, France ; \* desutter@mnhn.fr

<sup>2</sup> INCI, UPR 3212 CNRS, Université de Strasbourg, 5 rue Blaise Pascal, F – 67084 Strasbourg Cedex, France

Phalangopsidae crickets have long been known for their taxonomic and phylogenetic diversity. More than 170 genera are recognized today in the Orthoptera Species File, but it is clear that the actual diversity of the clade is much higher, due to inadequacies in today's taxonomy and a large number of taxa remaining to be described. This diversity is paralleled by a huge ecological and behavioural diversity, unequalled in other cricket clades. In particular, Phalangopsidae present very diverse courtship behaviours and a wide array of communication modalities, from usual 'cricket-like' acoustic communication to chemical communication with air-vortices. Similarly, phalangopsids occupy a variety of specialized habitats. They have for example conquered caves many times, with large resultant troglitic clades, such as the Gryllomorphi – Petaloptelini (wrongly placed in Gryllidae until recently) in the Mediterranean region, and the Amphiacustina in the Caribbean and Central America.

A well-supported phylogeny for the whole Phalangopsidae clade is clearly needed to study their distribution patterns, and the evolution of their behavioural and ecological characters in a comparative framework. Furthermore, their taxonomy at a tribal and subfamilial levels is far from settled.

The first molecular phylogeny including phalangopsid representatives (Chintauan-Marquier et al. 2016) resulted in a pattern that raised many questions, especially with respect to "traditional" subfamilies. Although several

of genera were included in the analysis, they were too few to fully represent the whole clade.

We have resumed the study of Phalangopsidae phylogeny, complementing the data set used in 2016 by Chintauan-Marquier et al. with new taxa and a new molecular marker.

Our aim is to define a general phylogenetic framework for the whole clade in order to:

- 1/ allow the diagnoses of well-supported subfamilies,
- 2/ focus subsequent biogeographical analyses on unambiguously monophyletic entities,
- 3/ initiate comparative studies on the evolution of communication modalities, signal structures, courtship behaviours and habitat use for selected clades,
- 4/ develop a collaborative analysis of the morphological phylogeny of the whole family.



**Key Words:** Grylloidea, Phylogeny, Classification, Evolution, Diversity, Biogeography.



## Evolution, diversification and biogeography of Orthoptera

### CARDENOLIDE INSENSITIVITY EVOLUTION IN PYRGOMORPHIDAE

Lu Yang<sup>1</sup>, Nitin Achari<sup>2</sup>, Ricardo Mariño-Pérez<sup>3</sup>, Riddhi Deshmukh<sup>2</sup>, Krushnamegh Kunte<sup>2</sup>, Hojun Song<sup>3</sup>, Peter Andolfatto<sup>4</sup>

<sup>1</sup> Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ, USA.

<sup>2</sup> National Center for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru, India.

<sup>3</sup> Department of Entomology, Texas A&M University, College Station, TX, USA.

<sup>4</sup> Department of Biological Sciences, Columbia University, New York, NY, USA.

Insensitivity to toxic plant secondary compounds has evolved multiple times in different herbivorous insects. Previous work has documented five insect orders (Lepidoptera, Diptera, Coleoptera, Hymenoptera and Hemiptera) that have evolved an ability to feed on cardenolide-producing plants. Some of these insects even sequester toxins for their own defense. Our study incorporates Orthoptera, represented by Pyrgomorphidae into this picture, increasing the time span over which convergence has occurred to nearly 400 million years. From a gene survey of the toxin target Na<sup>+</sup>, K<sup>+</sup>-ATPase in six grasshopper species representing ten genera in the family Pyrgomorphidae (*Sphenarium purpurascens* from Mexico, *Aularches miliaris* and *Poekilocerus pictus* from India and *Dictyophorus spumans*, *Taphronota calliparea*, *Zonocerus elegans* (Fig. 1), *Phymateus leprosus*, *Chrotogonus hemipterus*, *Atractomorpha acutipennis*, and *Ochrophlebia cafra* from Southern Africa), we found in some that not only amino acid substitutions that are parallel with the other five insect orders, but also a duplication event with subsequent tissue-specific differential expression.

The main results are:

1. Parallel amino acid substitutions found in other milkweed-adapted insects are also found in pyrgomorphs, especially at hotspots such as 111 (significantly positively selected in all milkweed feeders), 119 and 122.
2. Two genera *Poekilocerus* and *Phymateus* possess two copies of ATP1 $\alpha$ , and the duplication dates back to 36 mya.
3. Same as that in other species, one copy bears more mutations while the other remains relatively sensitive and conserved. Also in *Poekilocerus* and *Phymateus* we found a 6nt insertion between 118

and 119. This is unique to Orthoptera.

4. There is differential expression of the two copies in *Poekilocerus* and *Phymateus*.

5. Protein-ligand binding shows the copy with more mutations releases less energy upon binding, indicating its interaction with cardenolides is less stable.

6. Toxin resistance is mainly conferred by N122H.

Both morphological and molecular phylogenies group certain genera together, which are characterized by having aposematic coloration and different mechanisms of chemical defense, such as excretions from an unique mid-dorsal abdominal gland (*Zonocerus elegans*, *Poekilocerus pictus* and *Phymateus leprosus*) and foam production consisting of haemolymph excretions through pores combined with air (*Aularches miliaris*, *Dictyophorus griseus* and *Taphronota calliparea*). Others such as *Ochrophlebia cafra* is considered aposematic but without gland or foam.



Figure 1. *Zonocerus elegans* male, South Africa

**Key Words:** Gaudy grasshoppers, Pyrgomorphidae, Coevolution, Cardenolide.



## SYMPOSIUM 6

# Speciation and adaptation in Polyneoptera

**Organizer: Ioana Chintauan-Marquier<sup>1</sup> and Haruki Tatsuta<sup>2</sup>**

<sup>1</sup>Institut de Systématique Evolution Biodiversité (ISYEB), UMR 7205 Muséum National d'Histoire Naturelle, CNRS, Sorbonne Université, EPHE, UA, 45 Rue Buffon, CP50, 75005, PARIS, France.  
ioana.marquier@mnhn.fr

<sup>2</sup>Department of Ecology and Environmental Science, Faculty of Agriculture, University of the Ryukyus, Nishihara, Japan; htatsuta@agr.u-ryukyu.ac.jp

- Alexander Bugrov, Ilyas Jetybayev, Olesya Buleu, Elzbieta Warchalowska-Sliwa, Beata Grzywacz, Haruki Tatsuta.** MOLECULAR MARKERS OF CHROMOSOME EVOLUTION IN PODISMINI GRASSHOPPERS (ORTHOPTERA, ACRIDIDAE, PODISMINAE)
- Beata Grzywacz & Haruki Tatsuta.** MOLECULAR PHYLOGENY OF THE JAPANESE PODISMINI
- Maciej Kociński, Dragan Chobanov, Elzbieta Warchalowska-Sliwa, Beata Grzywacz.** MOLECULAR PHYLOGENY OF POECILIMON ORNATUS GROUP (ORTHOPTERA)
- Abhijeet Shah, Joe Hoffma<sup>2</sup>, Holger Schielzeth.** TRANSCRIPTOME ASSEMBLY AND ANALYSIS OF THE CLUB-LEGGED GRASSHOPPER (GOMPHOCERUS SIBIRICUS)
- Matan Shelomi, Benjamin Wipfler, Xin Zhou, Rüdiger Plarre, Yannick Pauchet.** ACTIVITIES AND EVOLUTION OF POLYNEOPTERAN CELLULOLYTIC ENZYMES
- Haruki Tatsuta, Alexander Bugrov, Daisuke Kageyama, Elzbieta Warchalowska-Sliwa, Shin-ichi Akimoto.** WHAT WE KNOW ABOUT PODISMA SAPPORENSIS: EVIDENCE FROM A LONG TERM INVESTIGATION
- Elzbieta Warchalowska-Sliwa, Beata Grzywacz, Klaus-Gerhard Heller, Claudia Hemp.** COMPARATIVE GENOME STUDIES OF AN AFRICAN GENUS OF BUSH-CRICKETS (GONATOXIA, PHANEROPTERINAE)
- Ioana C. Chintauan-Marquier, Mark C. Harrison, Laure Desutter-Grandcolas.** COMPARATIVE TRANSCRIPTOMICS REVEALS PATTERNS OF ADAPTIVE EVOLUTION ASSOCIATED WITH ENVIRONMENTAL PERTURBATIONS IN TWO SPECIES OF CRICKETS ENDEMIC FOR NEW CALEDONIA: KOGHIELLA NIGRIS AND KOGHIELLA FLAMMEA (ENSIFERA, TRIGONIDIIDAE, NEMOBIINAE)



## Speciation and adaptation in Polyneoptera

# MOLECULAR MARKERS OF CHROMOSOME EVOLUTION IN PODISMINI GRASSHOPPERS (ORTHOPTERA, ACRIDIDAE, PODISMINAE)

Alexander Bugrov<sup>1,2</sup>, Ilyas Jetybayev<sup>1,3</sup>, Olesya Buleu<sup>1,2</sup>, Elzbieta Warchalowska-Sliwa<sup>4</sup>, Beata Grzywacz<sup>4</sup>, Haruki Tatsuta<sup>5</sup>

<sup>1</sup> Institute of Systematics and Ecology of Animals, Russian Academy of Sciences, Siberian Branch, Novosibirsk, Russia; bugrov04@yahoo.co.uk

<sup>2</sup> Novosibirsk State University, Str. Pirogova, 2, Novosibirsk 630090, Russia; bugrov@fen.nsu.ru

<sup>3</sup> Institute of Cytology and Genetics, Russian Academy of Sciences, Siberian Branch, Pr. Lavrentjeva 10, 630090 Novosibirsk, Russia, jetybayev@mail.ru

<sup>4</sup> Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Krakow, Poland; warchalowska@isez.pan.krakow.pl

<sup>5</sup> Department of Ecology and Environmental Science, Faculty of Agriculture, University of the Ryukyus, Nishihara, Japan; htatsuta@agr.u-ryukyu.ac.jp

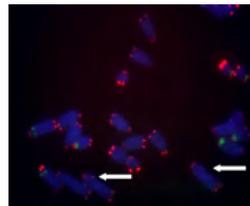
The majority of Palearctic grasshoppers belonging to the Podismini have karyotypes consist of 22 acrocentric autosomes and X0 (male) or XX (female) sex chromosomes. However, *Zubovskya koeppeni*, *Miramella solitaria*, *M. alpina*, *Parapodisma species*, *Anapodisma miramae*, and *Sinopodisma punctata* have 20 acrocentric autosomes and X0 (male) or XX (female) sex chromosomes. The formation process of the 2n=21 karyotype from the ancestral Acrididae 2n = 23 karyotype is an unsolved problem of Orthoptera comparative cytogenetics.

We used standard cytogenetic techniques, as well as molecular-cytogenetic methods, to find additional markers of linear chromosome differentiation in Podismini grasshoppers. The fluorescence in situ hybridization (FISH) method was employed to localize the clusters of rDNA and telomeric (TTAGG)<sub>n</sub> repeats.

The rDNA clusters localized in pericentric regions of different chromosomes in both 23- and 21-chromosome species group. The specific feature of Podismini grasshoppers is that many C-positive regions of chromosomes are enriched with rDNA repeats. The telomeric DNA repeats in 23 chromosome species revealed clusters of this probe only in the terminal regions of the chromosomes. In some 21-chromosome species, the presence of (TTAGG)<sub>n</sub> repeats was revealed not only in the terminal regions of the chromosome arms, but

also in the intercalary region of a large pair of acrocentric chromosomes (Fig. 1). Apparently, these clusters are the remnants of the telomeric repeats of one of the chromosomes, which entered into the telomere-centromere fusion. This result supports the hypothesis that the 21-chromosome karyotype in the Podismini grasshoppers was originated by tandem translocation of two pairs of autosomes.

The fact that not all 21-chromosome species have the interstitial cluster of telomeric DNA in large autosome implies the evidence on polyphyly of 21-chromosome group of species in Podismini tribe.



**Figure 1.** Two-colours FISH of telomeric probe (red signal) and rDNA (green signal) probes in *Anapodisma miramae* embryometaphase. Arrows indicate the telomeric clusters in interstitial region of an autosome.

This work was funded by the grant from the Russian Foundation for Basic Research 18-04-00192-a

**Key Words:** Grylloidea, Phylogeny, Classification, Evolution, Diversity, Biogeography.



## Speciation and adaptation in Polyneoptera

# MOLECULAR PHYLOGENY OF THE JAPANESE PODISMINI

Beata Grzywacz<sup>1</sup> & Haruki Tatsuta<sup>2</sup>

<sup>1</sup> Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Stawkowska 17, 31-016 Krakow, Poland; grzywacz@isez.pan.krakow.pl

<sup>2</sup> Department of Ecology and Environmental Sciences, Faculty of Agriculture, University of the Ryukyus, Nishihara, Okinawa, Japan; htatsuta@agr.u-ryukyu.ac.jp

Japanese Podismini Jacobson, 1905 comprises nine genera and 22 species. It is suggested that the geographical isolation of Japan from Eurasia had begun in the Miocene. The formation of the Japanese Archipelago had almost been completed until the end of the Pleistocene. Land bridges between the continent and the islands had formed at least three times between Pliocene and Pleistocene. These cyclical events are considered to have impacted the present flora and fauna in Japan. Together with the formation of the Japanese Islands, the speciation events in Podismini have presumably launched. Most species of Japanese Podismini have degenerated wings, and some of them show conspicuous intraspecific variation in external morphology and karyotypes. The aim of the present study is to unravel the relationships between species in Podismini, especially among the Japanese genera and to infer their phylogeographic history.

In order to resolve the phylogenetic relationship of Japanese Podismini, we have obtained 2330 base pairs DNA sequences from four different genes [the mitochondrial gene (cytochrome c oxidase subunit I – COI and 16S), the nuclear genes (elongation factor 1-alpha – EF1a), and the internal transcribed spacers of ribosomal DNA ITS2] for 27 species of Podismini, containing all of the present Japanese species. Based on the maximum likelihood and Bayesian phylogenetic trees, we examined the evolutionary history of

these species. The inferred phylogenetic tree consisted of three major species groups within Japanese Podismini: (1) Miramellina consisting of *Anapodisma beybienkoi*, *Italopodisma ebneri*, *Oropodisma chelmosiand* *Zubovskya koeppeniparvula*; (2) Podismina consisting of *Ognevia longipennis*, *Podisma kanoian* and *P. sapporensis*; (3) Tonkinacridina consisting of *Fruhstorferiola okinawaensis*, *Parapodisma awagatakensis*, *P. caelestis*, *P. dairisama*, *P. etsukoana*, *P. mikado*, *P. niihamensis*, *P. setouchiensis*, *P. subastris*, *P. takeii*, *P. tanbaensis*, *P. tenryuensis*, *P. yasumatsui*, *Sinopodisma aurata*, *S. kodamae*, *S. punctata*, *Tonkinacris ruficerus* and *T. yaeyamaensis*. The monophyly of Japanese Podismini was confirmed by the present molecular dataset. The time-calibrated Bayesian phylogeny implies the tribe had started to colonize in the Japanese Archipelago during the Middle Eocene. The subtribe Tonkinacridina had derived from the clade of Miramellina and Podismina. We will also discuss the patterns of morphological diversification along with the speciation processes.

This work has been supported in part by JSPS KAKENHI Grant Numbers 15F15762, 25291088, and 25304014 to HT and BG.

**Key Words:** Grasshopper, Orthoptera, Acrididae, Melanoplinae, DNA, species-level phylogeny, taxon sampling.



## Speciation and adaptation in Polyneoptera

# MOLECULAR PHYLOGENY OF POECILIMON ORNATUS GROUP (ORTHOPTERA)

Maciej Kociński<sup>1</sup>, Dragan Chobanov<sup>2</sup>, Elżbieta Warchałowska-Śliwa<sup>1</sup>, Beata Grzywacz<sup>1</sup>

<sup>1</sup> Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Stawkowska 17, 31-016 Kraków, Poland; kocinski@isez.pan.krakow.pl

<sup>2</sup> Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Boul., 1000 Sofia, Bulgaria

*Poecilimon* (Fischer, 1853) is the most diverse Palaearctic genus of bush-crickets (Tettigonioidae) with 136 species, distributed from the Apennines to Western Siberia and Central Tien-Schan and concentrated with the highest number of endemic species in the Aegean and Pontic areas. The group includes herbivorous sluggish short-winged bush-crickets that are characterized by a complex acoustic communication. One group for which the phylogeny is unclear is the *Poecilimon ornatus* group (POG), which contains 17 valid taxa (13 species) out of 36 described taxa. The widest distributed species within POG is *Poecilimon affinis* (Fivaldszky, 1868); found in mountainous areas from northern Greece, through the central and western Balkans to the Carpathians in Romania and in an isolated spot in Ukraine. In the central and western Balkans a multitude of forms has been described, including 13 taxa additional to the nominotypical taxon. Five taxa currently having subspecies status and two of a species status are here named *Poecilimon affinis* complex – PAC. While the systematics and taxonomy of most species of the POG are generally agreed on, the latter does not apply to the taxa most closely related to *Poecilimon affinis*. Currently, the systematics of the POG and specifically PAC is based on morphological and acoustic characters, yet, some taxa are

known only from old morphological descriptions and a few preserved specimens. The single use of phenotypic characters in groups of closely related taxa may be misleading because of the frequent appearance of homoplasies.

The aim of this study was to clarify relationships between species/subspecies within *Poecilimon ornatus* group by analyzing mitochondrial DNA sequences of the cytochrome c oxidase I gene (COI) and nuclear DNA sequences of the internal transcribed spacer 1 (ITS1). A total of 13 taxa of *Poecilimon affinis* complex from 32 locations, seven species of *Poecilimon ornatus* group, and *Poecilimon ampliatus* as an outgroup were used in the present analyses. The final alignment consisted of 830 (COI) and 450 (ITS1) base pairs. Phylogenetic trees were constructed using Maximum Likelihood estimation and Bayesian Inference analyses. The COI phylogeny does not support with current systematics which can be a result of hybridization. On the other hand, ITS1 confirms that species of *Poecilimon affinis* complex are separated from the other members of the *Poecilimon ornatus* group.

**Key Words:** Phaneropterinae, bush-crickets, Palearctic, nuclear and mitochondrial DNA, polymorphism, taxonomy.



## Speciation and adaptation in Polyneoptera

# TRANSCRIPTOME ASSEMBLY AND ANALYSIS OF THE CLUB-LEGGED GRASSHOPPER (*GOMPHOCERUS SIBIRICUS*)

Abhijeet Shah<sup>1,2</sup>, Joe Hoffman<sup>2</sup>, Holger Schielzeth<sup>1</sup>

<sup>1</sup> Institute of Ecology and Evolution, Friedrich Schiller University, Jena, Germany;  
abhijeet.shah@uni-jena.de

<sup>2</sup> Department of Animal Behaviour, Bielefeld University, Bielefeld, Germany

The club-legged grasshopper *Gomphocerus sibiricus* is a Gomphocerinae grasshopper with a promising future as model species for studying the maintenance of colour-polymorphism, the genetics of sexual ornamentation and genome size evolution. However, limited molecular resources are so far available for this species. Here, we present a de novo transcriptome assembly as reference resource for gene expression studies. We used high-throughput Illumina sequencing that resulted in 507,0036 paired-end reads after quality filtering. We then combined the best-assembled contigs from three different de novo transcriptome assemblers (Trinity, SOAPdenovo-trans and Oases/Velvet) into a single assembly. This resulted in 82,251 contigs with a N50 of 1,357 and TransRate assembly score of 0.325, which compares favorably with other orthopteran transcriptome assemblies. Around 87% of the transcripts could be annotated using InterProScan 5, BLASTx and the *dammit!* annotation pipeline. We identified

a number of genes involved in pigmentation and green pigment metabolism pathways. Furthermore, we identified 76,221 putative single nucleotide polymorphisms residing in 8,400 contigs.

We also assembled the mitochondrial genome and compared sequence divergence with other species from the genus *Gomphocerus*. Finally, we also detected and assembled *Wolbachia* sequences, which revealed close sequence similarity to the strain pel wPip. Our study has generated a significant resource for uncovering genotype-phenotype associations in a species with an extraordinarily large genome, while also providing mitochondrial and *Wolbachia* sequences that will be useful for comparative studies.

**Key Words:** Orthoptera, Acrididae, Gomphocerinae, transcriptome, mitochondria, *Wolbachia*.



## Speciation and adaptation in Polyneoptera

# ACTIVITIES AND EVOLUTION OF POLYNEOPTERAN CELLULOLYTIC ENZYMES

Matan Shelomi<sup>1</sup>, Benjamin Wipfler<sup>2</sup>, Xin Zhou<sup>3</sup>, Rüdiger Plarre<sup>4</sup>, Yannick Pauchet<sup>5</sup>

<sup>1</sup> Dept. of Entomology, National Taiwan University, No 27 Lane 113 Sec 4 Roosevelt Rd, Taipei, 10617, Taiwan  
mshelomi@ntu.edu.tw

<sup>2</sup> Friedrich-Schiller-Universität, Jena, Germany

<sup>3</sup> China National GeneBank, BGI-Shenzhen, Shenzhen, China

<sup>4</sup> Bundesanstalt für Materialforschung und -prüfung, Berlin, Germany

<sup>5</sup> Max-Planck Institute for Chemical Ecology, Jena, Germany

Many hemimetabolous insects produce their own, endogenous cellulase enzymes from the glycoside hydrolase family 9, first observed in the termites and the cockroaches. The Phasmatodea were discovered to have multiple copies of these enzymes, some of which were able to degrade xylan or xyloglucan in addition to cellulose. To discover when these abilities evolved, we identified the cellulases from the insects sampled by the 1000 Insect Transcriptome and Evolution (IKITE) project, with a focus on the Polyneoptera, a clade that includes Orthoptera, Phasmatodea, Blattodea, and Embioptera. We were hoping to identify what role enzyme substrate diversity has on the evolution of dietary specification, such as the leaf-feeding of Phasmatodea or wood-feeding of termites. Putative cellulases were identified from the transcriptomes and, from an exemplar set of Polyneoptera species, these cellulases were amplified and their full open reading frames produced using RACE PCR. The complete enzymes

were heterologously expressed in an insect cell line, harvested, and tested against different plant cell wall component polysaccharides for their digestive abilities.

Phylogenetic trees were also produced from these and the other IKITE cellulases. We identified several bifunctional xyloglucanolytic enzymes in the other Polyneoptera, as well as a large group of cellulase-like enzymes found in nearly all insect orders with no discernable digestive ability. Bi-functional xylanolytic cellulases remain Phasmatodea only. Ultimately the presence or absence of multifunctional enzymes does not seem to impact dietary specification, but we conclude that having multiple cellulase genes is an ancestral state for Polyneoptera and possibly Insecta. The prevalence of bifunctional cellulases in Metazoa demands investigation.

**Key Words:** Cellulase, Polyneoptera, Transcriptomics, Evolution.

## Speciation and adaptation in Polyneoptera

# WHAT WE KNOW ABOUT *PODISMA SAPPORENSIS*: EVIDENCE FROM A LONG TERM INVESTIGATION

Haruki Tatsuta<sup>1</sup>, Alexander Bugrov<sup>2</sup>, Daisuke Kageyama<sup>3</sup>, Elzbieta Warchalowska-Sliwa<sup>4</sup>, Shin-ichi Akimoto<sup>5</sup>

<sup>1</sup> Department of Ecology and Environmental Science, Faculty of Agriculture, University of the Ryukyus, Nishihara, Japan; htatsuta@agr.u-ryukyuu.ac.jp

<sup>2</sup> Institute of Systematics and Ecology of Animals, Russian Academy of Sciences, Siberian Branch, Novosibirsk, Russia; bugrov04@yahoo.co.uk

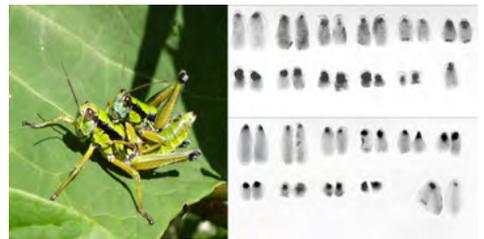
<sup>3</sup> Insect-Microbe Research Unit, Division of Insect Sciences, Institute of Agrobiological Sciences, National Agriculture and Food Research Organization (NARO), Tsukuba, Japan; kagymad@affrc.go.jp

<sup>4</sup> Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Krakow, Poland; warchalowska@isez.pan.krakow.pl

<sup>5</sup> Laboratory of Systematic Entomology, Graduate School of Agriculture, Hokkaido University, Sapporo, Japan; akimoto@res.agr.hokudai.ac.jp

In retrospect, more than 30-year term has passed since we started to carry out the research of brachypterous grasshopper, *Podisma sapporensis* Shiraki. *P. sapporensis* represents an ideal model system for the study of reproduction and speciation, as this species shows conspicuous morphological variation and contains chromosomal races. In the beginning of the study, we primarily focused on morphological variation between localities and some marked variation was detected in wings and genitalia (Tatsuta & Akimoto 1998, 2000). The first discovery of the chromosomal races was achieved by Bugrov et al. (2000), in which two major races differing in sex chromosome system were determined; one is XO/XX race and the other is neo-XY/neo-XX race, the latter of which has derived from Robertsonian (Rb) fusion between an autosome and the X-chromosome. Furthermore, each chromosomal race can be divided into several chromosomal subraces on the basis of variation in pericentric inversions (Bugrov et al. 2001). The same chromosomal races derived from Rb fusion have also been revealed in a closely related species, *P. pedestris* (Hewitt 1975). Although *P. pedestris* constitutes a distinctive cline where the two chromosomal races meet and hybridize, such a distinctive cline has not been found in *P. sapporensis*, except a few local points. A lack of hybrid zone might be owing to the strong selection against hybrids; however, experimental hybridization

between chromosomal races and subraces revealed that hybridization between chromosomal races produced viable offspring despite many differences in chromosomal structures (Bugrov et al. 2004). Recently we have revealed that *P. sapporensis* is infected with endosymbiotic *Wolbachia*, a maternally transmitted cytoplasmic parasite, which is known to induce reproductive isolation via cytoplasmic incompatibility (Bugrov et al. 2016). We are also searching for other endosymbionts that have potential to induce reproductive isolation in *P. sapporensis*. We will present what we have revealed in *P. sapporensis* through a long term field and laboratory studies and also report recent progress especially on parasite infection.



**Figure 1.** *Podisma sapporensis* adults (left); karyotype of XO (upper right) and that of neo-XY (bottom right)

**Key Words:** karyotypes, Robertsonian fusion, speciation, reproductive isolation, parasite.

## Speciation and adaptation in Polyneoptera

# COMPARATIVE GENOME STUDIES OF AN AFRICAN GENUS OF BUSH-CRICKETS (GONATOXIA, PHANEROPTERINAE)

Elżbieta Warchałowska-Śliwa<sup>1</sup>, Beata Grzywacz<sup>1</sup>, Klaus-Gerhard Heller<sup>2</sup>, Claudia Hemp<sup>3</sup>

<sup>1</sup> Institute of Systematics and Evolution of Animals Polish Academy of Sciences, Krakow, Poland; warchalowska@isez.pan.krakow.pl

<sup>2</sup> Grillenstieg 18, 39120 Magdeburg, Germany

<sup>3</sup> Biodiversity and Climate Research Centre (BiK-F), Frankfurt, Germany

East Africa is a hotspot of diversity for many Orthoptera including bush-crickets. The analysis of chromosomes may help (as one of the markers) to illuminate relationships between species, to interpret their evolutionary pathways and explain the importance of chromosomal reorganization in the light of the theoretical model of introgression and speciation.

The karyotype of most East African Phaneropterinae is more or less uniform with a diploid chromosomal number of  $2n_{\text{♂}} = 31$  or 29). However, the four species of *Gonatoxia* Karsch, 1889 possess quite different cytogenetic systems. Thus this genus is an excellent group to study genomic evolution: *Gonatoxia* species show an unusual high chromosome differentiation between the species ( $2n_{\text{♂}} = 29, 27, 7$ ). An interesting case is *G. helleri* C. Hemp, 2016 which has the lowest number of chromosomes ( $2n_{\text{♂}} = 7$ ) compared to other species of this genus and Phaneropterinae as a whole.

*Gonatoxia* is a poorly known genus restricted to East Africa. Some species of this genus occupy similar habitats, are wide-spread or restricted to an area or even endemic to a certain mountainous range in various geologically and environmentally diverse areas.

With the aim to understand their chromosomal evolution, we examined the genome organization using molecular (fluorescence in

situ hybridization with probes containing rDNA and telomeric DNA) and classical cytogenetic methods.

The results show a significant chromosomal polymorphism between and within the species. In the karyotype of *Gonatoxia* species instability of the chromosome number, fusion, inversion, mitotic and meiotic instability and a high level of heterozygosity (the occurrence of rDNA loci only on one of two homologous chromosomes) of different localities was observed. Chromosomal localization of ribosomal gene in these species has been associated with C-positive regions, GC-rich heterochromatin and active NORs. From a karyological point of view the variation in the position of 18S sites, heteromorphism in the size of the cluster in homologous chromosomes and presence of additional interstitial sites of the (TTAGG) $n$  sequences in individuals/populations could indicate that they are in a phase of active evolutionary changes.

So, the significant chromosomal polymorphism within and between species and individuals of *Gonatoxia*, may indicate the presence of a hybrid zone. Our data are a first step towards elucidating genome evolution in this interesting orthopteran group.

**Key Words:** East Africa, cytogenetics, karyotype evolution, fluorescence *in situ* hybridization, rDNA sites, telomeric DNA, chromosome banding.

## Speciation and adaptation in Polyneoptera

# COMPARATIVE TRANSCRIPTOMICS REVEALS PATTERNS OF ADAPTIVE EVOLUTION ASSOCIATED WITH ENVIRONMENTAL PERTURBATIONS IN TWO SPECIES OF CRICKETS ENDEMIC FOR NEW CALEDONIA: *KOGHIELLA NIGRIS* AND *KOGHIELLA FLAMMEA* (ENSIFERA, TRIGONIDIIDAE, NEMOBIINAE)

Ioana C. Chintauan-Marquier<sup>1\*</sup>, Mark C. Harrison<sup>2</sup>, Laure Desutter-Grandcolas<sup>1</sup>

<sup>1</sup> Institut de SYstématique Evolution Biodiversité (ISYEB), UMR 7205 Muséum National d'Histoire Naturelle, CNRS, Sorbonne Université, EPHE, UA, 45 Rue Buffon, CP50, 75005, PARIS, France. ioana.marquier@mnhn.fr; icchintauan.marquier@gmail.com

<sup>2</sup> Institut for Evolution and Biodiversity, University of Münster, Münster, Germany.

Species extinction during current biodiversity crisis is a real and serious problem in biodiversity hotspots, where the richness of fauna in disturbed habitats challenges research and conservation. In New Caledonia, the environment is being modified by anthropogenic activities, e.g. mining and nickel exploitation. The ability of animal communities to resist environmental perturbations can be characterized by the comparative analysis of the genomes of bio-indicators species. The crickets, which represent a huge part of insect communities in New Caledonia, are recognized as bio-indicators of the evolution of their communities.

In this context, we aimed at understanding the molecular mechanisms of biodiversity maintenance in disturbed habitats using RNA-seq (i.e. transcriptome) data from two Nemoibiinae (Grylloidea, Trigonidiidae) endemic to New Caledonia: *Koghiella nigris* occurring in wet

forests, and *K. flammea* present in nickel mining scrubs. We answered three main questions: (i) how much variation in gene expression is there and how is it structured? (ii) how do environmental stimuli affect gene expression?, and (iii) how does gene expression affect phenotype in the two species? We highlighted future directions of research in the molecular ecology of New Caledonian cricket communities, particularly related to moving beyond correlation and the development of additional annotation resources for known biological units and start assembling gene-expression community-level understanding of how organisms respond to environmental challenges. Measuring gene expression across an array of taxa in ecological settings promises to enrich our understanding of ecology and genome adaptation in insects.

**Key Words:** adaptation, biodiversity, cricket, ecology, evolution, New Caledonia, transcriptome.



## SYMPOSIUM 7

# Effects of climate and environmental change on Orthoptera

### Organizer: David Hunter

Locust and Grasshopper Control, 125 William Webb Drive, McKellar ACT 2617 Australia.  
davidmhunter100@gmail.com

1. **David Hunter.** AN OVERVIEW OF CHANGES IN THE ENVIRONMENT AND CLIMATE
2. **Arianne J. Cease, Rick Overson, Douglas Lawton, Marion Le Gall.** LOCUSTS AND LAND USE CHANGE: PLANT-INSECT INTERACTIONS AND NEW MANAGEMENT APPROACHES
3. **Ted Deveson.** KNOWN AND UNKNOWN EFFECTS OF ENVIRONMENTAL AND CLIMATE CHANGES ON SOUTHERN AUSTRALIAN LOCUSTS
4. **Zoltán Kenyeres, Norbert Bauer.** RESPONSE OF ORTHOPTERANS TO ENVIRONMENTAL CHANGES IN CENTRAL-EUROPEAN MESIC AND HUMID GRASSLANDS.
5. **Idrissa Halidou Maiga.** EFFECT OF RAINFALL PATTERN ON THE SENEGALESE GRASSHOPPER OUTPAUSES IN NIGER - AN ANALYSIS OF HISTORICAL DATA
6. **Shuguang Hao.** RESPONSE OF GRASSHOPPER EGG DEVELOPMENT TO CLIMATE WARMING
7. **Mario A. Poot-Pech.** THE EFFECT OF INCREASING TEMPERATURES ON OUTPAUSES OF TROPIDACRIS SPP IN THE AMERICAS
8. **Armin Landmann.** ARE ALTITUDINAL RANGE SHIFTS OF ORTHOPTERA ACCOMPANYING CLIMATE WARMING IN THE AUSTRIAN ALPS?
9. **Roy Kleukers, Baudewijn Odé.** SHIFTS IN DISTRIBUTION PATTERNS OF ORTHOPTERA IN THE NETHERLANDS
10. **Christine N. Meynard, Pierre-Emmanuel Gay, Michel Lecoq, Antoine Foucart, Cyril Piou, Marie-Pierre Chapuis.** CLIMATE-DRIVEN GEOGRAPHIC DISTRIBUTION OF THE DESERT LOCUST DURING RECESSION PERIODS: SUBSPECIES' NICHE DIFFERENTIATION AND RELATIVE RISKS UNDER SCENARIOS OF CLIMATE CHANGE
11. **Alexandre Latchininsky.** LOCUSTS, GRASSHOPPERS AND CLIMATE CHANGE: WHAT TO EXPECT?
12. **Michael Kearney, James Maino, Ted Deveson.** NEW APPROACHES TO MODELLING THE CLIMATIC RESPONSES OF LOCUSTS APPLIED TO CHORTOICETES AND AUSTROICETES IN AUSTRALIA
13. **Dan Johnson.** MODELLING THE EFFECTS OF CLIMATE CHANGE ON GRASSHOPPERS



## Effects of climate and environmental change on Orthoptera AN OVERVIEW OF CHANGES IN THE ENVIRONMENT AND CLIMATE

*David Hunter*

*Locust and Grasshopper Control, 125 William Webb Drive, McKellar, Canberra, Australia;  
davidmhunter100@gmail.com*

---

As part of the Congress theme "Challenges in front of climatic and environmental changes", this symposium on the "Effects of climate and environmental change on Orthoptera" is most appropriate. Our substantial alteration of the environment through agriculture and our settlement into cities has been occurring for millennia as part of what has been called the "Anthropocene" and has led to extinctions of many species while increasing outbreaks of others.

These effects are occurring at an accelerating pace due to the increasing human population and the increasing levels of greenhouse gases leading to climate change.

This talk will outline some of the ways climate is changing with some examples of how insects are responding to such changes as an introduction to further effects that will be outlined by various speakers in this symposium.

The aim of this symposium will be to outline what is currently known about climate change and to recognize that there are gaps in knowledge that will require further studies on this increasingly important subject.

**Key Words:** environment, climate change.



## Effects of climate and environmental change on Orthoptera

# LOCUSTS AND LAND USE CHANGE: PLANT-INSECT INTERACTIONS AND NEW MANAGEMENT APPROACHES

Arianne J. Cease<sup>1,2</sup>, Rick Overson<sup>1</sup>, Douglas Lawton<sup>2</sup>, Marion Le Gall<sup>1</sup>

<sup>1</sup> School of Sustainability, Arizona State University, Tempe, Arizona, USA; [acease@asu.edu](mailto:acease@asu.edu)

<sup>2</sup> School of Life Sciences, Arizona State University, Tempe, Arizona, USA

Connections between locusts and people date back millennia and remain a major food security challenge today throughout the world. The unpredictability and overwhelming nature of these outbreaks has likely contributed to the perception that, outside of active control, people are passive recipients of swarms. However, increasing evidence suggests that human decisions about how we manage our land influence locust population dynamics. For example, in Inner Mongolia, China, heavy livestock grazing promotes *Oedaleus asiaticus* outbreaks by lowering plant nitrogen (N) content. The Senegalese grasshopper, *Oedaleus senegalensis* is a non-model locust that has become the most prominent pest of the staple crop millet in the Sahel since the 1970's, potentially due to climate change and/or land use and land cover change.

In this talk, I will give an overview of our recent research and current projects in Australia, South America, and Senegal studying *C. terminifera*, *Schistocerca cancellata*, and *Oedaleus senegalensis* in coupled natural-human systems. Our results support the general hypothesis that soil management practices can affect locust dynamics by altering plant nutrient content. For instance, plants growing in soils poor in N will be low in N themselves and typically have low protein and high carbohydrate contents. These locust species prefer and have higher growth and survival on this carbohydrate-biased diet. For example, *O. senegalensis* selected unfertilized over N-fertilized millet. Accordingly,

this species had higher performance as nymphs on carb-biased artificial diets and longer survival times as adults when eating unfertilized millet. This suggests that high N cereal crops may stave off foraging by *O. senegalensis* nymphs at the vulnerable seedling stage and also decrease locust survival. However, adults eating fertilized millet laid eggs that were heavier on average than adults eating unfertilized millet, suggesting there may be a nutritional trade-off between lifespan and reproduction. These results are in line with other research and working knowledge that suggests that distinct management approaches are important for first-generation nymphs attacking crop seedlings vs. adults and later generation *O. senegalensis*.

Moving forward, we are initiating a pilot test of an area-wide integrated pest management (AW-IPM) approach in Senegal using soil amendments to increase the N content of young millet plants. We will measure the impact on crop yield, livelihoods, and *O. senegalensis* populations. If successful, this or similar AW-IPM approaches may move farmers from being passive recipients of locusts to being active participants in regional management programs.

**Key Words:** nutrition, plant-insect interactions, land use and land cover change, agroecology, area-wide integrated pest management.



## Effects of climate and environmental change on Orthoptera

# HISTORICAL EXAMINATION OF THE EFFECTS OF ENVIRONMENTAL CHANGES ON SOUTHERN AUSTRALIAN LOCUSTS

Ted Deveson<sup>1,2</sup>

<sup>1</sup> Australian Plague Locust Commission, Department of Agriculture and Water Resources, Canberra, Australia; ted.deveson@agriculture.gov.au

<sup>2</sup> Fenner School of Environment and Society, Australian National University, Canberra, Australia.

This paper addresses both related themes of this symposium using Australian species. There are numerous documented worldwide examples of increased locust swarming, and some of a decrease, linked to changes in land use practices. Because human modification of habitats is ubiquitous there are few exemptions in a list of pest species that have responded to environmental changes. Of particular relevance is recent research demonstrating that the lower protein content of overgrazed grasses favours larger locust populations. It provides a potential causal explanation for species of semi-arid grasslands. There are many other reasons, ranging from forest clearing to wadi agriculture.

As European empires expanded, settlers on the temperate grasslands of the Americas, southern Africa and Australia were confronted by swarms of locusts and grasshoppers that threatened the success of their imported agriculture. The introduction of European livestock coincided with increased swarming in several places. This is clearly demonstrated in Australia, where, in just fifty years from the start of pastoralism in the inland, 100 million sheep walked the plains, ate the haystack and expanded the habitats of the southern locust species. Evidence for an increase in swarming frequency and distribution in the Australian plague locust and small plague grasshopper, comes from a new analysis of the historical record, supported by climatic sequences and the history of landscape

changes. These taxonomically related species and look very similar. Their ecologies however are distinctly different and this has allowed their separation in the historical records of most major outbreaks.

The nature of future climates and the dual impact they could have on locust biology and habitats is generating intense current research interest. While being addressed in a variety of ways, the uncertainty over the rate and intensity of climate change renders similar levels of uncertainty over the results.

For Australia, models of near-future regional climate predict higher temperatures and lower rainfall in temperate areas and more extreme weather events. The likely effects of temperature extremes are being tested in the laboratory by exposing nymphs to current high summer temperatures over credible repeat daily sequences to test for effects on mortality and subsequent fecundity.

Preliminary results are outlined and the possible outcomes for continuity and increase of low density populations in arid inland regions are discussed.

**Key Words:** Land use, locust ecology, *Chortoicetes terminifera*, *Austroicetes cruciata*, outbreak history, climate change, high temperature exposure.



## Effects of climate and environmental change on Orthoptera

# RESPONSE OF ORTHOPTERANS TO ENVIRONMENTAL CHANGES IN CENTRAL-EUROPEAN MESIC AND HUMID GRASSLANDS

Zoltán Kenyeres<sup>1</sup>, Norbert Bauer<sup>2</sup>

<sup>1</sup> *Acrida Conservational Research L.P., Tapolca, Hungary; kenyeres@acridabt.hu*

<sup>2</sup> *Hungarian Natural History Museum, Department of Botany, Budapest, Hungary*

Based on our research, climate change in Central-Europe affects mostly orthopteran assemblages occurring in mesic and humid habitats. The current presentation sums the main results of three case studies: monitoring of grasslands of two regions (1a: 2003–2011, 1b: 2002–2017) under intensive land use non-adapted to climate changes [time and method of the annual land use (mowing/grazing) was independent from the weather of the given year]; (2) monitoring of a grassland (2006–2016) under land use adapted to climate changes [mosaic-like mowing/no treatment in drought years]. The focus of the studies was on the following parameters and relations: (a) changes in relative frequencies of life-forms, eco-types and characteristic species of the assemblages; (b) correlations among the parameters of orthopteran assemblages and macroclimate; (c) effects of land use on the primary changes. In the meteorological datasets, the annual precipitation showed extremes related to every case study, but trends were not detected. A statistically significant increasing trend was seen for annual mean temperature in case study 1b. According to our results, in the Central-European mesic and humid grasslands (a) species richness and abundance of the graminicol species related to short grasslands were mostly influenced by the interference of microclimate and land use; (b) abundance of the pratinicol species related to tall grasslands with dense vertical structure was affected by microclimate, macroclimate and the interactions of the latter two parameters with land use; (c) in the values of some important components of microclimate (humidity and temperature) the seasonal macroclimate (from June to September) is the determinant; (d) in the case of land use non-adapted to climate changes

statistically significant decreasing trend was detected in relative frequency of moderately-hygrophilic species, and significant increasing trend in species number; (e) diversity of the assemblages were positively influenced by mean temperature in summer; (f) fluctuation in abundance of mesophilic and hygrophilic species along the annual macroclimatic parameters can be significantly reduced by land use adapted to climate changes.

Our case studies confirmed that species adapted to a cooler climate are more sensitive to climate change than thermophilic or moderately-thermophilic ones (in the studied Central-European region, climate change results warming and drying in macroclimate). Expansion of thermophilic and moderately-thermophilic species were detected within the area – they now occupy habitats that were not suitable for them formerly. An increase in the number and diversity the species in the studied orthopteran assemblages is not a positive change from conservational point of view: warming of the global climate has resulted local regression of the character species of Central-European humid grasslands. For local mitigation of global climate change, we have the following possibilities in the mesic and humid grasslands: (1) Mosaic-like treatment, with patches unused in all seasons, but annually on different sites of the parcel. (2) Exclusion of grazing, or extensive grazing just in autumn. (3) Altering the timing and number of mowings depending on annual temperature and rainfall.

**Key Words:** Climate change, Microclimate, Land use, Adaptation, Monitoring, Assemblages.



## Effects of climate and environmental change on Orthoptera

# EFFECT OF RAINFALL PATTERN ON THE SENEGALESE GRASSHOPPER OUTBREAKS IN NIGER - AN ANALYSIS OF HISTORICAL DATA

*Idrissa Halidou Maiga*

*AGRHYMET Regional Centre, Niamey, Niger; idrissa.maiga@cilss.int*

The serious outbreaks of the Senegalese grasshopper (SG) after the severe drought of the early 1970s, in association with some other grasshopper species, have highlighted the economic importance of this species.

In the years 1974-1975, outbreaks were widespread in West Africa, affecting about 3,500,000 hectares. Since then, *O. senegalensis* has maintained its status as the main Sahelian acridian pest of cereal crops and became chronic even though the extent of the problem varies naturally according to the spatial and temporal distribution depending on the ecological conditions. SG control remain one of the main activities of the plant protection services in Sahel countries over the last 30 years.

A description of recent cycles of SG outbreaks (over 15 years) and an analysis of the relationships between outbreaks and rainfall conditions have been conducted in Niger in an attempt to obtain potential indicators of the species outbreak risk.

Infestations data from 15 departments in the areas of traditional SG outbreaks in Niger were used for this historical data analysis. For each department, monthly and ten-day information were available, quite regularly, from 1989 to 2004. The distribution of late-season eggs (diapausing eggs) and the level of parasitism as a function of the latitude and the ITCZ position were also studied.

As densities were not systematically scored or have been evaluated according to different methods, their comparison was not suitable. Furthermore, the annual size of treated areas depend not only on the infestation level, but also largely on resources available to the plant protection service. Thus, only infestation data are selected for a cross-

analysis with rainfall parameters. According to the criterion used by the plant protection officers, an area is infested from a density of five individuals or more per m<sup>2</sup>.

The correlation analysis between the infestation level and various rainfall parameters at the local level shows obviously a global relationship between outbreaks and rainfall at both decadal and annual level. However, in detail, beyond this simple statement of common sense, it is not possible to go further and to relate an intensity of outbreak and the level of local rainfall for a given site despite the important period of observation (14 years). All this limits undoubtedly the possibility of looking for fine relationship between infestation level and rains. It is therefore impossible to identify, with local rainfall measurement (ground gauge) or estimation (RFE), a simple index that would make it possible to envisage a forecast of the level of outbreaks and there is obviously the need for a comprehensive approach, integrating the local dynamics of the insect and its regional migration.

Light trap catches confirm the southward movement of adults in connection with the withdrawal of the ITCZ. The spatial distribution of the last generation egg pods shows a large interannual variability and the latitudinal distribution is strongly different from the one assumed. G3 egg pods appear regularly distributed from north to south at least in the study area between 12°N and 16°N.

**Key Words:** egg pods distribution, ITCZ, outbreaks, Senegalese grasshopper, rain.

Effects of climate and environmental change on Orthoptera

**RESPONSE OF GRASSHOPPER EGG DEVELOPMENT TO CLIMATE WARMING**

Shuang Hao

State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing, China; Haosg@ioz.ac.cn

The most studied ecological responses of organisms to climate warming are shifts in distribution ranges, changes in phenology, and declines in mean body size. All of those directly deal with the development and growth of ectotherms, especially insect. We conducted a series of field and lab manipulation experiments to investigate developmental responses of grasshopper species to warming in Inner Mongolia. These grasshoppers include three species that are sympatric but differ in phenology, and a species which is widely distributed in varied latitudinal regions. We found that warming advanced the timing for egg hatching and grasshopper eclosion in each of the species. However, grasshopper diapause appeared to offset the effect of warming on egg development. Hatching and development were more strongly affected by warming in non-diapause *Chorthippus fallax* relative to the diapausing *Dasyhippus barbipes*. We also found that the developmental rate of the lowest latitudinal population of *Chorthippus dubius* significantly slowed in comparison to the higher latitudinal populations, which were more sensitive to warming. Interestingly, there was no difference in Low Development Threshold Temperatures (LDTT) among geographic populations, but higher latitudinal populations had lower Effective Accumulated Degree-Days (EADD) compared to low-latitude populations. The higher EADD of lower latitudinal populations appeared to buffer influences of climate warming, facilitating them to conserve their univoltine lifecycle.

These results suggest that there are significant developmental strategies between species and geographic populations of grasshoppers in response to climate warming. These strategies provide an adjustable possibility of preserving

their univoltine status for a single year's cycle while simultaneously encountering a warmer climate. Therefore, in the case of global climate warming, insects might be able to adapt to the prolonged growing season while maintaining the stability of their life cycle.

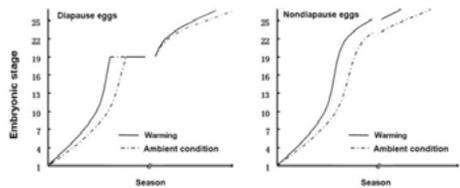


Figure 1. Developmental divergence of non- and diapause eggs in warming and ambient conditions.

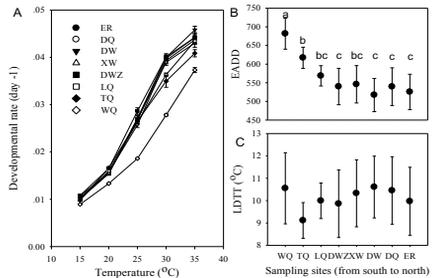


Figure 2. The developmental rate (reciprocal of developmental duration) of eggs collected from different geographic populations of *Chorthippus dubius* at varied constant temperatures. B: The Effective Accumulated Degree-Days (EADD) of eggs collected from different geographical populations of *C. dubius*. C: The Low Development Threshold Temperatures (LDTT) of eggs collected from different geographical populations of *C. dubius*. Mean ±SE.

**Key Words:** Climate warming, grasshopper, development, phenology, diapause, Inner Mongolia.

## Effects of climate and environmental change on Orthoptera

# THE EFFECT OF INCREASING TEMPERATURES ON OUTBREAKS OF TROPIDACRIS SPP IN THE AMERICAS

Mario A. Poot-Pech

Locust Control Program. Plant Health in Yucatán State (CESVY-SENASICA-Yucatán Government), México;  
 mario.poot@cesvy.org.mx

Members of the genus *Tropidacris* Scudder 1869 (Orthoptera: Romaleidae) are known as giant grasshoppers (GG) and considered important pests for damaging forests and cultivated plants in Central and South America. Two important *Tropidacris* of the Neotropical region are *T. cristata* (Drury) from SE Mexico through to Nicaragua and *T. collaris* (Stoll) from Colombia to Central Argentina (Carbonell 1986). In recent years there were important GG outbreaks in the Americas: during 2013 and 2016 in Yucatán, México, during 2017 in Guatemala and Honduras; in 2013, 2015 and 2017 in Argentina with presence in 2018 also in Paraguay.

We studied the association of temperature, precipitation and MEI (Multivariate ENSO index), Rank emitted by NOAA (National Oceanic and Atmospheric Administration) on GG outbreaks in each region: these variables were analyzed with a correlation matrix (CM) additionally. We also analyzed the changes in the NDVI (Normalized Difference Vegetation Index) values in Landsat images where the GG outbreaks occurred.

The results indicated that the GG outbreaks are very much associated with maximum temperature especially in Honduras with 31.2oC (CM:0.71) and Argentina 36.6oC (CM:0.59), in case of México apparently no direct effect to 32.2oC (CM:-0.37).

According to NOAA the MEI ranks are 1 to 69 where the lowest number (1) would denote the strongest "La Nina" case for that bimonthly season, while the highest number (68 or 69) would indicate the strongest El Nino case. In México the GG is high influenced by the 3 first

MEI ranks (December-March), which the average 51.8 (CM:0.62), in Honduras the next three periods

(March-June) average 59.6 (CM:0.33) and Argentina average 43.3 (CM: -0.01). On the other hand, the NDVI values of the places where the GG occurred are lower, indicating less green vegetation.

The forests in America have been affected by the change in land use or deforestation due to two economic reasons: seasonal agriculture and rangeland for livestock development. This has a direct effect on the increase in temperature, and consequently, the pest outbreak. The maximum temperature imposes a significant effect of leading to a continuous GG presence. Rainfall also has a positive effect on the grasshopper population in that it results in there being good food disposition at the end of the season.

The effect of climate change on *T. cristata* was hypothesized by Diniz-Filho et al. (2010) through previous reports of the presence of GG and models of development, the results here suggest the frequent outbreaks of GG as a possible effect of increased temperature and changes in land use. These results can be useful in the construction of forecast models for GG throughout the Americas.

Carbonell C.S. 1986. Revision of the Neotropical Genus *Tropidacris* (Orthoptera, Acridoidea, Romaleidae, Romaleinae). Proceedings of the Academy of Natural Sciences of Philadelphia 138: 366-402.

Diniz-Filho J.A.F., Nabout J.C., Bini L.M., Loyola R.D., Rangel T.F., Noguees-Bravo D., Araújo M.B. 2010. Ensemble forecasting shifts in climatically suitable areas for *Tropidacris cristata* (Orthoptera: Acridoidea: Romaleidae). Insect conservation and diversity 3:213-221.

**Key Words:** ENOS, NDVI, climate change.

## Effects of climate and environmental change on Orthoptera ARE ALTITUDINAL RANGE SHIFTS OF ORTHOPTERA ACCOMPANYING CLIMATE WARMING IN THE AUSTRIAN ALPS?

Armin Landmann

Institute of Zoology, University of Innsbruck, Innsbruck, Austria; armin.landmann@uibk.ac.at

More than 62 % of the surface of Austria is covered by the Eastern Alps which can be subdivided into three major ranges – the Northern Calcareous Alps (summits up to 3031 m asl.), the Central Alps (highest summit: 3797 m), and the Southern Calcareous Alps (up to 2780 m). In addition, about 10 % of the surface of Austria is covered by the Bohemian Forest north of the Danube, a lower mountain range rising up to only 1378 m but with harsh weather conditions that change with altitude as well.

Since 1980 in Austria the mean annual temperature showed an increased rise of approximately 1 C compared to the global increase of about 0.5°C. Signals of accompanying altitudinal range expansions and contractions so far have been demonstrated mainly for vascular plants in the high Alps but are not well investigated for animals. However, the topographical as well as climatic settings of Austria make this country especially promising to investigate effects of the climate warming in the Alps on altitudinal distribution and abundance patterns of Orthoptera. As these patterns as well as life cycles of the thermophilic Orthoptera in mountainous regions are primarily shaped by the recurrence of adverse climatic conditions and by the dominating temperature regimes at different altitudes, strong responses of Orthoptera to climate warming can be expected there. For instance, one could forecast elevational distribution bands of low- and midland species to show an upward movement, and on the contrary could fear range contractions for specialized high-altitude species (Fig. 1) which would also raise concerns from a conservation point of view. The Austrian Orthoptera working group can dispose over a rather huge stock of more than

283.000 altitudinal records of the 139 extant species. Most of our data (> 95%) stem from recent decades which is especially promising in the light of climatic developments. In particular data of “elevational ubiquists” and of some high-altitude species offer excellent possibilities to test for effects of climate warming. Although there are some indications for an increase of records at very high altitudes for some species, patterns are inconsistent between species and between the main mountain ranges. Overall there is - at the moment- no clear evidence for a general pronounced recent upward movement of elevational distribution bands of Orthoptera in the Austrian Alps. Our findings thus warn against expecting simple responses of mountain grasshopper communities to climate warming.



**Figure 1.** The arcto-alpine *Melanoptus frigidus* is probably the most cold-adapted high-altitude Orthoptera of the Alps (here sitting on the most famous alpine flower *Leontopodium alpinum*) and could be threatened by climate warming (Salzburg Central Alps, 2470 m; I. Illich)

**Key Words:** Austrian Alps, climate warming; changes in altitudinal distribution patterns.



## Effects of climate and environmental change on Orthoptera

# SHIFTS IN DISTRIBUTION PATTERNS OF ORTHOPTERA IN THE NETHERLANDS

Roy Kleukers<sup>1</sup>, Baudewijn Odé<sup>2</sup>

<sup>1</sup> EIS Kenniscentrum Insecten/Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands, [kleukers@naturalis.nl](mailto:kleukers@naturalis.nl)

<sup>2</sup> De Bongerd 29, 6584 DG Molenhoek, The Netherlands

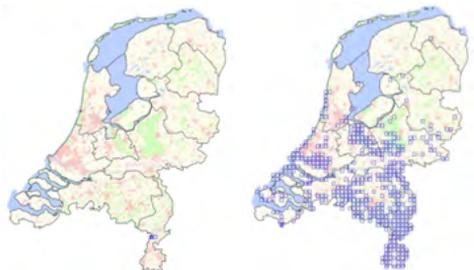
In the Netherlands, Orthopteran fauna have traditionally been investigated quite intensively, and there being only 50 species is helpful in this respect. During the period 1990-1995, the first distribution atlas was produced with the help of 385 professional and volunteer observers. This yielded nearly 60,000 observations and resulted in accurate distribution maps for all species.

In the period 2006-2014, a new atlas has been produced. In this atlas data collection has been predominantly internet-based, with the use of Observation.org with up-to-date maps and apps for mobile phones to easily collect data in the field. This yielded in a much higher number of participants (3,794) and observations (320,000).

A comparison of both periods shows that big changes have occurred, including the arrival of four new species to our country along with a strong increase in nine native species. These changes remained intact, when taking into account the difference in search intensity of both periods.

All expanding and new species show a European distribution pattern south of The Netherlands. Several of these species are good flyers, that could easily expand to other favourable areas. Examples are *Sphingonotus caeruleus*, *Phaneroptera falcata* and *Conocephalus fuscus*. Yet, several of the increased species are flightless or only rarely produce long-winged specimens. Some of those species have been traveling with humans, e.g. by cars. Especially *Meconema meridionale*

found its way from Italy northwards via cars and established itself in the climatically warmer cities of NW-Europe. Other less mobile species seem to have profited from large scale natural grassland habitats e.g. in the riverine area of our country. This partly holds for *Chrysochraon dispar* and *Oecanthus pellucens*. In rare cases a species could have been brought to our country with imported products. This may hold for a population of *Eumodicogryllus bordigalensis*, that already resides as a population along a railroad for 8 years. The evidence suggests that the Netherlands has become more favourable for many southern species. The warmer summers resulting from climate change have led to some species establishing in new areas while southern species have found urban areas more favourable.



**Figure 1.** Distribution of *Phaneroptera falcata* in the Netherlands in 1990 (left) and 2012 (right).

**Key Words:** Climate change, range shift, citizen science.

## Effects of climate and environmental change on Orthoptera

# CLIMATE-DRIVEN GEOGRAPHIC DISTRIBUTION OF THE DESERT LOCUST DURING RECESSION PERIODS: SUBSPECIES' NICHE DIFFERENTIATION AND RELATIVE RISKS UNDER SCENARIOS OF CLIMATE CHANGE

Christine N. Meynard<sup>1</sup>, Pierre-Emmanuel Gay<sup>2,3</sup>, Michel Lecoq<sup>2,3</sup>, Antoine Foucart<sup>2,3</sup>, Cyril Piou<sup>2,3</sup>, Marie-Pierre Chapuis<sup>2,3</sup>

<sup>1</sup> Institut National de la Recherche Agronomique (INRA), UMR Centre de Biologie pour la Gestion des Populations (CBGP), CS 30016, Montferrier-sur-Lez, France; christine.meynard@inra.fr

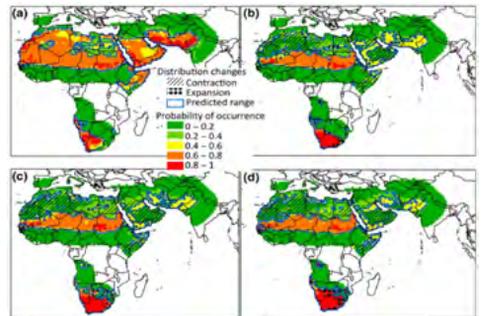
<sup>2</sup> CIRAD, CBGP, Montpellier, France

<sup>3</sup> CBGP, CIRAD, INRA, IRD, Montpellier SupAgro, Univ Montpellier, Montpellier, France

The desert locust is an agricultural pest that is able to switch from a harmless solitary stage during recession periods, to swarms of gregarious individuals that disperse long distances and affect areas from western Africa to India during outbreak periods. Large outbreaks have been recorded through centuries, and the Food and Agriculture Organization keeps a long-term, large-scale monitoring survey database in the area. However, there is also a much less known subspecies that occupies a limited area in southern Africa. We used large-scale climatic and occurrence data of the solitary phase of each subspecies during recession periods to understand whether both subspecies' climatic niches differ from each other, what is the current potential geographical distribution of each subspecies, and how climate change is likely to shift their potential distribution with respect to current conditions. We evaluated whether subspecies are significantly specialized along available climate gradients by using null models of background climatic differences within and between southern and northern ranges, and applying niche similarity and niche equivalency tests. The results point to climatic niche conservatism between the two clades. We complemented this analysis with species distribution modeling to characterize current solitary distributions and forecast potential recession range shifts under two extreme climate change scenarios at the 2050 and 2090 time horizon. Projections suggest that, at a global

scale, the northern clade could contract its solitary recession range, while the southern clade is likely to expand its recession range.

However, local expansions were also predicted in the northern clade, in particular in southern and northern margins of the current geographical distribution. In conclusion, monitoring and management practices should remain in place in northern Africa, and in southern Africa the potential for the subspecies to pose a threat in the future should be investigated more closely.



**Figure 1.** Predictions of distribution changes under two different climate change scenarios (A1B on the left, A2 on the right), for two time-steps (2050 in the upper row, 2090 in the lower row).

**Key Words:** *Schistocerca gregaria*, pest, species distribution models, niche differentiation, niche overlap, forecasting, phase polyphenism.



## Effects of climate and environmental change on Orthoptera

# LOCUSTS, GRASSHOPPERS AND CLIMATE CHANGE: WHAT TO EXPECT?

Alexandre Latchininsky

Food and Agriculture Organization of the United Nations (FAO UN), Rome, Italy,  
alexandre.latchininsky@fao.org

One of the most powerful manifestations of climate change is global warming. Over the past 100 years the average temperature of the atmosphere near the Earth's surface has increased by almost 1 °C. By the end of the 21st century, the Earth's temperature is estimated to rise by 4 °C. Global warming is attributed to a sharp increase in carbon dioxide in the atmosphere due to human activity, which leads to "greenhouse effect."

Like all insects, locusts and grasshoppers (Orthoptera: Acridoidea) are ectothermic animals, their body temperature varies depending on the ambient air temperature. Their life cycles are relatively short, and thus even small temperature changes can have a strong impact on their population dynamics. Temperature increase is usually beneficial for acridoids and can trigger a number of responses from them.

First, their distribution areas can change. In the northern hemisphere, the northern boundary of the distribution area of certain species expands to the north. Alternatively, species may start to inhabit higher altitudes in the mountains. The latter is true for the Moroccan Locust *Docioptaurus maroccanus* in Central Asia. In the 20th century, its breeding areas were situated between 800 and 1200 m a.s.l. while in the 21st century, it frequently breeds at 1500 m and even 1750 m a.s.l. in Uzbekistan and Tajikistan.

Second, phenology and seasonal development of insects change. Higher daily temperatures increase degree-day accumulations so the hatching of insects will occur earlier and their development will be faster in comparison with the multi-year averages. This was shown to be true for grasshopper assemblages of the Rocky Mountains in North America.

Third, the number of annual generations may increase. For example, grasshopper *Melanoplus sanguinipes* in Arizona and Asian Migratory Locust *Locusta migratoria migratoria* in S. Russia and Central Asia recently produced two generations per

year although typically, they are univoltine. Because of the warming climate, phenology of these insects shifted to earlier dates allowing for a second generation to start in late summer.

Evidently, such new trends in locust and grasshopper phenology and life strategies caused by climate warming present problems for locust control services. Monitoring and managing Moroccan locust populations at higher altitudes is extremely difficult and time- and resource-consuming. As for the Asian Migratory Locust, its late-season hatching of the second generation occurs when the treatment campaign is already over and there are no more resources (pesticides, fuel, scouts) to conduct anti-locust treatments. As a result, a large proportion of the population remains uncontrolled and can produce swarm flights. Pest grasshoppers (*Melanoplus spp.*), which started to produce second annual generation in North America, present a similar problem.

To sum up, we should expect that locust and grasshopper outbreaks might become more frequent and severe under warming climatic conditions. Climate warming, which causes shifts in acridid distribution, phenology and voltinism, is a challenge for their monitoring and management.

**Key Words:** Locusts, Grasshoppers, Climate warming, Voltinism, Distribution area, Monitoring, Management.



## Effects of climate and environmental change on Orthoptera

# NEW APPROACHES TO MODELLING THE CLIMATIC RESPONSES OF LOCUSTS APPLIED TO CHORTOICETES AND AUSTRICETES IN AUSTRALIA

Michael Kearney<sup>1</sup>, James Maino<sup>2</sup>, Ted Deveson<sup>3</sup>

<sup>1</sup> The University of Melbourne, Melbourne, Australia; mrke@unimelb.edu.au

<sup>2</sup> CESAR Australia, Melbourne, Australia

<sup>3</sup> Australian Plague Locust Commission, Canberra, Australia

The dynamics of insect populations are often strongly tied to climate and weather, especially via soil temperature and moisture conditions and their influence on development and food availability. They also depend on the experienced body temperature and how this affects metabolic rates and hence the speed of the life cycle. To make accurate forecasts of the effects of climate and climate change on grasshoppers and locusts we ideally want models that are maximally based on fundamental physical processes. Here we present new models for predicting grasshopper responses to climate developed under the NicheMapR mechanistic niche modelling package for the R programming environment. The approach incorporates fully physical models of microclimate, heat and water exchange, and the metabolism. The microclimate model predicts hourly soil temperature and moisture as a function of gridded environmental data. It handles variable soil properties with depth, and includes transpiration processes and their effect on soil moisture. The heat and water exchange model includes behavioural thermoregulation responses.

The metabolic model, derived from Dynamic Energy Budget theory, captures the dynamics of the full life cycle from egg to senescence and how it is influenced by variable food and temperature environments, as well as integrating with the water budget. We illustrate the model through applications to the two major pest grasshopper species in Australia, the Australian Plague Locust *Chortoicetes terminifera* and *Austroicetes cruciata*. The models include details of egg diapause responses. Model results are compared 20 years of observations made by the Australian Plague Locust Commission. We discuss the success of the modelling approach in predicting observed grasshopper and food plant dynamics, and its potential role in guiding future ecophysiological research on these important pest species.

**Key Words:** mechanistic niche model, biophysical ecology, climate responses, metabolic theory, microclimate, ecophysiology, life cycle.



## Effects of climate and environmental change on Orthoptera

# MODELLING THE EFFECTS OF CLIMATE CHANGE ON GRASSHOPPERS

*Dan Johnson*

*University of Lethbridge, Lethbridge, Alberta, Canada; dan.johnson@ulethl.ca*

---

Several approaches are used to assess climate impacts on grasshoppers in northern grassland in North America, and forecast expected changes in abundance, timing, and dispersion for key pest and non-pest species. Individual species developmental curves of thermal requirements, historical climate matching, and weather-survival analysis are applied based on a recently compiled database of over 73,000 Alberta survey sites with observations on grasshopper counts at individual survey and research sites during 1970-2016. Current research is underway to determine

expectations under future climate scenarios and add geographic patterns of variables such as insolation.

**Key Words:** mechanistic niche model, biophysical ecology, climate responses, metabolic theory, microclimate, ecophysiology, life cycle.



## SYMPOSIUM 8

# Communication and Behaviour of Orthopteran Insects

### Organizers: Long Zhang<sup>1</sup> & Berthold Hedwig<sup>2</sup>

<sup>1</sup> China Agricultural University, Beijing 100193, PR China;  
locust@cau.edu.cn;

<sup>2</sup> Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, UK,  
bh202@cam.ac.uk

1. **Berthold Hedwig.** COMMUNICATION AND BEHAVIOUR OF ORTHOPTERAN INSECTS: A NEUROBIOLOGISTS PERSPECTIVE
2. **Hannah ter Hofstede, Ciara Kernan, Jessica Ralston, Mia Phillips, Stefan Schöneich, Tony Robillard.** THE ACOUSTIC-VIBRATIONAL DUET OF LEBINTHINE CRICKETS
3. **Stefan Schöneich, Jan Scherberich, Jennifer Hummel, Manuela Nowotny.** SEXUAL DIMORPHISM OF AN AUDITORY FOVEA IN THE EARS OF THE DUETTING BUSHCRICKET ANCYLECHA FENESTRATA
4. **Heiner Römer.** THE IMPACT OF ACOUSTIC BACKGROUND ON COMMUNICATION AND PREDATOR DETECTION/AVOIDANCE IN RAINFOREST ORTHOPTERA
5. **Xinyang Zhang and Berthold Hedwig.** EXPLORING THE RESPONSE TO ATTRACTIVE AND NON-ATTRACTIVE PULSE PATTERNS IN THE SONG RECOGNITION NETWORK OF A CRICKET
6. **Athanasios Ntelezos, Berthold Hedwig.** DIRECTIONAL HEARING AND AUDITORY MOTOR RESPONSES OF FEMALE FIELD CRICKETS
7. **Varvara Vedenina, Lev Shestakov.** HOW DOES MALE DOMINANCE STATUS DETERMINES IT'S MATING SUCCESS IN CRICKET GRYLLUS BIMACULATUS?
8. **Heinz Breer, Xingcong Jiang, Jürgen Krieger, Pablo Pregitzer.** MOLECULAR ELEMENTS OF OLFACTION IN ANTENNAE OF THE DESERT LOCUST
9. **Jia Li , Xiaoqi Wang , Long Zhang.** IDENTIFICATION AND OLFACTOMETRIC BIOASSAY OF SEX-SPECIFIC VOLATILE COMPOUNDS IN ADULT LOCUST LOCUSTA MIGRATORIA (MEYEN) (ORTHOPTERA: ACRIDIDAE)
10. **Peng Wang, Xuwei Yin, Long Zhang.** PLANT APPROACH-AVOIDANCE RESPONSE IN LOCUSTS DRIVEN BY PLANT VOLATILE SENSING AT AT DIFFERENT RANGES.



## Communication and Behaviour of Orthopteran Insects

# COMMUNICATION AND BEHAVIOUR OF ORTHOPTERAN INSECTS: A NEUROBIOLOGIST'S PERSPECTIVE

*Berthold Hedwig*

*Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, UK, e-mail: bh202@cam.ac.uk*

The approximately 20000 recent orthopteran species, with their wide variety of adaptations in morphology, behaviour and lifestyle provide fascinating material for neurobiological research. They can be used to understand the fundamental principles that underlie behaviour: from sensory processing to motor pattern generation, and the adaptive changes that occur over a lifetime. The salient behaviours of some orthoptera have of course attracted particular interest. The need for pest control drives research in the case of locusts, which in their gregarious phase can form massive swarms with devastating effects for farming communities. Understanding their flight behaviour, gregarisation and egg laying behaviour, and also their olfactory adaptations to detect conspecifics or food, are fundamental to limiting their impact on rural societies. Interest in the acoustic communication shown by so many orthopteran insects may initially have been driven by sheer curiosity. But as these insect have to solve very similar problems to acoustically communicating vertebrates, some species of grasshoppers and crickets have become "model" systems. Their comparatively simple nervous systems, in which individual neurons can be identified by structure and activity through electrophysiological recording and labelling techniques has greatly facilitated the understanding of principles of neuronal processing.

The variation in stridulatory mechanisms and auditory organs provide an example of

how evolution of these traits has been driven by the benefits of long distance acoustic communication, which allows mate attraction in cluttered environments. The generation of acoustic signals and auditory processing require well-adapted motor structures and sensory pathways. As in other systems, neurobiology aims to identify the fundamental principles underlying acoustic communication: What are the principles of acoustic signalling? How are motor patterns generated? How do the ears function? What are the neuronal mechanisms for directional hearing? How can these insects detect and process a species-specific sound pattern - and how does this function under natural conditions away from the well-controlled recording situation in the lab?

The continual development and fine tuning of research techniques fills and enriches the tool box of neurobiology. In Orthoptera we have just started to explore molecular-genetic techniques and the door is gradually opening to develop genetically encoded markers in sensory pathways or identified neurons. I am sure that in the near future we will have genetically encoded markers stably expressed within the peripheral or central nervous system to monitor neuronal activity. Combined with the strong approach of in-tracellular recording, this should strengthen the position of orthopteran insects as model systems in neurobiological research.

**Key Words:** Orthoptera, neurobiology.

## Communication and Behaviour of Orthopteran Insects

### THE ACOUSTIC-VIBRATIONAL DUET OF LEBINTHINE CRICKETS

Hannah ter Hofstede<sup>1</sup>, Ciara Kernan<sup>1</sup>, Jessica Ralston<sup>1</sup>, Mia Phillips<sup>1</sup>, Stefan Schöneich<sup>2</sup>, Tony Robillard<sup>3</sup>

<sup>1</sup> Dartmouth College, Hanover, NH, USA; [Hannah.ter.hofstede@dartmouth.edu](mailto:Hannah.ter.hofstede@dartmouth.edu)

<sup>2</sup> University of Leipzig, Leipzig, Germany

<sup>3</sup> Muséum national d'Histoire naturelle, Paris, France

In many cricket species, females move towards low-frequency sounds typical of the male calling song, and they move away from high-frequency sounds typical of the echolocation calls of predatory bats. Crickets in the subfamily Eneopterinae, tribe Lebinthini, have an alternative form of communication; males produce high-frequency calling song, in the range of frequencies that are usually aversive to other crickets, and females do not walk to the male but instead produce vibrational signals in response to male calls. Once a duet is established, males follow the vibrational signals to locate the female. In a previous study, we suggested that this acoustic-vibrational duet might have evolved from an acoustic startle response to high-frequency sounds.

Current research on communication in this group of crickets is investigating how selection by males and females shapes male and female signals. Males *Lebinthus bitaeniatus* (Fig. 1A), produce high-frequency acoustic calls (20 kHz) consisting of two components: ticks and trills (Fig. 1B). Ticks are individual pulses produced at long intervals before the trill. Trills are bursts of shorter duration pulses produced at a much higher rate. The number of ticks before the trill is highly variable, ranging from just a few to up to 80, whereas the timing and duration of the trill component is highly conserved. This suggests that the trill component might be important for species recognition, whereas ticks might be a signal of male quality.

Playback experiments show that the trill is the component of the signal that elicits the female vibrational reply. However, the number of ticks preceding the trill influences both male and female signalling behaviour. When males hear

other males calling, they produce more ticks than when singing in silence, suggesting that ticks play a role in male-male competition. Likewise, females produce a larger amplitude vibrational reply in response to male calls that have a greater number of ticks, suggesting that females prefer males that produce more energetically costly signals or that the additional ticks alert the female to prepare her response. Females also produced larger amplitude vibrational signals in response

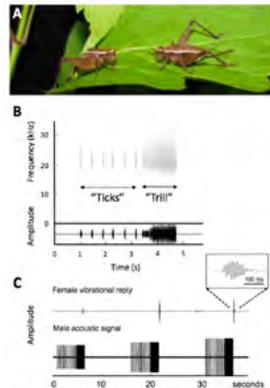


Fig. 1: Acoustic-vibrational duets in *Lebinthus bitaeniatus*. (A) A male and female meeting on a leaf. (B) Spectrogram and oscillogram of the male acoustic call, showing the two components (ticks and a trill). (C) Accelerometer recording of female vibrational reply to male calling song.

to greater amplitude male calls (Fig. 1C). Given the difference in attenuation between acoustic and vibrational signals, it is possible that the variation in the amplitude of the female reply is providing information about distance to the male.

**Key Words:** Crickets, vibrational signals, duet, acoustic startle response, Eneopterinae.

## Communication and Behaviour of Orthopteran Insects

# SEXUAL DIMORPHISM OF AN AUDITORY FOVEA IN THE EARS OF THE DUETTING BUSHCRICKET *ANCYLECHA FENESTRATA*

Stefan Schöneich<sup>1</sup>, Jan Scherberich<sup>2</sup>, Jennifer Hummel<sup>2</sup>, Manuela Nowotny<sup>2</sup>

<sup>1</sup> University of Leipzig, Institute for Biology, Talstr. 33, 04103 Leipzig, Germany;

Stefan.Schoeneich@uni-leipzig.de

<sup>2</sup> Goethe University Frankfurt, Institute for Cell Biology and Neuroscience, Germany

In the duetting bushcricket *Ancylecha fenestrata* (Tettigoniidae: Phaneropterinae), the mutual acoustic communication between males and females is asymmetrical. For mate attraction, males and females produce short sound pulses with sex-specific dominant frequencies of about 30 and 10 kHz, respectively. Males repeatedly call at nighttime and females occasionally respond to a male call by a single sound pulse after a fixed time delay of about 150 ms. Playback experiments revealed that males phonotactically approach the sound source of female calls, whereas females in most cases did not show any locomotory responses to the male calls.

Both sexes have tympanic ears in their forelegs, but male ears possess a significantly longer crista acustica containing 35 % more scolopidia than the female ears. With more sensory cells to cover a similar overall frequency range, the male hearing organ shows a significantly expanded auditory fovea that is tuned to the dominant frequency of the female reply. About 50 % of the sensory neurons in the male's crista acustica are tuned to a narrow frequency range of about 10 kHz. This sex-specifically extended auditory fovea is demonstrated in the mechanical and neuronal responses along the tonotopically organized crista acustica by laser vibrometric and electrophysiological frequency mapping, respectively.

Morphometric analysis of histological cross-sections of the crista acustica revealed a constant organ height only within the fovea region, whereas other anatomical parameters like cap cell size and width of the dorsal wall decrease continuously from proximal to distal. The organ height

therefore appears to be the crucial anatomical parameter accounting for the biomechanical basis of the tonotopy in the ear and its discontinuity in the auditory fovea region.

Combining behavioural, anatomical, biomechanical and neurophysiological data, we found strong evidence of a pronounced auditory fovea as a sex-specific adaptation of an insect hearing organ for intraspecific acoustic communication in *Ancylecha fenestrata*. Similar overrepresentation of a narrow and behaviourally relevant frequency range (auditory fovea) had been extensively studied in bats and barn owls in the context of echolocation and auditory prey localization, respectively. Our data provides evidence for sex-specific adaptation of an auditory fovea in an insect ear that reflects the asymmetric signalling in reciprocal acoustic communication. The population coding by similarly tuned afferents may allow for hyperacute temporal signal processing, which can help males to localize the short acoustic reply of a responding female more precisely.

Scherberich J\*, Hummel J\*, Schöneich S\*, Nowotny M\* (2016) Auditory fovea in the ear of a duetting katydid shows male-specific adaptation to the female call. *Curr Biol* 26(23): R1222-R1223

Scherberich J\*, Hummel J\*, Schöneich S\*, Nowotny M\* (2017) Functional basis of the sexual dimorphism in the auditory fovea of the duetting bushcricket *Ancylecha fenestrata*. *Proc R Soc B* 284(1865): 20171426 (\*Co-first author; °Co-senior author)

**Key Words:** Katydid, acoustic communication, duet, ear, crista acustica, frequency tuning, sexual dimorphism.



## Communication and Behaviour of Orthopteran Insects

# THE IMPACT OF ACOUSTIC BACKGROUND ON COMMUNICATION AND PREDATOR DETECTION/AVOIDANCE IN RAINFOREST ORTHOPTERA

*Heiner Römer*

*Institute of Biology, Graz University, Graz, Austria; heinrich.roemer@uni-graz.at*

To perform adaptive behavioral decisions in response to sensory stimuli for reproduction and survival, these stimuli have to be discriminated from irrelevant, noisy events in the background. Not surprisingly, given the tremendous diversity of signals used in communication between the sexes and rivals in orthoptera, several solutions have evolved to cope with such background noise. Apart from behavioural solutions such as temporal and/or spatial partitioning, adaptations at the neuronal level (sharpening of frequency filters, selective attention mechanisms or spatial release from masking) contribute to favour the representation of behaviourally relevant stimuli in the brain of receivers. In my talk I shortly summarize these mechanisms.

Orthoptera use their ears also to detect and avoid predators. For almost any nocturnal cricket or katydid on the wing one of the most important group of predators are insectivorous bats, through their ability to detect their prey by echolocation. These insects initiate evasive behaviors such as dives or flight away from the direction of echolocation calls.

Despite numerous studies on the sensory arms race between insectivorous bats and their eared prey our knowledge about Orthoptera is limited to only a handful of species. Moreover, behavioural and neuronal studies have typically been conducted under controlled laboratory conditions, ignoring several ecological factors, including the potential impact of background noise. Here I report results on two species of rainforest crickets, which differ from previous

field crickets strongly in size and behavior. In particular, species in the family of Trigonidae are very small (sometimes called the "plankton" of the rainforest). Members of this family perform a short cessation of flight in response to high-frequency stimuli, but this behavior exhibits unusual high thresholds in the range of 80 dB SPL. In the sensory arms race between predator and prey the most important parameter is the detection distance, giving significant advantage for a catch or escape with a larger detection distance. Thus, these small crickets seem to ignore the rule. In addition to high behavioral thresholds for predator avoidance their behavior differs in another major aspect, since they do not respond only to the repetitive echolocation sequence typical of the approach phase of a bat, but even to single, short high frequency events. Many acoustic signals of rainforest katydids are short, high frequency events, and when tested in the flight paradigm at intensities above 80 dB SPL, the crickets respond with flight stops in a similar way as to echolocation pulses. In my talk I present behavioral and neurophysiological data favoring the hypothesis that under the high background noise of the nocturnal rainforest high thresholds for predator avoidance are nevertheless adaptive, since the small size of the crickets decreases the target strength for the bats, bringing the advantage back to the prey.

**Key Words:** cricket, katydid, background noise, acoustic communication, predator avoidance, detection distance.



## Communication and Behaviour of Orthopteran Insects

# EXPLORING THE RESPONSE TO ATTRACTIVE AND NON-ATTRACTIVE PULSE PATTERNS IN THE SONG RECOGNITION NETWORK OF A CRICKET

Xinyang Zhang<sup>1</sup> and Berthold Hedwig<sup>2</sup>

Department of Zoology, University of Cambridge, Cambridge, UK; xz334@cam.ac.uk<sup>1</sup>,  
bh202@cam.ac.uk<sup>2</sup>

The phonotactic behaviour of crickets is a model system for analysing the neural basis of auditory processing and may shed light on understanding fundamental principles underlying sound pattern recognition across animals. In *Gryllus bimaculatus* the calling song is composed of chirps in which 3 to 5 20-ms sound pulses are repeated with a pulse period of 30–40 ms. This acoustic cue provides guidance for females to walk or fly towards conspecific singing males. Successful phonotaxis requires a highly adapted neural network to process and identify the temporal characteristics of the pulse pattern and to finally generate a motor command driving the behaviour. Recently a concept of pattern recognition has been proposed based on a delay-line and coincidence detector circuit in the brain: the sound signal is processed in a direct pathway and a delayed pathway. Responses to sound pulses are directly forwarded to the coincidence detector in the direct pathway, whereas in the delayed pathway the response arrives with a specific time delay. The direct and delayed responses will coincide at the coincidence detector if the pulse period matches the internal delay. The coincidence detector will finally activate a feature detector that responds only to the species-specific song.

To explore the mechanism of the delay-line and coincidence detector circuit, behavioural tests with systematically varying pulse duration and inter-pulse intervals in a three-pulse chirp were performed. The results provided a detailed picture of the impact of individual pulses and intervals on pattern recognition and lead to the design of specific attractive and non-attractive chirps.

Chirps composed of three sound pulses with a duration of 5, 20 and 50 ms, have a high attractiveness to females, however they are non-attractive, when played in reversed order. This paradigm gave us the opportunity to analyse at the neuronal level how altering the sequence of pulses impacts on the attractiveness of the chirp pattern.

The neuronal network of the delay-line coincidence detector consists of an ascending auditory interneuron and 4 local brain neurons. Our research by intracellular recordings of the pattern recognition neurons shows that they respond very differently to the attractive and non-attractive pulse patterns. The results revealed how processing of an individual sound pulse impacts on processing of the subsequent pulse and provided evidence why chirps with identical sets of sound pulses, just played in reverse order, result in different degrees of the phonotactic response. For example, when the attractive pattern is presented, the coincidence detector neuron and the feature detector strongly respond to the last two pulses of the chirp. This is very similar to the neuronal response evoked by a normal chirp pattern with three 20 ms pulses. The non-attractive pattern however, elicits only a response to one pulse of the chirp in the coincidence detector neuron and the feature detector neuron. We conclude that this difference in the activation of the coincidence detector and feature detector neurons is crucial for the control of phonotactic behaviour.

**Key Words:** cricket, acoustic communication, phonotactic behaviour, song pattern recognition, brain neurons, invertebrate neurobiology.

## Communication and Behaviour of Orthopteran Insects

# DIRECTIONAL HEARING AND AUDITORY MOTOR RESPONSES OF FEMALE FIELD CRICKETS

Athanasios Ntelezos<sup>1</sup>, Berthold Hedwig<sup>1</sup>

<sup>1</sup> University of Cambridge, Cambridge, UK; an478@cam.ac.uk

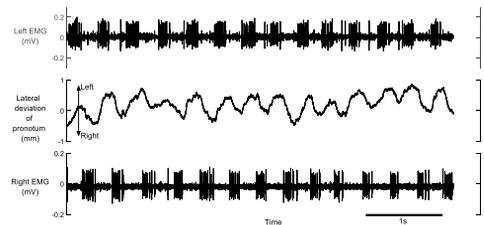
Male *Gryllus bimaculatus* use a file and scraper mechanism on their wings to produce sound pulses grouped into chirps of regular time intervals. The females possess a pair of ears on the tibia of their forelegs and orient towards the 'singing' males, a behaviour termed phonotaxis.

To study the accuracy of female phonotaxis, we used a trackball system (a Rohacell ball with a cricket on top of it, and an optical sensor that tracks the ball rotation) to investigate how accurately the females can orient towards the male song played by a speaker rotating in front of the animals, with a speed of 1°/deg/sec. The results showed that in this dynamic stimulus situation the females could resolve angles as small as 3° in their frontal range. In addition, for stimulus angles >30° there are no significant differences in the orientation angles of the animals.

Secondly, we investigated the sensory-to-motor interface, i.e. how female crickets integrate the auditory input into a motor response. To date, no local or descending motor or pre-motor neurons that receive auditory input have been identified. Previous studies (Hedwig and Poulet 2004, 2005) showed that the females steer towards individual pulses of the male song, suggesting 1:1 coupling between sound and steering. However, the movement of the front legs or the activity of tibial motor-neurons is not coupled to the pulses/chirps of the male song (Baden and Hedwig, 2008; Witney and Hedwig, 2011). Based on the flexibility of the joint-like structure between the prothorax and the mesothorax, we used an opto-electronic device (Hedwig, 2000) to measure the lateral

bending of the prothorax against the mesothorax and to investigate how this contributes to the

auditory steering during phonotaxis. The data from the opto-electronic device showed that the prothorax oscillates left/right in accordance to the stepping pattern, and, when the animals perform phonotactic steering, the prothorax bends towards the direction of the sound source. The prothoracic bending is coupled to the male song at least to the level of individual chirps. The animals are also able to rapidly steer towards the individual sound pulses when a chirp consisting of 5 pulses is split between two speakers: 3 pulses from a speaker to the left of the animal, 2 pulses to the right. In addition, we tested several muscles that connect the prothoracic to the mesothoracic segment for evidence of activity coupled to the lateral movement of the prothorax. Dorsal muscle #56 (Furukawa et al., 1983) fires in accordance to the stepping pattern and is also a candidate for contribution to the prothoracic bending during phonotactic steering.



**Figure 1.** Example of prothoracic movement in a walking animal and EMG of dorsal prothoracic muscle 56. The activity between left and right side alternates in accordance to the stepping cycle.

**Key Words:** *Gryllus bimaculatus*, phonotaxis, cricket, auditory processing, sound localisation.

## Communication and Behaviour of Orthopteran Insects

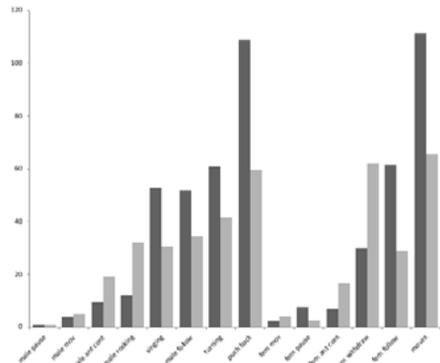
# HOW DOES MALE DOMINANCE STATUS DETERMINE IT'S MATING SUCCESS IN CRICKET *Gryllus bimaculatus*?

Varvara Vedenina<sup>1</sup>, Lev Shestakov<sup>1</sup>

<sup>1</sup> Institute for Information Transmission Problems, Russian Academy of Sciences, Moscow, Russia; [vedenin@iitp.ru](mailto:vedenin@iitp.ru)

Animal females are generally assumed to prefer males that win fights. However, a growing number of studies in numerous animal taxa demonstrate no correlation between male fighting ability and their attractiveness, or even female preferences for fight losers. One of the methods to measure female preferences employs no-choice tests that evaluate a female's latency to mating when placed with a single male. Considering that courtship behavior generally contains multimodal signaling, we analyzed 19 behavioral elements demonstrated by both sexes of the cricket *Gryllus bimaculatus* during courtship. To estimate male dominance status, males were preliminarily tested in two rounds of fights. Only those males that lost ( $n=27$ ) or won ( $n=29$ ) both contests were used in subsequent experiments with females. The advantage of this method was that every male always competed against another male with the same recent fight history, since the success in previous fights has been shown to increase the likelihood of victory in subsequent fights in crickets. Females mounted males with different fighting ability equally often, but the latencies from the start of antennal contact to mount were shorter in fight losers than fight winners (Fig. 1). During courtship, males with high fighting ability demonstrated one of the elements of agonistic display, rocking the body, more frequently and for longer durations than males with low fighting ability. This element was negatively correlated with singing in fight winners but was positively correlated with singing a courtship song in fight losers. Rocking is thereby suggested to have multiple signaling functions in agonistic and

winners, rather than fight losers, tended to produce a higher number of calling chirps, which could be explained by the inability of males with high fighting ability to quickly shift from aggression to courtship behavior. The results suggest that increased aggression in fight winners is likely to interfere with subsequent courtship.



**Figure 1.** Latencies (median values) from the onset of experiment to the start of behavioral elements in courtships of fight winners (black bars) and fight losers (grey bars) in *Gryllus bimaculatus*. Experiments with successful courtships are only included ( $n = 17$  for dominant males and  $n = 18$  for subordinate males).

**Key Words:** cricket, *Gryllus bimaculatus*, multimodal signaling, courtship song, dominance status, aggressiveness, female preference.

courtship behavior. The song parameters were poorly related with male mating success. Fight



## Communication and Behaviour of Orthopteran Insects

# MOLECULAR ELEMENTS OF OLFACTION IN ANTENNAE OF THE DESERT LOCUST

Heinz Breer<sup>1</sup>, Xingcong Jiang<sup>1</sup>, Jürgen Krieger<sup>1,2</sup>, Pablo Pregitzer<sup>1</sup>

<sup>1</sup> University of Hohenheim, Institute of Physiology, Stuttgart, Germany

<sup>2</sup> University Halle-Wittenberg, Institute of Biology/Zoology, Halle, Germany

The desert locust *Schistocerca gregaria* is endemic in Africa, the Middle East and parts of Asia, where locusts are feared due to their potential to swarm and devastate agriculture. The hemimetabolous locusts are characterized by a striking population density dependent phase polyphenism, consisting of solitary and gregarious phases. The phase transition coincides with a rapidly changing olfactory preference, which is considered as a critical trigger for the formation of large swarms. The perception of behavioral relevant semiochemicals is mediated by specialized sensory cells located in various sensilla types on the antennae. The identification of molecular elements, such as odorant binding proteins (OBPs), odorant receptors (ORs) and "sensory neuron marker proteins (SNMPs), underlying the process of odorant reception is an essential prerequisite for understanding the chemosensory system of the orthopteran insects. In our studies, we found only a relatively small number (14) of genes in the genome of *S. gregaria* encoding OBPs.

The various OBP-subtypes could be classified into several categories and were found to be

expressed by distinct subsets of cells in the four sensilla types of the antennae. Only three OBP subtypes were specifically expressed in sensilla basiconica and sensilla trichodea were odorant receptors (ORs) are expressed. A relatively high number (119) of odorant receptors were found to be expressed in the antennae of *S. gregaria*. Among these receptors, a subgroup is supposed to be specifically tuned for the reception of intraspecific chemical signals (pheromones). These receptor types, especially those for

compounds involved in controlling reproductive and aggregation behavior are of particular interest for the desert locust. In view of the sparse information about the locust pheromone system, a search for candidate pheromone receptors was performed based on the paradigm that SNMP1 is expressed in insect sensory neurons, which respond to pheromones.

**Key Words:** Desert locust, *Schistocerca gregaria*, Semiochemicals, Chemoreception, Odorant-binding proteins, Odorant receptors, Expression patterns.



## Communication and Behaviour of Orthopteran Insects

# PLANT APPROACH-AVOIDANCE RESPONSE IN LOCUSTS DRIVEN BY PLANT VOLATILE SENSING AT DIFFERENT RANGES

Peng Wang<sup>1</sup>, Xuewei Yin<sup>1</sup> Long Zhang<sup>1</sup>

<sup>1</sup> China Agricultural University, Beijing 100193, PR China; \*locust@cau.edu.cn

Several hypotheses have been proposed to explain how herbivorous insects approach plants by sensing plant volatiles. Insect antennae and maxillary palps are believed to have crucial roles in the detection of host plant volatiles. However, few studies have assessed the roles of these olfactory organs in food selection in terms of the effects of individual volatile compounds from plants at various distances. Therefore, we assessed the palp-opening response (POR), biting response, and selection behavior of locust (*Locusta migratoria*) nymphs in response to volatile compounds from host and non-host plants at various distances. Thirty odorants were identified as the active volatiles to locust by the POR tests. At a distance of 3 m, locusts were attracted to a few common volatiles (1% v/v) of both host and non-host plants, while few components of volatiles acted as repellants at this distance. At a distance of 1 m, locusts responded more readily to volatile compounds. At a distance of 1 cm, locusts mainly used their palps to detect volatiles.

However, some components that acted as attractants at long distances had no effect on the biting response at a short distance.

Together, the results suggest that plant volatiles generally attract locust nymphs at long distances, but the effects are influenced by distance and concentration. Moreover, there are substantial functional differences in the use of antennae and palps for detecting volatiles at various distances. Overall, the mechanism of food selection by locusts via olfaction can be divided into several continuous ranges according to the sensitivities of the two chemosensory organs and the characteristics of the plant odorants.

**Key Words:** Chemosensory organs, distance, food selection, herbivorous insect, locust, plant volatiles.



## Communication and Behaviour of Orthopteran Insects

# A BROADLY TUNED ODORANT RECEPTOR IN NEURONS OF TRICHOID SENSILLA IN LOCUST, *LOCUSTA MIGRATORIA*

Yinwei You<sup>1,2</sup>, Dean P. Smith<sup>3</sup>, Mingyue Lv<sup>1</sup>, Long Zhang<sup>1\*</sup>

<sup>1</sup> China Agricultural University, Beijing, China; \*locust@cau.edu.cn

<sup>2</sup> Bio-tech Research Center, Shandong Academy of Agricultural Sciences, Jinan, China

<sup>3</sup> Departments of Pharmacology and Neuroscience, University of Texas Southwestern Medical Center, Dallas, Texas, USA

Insects have evolved their sophisticated olfactory reception system to sense exogenous chemical signals. Odorant receptors (ORs) on the membrane of chemosensory neurons are believed to be key molecules in sensing exogenous chemical cues. ORs in different species of insect are different and should tune their own specific semiochemicals. Orthopteran insect, locust (*Locusta migratoria*), is a model hemimetabolous insect. There is very limited knowledge on the functions of locust ORs although many locust OR genes have been identified. In this paper, a locust OR, LmigOR3 was localized in the neurons housed in trichoid sensilla by in situ hybridization. LmigOR3 was expressed as a transgene in *Drosophila* trichoid olfactory neurons (aT1) and the olfactory tuning curve and dose-response curves were established for this receptor.

The results show that LmigOR3 responds to ketones, esters and heterocyclic compounds, indicating that LmigOR3 is a broadly tuned receptor. LmigOR3 is the first odorant receptor from Orthoptera for functional analysis in the *Drosophila* aT1 system. This work demonstrates the utility of the *Drosophila* aT1 system for functional analysis of locust odorant receptors. Our results suggest that LmigOR3 may be involved in detecting food odorants, or perhaps locust body volatiles that may help us to develop new control methods for locust.

**Key Words:** odorant receptor; localization; locust; trichoid sensilla; transgenic *Drosophila* aT1 system; odorants tuning.



## SYMPOSIUM 9

# Locust and Grasshopper Management and Control

### Organizer: Mohamed Abdallahi Ould Babah Ebbe

Directeur Général de l'Institut du Sahel (INSAH) MALI  
maebbe@gmail.com

1. **Mohamed Etheimine, Sid'Ahmed Mohamed, Mohamed Abdellahi Ould babah Ebbe** OPERATIONAL USE OF METARHIZIUM ACRIDUM FOR DESERT LOCUST CONTROL: EFFICACY AND FORMULATION STORABILITY
2. **Gapparov F.A., Tufliev N. Kh., Nurjanov A.A., Haytmuratov A. F., Medetov M. J.**NOVACRID TC AGAINST HARMFUL LOCUSTS IN PASTURES OF THE REPUBLIC OF UZBEKISTAN
3. **Mohamed Lemine Hamouny.** HOW DESERT LOCUST PREVENTIVE CONTROL STRATEGY CAN BE SUSTAINABLE: THE ISSUE OF ADEQUATE FUNDING FROM THE CONCERNED COUNTRIES
4. **Christiaan Kooyman, Yann Miège.** CONTROL OF LOCUSTS AND GRASSHOPPERS WITH THE BIOPESTICIDE NOVACRID® (METARHIZIUM ACRIDUM)
5. **Mohammed Lazar, Cyril Piou, Bahia Doumandji-Mitiche, Michel Lecoq.** IMPORTANCE OF SOLITARIOUS DESERT LOCUST POPULATION DYNAMICS: LESSONS FROM HISTORICAL SURVEY DATA IN ALGERIA
6. **Koutaro Ould Maeno, Sid'Ahmed Ould Mohamed, Mohamed Abdallahi Ould Babah Ebbe.** FIELD RESEARCH FOR DEVELOPMENT OF A PREVENTIVE CONTROL PLAN FOR THE DESERT LOCUSTS IN MAURITANIA
7. **Annie Monard.** FAO LOCUST MANAGEMENT
8. **Mohamed Abdellahi Ould Babah Ebbe, Mohamed EL Hacen Jaavar Bacar, Fall Ahmed Maouloud (Posthum), Sidi Ould Ely , Ahmed Salem Bennah, Ahmed Elhaj , Abderrahmane Ould Sidi, Mohamed Elhady Taleb Sidatt , Mohamed Lemine Hamouny , Noureddine Ould Abdelvettah, Mohamed Atheimine, Diallo Amadou, Sy Amadou , Sidi Camara, Elhambelli Mohamed, Bady Ould Oubeid, Mohamed Lemine Ould Yedali, Koutaro Ould Maeno, Sid Ahmed Med.** DESERT LOCUST PREVENTATIVE CONTROL STRATEGY:THE CASE OF MAURITANIA
9. **Long Zhang.** NOSEMA LOCUSTAE, AN EFFECTIVE BIOCONTROL AGENT AGAINST YELLOW-SPINED BAMBOO LOCUST (CERACRIS KIANGSU) IN LAO PDR.

## Locust and grasshopper management and control

# OPERATIONAL USE OF METARHIZIUM ACRIDUM FOR DESERT LOCUST CONTROL: EFFICACY AND FORMULATION STORABILITY

Mohamed Etheimine<sup>1</sup>, Sid'Ahmed Mohamed<sup>2</sup>, Mohamed Abdellahi Ould babah Ebbe<sup>3</sup>

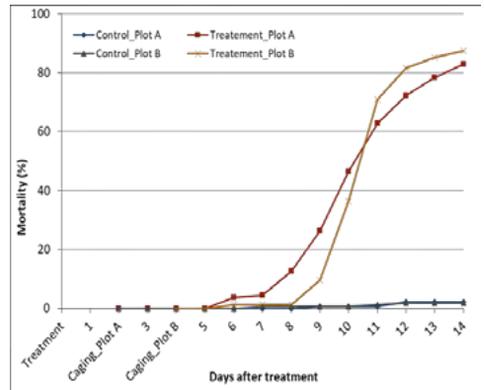
<sup>1</sup> Desert locust control centre, Nouakchott, Mauritania ; mohamed.atheimine@gmail.com

<sup>2</sup> Desert locust control centre, Nouakchott, Mauritania ; sidmd2002@yahoo.fr

<sup>3</sup> Institut du Sahel, Bamako, Mali ; maouldbabah@yahoo.fr

Desert locust, *Schistocerca gregaria*, is a devastating pest that causes substantial crop and pasture losses. Despite their high risk on human health and environment, conventional chemical insecticides remain the main effective and available control products. The fungal based biopesticide *Metarhizium acridum* is a promising and environmentally friendly option for Desert locust control. However, its efficacy and storability under operational conditions remain the main obstacles to a large-scale use. In 2014, a quantity of 50 kg of a powder formulation of Green Muscle<sup>®</sup> was purchased and stored in a fridge at 4°C. The viability of the conidia was checked every year. We sprayed gregarious hopper bands with the *Metarhizium acridum* at 4<sup>th</sup>, and 8<sup>th</sup> day during which the product was held under operational conditions. The biopesticide was from stored formulation (two years of storage). The recommended dose of 50 g/ha, mixed with 2 litres of diesel, was applied by using a hand-held sprayer. Two weeks after treatment, population density in sprayed plots was reduced by 60 - 70 %. In observation cages, the mortality exceeded 80 % in the samples from the treated plots compared to 3 % in the control plot. Conidial viability for the formulation at the reception was at 98 %. No reduction of conidial viability was observed after (i) one month under field conditions (tree shade), and (ii) four years under refrigeration

(fridge). The biopesticide efficacy and storability under the above conditions can promote the use of *Metarhizium acridum* in Desert locust outbreak control and will reduce the reliance on conventional chemical insecticide.



**Figure 1.** Mortality of caged insects collected from Plot A and Plot B sprayed at 4<sup>th</sup> and 8<sup>th</sup> days of storage under operational conditions, respectively. Three cages with 100 locusts per cage were taken from each plot. The same number of untreated locusts was taken as control. All cages were placed under tree shade for monitoring. During observation period, temperature was between 9 – 35 °C.

**Key Words:** *Metarhizium acridum*, Desert locust, biopesticide, storability, operational conditions.



## Locust and grasshopper management and control

# NOVACRIDTC AGAINST HARMFUL LOCUSTS IN PASTURES OF THE REPUBLIC OF UZBEKISTAN

Gapparov F.A.<sup>1</sup>, Tufliev N. Kh.<sup>1</sup>, Nurjanov A.A.<sup>2</sup>, Haytmuratov A. F.<sup>1</sup>, Medetov M. J.<sup>2</sup>

<sup>1</sup> Uzbek Research Institute of Plant Protection, Uzbekistan; furkat\_g@mail.ru

<sup>2</sup> Institute of Zoology of the Academy of Sciences of the Republic of Uzbekistan

The biological characteristics of the product NOVACRID are given in the article. Its efficacy against the main harmful species of locust such as the Italian locust (*Calliptamus italicus* L.), the Asian migratory locust (*Locusta migratoria migratoria* L.) and the Moroccan locust (*Docio-staurus maroccanus* Thunb.) is shown. It is also described where and when tests were carried out and what the biological efficacy was.

In the territory of Uzbekistan, three very dangerous species of gregarious locust are widespread: the Italian locust (*Calliptamus italicus* L.), the Asian migratory locust (*Locusta migratoria migratoria* L.) and the Moroccan locust (*Docio-staurus maroccanus* Thunb.), and these are also having a huge area of distribution worldwide. In periods of mass multiplication, chemical treatments against these insects are carried out in huge areas. In order to reduce the volumes of chemicals applied, it is necessary to develop environmentally safe methods of control.

Under the conditions of Uzbekistan, locusts still remain serious destroyers of pastures and crops. Annually in the republic, more than 300-400 thousand hectares are treated against them. To reduce the volume of treatments with chemical pesticides and in order to introduce biological control of locusts, we have carried out a trial of a fungal biological product NOVACRID TC basis on the fungus *Metarhizium*

*acridum* EVCH 077 from Groupe Eléphant Vert. To carry out the trial, the habitat area of the Moroccan locust was chosen in the Farish region, which is located in the north-west of the Jizzakh region and against older instar larvae of the Italian locust in the Republic of Karakalpakstan, in the Kegeyli region of the "Bashir Shishil" site of the Nagalai Yailevy tract.

### Conclusions:

1. The microbiological product NOVACRID TC caused high mortality of larvae of different instars of Moroccan and Italian locusts; the efficacy of the insecticide at the dose rate of 0,025 kg/hectare for the 15th day was 95,4-89,9%.
2. After the biological product NOVACRID had already been registered for a dose of 0.05 kg/ha, these results of production tests allow a recommendation to the State chemical commission of RUZ to include the product in "The list of the products allowed for application in the Republic of Uzbekistan" at a dose rate of 0,025 kg/hectare against younger and advanced instars of the Moroccan and Italian locusts by way of full area treatment.

**Key Words:** gregarious locusts, Asian and Moroccan locusts, biological efficacy, entomopathogenic fungus, microbiological product, methods of protection.

## Locust and grasshopper management and control

# HOW DESERT LOCUST PREVENTIVE CONTROL STRATEGY CAN BE SUSTAINABLE : THE ISSUE OF ADEQUATE FUNDING FROM THE CONCERNED COUNTRIES

*Mohamed Lemine Hamouny*

*Executive Secretary, Commission for controlling the Desert Locust in the Western Region (CLCPRO), 30, rue Asselah Hocine, BP 270 RP, Alger, Algérie; MohamedLemine.Hamouny@fao.org*

The international community today agrees that the only way to sustainably deal with Desert Locust plagues and reduce the risks is to implement a preventive control strategy. This strategy consists in early detection of the groups of gregarizing locusts and rapid intervention to prevent the situation from escalating to an upsurge or even an invasion. This preventive strategy is the only way to save lives and to protect population's livelihoods at the lowest cost in a sustainable way. It helps strengthen the resilience of the countries as it includes a better anticipation and crisis preparedness. It also mitigates the effects if this crisis were to occur, allowing to return as quickly as possible to a locust remission situation.

As part of this strategy, much progress has been achieved in recent years. The national locust control units of the member countries of the Commission for Controlling the Desert Locust in the Western Region (CLCPRO), as well as this regional Commission, are now better organized and their operational capacities are strengthened. Nevertheless, this progress should be consolidated and sustained by financial and operational instruments aiming to implement the preventive control strategy in a sustainable manner and to better deal with locust emergencies.

The CLCPRO has adopted a funding system composed of financial instruments aligned with the dynamics of locust development, which means that for each locust situation remission, recrudescence or invasion - financial mechanisms are identified.

According to the guiding principle of this funding system, the funding of the preventive control is mainly the responsibility of the countries directly concerned, while the funding for locust-critical situations relies primarily on South-South cooperation.

South-South cooperation is already expressed through the regular contributions by member countries to the Commission's Trust Fund for preventive control actions during the remission or low outbreak situations. This cooperation is justified in terms of regional solidarity: no country can handle alone the problem posed by this trans-boundary pest, but all have an huge interest in seeing any locust upsurge quickly stopped.

It is therefore proposed that this South-South co-operation is also expressed through (1) The regional Locust Risk Management Fund (FRGRA-Fonds regional de gestion du risque acridien), a new financial instrument dedicated to locust situations that are critical such as a major outbreak or the beginning of an upsurge, and (2) A regional intervention force (FIRO), a new operational arm of the CLCPRO, to assist regional countries facing a major crisis.

For example, the \$ 570 million spent on the 2003-2005 con-trol campaign would have funded 170 years of preventive control in West and North-West Africa (CLCPRO, 2009).

**Key Words:** Desert locust, preventative control strategy, CLC PRO, FAO; sustainability.



## Locust and grasshopper management and control

# CONTROL OF LOCUSTS AND GRASSHOPPERS WITH THE BIOPESTICIDE NOVACRID® (*Metarhizium acridum*)

Christiaan Kooyman<sup>1</sup>, Yann Miège<sup>2</sup>

<sup>1</sup> ELEPHANT VERT, Nairobi, Kenya; christiaan.kooyman@elephantvert.ch

<sup>2</sup> ELEPHANT VERT, Paris, France

Locusts and grasshoppers have been controlled with chemical pesticides for almost 100 years. However, after the huge outbreaks of the 1980s, international donor countries, and increasingly locust-affected countries, have encouraged the search for alternative control methods. Therefore, an international research programme, called LUBILOSA, developed a bio-insecticide based on the entomopathogenic fungus *Metarhizium acridum*. This product has been produced and sold in Africa for a number of years, but after several company takeovers, the product disappeared from the market. The biopesticide and biofertilizer company ELEPHANT VERT then decided to develop a new product, NOVACRID®, based on another strain of the same fungus, which may even be better judging from field trial results.

NOVACRID has been field tested in Africa and Central Asia in the following countries: Algeria, Morocco, Niger, Senegal, Tanzania, Kazakhstan

and Uzbekistan. In most cases, the applied dose was 50 g of dry spores per ha mixed with diesel. Lower doses have also been tested. No significant differences in efficacy were found when using 25 and 12,5 g/ha. Peak mortality typically occurred between 9 and 12 days and >80% mortality was usually achieved in about 2,5 weeks. Red cadavers, a sign of fungus-induced mortality, were fairly abundant in trial plots in Kazakhstan and Uzbekistan, presumably because the activity of predators and scavengers was relatively low. In contrast, few cadavers were recovered during trials in Africa. However, locusts and grasshoppers sampled from NOVACRID plots succumbed to

the fungus, became red and were subsequently covered by the green *Metarhizium* spores.

**Key Words:** NOVACRID, *Metarhizium acridum*, locusts, grasshoppers, biological control, entomopathogenic fungus.



## Locust and grasshopper management and control

# IMPORTANCE OF SOLITARIOUS DESERT LOCUST POPULATION DYNAMICS: LESSONS FROM HISTORICAL SURVEY DATA IN ALGERIA

Mohammed Lazar<sup>1</sup>, Cyril Piou<sup>2,4,5</sup>, Bahia Doumandji-Mitiche<sup>3</sup>, Michel Lecoq<sup>2</sup>

<sup>1</sup> Institut National de la Protection des Végétaux, Alger, Algeria ; lazar.mohammed@gmail.com

<sup>2</sup> CIRAD, UMR CBGP, 34398 Montpellier, France

<sup>3</sup> Ecole Nationale Supérieure Agronomique, Alger, Algeria

<sup>4</sup> CNLAA, BP 125, 86343 Inezgane, Morocco

<sup>5</sup> Université IbnZohr, Agadir, Morocco

The desert locust, *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae), is a major pest and well known in its gregarious phase. However, it is not well understood during recession periods, when the solitary phase populations are discrete. Nonetheless, these populations are at the origin of the invasions when ecological conditions become favourable. This lack of knowledge of the solitary phase individuals impedes effective preventive management of this pest.

Archive data collected in Algeria from 1980 to 2011 were used to analyse solitary population dynamics across the Algerian Sahara where some outbreak areas are located that play a major role in the invasion process. The results confirm previous empirical observations on solitary population dynamics. First, a clear difference could be documented between the northern and southern Saharan regions of Algeria concerning the locust dynamics and the impact of environmental conditions. The importance of runoff was clear to create suitable habitats over a long period and to very distant places from rainy areas. Second, a link, on an annual basis, between green vegetation and presence of solitary locusts was found.

Third, statistical relationships between various locations demonstrated a clear regional dynamics. Our study confirmed the importance of migrations of solitary populations among Algerian regions and more generally within the recession area of this species. The operational implications of these findings are multiple.

First, they confirm the need of a flexible and scalable preventive system during the year, from 1 year to another and with a clear distinction between the northern and southern Saharan areas of Algeria. Second, they also confirm the necessity for the inclusion of wadis and soil moisture estimations from remote sensing in geographic information systems for preventive management. And third, they clearly illustrate the importance to target solitary locusts for more efficient preventive survey operations.

**Key Words:** *Schistocerca gregaria*, phase polyphenism, migration, meteorological data, Orthoptera, Acrididae.

## Locust and grasshopper management and control

# FIELD RESEARCH FOR DEVELOPMENT OF A PREVENTIVE CONTROL PLAN FOR THE DESERT LOCUSTS IN MAURITANIA

*Koutaro Ould Maeno<sup>1,2</sup>, Sid'Ahmed Ould Mohamed<sup>2</sup>, Mohamed Abdallahi Ould Babah Ebbe<sup>2,3</sup>*

<sup>1</sup> Japan International Research Centre for Agricultural Sciences (JIRCAS), Tsukuba, Japan; [kmaeno@affrc.go.jp](mailto:kmaeno@affrc.go.jp)

<sup>2</sup> The Mauritanian Desert Locust Centre: Centre National de Lutte Antiacridienne (CNLA), Nouakchott, Mauritania

<sup>3</sup> Institut du Sahel (INSAH)/CILSS, Bamako, Mali

The desert locust is one of the most destructive pests in the world especially in Africa. Sometimes, desert locust populations grow explosively, forming swarms and causing locust plagues. Gathering information about the ecological aspects of the locusts in nature is essential to control locusts effectively, but the numbers of field studies have reduced since 1960s. To obtain such fundamental information, we have conducted field surveys in Mauritania where is an important area for the desert locust outbreaks.

Desert locusts change their behaviors within a day. For example, most gregarious nymphs roost high in larger trees and bushes at night, descend to the ground at dawn, feed and march until around noon, shelter in the shade or low plants during the hottest part of the day, march and feed again in the afternoon, then ascend nocturnal roosting plants around dusk. If we can understand the spatiotemporal distribution of gregarious locusts, we can predict their aggregation site and control them efficiently using only small amounts of pesticides.

Although we have not developed novel control techniques yet, we would like to introduce some idea how to control locusts based on their behavioral characteristics.



**Figure 1.** Part of a Desert Locust hopper band.

**Key Words:** desert locusts, gregarious locusts, preventive control.



## Locust and grasshopper management and control

### FAO LOCUST MANAGEMENT

Annie MONARD

FAO/AGPM –Rome, Italie ; [annie.monard@fao.org](mailto:annie.monard@fao.org)

The mandate of the Food and Agriculture Organization (FAO), a technical agency of the United Nations, concerning locust management will be provided and the normative and emergency activities implemented by the “Locusts and transboundary plant pests and diseases” Team will be described. The principles of the locust preventive control strategy that is promoted for decades by FAO will be presented. A number of examples will be given concerning the successful implementation of that strategy as well as responses to locust crises in particular:

(1) The technical and institutional management and permanent monitoring of the Desert Locust (*Schistocerca gregaria*) throughout its distribution area, from western Africa to the Indo-Pakistan border, and the respective roles of the three FAO commissions for controlling that locust pest (in western and north-western Africa, around the Red Sea and in south-west Asia) and of the Desert Locust Information Service at FAO Headquarter.

(2) The extension of experience and lessons learnt from Desert Locust management to other locust pests and geographical areas with the FAO Programme to improve national and regional management of three locust pests (*Calliptamus italicus*, *Dociostaurus maroccanus*, *Locusta migratoria*) in ten countries of the Caucasus and Central Asia. First activities in the region, which started 20 years ago, will be mentioned and results achieved since the preliminary steps of the current programme will be described.

(3) An overview of the three-year FAO emergency Programme in response to the Migratory Locust (*Locusta migratoria capito*) plague in Madagascar will be presented.

**Key Words:** Locust management, Desert locust, *Calliptamus italicus*, *Dociostaurus maroccanus*, Migratory locust, control strategy, FAO.



## Locust and grasshopper management and control

### DESERT LOCUST PREVENTATIVE CONTROL STRATEGY: THE CASE OF MAURITANIA

Mohamed Abdellahi Ould Babah Ebbe<sup>1,2</sup>, Mohamed El Hacen Jaavar Bacar<sup>1</sup>, Fall Ahmed Maouloud (Posthum)<sup>1</sup>, Sidi Ould Ely<sup>1</sup>, Ahmed Salem Bennahi<sup>1</sup>, Ahmed Elhadj<sup>1,3</sup>, Abderrahmane Ould Sidi<sup>1</sup>, Mohamed Elhady Taleb Sidatt<sup>1,4</sup>, Mohamed Lemine Hamouny<sup>1,5</sup>, Noureddine Ould Abdelvettah<sup>1</sup>, Mohamed Atheimine<sup>1</sup>, Diallo Amadou<sup>1</sup>, Sy Amadou<sup>1</sup>, Sidi Camara<sup>1</sup>, Elhambelli Mohamed<sup>1</sup>, Bady Ould Oubeid<sup>1</sup>, Mohamed Lemine Ould Yedali<sup>1</sup>, Koutaro Ould Maeno<sup>1,6</sup>, Sid'Ahmed Mohamed<sup>1e,2,3</sup>

<sup>1</sup> Centre National de Lutte Antiacridienne (CNLA), BP : 665, Nouakchott, République Islamique de Mauritanie ; (Corresponding author:maouldbabah@yahoo.fr)

<sup>2</sup> Institut du Sahel/CILSS, Bamako, Mali

<sup>3</sup> Institut Supérieur d'Enseignement Technologique de Rosso

<sup>4</sup> FAO-Regional Tunis

<sup>5</sup> CLCPRO-FAO, Alger

<sup>6</sup> Japan International Research Centre for Agricultural Sciences (JIRCAS), Ohwash 1-1, Tsukuba, Ibaraki, 305-8686, Japan

The Desert Locust, *Schistocerca gregaria* (Forskål, 1775) has been seen, since the Middle Ages, as a major threat to the agro-pastoral resources in the world's most warm and temperate climates, including the Sahara. The plagues of this phytophagous, that although intermittent, can be extremely destructive and cause substantial losses to crops and pastures.

As an example of affected countries, Mauritania, a Sahelian country, shelter many permanent habitats and outbreaks areas of the Desert Locust. Since the 1950's, a preventative control strategy was progressively applied in various organizational and operational forms, starting by the OCLALAV (Organisation commune de lutte antiacridienne et de lutte antiaviaire), followed successively by two regional locust control organizations: FAO/CLCPANO (Commission for controlling the Desert Locust in Northwest Africa), then FAO/CLCPRO (Commission for Desert Locust Control in the Western Region). The Mauritanian government began to take over the responsibility for Desert Locust survey and control in 1980. A specialized national unit in charge of early warning and early control operations was created in 1989, then transformed into a National Anti-locust Center in 1995 and finally upgraded as an autonomous institution since 2006 called The Mauritanian National Anti-Locust Centre (CNLA). CNLA is in charge of monitoring and control of the Desert Locust. The creation of CNLA is the result (i) of a

national political conviction progressively raised by the governmental authorities, (ii) has been favored by several successive strong up CNLA is in charge of monitoring and control of the Desert Locust. The creation of CNLA is the result (i) of a national political conviction progressively raised by the governmental authorities, (ii) has been favored by several successive strong upsurges in the recent years (1987-1988, 1993-1995, 2003-2005), interspersed with more localized outbreaks that had to be addressed almost every year (iii) and finally benefited from an ongoing advocacy by various local, regional and international partners.

Since its creation, the CNLA has developed important human, institutional, infrastructural, financial, operational and applied-research capabilities, as well as preventive and curative locust control capabilities and tools. All this with the support of its regional and international partners, including - since 2010 - the stabilization of a sustained annual budget of US \$ 1 million on the Mauritanian government's own resources. All this has led to many successes to prevent and cope with many locust infestations. The results obtained have profound and beneficial repercussions on the preventive and curative control strategy in Mauritania and in the subregion.

**Key Words:** Desert locust, Mauritania, preventative control strategy, CNLA, CLCPRO, FAO.

## Locust and grasshopper management and control

# NOSEMA LOCUSTAE, AN EFFECTIVE BIOCONTROL AGENT AGAINST YELLOW-SPINED BAMBOO LOCUST (CERACRISKIANGSU) IN LAO PDR

Long Zhang

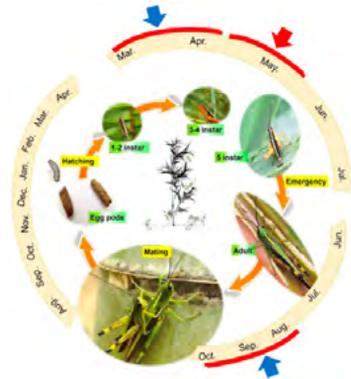
China Agricultural University, Beijing, 100193, China; locust@cau.edu

Yellow spined bamboo locust (YSBL) (*Ceracris kiangsu*) is an important pest of (bamboo, rice, corn, some grasses...) in China, Lao and Vietnam. YSBL outbreak in Lao has occurred for 5 years, since 2014, and caused huge economic losses threatening food security. *Nosema locustae* (*Paranosema locustae*) is a microsporidian parasite of over 100 orthopteran species. Its use for controlling grasshoppers was first developed in USA and China since 1980s. It has been considered as a long term control agent because it acts slowly and produces low mortality. Its efficiency is limited when grasshoppers and locusts are at high density. It was not known whether *N. locustae* could be effective in the ecological conditions of Laos, in forested areas of higher mountains and with high temperatures.

YSBL has one generation a year in Lao PDR. It mainly lay eggs in soils under the bamboo trees, and then first instar nymphs hatch from eggs during March. Thereafter, YSBL develop into 2<sup>nd</sup> to 5<sup>th</sup> instar during March to the end of June, then they emerge into adult in July and August. They mate and lay eggs during August to October. From the life cycle, two critical periods have been identified for monitoring YSBL population dynamics in Lao and biocontrol actions. One from March to April (2<sup>nd</sup> to 4<sup>th</sup> instars) proper for monitoring density and development. Another period in August/September (adults) for monitoring egg laying which will provide useful information on distribution area and density next year. The first period is the most suitable for performing biocontrol.

In field trials, *N. locustae* was applied on the 10<sup>th</sup> of May at an application rate of  $2 \times 10^7$  spores/ml in the bamboo tree field where locust densities were over 100 individuals/m<sup>2</sup> at 3<sup>rd</sup> to 4<sup>th</sup> instar of YSBL nymphs in mountains of Northern Lao. 17

days after the application plenty of dead locusts were observed. The locust density was reduced by more than 90% compared to the blank control. And 46% of survival YSBLs were infected by *N. locustae* in treated plot after 50 days, which means that *Nosema* disease could be persisting in YSBL populations as a long term control factor.



**Figure 1.** The critical periods for monitoring and control of YSBL in Lao. Red curvy lines are the critical periods (red arrow for biocontrol; blue arrows for monitoring).

Overall, our results indicate that (1) *N. locustae* is effective and should be one of the best choices for controlling YSBL in Lao; (2) A proper application method of *Nosema* has been established in high mountain of northern Lao; (3) This is the first successful field trial for controlling YSBL with biocontrol agent which shows great potential in YSBL control programs in Lao.

**Key Words:** Locust management, Desert locust, *Calliptamus italicus*, *Dociostaurus maroccanus*, Migratory locust, control strategy, FAO.



## SYMPOSIUM 10

# Bioecology of North African Orthoptera

### Organizer: Lahsen El Ghadraoui

University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immuouzer, BP. 2202, Fez ;  
abderrahim.lazraq@usmba.ac.ma

1. **Lazraq Abderrahim, Errabhi Nabil, Zahri Aziz, Chater Oumaima , El Ghadraoui Lahsen.** STUDIES ON THE EFFECTS OF SOME MEDICINAL PLANTS ESSENTIAL OILS ON THE ADULTS OF SCHISTOCERCA GREGARIA AND DOCIOSTAURUS MAROCCANUS
2. **Azzouzi Amal, Errabhi Nabil, Zahri Aziz, Chater Oumaima, El Ghadraoui Lahsen.** DIETARY STUDY OF THREE SPECIES OF THE GENUS DOCIOSTAURUS
3. **Bouchama El Ouazna, Chater Oumaima, Zahri Aziz, El Ghadraoui Lahsen, Errachidi Faouzi.** INTESTINAL MICROBIAL DIVERSITY OF SOME LOCUST SPECIES IN MOROCCAN MIDDLE ATLAS
4. **Errachidi Faouzi, Errabhi Nabil, Bouchama El Ouazna, Zahri Aziz, El Ghadraoui Lahsen.** LOCUST AS ANIMAL MODEL FOR OXIDATIVE STRESS STUDIES
5. **Benjelloun Meryem, Al Figuigui Jamila, Essakhi Driss, Zahri Aziz, El Ghadraoui Lahsen.** ECOLOGY OF SOME LOCUSTS IN THE MOROCCAN MIDDLE ATLAS
6. **Rochdi Mouad, Chater Oumaima, Errachidi Faouzi, El Ghadraoui Lahsen, Haloti Said.** EFFECT OF DIETARY COMPONENTS ON DEVELOPMENT OF DESERT LOCUST SCHISTOCERCA GREGARIA (FORSK. 1775)
7. **Haithem Tlili, Khemais Abdellaoui, Manel Ben Chouikha, Mouna Mhafdh, Adel Jammezi, Mo-hamed Ammar, Laure Desutter-Grandcolas.** A CENTURY AND ONE HALF OF GRASSHOPPERS (ORTHOPTERA: CAELIFERA) STUDY IN SOUTH WEST TUNISIA
8. **Naima Benkenana, Harrat Abboud, Petit Daniel, Bruno Massa.** INVENTORY OF THE GRASSHOPPER FAUNA OF EASTERN ALGERIA
9. **Errabhi Nabil, Zahri Aziz, Lazraq Abderrahim, Chater Oumaima, & Errachidi Faouzi.** FACTORS INVOLVED IN TROPHIC REGIME DETERMINATION OF LOCUST SPECIES IN MOROCCAN MIDDLE ATLAS



## Bioecology of North African Orthoptera

# STUDIES ON THE EFFECTS OF SOME MEDICINAL PLANTS ESSENTIAL OILS ON THE ADULTS OF *SCHISTOCERCA GREGARIA* AND *DOCIOSTAURUS MAROCCANUS*

Lazraq Abderrahim<sup>1</sup>, Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Chater Oumaima<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; [abderrahim.lazraq@usmba.ac.ma](mailto:abderrahim.lazraq@usmba.ac.ma)

This study target the assessment of some medicinal plants and their essential oils on *Dociostaurus maroccanus* Thunberg and *Schistocerca gregaria* Forsk. in order to develop a sustainable method of pest control.

Essential oil toxicity on individuals seems to be induced by majority compounds or by the synergy of all the compounds of plant essential oils.

Moroccan medicinal plants and their essential oils seem potent in fighting insect pests. These

natural compounds could be the basic elements of beneficial products for a sustainable locust control.

**Key Words:** *Dociostaurus maroccanus*, *Schistocerca gregaria*, essential oils, natural compounds, biological control.



## Bioecology of North African Orthoptera

# DIETARY STUDY OF THREE SPECIES OF THE GENUS DOCIOSTAURUS

Azzouzi Amal<sup>1</sup>, Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Chater Oumaima<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; amal.azzouzi@usmba.ac.ma

Dietary analysis of three locusts belonging to the genus *Dociostaurus* (*D. maroccanus*, *D. dantini* and *D. jagoi*) collected from Moroccan Middle Atlas, done by faecal technique showed a diversity of trophic sources. The two species *Dociostaurus maroccanus* and *Dociostaurus dantini* are characterized by their diet diversity when compared to *Dociostaurus jagoi*. Besides, we noticed that *D. jagoi* had very limited distribution when compared to the other two species.

We conclude that many factors influence the trophic regime of these species, such as the nature of the vegetation cover and their ability to move. Similarly, in this semi-arid zone, changes in climatic conditions, such as temperature and altitude, affect the food spectrum of these locusts.

**Key Words:** *Dociostaurus*, trophic diet, vegetal cover, ability to move.



## Bioecology of North African Orthoptera

# INTESTINAL MICROBIAL DIVERSITY OF SOME LOCUST SPECIES IN MOROCCAN MIDDLE ATLASS

*Bouchama El Ouazna<sup>1</sup>, Chater Oumaima<sup>1</sup>, Zahri Aziz<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>, Errachidi Faouzi<sup>1</sup>*

*<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; elouazna.bouchamma@usmba.ac.ma*

---

Like other insects, locusts are characterized by the presence of a microbial diversity in their digestive tract. This one seems to play an important role in the digestion and assimilation of nutritious sources. Some locust species are able to feed on many plant species, while others are limited in their food choices. In the present work, we seek to highlight microbial diversity of intestinal flora in certain locust species collected in the Middle Atlas and relate it to the nature of their trophic diet.

Thus, microorganisms present in the digestive tract of adult locusts are isolated and identified, using conventional and molecular methods, to locate their taxonomical position.

The results obtained show the presence of associations formed by bacteria and fungi that are strongly correlated with trophic sources tendency in common between locusts and microorganisms association.

**Key Words:** Locusts, trophic diet, intestinal flora, isolation, digestion, taxonomy.



## Bioecology of North African Orthoptera

# LOCUST AS ANIMAL MODEL FOR OXIDATIVE STRESS STUDIES

*Errachidi Faouzi<sup>1</sup>, Errabhi Nabil<sup>1</sup>, Bouchama El Ouazna<sup>1</sup>, Zahri Aziz<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>*

*<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez; faouzi.errachidi@usmba.ac.ma*

---

Oxidative stress is involved in a wide variety of pathological processes. Some of these oxidation-related disorders may be aggravated, perhaps even initiated, by many environmental pro-oxidants and/or pro-oxidant drugs and foods. Animal testing is essential to understand the pathogenesis, actions of therapeutic agents and genetic or environmental influences that increase the risk of disease. In general, smaller animals are preferred because they are easier to manage and the experiments are less expensive.

The characteristics of the evolutionary development of locust have defined a particular role of oxidative stress and mechanisms of its regulation in the processes associated with the

preservation of homeostasis by an individual and insect association.

Nevertheless, oxidative stress is actively used by insects in general as a defense mechanism to neutralize xenobiotics and fight pathogens in the processes of morphogenesis and regulation of life span.

This work examines the role of oxidative stress in the process of determining the preservation of homeostasis by both a locust organism and a gregarious.

**Key Words:** locust, oxidative stress, model organism, solitary, association.



## Bioecology of North African Orthoptera

### ECOLOGY OF SOME LOCUSTS IN THE MOROCCAN MIDDLE ATLAS

*Benjelloun Meryem<sup>1</sup>, Al Figuigui Jamila<sup>1</sup>, Essakhi Driss<sup>1</sup>, Zahri Aziz<sup>2</sup>, El Ghadraoui Lahsen<sup>1</sup>*

*<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; meryem.benjelloun@usmba.ac.ma*

---

In Morocco, research on locusts is still embryonic. Some work has been done in the Middle Atlas on locust pest species; however, their ecology remains little known. This work was undertaken with the objective of contributing to the ecological study of the locust species of the Middle Atlas. Four stations in the Moroccan Middle Atlas have been studied, spread along an altitudinal transect of 100 km. The collect of the different species was carried out once a fortnight, throughout a period from March to October of 2012.

To try to understand the ecological requirements of these species and their dynamics, the variation

of the number of individuals according to the seasons, the effect of the altitude on the specific richness and the computation of the ecological indices were determined. Altitude seems to be one of the most influential factors in the distribution of species. Thus, the lowest station host 18 species against 10 species only found at the highest station. The frequency allows us to distinguish between the different species collected.

**Key Words:** Orthoptera, diversity, ecology, middle Atlas, altitude.



## Bioecology of North African Orthoptera

# EFFECT OF DIETARY COMPONENTS ON DEVELOPMENT OF DESERT LOCUST *SCHISTOCERCA GREGARIA* (FORSK. 1775)

Rochdi Mouad<sup>1</sup>, Chater Oumaima<sup>1</sup>, Errachidi Faouzi<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>, Haloti Said<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; Moad9700@gmail.com

In this work, we investigated the nutritional behavior of the Desert Locust (*Schistocerca gregaria*) in laboratory conditions. The larvae after hatching were grouped into four experimental batches. The first is fed with grasses, the second with lettuce, the third with wheat bran and the fourth with a mixture of plants. Weight and size were monitored during larval growth and development, while labrum sensilla were analyzed at adult stage.

The individuals in lots 4 and 1 reached the

adult stage in 26 days, those in lot 3 in 34 days and those in lot 2 in 40 days (with a mortality rate exceeding 70%). Adult's labrum sensilla analysis of the four experimental batches shows a variation depending on the nature of the diet. Polyphagous individuals have a larger number of sensilla, which allows them to attack a large number of plants.

**Key Words:** desert locust, nutritional behavior, sensilla.

## Bioecology of North African Orthoptera

# A CENTURY AND ONE-HALF OF GRASSHOPPERS (ORTHOPTERA: CAELIFERA) STUDY IN SOUTH WEST TUNISIA: CHECKLIST AND BIBLIOGRAPHY

Haithem Tlili<sup>1,5,6\*</sup>, Khemais Abdellaoui<sup>2</sup>, Manel Ben Chouikha<sup>3,5</sup>, Mouna Mhafdh<sup>4</sup>, Adel Jammezi<sup>4</sup>, Mohamed Ammar<sup>5,§</sup>, Laure Desutter-Grandcolas<sup>6,§</sup>

<sup>1</sup> Department of Biological Sciences, Faculty of Science of Tunis, University Tunis El Manar, Tunisia;

\*haithem.tlili@fst.utm.tn

<sup>2</sup> Department of Biological Sciences and Plants Protection, Higher Agronomic Institute of Chott Mariem, Sousse University, Tunisia

<sup>3</sup> Department of Biology, Faculty of Sciences of Gabes, University of Gabes, Tunisia

<sup>4</sup> General Directorate of Plant Health and Agricultural Inputs Control, Ministry of Agriculture Water Resources and Fisheries, Tunisia

<sup>5</sup> Laboratory of Bioaggressors and Integrated Protection in Agriculture, National Institute of Agronomy of Tunisia, University of Cartage, Tunisia

<sup>6</sup> Institut de Systématique, Evolution, Biodiversité (ISYEB) Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, EPHE, Paris, France

§ Last co-authors with equal rank

About 241 Acridomorpha species are recorded today in northern and North West Africa. These insects have been poorly studied in Tunisia comparatively to other countries of the Maghreb such as Morocco, Algeria and Libya. Available data for Tunisia actually show a lower level of endemism, but very few publications are available concerning this subject. The locust fauna of Tunisia is thus still poorly known.

The first zoological expedition to Tunisia was probably that of Letourneux and Sédillot and Valéry Mayet between 1883 and 1884. The Orthoptera fauna of Tunisia was further studied by Bonnet and Finot (1884) and then by Chopard (1943) in his book on the Orthoptera from Northern Africa. More than 50 years later, Tunisian Acridomorpha were studied by Massa and Rizzo (1998), and still later by Massa (2013) and finally by Tlili *et al.* (2018).

One of us (HT) has initiated a comprehensive survey of the Acridomorpha fauna in Tunisia, using standardized sampling effort in the different

habitats identified in each phytogeographic province of the country.

We compare here data on the presence of grasshopper species in Tunisia through time to evaluate the stability of the fauna composition. Results are interpreted taking into account the current climate change and the impact of urbanization and pollution on the environment.



Figure 1. Number of species by author.

**Key Words:** North Africa, Taxonomy, Pollution, Inventory, Conservation, Ecology.

## Bioecology of North African Orthoptera

# INVENTORY OF THE GRASSHOPPER FAUNA OF EASTERN ALGERIA

*Naima Benkenana<sup>1</sup>, Harrat Abboud<sup>1</sup>, Petit Daniel<sup>2</sup>, Bruno Massa<sup>3</sup>*

<sup>1</sup> *Laboratory of Biosystematics and Ecology of Arthropods, Department of Animal Biology, Faculty of Natural Science and Life, Constantine 1 University; benkenanan@yahoo.co.nz*

<sup>2</sup> *Laboratoire Pereine, Université de Limoges, 123 avenue Albert Thomas 87060 Limoges cedex, France; daniel.petit@unilim.fr*

<sup>3</sup> *Department of Agriculture, Food and Forest Sciences, University of Palermo, Viale Scienze 13, 90128 Palermo, Italy; bruno.massa@unipa.it*

The inventory of grasshopper fauna in several stations in eastern Algeria revealed the presence of more than 80 species. They belong to five families and 14 sub-families. Acrididae being the best represented with 8 sub-families and 42 species.

We recorded 16 species of grasshoppers belonging to the family Pamphagidae. The Belezma National Park, near Batna city, appears to be the richest region for this family, with 10 species. Within the Pamphagus djelfensis complex, a species has recently been described, *P. batnensis* Benkenana & Petit, 2012, easily distinguishable by its epiphallid characters. *Pamphagus milevitanus* Benkenana & Massa, was also recently described in 2017. It occurs in the North and South highlands of Constantine, in Mila, Setif and Oum-el Bouaghi provinces, where it is fairly common. This species was formerly confused with *P. marmoratus* from Sicily. Overall these recent findings suggest that other species will be certainly described in this previously neglected region.

We studied the diet of 10 species of grasshopper belonging to the family Pamphagidae. The species of plants consumed by the grasshoppers was determined by comparing slide mounted specimens of the pieces of plant epidermis in their faeces with those in a reference collection of identified plants collected from the same

localities. The percentages of occurrence of the different species of plants in the faeces of the grasshoppers were not related to the abundance of the plants at the sites studied. All the grasshoppers were polyphagous but differed in the percentage of Poaceae in their diets. The diet of *Tmethis* and *Ocneridia* contained a higher percentage of Poaceae than the other species and are considered to be ambivores. The three species in the *Pamphagus djelfensis* complex differ in their diets but all tend to avoid consuming Poaceae and are categorized as forbivores.

The Pyrgomorphidae family is represented by one sub-family with 4 species and *Dericorythidae* and *Tetrigidae* families with only one species. Moreover, among the other species of Acrididae recorded, some could be of economic importance in eastern Algeria: *Anacridium aegyptium*, *Ocneridia volxemii*, *Calliptamus b. barbarus* and *Dociostaurus maroccanus*.

**Key Words:** Inventory, eastern algerian, Grasshopper, Pamphagidae.

**References:**

- Benkenana N., Harrat A., Petit D., 2012. The Pamphagidae (Orthoptera) from East Algeria and description of a new species. *Zootaxa* 3168: 22–38.
- Benkenana N., Massa B., 2017. A new species of *Pamphagus* (Orthoptera: Pamphagidae) from Algeria with a key to all the species of the genus. *Zootaxa* 4254 (1): 102–11.

## Bioecology of North African Orthoptera

# FACTORS INVOLVED IN TROPHIC REGIME DETERMINATION OF LOCUST SPECIES IN MOROCCAN MIDDLE ATLAS

Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Lazraq Abderrahim<sup>1</sup>, Chater Oumaima<sup>1</sup>, Errachidi Faouzi<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez ; nabil.errabhi@usmba.ac.ma

The present work highlights the relationship between locusts and their host plants, by studying the diet of four species existing in the Moroccan Middle Atlas. The fecal analysis method allowed the diet to be determined by taking into account two factors: biotope floristic diversity and labrum-antennae sensilla composition in adults of *Dociostaurus maroccanus* (Thunberg, 1815), *D. jagoi* (Soltani, 1978) *Oedaleus decorus* (Germar, 1825) and *Euchorthippus elegantulus* (Maran, 1957). The first species is trophic polyphagous while the others are oligophagous.

A statistical analysis highlight the existence of a relationship between the diet and the sensory

composition of labrum and antennae in the individuals studied. The change in the number of sensilla of type A1 and A2 is related to the nature of the diet. It seems that the food choice of the species results from an adaptation to the conditions of their environment, involving a certain number of factors which can influence their behavior, in particular their capacities of displacement and the composition of the oral chemoreceptors.

**Key Words:** Middle Atlas, locusts, diet, sensilla number, antennas, floristic composition



## SYMPOSIUM 11

# Population and landscape genetics / genomics of Orthopterans

### Organizer: Marie Pierre Chapuis

CIRAD, UMR Centre de Biologie pour la Gestion des Populations (CBGP),  
CS 30016, Montferrier-sur-Lez, France;  
marie-pierre.chapuis@cirad.fr

1. **Bertrand Gauffre, Cécile Ribout, Sylvain Piry, Maylis Fayet, Isabelle Badenhausser.** LANDSCAPE GENETICS OF A FLIGHTLESS GRASSHOPPER IN AN AGRICULTURAL LANDSCAPE
2. **Michael D. Greenfield, Réjane Streiff, Yareli Esquer-Garrigos.** PLEISTOCENE ORIGINS OF CHORUSING DIVERSITY IN MEDITERRANEAN BUSHCRICKETS
3. **Marie-Pierre Chapuis, Laure Benoit, Antoine Foucart, Alexandre Dehne Garcia, Jean-Yves Rasplus, Nicolas Leménager, Bruno Michel, Armelle Coeur d'Acier.** INTEGRATIVE SYSTEMATIC REVISION REVEALS CRYPTIC SPECIES IN THE CALLIPTAMUS GENUS
4. **Hojun Song, Rachel A. Slatyer, Shichen Wang, Nikolai J. Tatarnic.** SPECIATION IN THE MOUNTAINS: PHYLOGENOMICS OF THE ALPINE GRASSHOPPER GENUS KOSCIUSCOLA (ORTHOPTERA: ACRIDIDAE).

## Population and landscape genomics of Orthopterans

# LANDSCAPE GENETICS OF A FLIGHTLESS GRASSHOPPER IN AN AGRICULTURAL LANDSCAPE

Bertrand Gauffre<sup>1</sup>, Cécile Ribout<sup>2</sup>, Sylvain Piry<sup>3</sup>, Maylis Fayet<sup>2</sup>, Isabelle Badenhausser<sup>2</sup>

<sup>1</sup> INRA, UR1115 Plantes et Systèmes de culture Horticoles, F-84914 Avignon, France, [bertrand.gauffre@inra.fr](mailto:bertrand.gauffre@inra.fr)

<sup>2</sup> CNRS – Université de La Rochelle, UMR 7372 CEBC, 79360 Villiers en Bois, France

<sup>3</sup> INRA, UMR CBGP, F-34398 Montpellier, France

Dispersal may be strongly influenced by landscape structure and habitat characteristics that could either enhance or restrict movements of organisms. Therefore, spatial heterogeneity in landscape structure could influence gene flow and the spatial structure of populations. In the past decades, agricultural intensification has led to the reduction of grassland surfaces, their fragmentation and intensification. Since these changes are not homogeneously distributed in space, they might result in spatial heterogeneity in population's genetic structure. Understanding the effect of landscape structure and habitat characteristics is thus critical for both studies in biodiversity conservation and pest's management.

In this study, we used eight microsatellite loci to assess spatial genetic structure and landscape genetics relationships of *Pezotettix giornae*, a small-sized grasshopper specialized on grassland and herbaceous habitats. Because it has wings unfit for flight, its ability to disperse long distances is supposed to be weak. We collected 1097 individuals from 231 grasslands in a 100 x 100 km agricultural area of Western France.

While the northern part of the study area consists of preserved hedged farmland, the southern part

has been profoundly converted for intensive crop production after WWII, with generally less intensified hedged farmland areas remaining alongside streams and rivers.

Over the entire study area, we did not detect genetic clusters in relation with landscape features. Spatial genetic autocorrelation analysis suggested small-scale dispersal, and the grasshopper population was characterized by a heterogeneous pattern of isolation by distance. We used individual-based landscape genetics approaches to investigate how landscape structure and habitats characteristics affect *P. giornae* genetic diversity and gene flow. Altogether, results suggested that, in the most intensive agricultural areas, *P. giornae* dispersal is enhanced by disturbance due to increasing habitat turnover. As a long-term consequence, one could expect the selection of increasing dispersal capacities. This hypothesis is consistent with differences measured on dispersal-related traits among *P. giornae* individuals from areas with contrasted level of disturbance.

**Key Words:** Gene flow, Dispersal, Genetic structure, Landscape genetics, Disturbance, *Pezotettix giornae*.

## Population and landscape genomics of Orthopterans

# PLEISTOCENE ORIGINS OF CHORUSING DIVERSITY IN MEDITERRANEAN BUSHCRICKETS

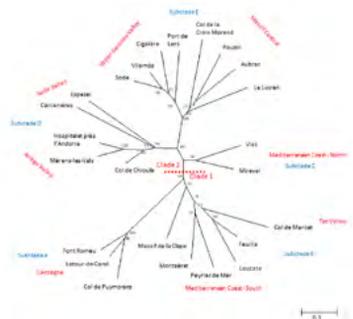
Michael D. Greenfield<sup>1</sup>, Réjane Streiff<sup>2</sup>, Yareli Esquer-Garrigos<sup>2</sup>

<sup>1</sup> University of Kansas, Lawrence, USA and CNRS, Tours, France; michael.greenfield@univ-tours.fr

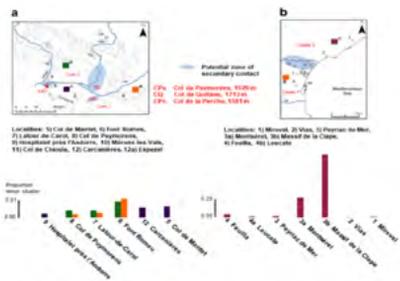
<sup>2</sup> CBGP, INRA, CIRAD, IRD, Montpellier SupAgro, DGIMI UMR 1333, Univ Montpellier, Montpellier, France

We studied the Pleistocene diversification of a relatively endemic Mediterranean insect (*Ephippiger diurnus*; Orthoptera: Tettigoniidae) to understand how species with restricted range may nonetheless exhibit the complex phylogeography normally associated with broad distribution. A time-calibrated molecular phylogeny based on two mitochondrial genes showed that *E. diurnus* diverged into two major clades, distinguished largely by male song, before or early during the Pleistocene. Several subclades also diverged before the most recent glacial period. Data from 20 microsatellite loci indicated higher genetic diversity in populations along the Mediterranean coast in France, consistent with the hypothesis that glacial refuges were located there. ‘Isolation by distance’ accounts for much genetic differentiation between populations, but some adjacent populations are highly differentiated. A Bayesian approach defined genetically distinct clusters and assigned individuals to their most probable cluster. Clusters corresponded to clades in the phylogenetic tree, and we used cluster assignments to estimate inter-clade gene flow in areas of potential secondary contact. Gene flow is negligible in potential contact areas in the Pyrenees, but a narrow hybrid zone featuring a steep cline exists on the coast. This hybrid zone suggests that the major clades represent distinct species that diverged within a restricted area during the Pleistocene.

**Key Words:** acoustic insects, cryptic species, Endemic species, hybrid zone, Pleistocene refuge, post-glacial expansion, secondary contact.



Unrooted neighbor-joining (NJ) tree of 24 *E. diurnus* populations, sampled in southern France and northeastern Spain (Table 1; Figure 1), as generated from 20 microsatellite loci. Scale at bottom right indicates 0.1 nucleotide substitutions per site; values at nodes represent posterior probabilities. Geographical regions and subclades are labelled in red and blue, respectively, outside the branches.



Zones of potential secondary contact between clades and levels of possible inter-clade introgression. Grey ellipses represent potential contact zones and colored squares designated by letters indicate the major genetic cluster on each side of the zone. Colored vertical bars below the maps indicate the identity and proportion of the minor genetic cluster(s) in each locality adjacent to or within the contact zones. a) Region of potential contacts surrounding the Cerdagne Valley in the Pyrenees. b) Region of potential contact midway along the Mediterranean coast. Minor cluster proportions are calculated as mean *q* values

## Population and landscape genomics of Orthopterans

# INTEGRATIVE SYSTEMATIC REVISION REVEALS CRYPTIC SPECIES IN THE CALLIPTAMUS GENUS

Marie-Pierre Chapuis<sup>1</sup>, Laure Benoit<sup>1</sup>, Antoine Foucart<sup>1</sup>, Alexandre Dehne Garcia<sup>2</sup>, Jean-Yves Rasplus<sup>2</sup>, Nicolas Leménager<sup>1</sup>, Bruno Michel<sup>1</sup>, Armelle Coeur d'Acier<sup>2</sup>

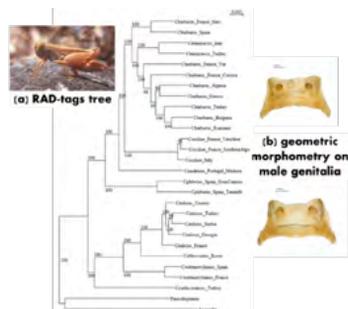
<sup>1</sup> Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), UMR Centre de Biologie pour la Gestion des Populations (CBGP), CS 30016, Montferrier-sur-Lez, France; marie-pierre.chapuis@cirad.fr

<sup>2</sup> INRA, UMR CBGP, F-34398 Montpellier, France

The systematics of the genus *Calliptamus* mainly relies on the shape of the wing and phallic complex, and on color pattern of hind femora of males only. However, geographical variation in these morphological characters hinders species determination. These difficulties may explain why the species delimitation within the genus *Calliptamus* has been controversial, with numerous confusions, descriptions, synonymies and subspecies. The purpose of this research is to provide a taxonomic review of the genus *Calliptamus*, based on an integrative approach including morphological, molecular and biological data. Beyond laying the foundations for a revised classification, this project will unravel the historical biogeography of the genus.

The Orthoptera Species File currently counts twelve species whose type depositories are known for the Palaearctic genus *Calliptamus*. We collected with success 9 species, represented by an average of 10 (from 1 to 25) individuals and 6 (from 1 to 17) localities. Since a phylogeny based on a few nuclear genes only may fail to resolve the basal relationships, we used the method of Restriction-site-associated DNA sequencing (RAD-seq), which showed promises to infer shallow relationships in insects. We showed a success of the method, despite the huge size for the genomes of *Calliptamus* sp., which we estimated to be ~7.65–8.39 Gb. We confirmed the two clades defined on the basis of genitalia shape: a Northern group includes species from the cold and wet temperate regions of Eurasia (e.g. *C. italicus*) and a southern

group includes species from the warm and dry mediterranean region (e.g. *C. barbarus*). We interpreted diversification within these two clades as the result of biogeographic factors, such as isolation in high mountain ranges and islands. We discovered that the species *C. barbarus* was not monophyletic and we used finer-scale sampling and the COI barcode to understand further its evolutionary history. Morphological analyses of numerous characters, including the hind wing, hind femur, shape of the pronotum and internal and external structures of the male genitalia, are in process to supplement genetic analyses.



**Figure 1.** Phylogenetic tree inferred from RADseq data for 26 *Calliptamus* individuals and 2 outgroup taxa using RADIS (a) and Illustration of geometric morphometry on male genitalia of *C. barbarus* and *C. italicus*.

**Key Words:** *Calliptamus*, RAD-Seq, morphology, cryptic species, haplotype network, glaciation.



## Population and landscape genomics of Orthopterans

# SPECIATION IN THE MOUNTAINS: PHYLOGENOMICS OF THE ALPINE GRASSHOPPER GENUS *KOSCIUSCOLA* (ORTHOPTERA: ACRIDIDAE)

Hojun Song<sup>1</sup>, Rachel A. Slatyer<sup>2</sup>, Shichen Wang<sup>3</sup>, Nikolai J. Tatarnic<sup>4</sup>

<sup>1</sup> Department of Entomology, Texas A&M University, College Station, TX, U.S.A. Email : [hsong@tamu.edu](mailto:hsong@tamu.edu)

<sup>2</sup> University of Melbourne, Victoria, Australia

<sup>3</sup> Texas A&M Genomics and Bioinformatics Service, College Station, TX, U.S.A.

<sup>4</sup> Western Australia Museum, Perth, Australia

Australia's alpine landscape exhibits high levels of endemism. For alpine specialists, these weathered peaks are isolated habitat islands where the potential for reproductive isolation and speciation is high. The flightless grasshopper genus *Kosciuscola* includes 5 species endemic to the region and distributed throughout the Australian Alpines, including Snowy Mountains, Victorian Alps, as well as Tasmania (Fig. 1). Within the genus, *K. tristis* is famous of exhibiting temperature-dependent color change, in which warm temperature induces the cuticle in males to become turquoise, while cold temperature causes the color to change to black. *Kosciuscola* species show elevational gradients in terms of distribution. For example, in Mount *Kosciuszko*, Australia's highest mountain, four species of *Kosciuscola* can be found. At the highest elevation, *K. tristis* is found, and at mid to high elevation, *K. usitatus* is found. At mid-to low elevation, *K. cognatus* is found, and at the very foothill of the mountain, *K. cuneatus* is found. This type of elevational gradient is found in different mountains throughout the entire range, even if two particular mountains are separated by valleys or flat lands. Some mountains with lower elevation lack *K. tristis*, but have the other three species. To investigate this interesting geographic distribution patterns, we have collected a large number of populations throughout the entire range of the genus and generated single nucleotide polymorphism (SNP) data using ddRAD-seq technology. Using these data, we calculated population genetics statistics and performed phylogeographic analyses to

understand the relationships among populations and how these recurring assemblages could have evolved. Independently, we also generated complete mitochondrial genome data to complement the RAD data. We have uncovered a hidden diversity of cryptic species within the genus, and new species will be described in light of these new findings. We show that the current distribution of the genus is achieved by complicated interactions between phylogeny and biogeography.



**Figure 1.** Species diversity within *Kosciuscola*. a. *K. tristis* from Mt. Kosciuszko; b. *K. tristis* from Mt. Buffalo; c. *K. usitatus*; d. *K. cognatus*; e. *K. cuneatus*; f. *K. tasmanicus*.

**Key Words:** *Kosciuscola*, RAD-Seq, phylogeny, population genetics, speciation.





# ORAL SESSION A

## Systematics & Molecular Biology

### Chairman: Kerry Shaw

Cornell University, NY, USA

1. **Elio Rodrigo D. Castillo, Francisco Ruiz-Ruano, Maria Marta Ciglino, Viviana Confalonieri, Dardo Marti, Maximilin M. Marnna, Juan Pedro M. Camacho.** HIGH-THROUGHPUT SATELLITOME ANALYSIS IN GRASSHOPPERS GENUS *DICHOPLUS* (ACRIDIDAE, MELANOPLINAE) WITH MULTIPLE NEO-XY SEX CHROMOSOME SYSTEMS.
2. **Oliver Hawlitschek, Stefan Schmidt.** ADMIXTURE AND FAST SPECIATION IN SPECIES COMPLEXES OF ACRIDIDAE: A MuseOMICS APPROACH
3. **Marcos Gonçalves Lhano.** CLADISTIC ANALYSIS OF *Stenopola* STAL, 1873 (ACRIDIDAE, TETRATAENIINI) BASED ON MORPHOLOGICAL CHARACTERS
4. **Pembe Nur Ozturk & Battal Ciplak.** MITOCHONDRIAL GENOME CHARACTERISTICS OF BARBITISTINI - A COMPERATIVE ANALYSIS WITHIN PHANEROPTERINAE
5. **Natallia Vicente, Karla Yotoko, Nicole Ibagon, Francisco De Mello and Tony Robillard.** EXPLORING THE DIVERSITY IN THE CRYPTIC SPECIES GENUS *LIGYPTERUS* (ENEOPTERINAE : ORTHOPTERA)
6. **Zina Sofrane, Salaheddine Doumandji, Anne-Geneviève Bargnères.** CHEMOTAXONOMY OF SPHINGONOTINI JOHNSTON, 1956 (ORTHOPTERA: ACRIDIDAE: OEDIPODINAE)
7. **Lara-Sophie Dey, Axel Horchkirch, Abdelhamid Moussi, Martin Huseman.** DIVERSIFICATION IN AND AROUND THE ATLAS MOUNTAINS- A REVIEW OF THE GENUS *THALPOMENA* SAUSSURE, 1884
8. **Ozgul Yahyaoglu, Ugur Karsi, Pembe Nur Ozturk, Onur Uluar, Sarp Kaya, Battal Ciplak.** EXISTING SPECIES CONCEPTS DO NOT REMEDIATE TAXONOMY OF *POECILIMON BOSPHORICUS* GROUP - WE NEED HELP FOR A DECISION
9. **Lucas Denadai de Campos, Pedro G.B. Souza-Dias, Laure Desutter-Grandcolas, Silvio Shigueo Nihei.** DIFFERENT WINGS, BUT SAME HISTORY? FOREWINGS EVOLUTION AND MOLECULAR PHYLOGENY OF TAFALISCINAE (ENSIFERA, GRYLLOIDEA, GRYLLIDAE)
10. **Nikita Sevastianov, Varvara Vedenina.** THE RATES OF EVOLUTION OF GRASSHOPPER SONG (ORTHOPTERA, ACRIDIDAE, GOMPHOCERINAE)
11. **Valeriya Vavilova, Igor Sukhikh, Alexander Blinov, Alexander Bugrov.** MOLECULAR PHYLOGENY OF THE PAMPHAGIDAE FAMILY (ORTHOPTERA: CAELIFERA).



## Systematics &amp; Molecular Biology

## H-THROUGHPUT SATELLITOME ANALYSIS IN GRASSHOPPERS GENUS *DICHROPLUS* (ACRIDIDAE, MELANOPLINAE) WITH MULTIPLE NEO-XY SEX CHROMOSOME SYSTEMS

Elio R.D. Castillo<sup>1</sup>, Francisco Ruiz-Ruano<sup>2</sup>, Maria Marta Cigliano<sup>3,4</sup>, Viviana Confalonieri<sup>5</sup>, Dardo Martí<sup>1</sup>, Maximiliano M. Maronna<sup>6</sup>, Juan Pedro M. Camacho<sup>2</sup>

<sup>1</sup> Laboratorio de Genética Evolutiva Dr. Claudio J. Bidau, IBS, CONICET-UNaM, Misiones, Argentina; castillo.eliordrigo@gmail.com

<sup>2</sup> Departamento de Genética, Facultad de Ciencias, Universidad de Granada, Granada, Spain

<sup>3</sup> Centro de Estudios Parasitológicos y de Vectores, CEPAVE, CONICET-CCT La Plata, Argentina

<sup>4</sup> Museo de La Plata, División Entomología; FCNyM-UNLP, La Plata, Argentina

<sup>5</sup> Departamento de Ecología, Genética y Evolución, FCEyN, Universidad de Buenos Aires (EGE-FCEN-UBA) and IEGEBA (UBA-CONICET), Ciudad Autónoma de Buenos Aires, Argentina

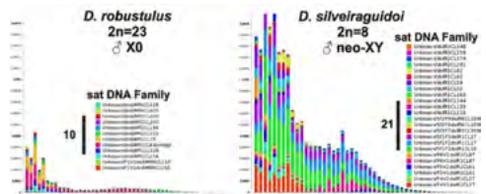
<sup>6</sup> Departamento de Zoología, Instituto de Biociências, Universidade de São Paulo, São Paulo, Brazil

Grasshoppers genus *Dichroplus* Stål are dominant in South American grasslands, and comprise representatives considered major pests of several crops, i.e., barley, rye, oats, wheat, flax or lucerne, as well as forages on natural pastures in Argentina. Additionally, in cytogenetics, this genus has received special attention due to its chromosomal diversity. While standard karyotypes in most Acrididae species consists of  $2n=23/24$  acro-telocentric chromosomes (with FN=23/24) and X0/XX sex chromosome determination system (SCDS), *Dichroplus* species show extensive variation in chromosome number, morphology and derived neo-SCDS. This extreme neo-SCDS diversity is explained by the occurrence of chromosomal rearrangements, mostly centric fusions between the X chromosome and an autosome, generating a neo-X, and the non-fused autosome partner becoming a neo-Y. These derived sex chromosomes frequently evolve through additional chromosomal rearrangements (e.g. inversions) and the accumulation of repetitive elements, mainly satellite DNA (satDNA) and Transposable Elements (TEs). However, current knowledge about repetitive DNA organization in *Dichroplus* chromosomes is scarce and absent in the *maculipennis* species group. For this reason, we have performed a genomic study inspecies with different SCDS: *D. robustulus* ( $2n=23♂/24♀; X0/XX$ ), *D. maculipennis* ( $2n=22♂/22♀; neo-XY/neo-XX$ ), *D. vittatus* ( $2n=20♂/20♀; neo-XY/neo-XX$ ), *D. obscurus* ( $2n=18♂/18♀; neo-XY/neo-XX$ ) and *D. silveiraguidoi* ( $2n=8♂/8♀; neo-XY/neo-XX$ ), the latter species showing the most dramatic case of chromosomal reduction in Orthoptera.

During last years, massive sequencing has proven as very resolutive to find large collections of satDNA families within a same genome (i.e. the

satellitome). Here, we performed a low coverage sequencing of genomic DNA from males in the Illumina HiSeq X platform, yielding about 5 Gb data of  $2 \times 150$  nt paired-end reads per individual, i.e.,  $\sim 1 \times$  coverage. To analyze this data, we performed a bioinformatic analysis using the satMiner protocol, a toolkit for mining and analyzing satDNA.

Comparison of satDNA content between males with different sex determination systems revealed variable numbers of satDNA families, with high values in species with neo-sex chromosomes (Fig.1). Although preliminary, these results suggest a differential accumulation of satDNA as a process involved in the degeneration process typical of sex chromosome evolution. The present study of satDNA is the first high-throughput characterization of repetitive elements in *Dichroplus*, thus contributing to the knowledge of the origin, structure and evolution of neo-sex chromosomes.



**Figure 1.** Repeat landscapes showing abundance and divergence values. Satellite DNA of *D. robustulus* (left) and *D. silveiraguidoi* (right) males are shown.

**Key Words:** *Dichroplus*, neo-sex chromosome, Satellite DNA, satMiner, degeneration process, sex chromosome evolution



## Systematics & Molecular Biology

# ADMIXTURE AND FAST SPECIATION IN SPECIES COMPLEXES OF ACRIDIDAE: A MUSEOMICS APPROACH

Oliver Hawlitschek<sup>1</sup>, Stefan Schmidt<sup>1</sup>

<sup>1</sup> Zoologische Staatssammlung München, Münchhausenstr. 21, 81247 Munich, Germany; Email: oliver.hawlitschek@gmx.de

---

Clusters of molecular OTUs, e.g., mitochondrial haplotypes or DNA barcodes, are considered to correspond closely to biological species. This generally holds true, but exceptions exist. In particular, acridid Orthoptera exhibit sharing of haplotypes across species complexes, even comprising different genera, and/or barcode divergence within species: The phenomenon was detected in >20% of species studied in this group. Potential reasons for haplotype sharing among species are hybridization, incomplete lineage sorting, nuclear mitochondrial pseudogenes (numts), and the influence of *Wolbachia* bacteria.

We studied a selection of species of the two groups from Central Europe and applied RAD sequencing to generate genomic data sets with the aim of detecting possible admixture. Specifically, we used the hyRAD approach for low-quality DNA samples, as many species were only available in the form of historical museum material. To study numts, we first isolated mitochondria from tissue to extract the barcode ortholog and then ran an amplicon sequencing to study the diversity of numts.

**Key Words:** Acrididae, Chorthippus, hybridization, speciation, numts, *Wolbachia*.



## Systematics & Molecular Biology

# CLADISTIC ANALYSIS OF STENOPOLA STÅL, 1873 (ACRIDIDAE, TETRATAENIINI) BASED ON MORPHOLOGICAL CHARACTERS

Marcos Gonçalves Lhano

Universidade Federal do Recôncavo da Bahia (UFRB), Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB). 44380-000. Cruz das Almas, BA, Brazil; marcos@ufrb.edu.br

The Neotropical subfamily Leptysminae (Orthoptera, Acrididae) was established by Amedegnato (1974), based mainly on the Nearctic tribe Leptysmini proposed by Rehn & Eades (1961) and on two Neotropical tribes: Chloropseustini and Tetrataeniini. This last one was revised by Roberts & Carbonell in 1980 and includes at present 10 genera, 32 species, and 17 subspecies. *Stenopola* Stål, 1873 is the largest genus of this tribe and actually comprises 13 species and 11 subspecies. This study aimed to test the monophyly of *Stenopola* and the relationship among its species, using a cladistic approach based on external morphological characters (male and female terminalia included) and the internal male genitalia. Specimens of 12 institutions and from field trips in Uruguay, Brazil and Paraguay were studied. Eighty four characters (53 from the external morphology and 31 from the phallic complex) and 20 terminals were used (all characters received the same weight and were treated as non-additive). Its related genus *Cornops* Scudder, 1875 was used as outgroups.

The matrix was analyzed using NONA 2.0 implemented inside WinClada ver. 1.00.08 (Nixon, 2002) and the strict consensus tree depicted the following intrageneric relationship for the genus: (*S. puncticeps* tenae ((*S. boliviana*, *S. pallida*, *S. puncticepseumera*, *S. viridis* (*S. puncticeps amazonica* (*S. puncticeps surinama* (*S. nigricans nigricans*, *S. puncticepslimbatipennis*)))) (*S. puncticeps curtippennis* (*S. flava* (*S. puncticeps puncticeps* (((*S. caatingae* (*S. dorsalis*, *S. nigricans laticera*)) (*S. bohlsii* (*S. rubrifrons mima* (*S. tigris*, *S. bicoloripes*, *S. rubrifrons rubrifrons*))))). Based on the results of the cladistic analysis the following conclusions were obtained: (1) the resultant topologies don't support the previously proposed classification for the genus, specially the subspecies; and (2) the genus *Stenopola* doesn't constitute a monophyletic group.

**Key Words:** Taxonomy, Grasshoppers, Leptysminae, Neotropics.



## Systematics & Molecular Biology

# MITOCHONDRIAL GENOME CHARACTERISTICS OF BARBITISTINI: A COMPERATIVE ANALYSIS WITHIN PHANEROPTERINAE

Pembe Nur Ozturk<sup>1</sup>, Battal Ciplak<sup>2</sup>

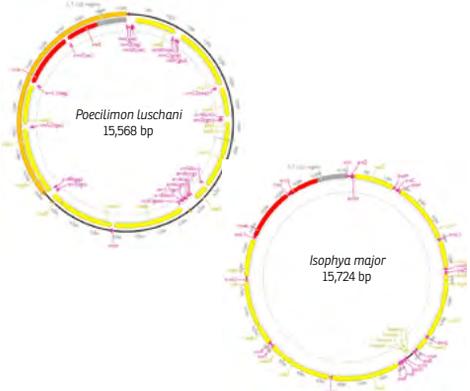
<sup>1</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey

<sup>2</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey; ciplak@akdeniz.edu.tr

Over the last 20 years, mitochondrial genome have been one of the main sources of data used in molecular evolution, population genetics, phylogenetic and other similar fields and approximately mitogenome of 150 orthopteran species has been sequenced and characterized. In this study, mitogenome of two species *Isophya major* and *Poecilimon luschani* representing Barbitistini were sequenced via the next generation sequencing and characterized in comparison with other members of Phaneropteridae (Orthoptera) using bioinformatics approaches. Mitogenome lengths were 15.724 and 15.568 base pairs in *Isophya major* and *Poecilimon luschani* respectively. The mitogenomes of both species are composed of 13 protein coding, 2 rRNA and 22 tRNA genes and an AT-rich region as the typical for other eukaryotes. The location of 37 genes in both species is identical to the Pantrustaceae mitogenome, which is regarded as the ancestral insect mitogenome. Different than the other a 183 base pair long non-coding region located between *trnR* and *trnN* genes was identified in *I. major*. In the protein coding genes the AT/GC ratios were found to be 65.4/34.6 and 68.4/31.6 in *I. major* and *P. luschani* respectively. The comparative analyses of 21 species in Phaneropteridae showed that there are several shared motifs in mitogenome of the family such as the location, the length, the overlapping/spacer sites between adjacent genes for total mitogenome, the start/stop codons of PCG, and the anticodons of tRNA genes. But still there are some motifs specific to the subfamilies or tribes. In the light of these data following conclusions were made: (i) These two species have a the typical multicellular

mitogenome characteristics, (ii) The ancestral gene locations are conserved in both species which

representing the tribe Barbitistini, though there gene re-location in some other phaneroptids, (iv) the anticodons of almost all members of the family are the same except the *trnL2* and *trnN*, different Pseudophyllinae, thus, highly conserved, (v) similar phylogenetic signs were also observed in overlapping region of the adjacent genes, and (v) the non-coding region of the 183 base pair length detected in *I. major* species may have been generated during mt-genomic replication or contain the transcription initiation region.



**Funding:** This study was supported as a project by Akdeniz University, Research Fund (Project No: FYL-2017-2524).

**Key Words:** Phaneropteridae, Barbitistini, *Isophya*, *Poecilimon*, mitogenome.

Systematics & Molecular Biology

EXPLORING THE DIVERSITY IN THE CRYPTIC SPECIES GENUS LIGYPTERUS (E NEOPTERINAE: ORTHOPTERA)

Natália Vicente<sup>1</sup>, Karla Yotoko<sup>1</sup>, Nicole Ibagón<sup>1</sup>, Francisco Mello<sup>2</sup>, Tony Robillard<sup>3</sup>

<sup>1</sup> Universidade Federal de Viçosa, Departamento de Entomologia. Av. PH Rolfs s/n. Viçosa, Minas Gerais, Brazil. CEP 36570-900; nataliavicente@gmail.com

<sup>2</sup> Universidade Estadual Paulista Júlio de Mesquita Filho, Departamento de Zoologia, Instituto de Biociências de Botucatu. Distrito de Rubião Júnior, S/N. Caixa Postal: 510 CEP: 18618-970 - Botucatu/SP, Brasil

<sup>3</sup> Muséum national d'Histoire naturelle, Institut de Systématique, Evolution et Biodiversité ISYEB, UMR 7205 CNRS MNHN UPM EPHE CP 50 (Entomologie), 75231 Paris Cedex 05, France

Ligypterus (Eneopterinae) is a neotropical cricket genus encompassing six described species based mainly on characters of the male genitalia. It is widely distributed in Brazil and French Guiana, but few localities have been documented so far. The remarkable similarity between the species of Ligypterus and, at the same time, subtle morphological variability within species along their distribution challenge species circumscription and identification. For these reasons, we integrate both DNA based and morphometric approaches in order to clarify its current diversity. A 348-bp fragment of the mitochondrial Cytb gene was sequenced from Ligypterus populations from eight localities of Brazil. We used different DNA-based species discovery approaches (Automatic Barcode Gap (ABGD), General Mixed Yule-Coalescent (GMYC) and Poisson Tree Process (PTP)). We also included in the genetic analyses sequences of previous studies (Ligypterus fuscus and Ligypterus pernambucensis) from specimens deposited in the Muséum national d'Histoire naturelle, Paris (MNHN). We also explored the diversity of Ligypterus mapping the phylogenetic tree onto shape change of the right forewing from 49 males sampled at the same eight localities. Our investigations of Ligypterus diversity using DNA were congruent among methods. Based on our analyses, the specimens from Itabuna, Cariacica, Murici and Manaus could be distinguished from the remaining specimens. Our analyses contain sequences from two recognized Ligypterus species: L. pernambucensis (from São Lourenço da Mata, Pernambuco State) and L. fuscus (from French Guiana). Our results show these taxa as separate species by the three DNA based species approaches, indicating possible new species in the localities sampled in this study. Itamaraju, Cariacica and Manaus exhibit a clear differentiation of shape without overlapping. Cariacica deserves

special attention as an interesting locality for future collections, since more than one putative species of Ligypterus may coexist there. Our results showed, on the other hand, conflicts between the DNA based approaches for specimens from Linhares and Itamaraju. These localities need additional morphological and molecular

Locality/ Sequence from previous studies	ABGD	GMYC	PTP
Cariacica	2	1	2
Manaus	1	1	1
Itamaraju	-	1	-
Murici	1	1	1
Linhares	-	1	-
Itabuna	1	1	2
<i>L. fuscus</i>	1	1	1
<i>L. pernambucensis</i>	1	1	1
Mucuri+Aimores	1	1	1
Itamaraju+Linhares	1	ng	1
<b>Total putative species</b>	<b>9</b>	<b>9</b>	<b>10</b>

information to confirm their diversity status.

**Table 1.** Putative number of species recovered of Ligypterus by all DNA approaches according to the locality or sequence from previous studies (*L. fuscus*, *L. pernambucensis*). Localities with (-) are the ones where the populations were gathered in one putative specie and ng = not gathered, means that for GMYC populations from Itamaraju and Linhares were recovered as separated putative species.

**Key Words:** ABGD, crickets, cryptic species, integrative taxonomy, geometric morphometrics, GMYC, PTP.



## Systematics & Molecular Biology

# CHEMOTAXONOMY OF SPHINGONOTINI JOHNSTON, 1956 (ORTHOPTERA: ACRIDIDAE: OEDIPODINAE)

Zina Sofrane<sup>1,2</sup>, Salaheddine Doumandji<sup>3</sup>, Anne-Geneviève Bagnères<sup>2,4</sup>

<sup>1</sup> Department of Animal Biology and Physiology, Faculty of Natural and Life Sciences, Setif1 University, Algeria; sofranezina1@yahoo.fr

<sup>2</sup> Research Institute for Insect Biology, UMR7261, CNRS-University François Rabelais, Parc Grandmont, Tours, France

<sup>3</sup> Research Laboratory of Plant Protection, Zoology, National Higher School of Agronomy, El-Harrach, Algiers, Algeria

<sup>4</sup> Centre d'Écologie Fonctionnelle et Évolutive, UMR 5175 CNRS-Universités de Montpellier, Route de Mende, Montpellier, France

The Sphingonotini constitute the tribe richest in species in the subfamily Oedipodinae in Algeria. A study on the chemical systematics was carried out on the neighboring genera of this tribe in order to identify their cuticular hydrocarbons. This work was carried out on 64 individuals belonging to three species *Sphingonotus maroccanus* (Uvarov 1930), *Pseudosphingonotus finotianus* (Saussure 1885) and *Sphingoderus carinatus* (Saussure 1888) collected in two different ecosystems in the region of Setif (northeastern Algeria).

The hydrocarbons identified by GC-MS in these specimens belong to four classes: the

n-alkanes representing with carbon chains of 23 to 39 carbon atoms, monomethylalkanes and dimethylalkanes with carbon chains of 25 to 39 carbon atoms, and trimethylalkanes with a carbon chain of 33 to 39 carbon atoms.

The results of this study revealed the similarities and the degree of divergence between different taxa.

**Key Words:** atics, hydrocarbons, Orthoptera, Oedipodinae, Sphingonotini.



## Systematics & Molecular Biology

# EXISTING SPECIES CONCEPTS DO NOT REMEDIATE TAXONOMY OF POECILIMON BOSPHORICUS GROUP: WE NEED HELP FOR A DECISION

Özgül Yahyaoglu<sup>1</sup>, Uğur Karşı<sup>1</sup>, Pembe Nur Ozturk<sup>1</sup>, Onur Uluar<sup>1</sup>, Sarp Kaya<sup>2</sup>, Battal Ciplak<sup>1</sup>

<sup>1</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey

<sup>2</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey; ciplak@akdeniz.edu.tr

There are several species concepts ranging from typological species concept of Linnaeus to unified species concept of De Queiroz. Each emphasize a specific aspect of the species unit and each has some advantages and disadvantages in application. Here we attempt to apply some commonly known concepts to taxonomy of *Poecilimon bosphoricus* species group (Orthoptera, Phaneropteridae, *Poecilimon*) ranged almost along total basin of Black Sea, excluding Romania and Lithuania. We used morphology, male calling songs and DNA sequences from two mitochondrial (COI and NAD2) and two nuclear (ITS1 and ITS2) markers to make species decisions. Morphology, mainly the male cercal structures, allows us to define some units to be called species in the group, but there are intermediate forms invalidating some species. Male calling song allowed us to establish three main clusters, a result in conflict with existing 23 valid species. We set our hopes on genetic data and analysed three different data matrices, as COI, NAD2 and ITS1+ITS2. Phylogenetic trees obtained from these matrices suggested almost all 23 species as poly- or paraphyletic. Moreover, these phylogenetic trees are in conflict for the relationships of the haplotypes, thus for the status of species. This is the case not only for the species with an indistinct phenotypical identity, even for the morphologically most aberrant species in the group. For example *P. cervus* is

the most aberrant and quite easily identified species, but, phylogeny of its haplotypes does not support a unique gene pool. Contrary to this *P. roseovidis* less easily can be distinguished, however, ITS1-ITS2 data suggest uniqueness its gene pool, but COI and NAD2 haplotypes are in contradiction. Phylogenetic trees prevented us to apply automatic species delimitation analyses. We eliminated haplotypes shared by species to analyse species specific haplotypes and to find a more-or-less solution. But, this strategy also failed. However, we know that there are some identifiable units which has identifiable ranges mostly parapatric or allopatric, but rarely sympatric with some other species in the group.

All these results together brought us to the following conclusions. There are some definable units in the *P. bosphoricus* species group, but they do not fit to any known species concept. The Linnaean concept of the species is the appropriate one explaining the diversity in the group. But, accepting this violate several other biological postulation especially those about population genetics theory and evolution, as data has several indication in these respects. Our final decision is that "we could not decide" and the reason for no decision is coming from accepting that biodiversity is organized as species."

**Key Words:** Species concept, *Poecilimon bosphoricus* species group.

## Systematics & Molecular Biology

# DIFFERENT WINGS, BUT SAME HISTORY? FOREWINGS EVOLUTION AND MOLECULAR PHYLOGENY OF TAFALISCINAE (ENSIFERA, GRYLLOIDEA, GRYLLOIDEA, GRYLLOIDEA, GRYLLOIDEA)

Lucas Denadai de Campos<sup>1</sup>, Pedro G. B. Souza-Dias<sup>2</sup>, Laure Desutter-Grandcolas<sup>3</sup>,  
Silvio Shigueo Nihei<sup>4</sup>

<sup>1,4</sup> Instituto de Biociências, Universidade de São Paulo, São Paulo, Brazil; lcdenadai@gmail.com

<sup>2</sup> Museu Nacional do Rio de Janeiro, Rio de Janeiro, Brazil

<sup>3</sup> Muséum national d'Histoire naturelle, Paris, France

Orthoptera systematics has been undergone through many controversies over the years. Recently, phylogenies of Orthoptera, Ensifera and Grylloidea started to clarify these relationships. Despite Tafaliscinae is not considered valid nowadays, this subfamily was recovered as monophyletic in a recent molecular phylogeny of Grylloidea. However, no taxonomic modification has been proposed to validate this group until now. The genera of Tafaliscinae are distributed in different tribes of Podoscirtinae. These crickets, exclusively Neotropical, show many morphological differences, mainly in the forewings. They also share some features, like the composition of apical spurs in the hind tibia, ovipositor flattened dorso ventrally, head shape and some structures in the male's phallic complex. The differences between forewings of Tafaliscinae crickets are however remarkable, from reduced forewings or aptery, to long forewings with only longitudinal veins, or complex compositions of veins that are associated to sound production. Auditory tympans are also variable, from absence to full development. Why are these crickets so diverse? What does this great heterogeneity in forewing condition means from the point of view of intraspecific communication? To answering these questions, it is necessary to analyze the diversity of Tafaliscinae in a phylogenetic frame. The aims of this study are to test the monophyly of Tafaliscinae using molecular data and to check the monophyly of the different tribes proposed for the subfamily. The material used for DNA extraction are from Museu de Zoologia da Universidade de São Paulo (MZSP); Department of Zoology, Institute of Biosciences, São Paulo State University, Botucatu Campus (UNESP); Instituto Nacional de Pesquisas da Amazônia (INPA) and from field trips in the

Brazilian Atlantic Forest and Cerrado. All the material was kept in ethanol 80% or 100%. For the analysis, seven molecular markers were used, four mitochondrial (12s, 16s, COI, CytB) and three nuclear (r18s, r28s, Histone) totaling ~4000 pb for each taxon. 47 terminals were sequenced, 30 of ingroup and 17 in the outgroup. Phylogenetic analyses were performed using parsimony and maximum likelihood. These analyses gave the same topology, only with a difference in the outgroup. The results present Tafaliscinae as a monophyletic group, sister-group of Podoscirtinae crickets. Recovering the tribes Tafaliscini and Paroecanthini within Tafaliscinae, different kinds of forewings appear in different clades. Long forewings with parallel and longitudinal veins (*Tafalisca*), long forewings with stridulatory veins slightly sinuous (*Amblyrthetus*), long forewings with bisinuous stridulatory veins (*Paroecanthus*) or with very reduced or absent forewings (*Cylindrogryllus*). These conditions are probably related to their life habits, courtship and calling behaviour. Tafaliscinae crickets with sound-producing structures are mainly registered as living on treetops, sometimes foraging on bushes near to the ground. On the other way, the Tafaliscinae crickets that are not capable to produces sound are mainly found on bushes close to the ground. Owing to its diversity, Tafaliscinae is an excellent model to study acoustic evolution and its relationship with habitats.

**Acknowledgments:** We thank São Paulo Research Foundation (FAPESP), grant 2017/11568-9, for financial support.

**Key Words:** crickets, forewings, evolution, molecular, systematics.

Systematics & Molecular Biology

**THE RATES OF EVOLUTION OF GRASSHOPPER SONG (ORTHOPTERA, ACRIDIDAE, GOMPHOCERINAE)**

Nikita Sevastianov<sup>1</sup>, Varvara Vedenina<sup>1</sup>

<sup>1</sup>Institute for Information Transmission Problems Russian Academy of Sciences, Moscow, Russia; met3254@yandex.ru

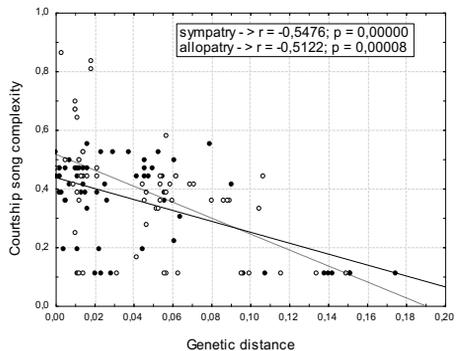
In grasshoppers of subfamily Gomphocerinae, song is the main component of reproductive isolation. Among singing Orthoptera, acoustic communication in Gomphocerinae is most developed in terms of complexity of stridulatory leg movements, the number of sound elements and mating strategies. The aim of the work was to compare rates of song evolution in grasshopper species with different mating strategies, which imply simple and complex courtship behaviour.

We analyzed calling and courtship songs from 120 pairs of closely related grasshopper species, which were selected from molecular phylogenetic trees. We used COI, ITS1 and ITS2 as genetic markers for estimation of divergence time of sister species. For the calling song analysis, 31 characters that included both sound and stridulatory leg movement parameters were chosen. For the estimation of the calling song complexity, we compared calling songs of analysed species with a plesiomorphic pattern of calling song. To estimate the courtship song complexity, we analyse both acoustic and visual components of courtship behaviour, and counted a summarized score of complexity. Each sister pair was categorized into data subsets based on geographical overlap (allopatric or sympatric) or mating strategy (simple or complex courtship). We conducted a correlation analyses between song complexity of calling and courtship signals and Euclidean distance between calling signals of sister species and genetic distance. Also, evolutionary rates of calling song divergence for each subset were calculated with EvoRAG software.

We found a negative correlation between a) genetic distance and calling song divergence, b) genetic distance and calling song complexity only in sympatric species pairs with simple courtship.

We suppose this to be a result of selection for isolation. Younger species pairs showed more complex courtship songs than distant relatives in both allopatry and sympatry (Fig. 1). We suggest that is a signature of sexual selection. We showed an increased rate of the calling song evolution under the gradient of the calling song complexity in sympatric species pairs with simple courtship. The rate of evolution was found to be constant in sympatric species with complex courtship and allopatric species pairs.

These results suggest that evolutionary rates in traits important to reproductive isolation and speciation in Gomphocerinae are influenced by both geographical overlap and mating strategies.



**Figure 1.** Correlation between courtship song complexity and genetic distance in sympatric (black dots) and allopatric (open dots) species.

**Key Words:** Gomphocerinae, acoustic communication, phylogeny, sexual selection, speciation.

## Systematics & Molecular Biology

# DIVERSIFICATION IN AND AROUND THE ATLAS MOUNTAINS: A REVIEW OF THE GENUS *THALPOMENA* SAUSSURE, 1884

Lara-Sophie Dey<sup>1</sup>, Axel Hochkirch<sup>2</sup>, Abdelhamid Moussi<sup>3</sup>, Martin Huseman<sup>1</sup>

<sup>1</sup> Center for Natural History, Hamburg University, Martin-Luther-King Platz 3, 20146 Hamburg, Germany; [larasophie.dey@gmail.com](mailto:larasophie.dey@gmail.com)

<sup>2</sup> Biogeographie, Universität Trier, Universitätsring 15, 54286 Trier, Deutschland

<sup>3</sup> Laboratory Valorization and Conservation of Natural Resources, University of Biskra, Algeria

*Thalpomena* Saussure, 1884 is a North African endemic genus, largely restricted to the Atlas Mountains and adjacent mountain ranges. Currently, seven species with four additional subspecies are described from the Atlas Mountains, one species occurs in Libya and one in the Somalian Highlands. The taxonomy of the genus has last been updated in 1949 by Dirsh, who published a revision of the genus including its allies (*Cophotylus*, *Crinita*, *Pseudocoelus*). However, in his descriptions he already mentioned the vague status of many taxa. Since then, the taxonomy of the genus has been largely untouched.

In our study, we investigate the systematic relationships within the genus for the first time using molecular methods. Our sampling includes all known species with more than 360 individuals from most of their distribution ranges.

We combined molecular data from six mitochondrial (COI, ND5, ND2, cytB, 16S & 12S)

and one nuclear gene (H3) with distribution data from collections and the literature and biometric measurements of 10 characters to obtain a comprehensive view of the interspecific relationships within the genus.

Our genetic as well as morphological analyses do not support the current taxonomy and suggests some synonymies. Wing coloration has little meaning for Oedipodinae taxonomy, yet wing-band shape seems to be a more useful trait. The genetic lineages obtained from the phylogenetic analyses correspond well with mountain barriers suggesting that the orography was a driver of diversification in the group.

**Key Words:** Atlas Mountains, biometrics, diversification, Oedipodinae, Phylogeny, *Thalpomena*, North Africa.



## Systematics & Molecular Biology

# MOLECULAR PHYLOGENY OF THE PAMPHAGIDAE FAMILY (ORTHOPTERA: CAELIFERA)

Valeriya Vavilova<sup>1</sup>, Igor Sukhikh<sup>1</sup>, Alexander Blinov<sup>1,2</sup>, Alexander Bugrov<sup>2,3</sup>

<sup>1</sup> Institute of Institute of Cytology and Genetics SB RAS, Novosibirsk, Russia; valeriya-vavilova@bionet.nsc.ru

<sup>2</sup> Novosibirsk State University, Novosibirsk, Russia

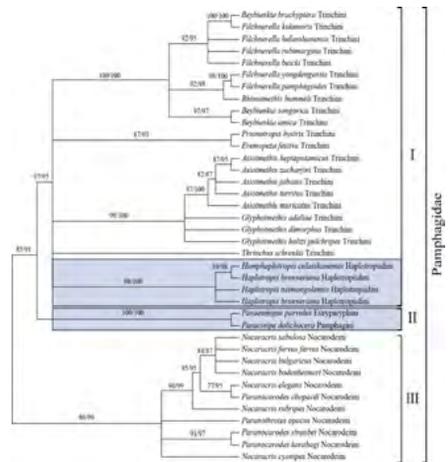
<sup>3</sup> Institute of Systematics and Ecology of Animals SB RAS, Novosibirsk, Russia

Pamphagidae family (Orthoptera: Caelifera) consists of approximately 600 species, mostly inhabiting deserted areas of Africa, Europe and Asia. This family is one of the smallest families among the Caelifera suborder, however, researchers have significant disagreements about its status and number of species. Phylogenetic relationships between different Pamphagidae taxa are poorly investigated, despite recent works on the complex analysis of their morphological structures. There are only a small number of studies concerning molecular phylogeny of Pamphagidae, most of which focus on several species, or on the broad selection of families from Caelifera suborder. Therefore, in order to establish phylogenetic relationships between problematic species, genera and subfamilies of the Pamphagidae family, a comprehensive molecular analysis of Pamphagidae grasshoppers is needed.

A significant number of nucleotide sequences of Pamphagidae species are gathered in GenBank database, with COI, COII mitochondrial genes and ITS2 nuclear region being the most commonly presented markers (<https://www.ncbi.nlm.nih.gov/genbank/>). However, these sequences weren't analysed in complex yet. In addition to this, we have new fauna material of Pamphagidae grasshoppers from North and South Africa, East and West Asia that complement the data presented in the Genbank database. Combination of these data serves as good prerequisites for a molecular phylogenetic analysis of Pamphagidae grasshoppers.

We present the reconstruction of phylogenetic relationships between Pamphagidae species and to offer a new solution of the taxonomic

problems in this family, based on the molecular data. Preliminary results of our analysis show that the Pamphaginae subfamily appears to be polyphyletic, and that the Haplotropidini tribe is inside the Trinchinae subfamily, not Pamphaginae. The project was supported by the Russian Foundation for Basic Research (No. 17-04-01615).



**Figure 1.** Phylogenetic tree of the Pamphagidae family deduced from COI mitochondrial gene. Roman numerals indicate groups that might have a subfamily status. Groups correlate to the current systematic as: I – Trinchinae; II and III – Pamphaginae. Marked blue branches show discrepancy with the current systematic.

**Key Words:** Pamphagidae, molecular phylogeny, mitochondrial DNA, ribosomal DNA.



## ORAL SESSION B

### Development & Physiology

#### Chairman: Marcos Gonçalves Lhano

Universidade Federal do Recôncavo da Bahia, BA, Brazil; marcos@ufrb.edu.br

1. **Bert Foquet, Hojun Song.** A COMPARATIVE STUDY OF BEHAVIORAL, MORPHOLOGICAL, AND MOLECULAR REACTION NORMS OF LOCUST PHASE POLYPHENISM
2. **Khemais Abdellaoui, Meriem Miladi, Elisabeth Marchal, Cynthia Lenaerts, Amel Ben Hamouda, Meriem Msaad Guerfali, Monia Ben Halima Kamel, Jozef Vanden Broeck.** EFFECTS OF PERGULARIA TOMENTOSA ACTIVE FRACTION ON THE OOGENESIS OF FEMALE LOCUST SCHISTOCERCA GREGARIA: OVARIAN BIOCHEMICAL COMPOSITION, ECDYSTEROID AMOUNTS AND TRANSCRIPTOMIC ANALYSIS
3. **Rick P. Overson, Eduardo Trumper, Natalia Thompson, Geordana Zeballos Cespedes, Jorge Frana, Alberto Gutierrez, Nelson Joaquim, Morion Le Gall, Jenni Learned, Carlos Maldonado, Hector Medina, Wilda Ramirez, Marcelino Lopez Rendon, Monica Roca, Luis Sanchez Shimura, Arianne Cease.** NUTRITIONAL PHYSIOLOGY AND ECOLOGY OF SOUTH AMERICAN LOCUST (SCHISTOCERCA CANCELLATA) DURING A 60-YEAR UPSURGE AND ROUGHLY 7-FOLD RANGE EXPANSION
4. **Maria Doria, Susan M. Bertram.** YOU ARE WHAT YOU EAT: HOW PROTEIN AND CARBOHYDRATE AVAILABILITY DURING DEVELOPMENT INFLUENCE ADULT CRICKET COGNITIVE PERFORMANCE
5. **Chrysantus M.Tanga, Magara H.J.O., Sevgan Subramanian, Sunday Ekesi.** BIOLOGY OF NEWLY DESCRIBED EDIBLE CRICKET SCAPSIPEDUS ICIPE HUGEL AND TANGA (ORTHOPTERA: GRILLIDAE) IN AFRICA
6. **Jozef Vanden Broeck.** RECENT ADVANCES IN THE STUDY OF NEUROPEPTIDES AND THEIR RECEPTORS IN LOCUST PHYSIOLOGY
7. **Meriem Miladi, Khemais Abdellaoui, Elisabeth Marchal, Cynthia Lenaerts, Amel Ben Hamouda, Mouna Mhafdhji, Monia Ben Halima-Kamel, Jozef Vanden Broeck.** PERGULARIA TOMENTOSA EFFECTS ON NUTRITIONAL PERFORMANCE DIGESTIVE ENZYMES ACTIVITY AND THE EXPRESSION OF TRYPSIN AND CHYMOTRYPSIN PROTEASE GENES OF LOCUSTA MIGRATORIA
8. **Chrysantus M.Tanga, Xavier Cheseto, Sevgan Subramanian, Sunday Ekesi.** POTENTIAL OF CRICKETS AND DESERT LOCUST FED MORINGA-BASED DIET AS NOVEL SOURCE OF BIOACTIVE PHENOLIC COMPOUNDS AND NATURAL ANTIOXIDANTS.

## Development & Physiology

# A COMPARATIVE STUDY OF BEHAVIORAL, MORPHOLOGICAL, AND MOLECULAR REACTION NORMS OF LOCUST PHASE POLYPHENISM

Bert Foquet <sup>1\*</sup>, Hojun Song<sup>1</sup>

<sup>1</sup> Department of Entomology, Texas A&M University, College Station, Texas, U. S. A.

Locusts are grasshoppers (Acrididae) that can form large migratory swarms or marching bands, and show an extreme form of density-dependent phenotypic plasticity, often known as locust phase polyphenism. Typically, locusts can exist between two extreme spectra called the phases, solitary phase and gregarious phase, which manifest in response to low and high population density, respectively. The two phases differ in several traits, including behavior, morphology, nymphal coloration, physiology and reproduction. Moreover, recent studies have shown clear molecular differences between both phases in two well-studied locust species, *Schistocerca gregaria* and *Locusta migratoria*. Taxonomically, locusts are rare among grasshoppers, representing only 19 species out of 6,700 species, and they are phylogenetically heterogeneous group, which strongly suggests that locust phase polyphenism convergently evolved multiple times. The genus *Schistocerca* contains three swarming locust species and more than 40 non-swarming sedentary species, and its phylogeny is now well understood. In this study, we focus on the Central American locust (*S. piceifrons*) and three closely related non-swarming grasshoppers: *S. americana*, *S. serialis cubense*, and *S. nitens*.

Together, these four species form a spectrum

in the degree of density-dependent phenotypic plasticity.

We quantified density-dependent reaction norms in all four species by rearing them in isolated and crowded conditions. The behaviour of 50 isolated-reared and 50 crowded-reared grasshoppers for each species were analysed using a behavioural assay described by Roessingh et al. (1993), and data were analysed in Ethovision. RNA was extracted from head and thorax tissue of five isolated-reared and five crowded-reared females for each species. These were sequenced using an Illumina HiSeq 4000, after which transcriptomes were assembled using Trinity and annotated using BLAST2GO. Differential gene expression was analysed with edgeR and DESeq2. Using our data, we establish that the spectrum of density-dependent phenotypic plasticity in this clade does not only extend to the behavioral level, but also to the molecular level. Further, our transcriptome analysis points towards clear similarities and differences in gene expression patterns among these four species. Finally, we compare and contrast our results in *S. piceifrons* to what is known from other locust species.

**Key Words:** reaction norms, phenotypic plasticity, Central American locust.

## Development & Physiology

# EFFECTS OF *PERGULARIA TOMENTOSA* ACTIVE FRACTION ON THE OOGENESIS OF FEMALE LOCUST *SCHISTOCERCA GREGARIA*: OVARIAN BIOCHEMICAL COMPOSITION, ECDYSTEROID AMOUNTS AND TRANSCRIPTOMIC ANALYSIS

Khemais Abdellaoui<sup>1§</sup>, Meriem Miladi<sup>1§</sup>, Elisabeth Marchal<sup>2</sup>, Cynthia Lenaerts<sup>2</sup>, Amel BEN Hamouda<sup>1</sup>, Meriem Msaad Guerfali<sup>3</sup>, Monia Ben Halima-Kamel<sup>1</sup>, Jozef Vanden Broeck<sup>2</sup>

<sup>1</sup> Higher Agronomic Institute of Chott Mariem, B.P 47, 4042 Chott Mariem, Sousse University, Tunisia

<sup>2</sup> Molecular Developmental Physiology and Signal Transduction, KU Leuven, Naamsestraat 59, P.O. Box 02465, B-3000, Leuven, Belgium

<sup>3</sup> Laboratory of Biotechnology and Nuclear Technologies, LR16CNSTN01, National Centre of Nuclear Sciences and Technologies, Technopole Sidi Thabet, Tunisia, Corresponding author: kemais\_a@yahoo.fr

<sup>§</sup> Authors with equal rank

Although they pose a serious risk to human health and environment, chemical insecticides remain the most used in locust control. To find a new and safe alternative to conventional pest management practices, we proceeded to the activity guided fractionation of the methanolic extract of *Pergularia tomentosa* using column chromatography. The obtained active fraction (AFP) was studied on several reproductive variables, the ovarian biochemical composition and the ecdysteroid signalling pathway of the desert locust *Schistocerca gregaria*, which is a voracious phytophagous swarming pest that can migrate over long distances causing significant crop and pastures damage in some of the world's poorest countries. The treatments were performed on adult females during the pre-ovipositional period, at three concentrations 0.12, 0.24 and 0.96 %. The AFP elicited a significant effect on *S. gregaria* reproductive potential resulting in a significant reduction in both fecundity and fertility. It also reduces the terminal

oocytes sizes, ovarian weight, and ovarian index. Biochemical analyses reveal a significant reduction of ovarian contents of proteins, lipids and carbohydrates, suggesting a disruption in the incorporation of the haemolymph metabolites in the oocytes and an interference of the AFP with the vitellogenesis process. The antigonadotrophic effect is confirmed by a histological study of the ovaries, which clearly shows a delay in ovarian development and in yolk accumulation in the basal oocytes of treated females. Moreover, our results indicate a significant decrease in ovarian and hemolymphatic ecdysteroids titres while increases the transcript levels of the ecdysone receptor (EcR) and the retinoid-X-receptor/ultraspiracle (RXR/USP) as well as Halloween genes involved in ecdysteroid biosynthesis Phm and Dib however Sad was down regulated.

**Key Words:** Locust, *Pergularia tomentosa*, reproduction, ecdysteroids, histology.



## Development & Physiology

# NUTRITIONAL PHYSIOLOGY AND ECOLOGY OF SOUTH AMERICAN LOCUSTS (*SCHISTOCERCA CANCELLATA*) DURING A -60YEAR UPSURGE AND ROUGHLY -7FOLD RANGE EXPANSION

Rick P. Overson<sup>1</sup>, Eduardo Trumper<sup>3</sup>, Natalia Thompson<sup>1</sup>, Geordana Zeballos Cespedes<sup>2</sup>, Jorge Frana<sup>3</sup>, Alberto Gutierrez<sup>4</sup>, Nelson Joaquin<sup>5</sup>, Marion Le Gall<sup>1</sup>, Jenni Learned<sup>1</sup>, Carlos Maldonado<sup>6</sup>, Hector Medina<sup>6</sup>, Wilda Ramirez<sup>6</sup>, Marcelino Lopez Rendon<sup>7</sup>, Monica Roca<sup>6</sup>, Luis Sanchez Shimura<sup>2</sup>, Arianne Cease<sup>1</sup>

<sup>1</sup> Arizona State University, USA; rickoverson@gmail.com

<sup>2</sup> Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria, Bolivia

<sup>3</sup> Instituto Nacional de Tecnología Agropecuaria, Argentina

<sup>4</sup> Instituto Nacional de Innovación Agropecuaria y Forestal, Bolivia

<sup>5</sup> Centro de Investigación Agrícola, Bolivia

<sup>6</sup> Servicio Nacional de Sanidad y Calidad Agroalimentaria, Argentina

<sup>7</sup> Instituto de Investigación Agrícolas, Bolivia

How physiological and ecological factors determine species' population levels across space and time remains a fundamental question in organismal biology. One important area that has received little attention is the role of plant macronutrient availability in determining the success or failure of invasive and sporadically outbreaking species, such as many insect pests, despite the fact that macronutrient balancing has emerged as a key factor regulating animal feeding behavior and performance. Here, we took advantage of the first significant population upsurge of the South American locust, *Schistocerca cancellata*, in 60 years. Since 2016 large swarms left their small permanent breeding zone in NW Argentina and invaded Bolivia and Paraguay, as well as an expanded area throughout Argentina. Our field experiments show that wild *S. cancellata*

strongly prefer carbohydrate over protein food options, suggesting that these locusts tend to be carbohydrate limited in contrast to the nitrogen limitation hypothesis. Our lab experiments showed that this species self-selected a highly carbohydrate-biased diet when given the option to balance protein and carbohydrate with synthetic diets – a ratio of 1:2 protein: carbohydrate. However, in both Argentina and Bolivia, we found that relatively few plants can provide this protein: carbohydrate ratio. These patterns are consistent with the observed preference for carbohydrate in the field and with our hypothesis that obtaining sufficient carbohydrates is a key, limiting nutrient for these locusts in their permanent breeding zone, and particularly under range expansion.

**Key Words:** nutritional ecology, physiology, locust, *Schistocerca*.



## Development & Physiology

# YOU ARE WHAT YOU EAT: HOW PROTEIN AND CARBOHYDRATE AVAILABILITY DURING DEVELOPMENT INFLUENCE ADULT CRICKET COGNITIVE PERFORMANCE

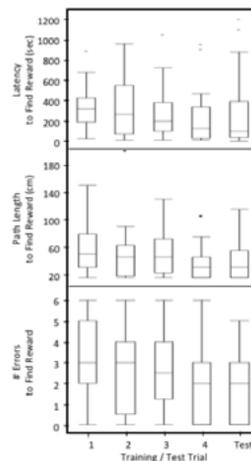
Maria Doria<sup>1\*</sup>, Susan M. Bertram<sup>1</sup>

<sup>1</sup> Carleton University, Ottawa, Canada; \* mariadoria@cmail.carleton.ca

Nutrient availability during development is known to influence various fitness measures across different taxa. However, little is known about how nutrient availability during development influences cognitive ability in adulthood, especially in invertebrates. Cognition is the mechanism by which animals acquire, process, store and act on information from their environment. Nutrient availability has the potential play a pivotal role in how cognitively able a species is, based on their nutrient acquisition during sensitive times of development. Information is lacking about individual variation in spatial cognitive abilities in invertebrates, what influences this variation, and how this variation is correlated with nutrient availability during development. In this study we quantified individual variation in spatial learning in male and female Texas field crickets (*Gryllus texensis*), who had been reared during their juvenile life stage on either a carbohydrate-rich (1:3 protein: carbohydrate) or protein-rich (3:1 protein: carbohydrate) diets. We investigated how these different diets influenced development time and body size at adulthood. We then repeatedly trained individuals to locate a food reward in a radial arm maze. We then tested their cognitive performance using a test (probe) trial, where no food was present. Our previous work revealed that after training, female crickets could remember the location of food, as latency to find the reward dish ( $p=0.0005$ ), distance travelled ( $p=0.0012$ ), number of complete arm entries ( $p=0.0003$ ), and number of errors ( $p=0.0002$ ) made prior to finding the reward dish all declined with repetitive training trials and during the test trial (Figure 1).

These findings suggest that field crickets can learn. Given this, we wished to ascertain the factors driving individual variation in cognitive

performance, with diet being the focal point of this study. We tested two hypotheses: (1) diet influences cognitive performance in male and female crickets, and (2) males and females differ in their cognitive performance. Based on these hypotheses we developed two predictions: (1) crickets fed a protein-rich diet during development will exhibit higher cognitive performance than crickets fed a carbohydrate-rich diet during development, and (2) males will exhibit higher spatial cognitive performance than females, as males have to remember the location of neighbours and their dominance status.



**Figure 1.** How female cricket cognition performance changes with training and testing.

**Key Words:** Cognitive performance, Nutrient availability, Development, Carbohydrates, Proteins, Individual variation

## Development & Physiology

# POTENTIAL OF CRICKETS AND DESERT LOCUST FED MORINGA-BASED DIET AS NOVEL SOURCE OF BIOACTIVE PHENOLIC COMPOUNDS AND NATURAL ANTIOXIDANTS

Chrysantus M. Tanga<sup>1</sup>, Xavier Cheseto<sup>1</sup>, Sevgan Subramanian<sup>1</sup>, Sunday Ekesi<sup>1</sup>

<sup>1</sup> International Centre of Insect Physiology and Ecology (icipe), P. O. Box 30772-00100, Nairobi, Kenya; ctanga@icipe.org

Insects are what they eat, as such they are increasingly being recognized not only as a source of food to feed the ever-growing world population but also as potential sources of new products and therapeutic agents. The study was to investigate the effect moringa-based diet on the development, survival, fecundity and longevity of the cricket *Scapsipedus icipe* and desert locust *Schistocerca gregaria*. Phenolic and flavonoid contents of the polar extracts of both insects were determined. Antioxidant capacities was measured using 2,2'-azino-bis (3-ethylbenzo thiazoline-6-sulfonic acid) (ABTS) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assays. Finally, gas chromatography-mass spectrometry (GC-MS) analyses of the extracts were performed. Crickets and locust fed *ad libitum* on moringa-based diets showed a unique pattern of development, survival and fecundity. Finally, GC-MS analyses revealed antimicrobial phenolic compounds and sterols.

DPPH and ABTS tests showed that the polar extracts possess significant antioxidant capacities, which corresponded to their phenolic and flavonoid contents with focus on those with potential importance as dietary and therapeutic components for humans. Our study shows that both insects are capable of ingesting phytosterols from a vegetative-based diet and, amplifies and metabolizes them into derivatives with potential valuable benefits. The study herein revealed that both insects fed moringa-based diets represented an excellent source of high natural antioxidants, particularly phenolic acids which may be applied in pharmaceutical, food and cosmetic industries.

**Key Words:** *Scapsipedus icipe*, *Schistocerca gregaria*, Gas chromatography-mass spectrometry, Phenolics, Flavonoids, Free radicals, Human health.

## Development & Physiology

# RECENT ADVANCES IN THE STUDY OF NEUROPEPTIDES AND THEIR RECEPTORS IN LOCUST PHYSIOLOGY

*Jozef Vanden Broeck*

*Molecular Developmental Physiology and Signal Transduction lab, Division of Animal Physiology and Neurobiology, Department of Biology, KU Leuven, Belgium; jozef.vandenbroeck@kuleuven.be*

---

Despite their huge biodiversity, some fundamental characteristics are shared by all animals. Insects, like other metazoans, are heterotrophs, implicating the basic need for the intake of food. Subsequently, their metabolism, growth, postembryonic development and reproduction will depend on this nutritional and energetic input. Therefore, it is crucial that they can rely on physiological mechanisms controlling and integrating these essential processes. Nutrient-sensing, hormonal and neuronal signalling systems are playing an important role in this complex regulation.

In this presentation, we will consider a few neuropeptide-mediated signalling pathways that are implicated in the regulation of developmental-physiological processes in insects. In particular, we will discuss recent data obtained in the locusts, *Schistocerca gregaria* and *Locusta migratoria*, which are swarming pest species that irregularly devastate the agricultural production in large areas of the world. In a physiological and neurobiological context, they have proven to be interesting experimental research organisms. We also evaluated the potential of peptidomimetic analogues to interfere with

neuropeptide receptor signalling, as well as downstream physiological processes. Moreover, RNA interference constitutes a highly efficient and robust method to silence the expression of peptide precursors and/or receptors in several insect species, including locusts.

We have identified several insect neuropeptide precursors and receptors and will report on our recent physiological and molecular biological studies that further illustrate the important role of neuropeptides and their receptors in locusts. The general aim of our work is to contribute to a better understanding of the regulation of postembryonic processes, as well as of the functional interactions between different regulatory pathways in an integrative -organismal/systemic - physiological context.

**Acknowledgements:** We gratefully acknowledge the EU (Horizon-2020 project nEUROSTRESSPEP), the Re-search Foundation of Flanders (FWO-Flanders), the Interuniversity Attraction Poles program (Belgian Science Policy Grant IAP P7/40) and the Special Re-search Fund of KU Leuven (C14/15/050) for financial support.

**Key Words:** hormone, locust, neuropeptide, peptide, receptor, reporter assay.



## Development & Physiology

# PERGULARIA TOMENTOSA EFFECTS ON NUTRITIONAL PERFORMANCE, DIGESTIVE ENZYMES ACTIVITY AND THE EXPRESSION OF TRYPSIN- AND CHYMOTRYPSIN PROTEASE GENES OF *LOCUSTA MIGRATORIA*

Meriem Miladi<sup>1§</sup>, Khemais Abdellaoui<sup>1§</sup>, Elisabeth Marchal<sup>2</sup>, Cynthia Lenaerts<sup>2</sup>, Amel Ben Hamouda<sup>1</sup>, Mouna Mhafdh<sup>3</sup>, Monia Ben Halima-Kamel<sup>1</sup>, You Jozef Vanden Broeck<sup>2</sup>

<sup>1</sup> Higher Agronomic Institute of Chott Mariem, B.P 47, 4042 Chott Mariem, Sousse University, Tunisia

<sup>2</sup> Molecular Developmental Physiology and Signal Transduction, KU Leuven, Naamsestraat 59, P.O. Box 02465, B-3000, Leuven, Belgium

<sup>3</sup> General Directorate of Plant Health and Agricultural Inputs Control, Ministry of Agriculture, Tunis, Tunisia

\* Meriem Miladi: meriamiladi@gmail.com

§ Authors with equal rank

The effects of *Pergularia tomentosa* active fraction (AFP) incorporated to the diet on larval growth, food consumption and utilization, digestive enzymes activity, and the histology of the alimentary canal were investigated during the fourth instar larvae of the migratory locust *Locusta migratoria*. Results revealed that the AFP caused strong antifeedant activity at 0.12 and 0.24% which appeared in a significant decrease in the food intake. The ability of the AFP to reduce growth rate and weight gain was also due to reduced approximate digestibility and efficiency of conversion of ingested food. The measurements of the digestive enzymes activity in the midgut showed that treatment of newly emerged fourth instar larvae resulted in a significant reduction in the total proteolytic activity with a dose-response relationship. However, the

endoproteases (trypsin and chymotrypsin) were upregulated. These observations were confirmed by transcript levels study for these representative enzymes by quantitative real time RT-PCR in the gut of treated and control larvae. The results demonstrated that the expression of Tryp 2B and CHY 2 serine proteases genes were increased. The AFP effect was also demonstrated by histopathological changes in the alimentary canal resulting in serious damage of the midgut, ceca, and proventriculus structure. Epithelial cells alterations, disintegrated regeneration crypts, vacuolarized cells, and rupture of muscular layer were observed in these organs.

**Key Words:** *Locusta migratoria*, *Pergularia tomentosa*, Digestion, Proteolytic Serine Protease, Genes expression.



## Development & Physiology

# BIOLOGY OF NEWLY DESCRIBED EDIBLE CRICKET *SCAPSIPEDUS ICIBE HUGEL AND TANGA* (ORTHOPTERA: GRYLLIDAE) IN AFRICA

Chrysantus M. Tanga<sup>1</sup>, Magara H. J. O.<sup>2</sup>, Sevgan Subramanian<sup>1</sup>, Sunday Ekési<sup>1</sup>

<sup>1</sup> International Centre of Insect Physiology and Ecology (*icipe*), P. O. Box 30772-00100, Nairobi, Kenya; ctanga@icipe.org

<sup>2</sup> School of Agriculture and Food Security, Jaramogi Oginga Odinga University Science and Technology (JOUUST), P.O. BOX 210, Bondo, Kenya

Currently, a new native edible cricket species *Scapsipedus icibe* was described in Africa with very no information on their biological fitness. We evaluated the effect of six diets composed to vary in protein, carbohydrate and fat content on the growth performance of *S. icibe*. The developmental time and survival rate of the different life stages varied considerably on the various diets, with the shortest development and highest survival rate recorded when fed wheat bran diet. Pre-oviposition duration was significantly longer on maize and carrot diets compared to that recorded on the other diets. We show that body weight and body length were significantly positively correlated in both sexes. Body size was also significantly correlated with longevity of either sex on most of the diets. Females of *Scapsipedus icibe* fed on protein-rich diets (fish offal, soybean and wheat bran)

had significantly higher lifetime fecundity and fertility when paired with larger body size male partners, suggesting that male size might have an influence on fecundity. Female-biased sex ratio was recorded on wheat bran, soya bean and carrot diets, whereas it was male-biased on maize and carrot diets. Our results clearly demonstrate that *S. icibe* has great potential for mass production but low quality-protein diets significant impact on their growth performance. These findings indicate the need to formulate nutrient-balanced feeds for effective mass production of this crickets.

**Key Words:** Edible cricket, *Scapsipedus icibe*, Morphological and molecular identification, Courtship, Diet composition, Biological fitness parameters.



## ORAL SESSION C

### Population Biology & Management

**Chairman: Cyril Piou**

CIRAD-CBGP, Montpellier, France

- 1. Abdelghani Bouaichi, Abdellah El Mouden.** EVALUATION OF THE TOXICITY AND THE PERSISTENCE OF METARIZHIUM ACRIDUM (GREEN MUSCLE®) AT DIFFERENT DOSES ON HOPPERS OF DESERT LOCUST SCHISTOCERCA GREGARIA UNDER DENSE OR SPARSE VEGETATION IN SEMI-FIELD CONDITIONS IN SOUSS-MASSA PARK, AGADIR, MOROCCO
- 2. David H. Branson, Zachary Sylvain.** INTERACTIVE EFFECTS OF NITROGEN AVAILABILITY AND DROUGHT ON GRASSHOPPERS AND BELOWGROUND PROCESSES
- 3. Giacomo Cavaletto, Paolo Fontana, Lorenzo Marini, Isabel Martinez-Sanudo, Mario Alberto Ronzani, Luca Mazzon.** FROM UNKNOWN TO OUTBREAKING - THE STRANGE CASE OF BARBITISTES VICETINUS
- 4. Douglas Lawton, Rick Overson, Jonah Broseman, Arianne Cease.** NOT ALL FOOD PATCHES ARE THE SAME - DISTRIBUTION OF PREFERRED DIETS IMPACTS LOCUST PHASE CHANGE
- 5. Robert Srygley.** DIET DRIVES THE COLLECTIVE MIGRATIONS AND AFFECTS THE IMMUNITY OF MORMON CRICKETS AND LOCUSTS
- 6. Derek A. Woller, Larry E. Jech, K. Chris Reuter, Lonnie R. Black, Dustin C. Krompetz, Michael Milam, Nathan Moses-Gonzales.** EXPLORING NEW FRONTIERS OF ORTHOPTERAN MANAGEMENT
- 7. Norbert Bauer, Zoltan Kenyeres.** PRELIMINARY RESULTS ABOUT HABITAT-REQUIREMENTS OF STENOBOTHRUS EURASIUS ON ITS WESTERN AREA-MARGIN
- 8. Manel Ben Chouikha, Mohsen Chammen, Khemais Abdellaoui, Haithem Tlili, Mouna Mhafdhi, Adel Jammezi, Laure Desutter-Grandcolas, Mohamed Ammar.** PRELIMINARY DATA ON SOLITARY POPULATION OF SCHISTOCERCA GREGARIA (FORSKÅL, 1775) IN TUNISIA.



## Population Biology & Management

# EVALUATION OF THE TOXICITY AND THE PERSISTENCE OF METARHIZIUM ACRIDUM (GREEN MUSCLE®) AT DIFFERENT DOSES ON HOPPERS OF DESERT LOCUST SCHISTOCERCA GREGARIA UNDER DENSE OR SPARSE VEGETATION IN SEMI-FIELD CONDITIONS IN SOUSS-MASSA PARK, AGADIR, MOROCCO

Abdelghani Bouaichi<sup>1</sup>, Abdellah El Mouden<sup>1</sup>

<sup>1</sup>Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Maroc ; bouaichi.agadir@gmail.com

According to a study on the mathematical modelling of barrier treatments using *Metarhizium acridum* strain IMI 330189 (Green Muscle®) against hopper bands of Desert locust *Schistocerca gregaria*, preliminary tests on the virulence, persistence and chronical and residual effects of a Green Muscle® were carried out on hoppers under dense or sparse vegetation in semi-field conditions in the Souss-Massa National Park.

Two doses (25 and 50 g conidia / hectare based on 5 x 10<sup>10</sup> conidia/ g) were assessed in a plot of one hectare each according to two types of vegetation structure either dense or sparse under semi-field conditions using the technique of Ultra-Low Volume (ULV). The monitoring of mortalities was carried out over three weeks on 4th instar hoppers maintained in cages under semi-field conditions at the rate of 10 hoppers per cage conducted in three repetitions of each treatment. The non-treated hoppers were located upstream of the treatment to avoid any type of contamination.

The virulence test showed that the 50 % efficacy (LT<sub>50</sub>) is only reached after two weeks in both cases of vegetation at the dose of 50 g conidia / hectare. After three weeks, the comparison between mortalities on dense and sparse

vegetation was not significant and exceeded 70% and 60% respectively.

The persistence test showed that the residual effect of *Metarhizium acridum* did not exceed 50% of mortality at the 20th day after their introduction. The same result was reached for all introductions at 4, 8 and 12 days after treatment. No significant effect was detected between the two vegetation structures.

The next step would be to propose a predictive barrier model based on current data in field and semi-field conditions highlighting widths and distances between barriers and then evaluate the effectiveness and efficiency of a large-scale barrier treatment of *Metarhizium acridum* on hopper bands of Desert Locust under field conditions according to the model requirements.

**Key Words:** Biopesticide, *Metarhizium acridum*, Green Muscle®, Desert locust, *Schistocerca gregaria*, dose-effect, semi-field condition.



## Population Biology & Management

# INTERACTIVE EFFECTS OF NITROGEN AVAILABILITY AND DROUGHT ON GRASSHOPPERS AND BELOWGROUND PROCESSES

David H Branson<sup>1</sup>, Zachary Sylvain<sup>1</sup>

<sup>1</sup>US Department of Agriculture, Agricultural Research Service, Sidney, Montana, USA;  
dave.branson@ars.usda.gov

Changing climate conditions are modifying patterns of precipitation, but how this will affect grasshopper population dynamics is not well understood. A better understanding of how interactions between weather variation, nutrient availability and grasshopper herbivory affect both grasshopper performance and belowground organisms is needed to understand implications of changing climate conditions. Previous work has shown that understanding the impacts of drought is critical for predicting rangeland grasshopper population dynamics in the northern Great Plains of North America, but no research has examined how drought and nutrient availability affects aboveground belowground interactions. We manipulated precipitation, grasshopper density and nitrogen in a field cage experiment in eastern Montana USA to examine the interactive effects of drought and nitrogen availability on grasshopper performance and belowground processes. Passive drought frames were used to modify patterns of precipitation. Soil nematodes were identified to functional group and phospholipid fatty acid analysis (PFLA) was conducted to assess soil bacterial and fungal communities.

The study was conducted during a severe natural drought, with the drought treatment strongly affecting vegetation production in the absence of grasshoppers. Grasshopper survival was not strongly affected by treatments, but drought and fertilization interacted and affected grasshopper body mass. Significantly more grasshoppers hatched in the following year in the drought-fertilized treatment. Nematodes were less abundant with fertilization, but were not affected by herbivory or drought. Although fungal communities were generally more responsive to fertilization and bacterial communities more responsive to drought, these responses frequently interacted with herbivory. Additional longer term experiments with other grasshopper species are required, but the results indicate that drought and nutrient availability can interact to affect grasshopper performance and belowground processes.

**Key Words:** drought, climate change, nitrogen, belowground, herbivory, Acrididae, *Ageneotettix deorum*.



## Population Biology & Management

# FROM UNKNOWN TO OUTBREAKING: THE STRANGE CASE OF *BARBITISTES VICETINUS*

Giacomo Cavaletto<sup>1</sup>, Paolo Fontana<sup>2</sup>, Lorenzo Marini<sup>1</sup>, Isabel Martinez-Sañudo<sup>1</sup>, Mario Alberto Ronzani<sup>2</sup>, Luca Mazzon<sup>1</sup>

<sup>1</sup> Department of Agronomy, Food, Natural Resources, Animals and Environment (DAFNAE), University of Padua, Italy

<sup>2</sup> Fondazione Edmund Mach, San Michele all'Adige (Trento), Italy; World Biodiversity Association (Verona), Italy; paolo\_api.fontana@fmach.it

*Barbitistes vicetinus* Galvagni and Fontana, 1993 (Fam. Tettigoniidae), is an endemic north-east Italian flightless bush cricket. Specimens of this species collected before the year of description were not found in collections. *B. vicetinus* remained a very rare species confined in small hilly areas for the following 15 years, confined mostly in the Veneto Region, between 200 to about 600 m a.s.l. After the identification of its bioacoustics pattern, *B. vicetinus* has been more intensively searched and it has been found in other localities.

In 2004 it has been found outside of the Veneto Region, in the Trentino district, in the Adige river valley. During these first years of studies, the species demonstrated to be associated with trees, especially *Ostrya carpinifolia*, *Ulmus* spp. and *Fraxinus ornus*. The first outbreak was recorded in 2006 on the Berici Hills, but since 2008 *B. vicetinus* started to produce severe outbreaks, in both Berici and Euganean Hills, showing high polyphagy and causing intense defoliations on broadleaf forests and on the neighbouring crops (mainly vineyards, olive groves and fruit orchards). In a few years the outbreaks restricted to the Euganean Hills, with limited attacks in Trentino vineyards. In addition, the outbreaks was source of annoyance to people living close to the outbreaking areas, as the bush crickets invade streets and gardens. The current defoliations caused by outbreaks of *B. vicetinus* in north-east Italy are the first ones known for this species, although within the genus *Barbitistes* other species are known to outbreaks, causing severe damage to woods or cultivated plants: *Barbitistes constrictus* Brunner v. W., 1878, *B. ocskayi* (Charpentier, 1850) and *B. serricauda* (Fabricius, 1794). During outbreaks, *B. vicetinus* changes its ethology showing a tendency to gather in large numbers in small patches with the appearance of a melanic form with aposematic coloration: black with white and yellow spots or lines and red on the joints and appendixes. The

first instar nymphs feed mainly on shrubs while, in subsequent weeks, the individuals climb up to the trees where they spend most of the time eating leaves. The first adults appear in May while mating and oviposition last for the entire June.

Like many European species of the family, *B. vicetinus* overwinters as an egg laid in the ground. In order to improve the knowledge currently available regarding the phenology and the reproduction of this species, the nymph population density and the hatching dynamics were inspected. The study was performed over 18 sites across the outbreak area of Euganean Hills in 4 consecutive years (2013–2016), using emergence traps. The hatching period was assessed and the influence of both vegetation type (forest, vineyard and hedgerow) and soil cover (broadleaf litter and grass) on the maternal laying preference was verified. Nymph density was assessed for the first time during outbreaks, showing mean values of over 1 million individuals/ha. In all the sampling years, the whole hatching period occurred in a restricted time, ever in few weeks between mid-March to mid-April. The highest nymph density was recorded in forest with soil covered by broadleaf litter, without a gradient from inner forest to edge. A significantly lower density was found under grass cover. Results indicated, however, that cultivated habitats did not offer suitable oviposition sites to *B. vicetinus*, although the adults are commonly found also in crops where they can cause severe damage. As observed in other species of orthopteran, this species would had survived at absolutely low density population for a long time. The ancient presence of this species in this region has recently been confirmed by molecular analysis

**Key Words:** *Barbitistes vicetinus*, outbreak, bush-cricket, emergence trap, population density, oviposition site preference, hatching period.

## Population Biology & Management

# NOT ALL FOOD PATCHES ARE THE SAME: DISTRIBUTION OF PREFERRED DIETS IMPACTS LOCUST PHASE CHANGE

Douglas Lawton<sup>1</sup>, Rick Overson<sup>2</sup>, Jonah Brosemann<sup>1</sup>, Arianne Cease<sup>1,2</sup>

<sup>1</sup> School of Life Sciences, Arizona State University, Tempe, USA; [ddlawton@asu.edu](mailto:ddlawton@asu.edu)

<sup>2</sup> School of Sustainability, Arizona State University, Tempe, USA

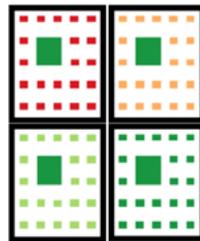
Spatial distribution and nutritional quality of food patches are important determinants of animal populations and distributions; however, the interactive effects are not well understood. For example, patchy as compared to random distributions of grasses promote desert locust (*Schistocerca gregaria*) gregarization through increasing conspecific interactions. Further, host plant nutrient content affects growth, survival, and distribution of many grasshopper and locust species, with the latter often preferring high carbohydrate (C), low protein (P) diets. However, considering how the distribution of nutritionally optimal plants effect locust gregarization has yet to be examined outside of *S. gregaria*. In this study, we investigated the impact of food quality distribution on Australia plague locust (*Chortoicetes terminifera*; APL) gregarization. We show that a clumped distribution of nutritionally optimal diets increases conspecific interaction and promotes gregarization. In contrast, evenly distributed optimal diets allow APL to avoid each other and remain solitary.

We placed solitary APL into four different treatments (fig. 1) of resource quality patchiness for 48 hours. We used artificial diets to control C:P ratios and provided ad lib water. To assess interactions among locusts, we filmed the treatment arenas and counted the number of individual direct contacts every five minutes. We weighed diet patches before and after each treatment to measure the amount consumed. At the end of the treatment, locusts were tested in a behavior arena with a locust stimulus group on one side and empty on the other. In the arena, we tracked overall movement, speed, and time spent near stimulus group.

Within patch nutritional variation impacted the spatial distribution of food consumption and gregarization of locusts. With the change of optimal diet distribution from a single patch to continuous

distribution, there was a decrease in gregarious behavior and locust fed randomly throughout the patch. In landscapes with a continuous distribution of suboptimal diet, locusts aggregated around the optimal diet patch, which increased conspecific contact.

Our results corroborate previous research on *S. gregaria* suggesting that the distribution of resource quality, in addition to overall distribution of resources, is important to identifying which landscapes promote gregarization. Our future studies will include field experiments and consider scaling issues to better understand the ecological relevance of this study. Understanding how the effect of inter-patch nutritional variation on gregarization changes from lab to continent scales may assist locust management programs as well as advance our basic understanding of how locusts aggregate and swarm.



**Figure 1.** Food quality diagram from suboptimal continuous (top left) to optimal continuous (bottom right). Optimal patch was kept constant. Red blocks represent suboptimal and green represent optimal food patches.

**Key Words:** Behavioral Ecology, Landscape Heterogeneity, Phase Polyphenism, Nutritional ecology.

## Population Biology & Management

# DIET DRIVES THE COLLECTIVE MIGRATIONS AND AFFECTS THE IMMUNITY OF MORMON CRICKETS AND LOCUSTS

Robert Srygley

USDA-Agricultural Research Service, Sidney MT, USA; robert.srygley@ars.usda.gov

Differential transmission of disease among individuals within a population or among species in a community can result in superspreaders, relatively rare individuals responsible for a large proportion of transmission events. Migrating Mormon crickets *Anabrus simplex* and nymphal locusts readily engage in cannibalistic attacks and necrophagy. Typically multiple individuals consume a cadaver, which fosters the spread of disease. Cannibalistic attacks result in aligned, coordinated movement of individuals in massive bands that march daily for weeks at a time. Coordinated movement reduces contact frequency, which not only reduces cannibalism but the risk of disease transmission. When crowded, Mormon crickets and locusts elevate their constitutive immunity, which further reduces the risk of disease transmission. Bands of Mormon crickets show a variety of macronutrient dietary deficiencies that determine whether they will be more susceptible to pathogenic bacteria or fungi. In some migratory bands, Mormon crickets seek carbohydrates and have less anti-bacterial activity. A lipid transport protein that functions in both fuelling migration and anti-bacterial activity may cause a trade-off between the two activities when carbohydrates are limited.

In other migratory bands, Mormon crickets prefer protein over carbohydrates, indicating protein-deficiency. In these bands, the generalized immunity of Mormon crickets, measured as phenoloxidase, is compromised, and the insects are more susceptible to *Beauveria bassiana* fungal infection. In locusts, a high protein diet resulted in greater susceptibility to another entomopathogenic fungus, *Metarhizium acridum*, whereas in Mormon crickets, both phenoloxidase titers and immunity to *M. acridum* increased with adult age. Color changes associated with death by either of these fungi diminishes cannibalism, but bands may cull infected or encounter cadavers too quickly to effectively reduce fungal transmission. As long as the insects show no signs of infection that ward off their conspecifics, then infected Mormon crickets and locusts in migratory bands could be superspreaders of disease. However the diseases that they are most likely to harbor and amplify may depend on the dietary deficiencies exhibited by members of the band.

**Key Words:** Cannibalism, Nutrition, Pathogen, Migration, Aggregation, Grasshopper, Katydid.

## Population Biology & Management

### EXPLORING NEW FRONTIERS OF ORTHOPTERAN MANAGEMENT

Derek A. Woller<sup>1</sup>, Larry E. Jech<sup>1</sup>, K. Chris Reuter<sup>1</sup>, Lonnie R. Black<sup>1</sup>, Dustin C. Krompetz<sup>2</sup>, Michael Milam<sup>2</sup>, Nathan Moses-Gonzales<sup>2</sup>

<sup>1</sup> USDA-APHIS-PPQ-S&T-CPHST Phoenix Lab, Phoenix, AZ, U.S.A.; [Derek.A.Woller@usda.gov](mailto:Derek.A.Woller@usda.gov)

<sup>2</sup> M3 Consulting Group, LLC, Dayton, OH, U.S.A

Grasshopper management on rangeland habitats (where domestic livestock graze) of the 17 western states of the United States of America (U.S.A.) can be summarized as a Sisyphean task because of complexity. This is due to: **1)** the high numbers of species that often exist in a given region, **2)** the threat of outbreak that several species present, **3)** the difficulties of monitoring for such outbreaks given the large size of these regions, **4)** a dwindling chemical arsenal available for adequate control, and **5)** decreasing levels of funds for all of the above. Adding a further layer of complexity is the occasional presence of another rangeland pest, the tettigoniid known locally as the Mormon cricket (*Anabrus simplex*). Often, this creature will outbreak into immense migratory bands that eat all available food and can vanish mysteriously for years, making them hard to predict and manage adequately.

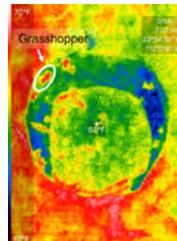
Thus, the need exists to explore new management frontiers for these orthopterans, such as **1)** disseminating insecticides in novel ways using unmanned aircraft systems (UAS) (e.g., see Fig. 1), **2)** surveying and population assessment via UAS using an array of sensors (e.g., see Fig. 2), **3)** field-testing new generic formulations of proven insecticides, **4)** developing and testing new and old biopesticides, **5)** investigating nutritional needs, **6)** considering unique forms of weaponry, like natural enemies, molecular insecticides, and more. The U.S. Department of Agriculture (USDA) has been at the forefront of this perpetual battle since 1877 and has made great strides in management methods through careful thought and extensive testing on wild populations. Often, the USDA works with cooperators and key stakeholders (federal, state, tribal, private) to enable these breakthroughs in techniques and technology.

The USDA is committed to its mandated mission to

test and develop better, cheaper, and ecologically-friendly methods of managing these rangeland pests. There is much to learn from international groups doing similar work on locusts and other pestiferous orthopterans, which is why the USDA is always interested in potential collaborations with likeminded entities.



**Figure 1.** An example of a large TOL-type UAS that is capable of longer missions and equipped with a LiDAR sensor for measuring relative vegetation height.



**Figure 1.** An example of an infrared thermal imaging sensor being tested. Grasshoppers are sometimes easily recognizable when they are warmer than the surrounding environment. Note that the cooler round structure in the center is an outdoor metal cage.

**Key Words:** Grasshopper, Katydid, Management, Rangeland, USDA, Agriculture, Insecticide.



## Population Biology & Management

# PRELIMINARY RESULTS ABOUT HABITAT-REQUIREMENTS OF STENOBOTHRUS EURASIUS ZUBOVSKI, 1898 ON ITS WESTERN AREA-MARGIN

Norbert Bauer<sup>1</sup>, Zoltán Kenyeres<sup>2</sup>

<sup>1</sup> Hungarian Natural History Museum, Department of Botany, Budapest, Hungary

<sup>2</sup> Acrida Conservational Research L.P., Tapolca, Hungary; [kenyeres@acridabt.hu](mailto:kenyeres@acridabt.hu)

*Stenobothrus eurasius* is an Eurasian-Continental species enlisted by the Natura 2000 program of the European Union. In the east, it reached to the Transbaikal Region with continuous distribution, but in the western margin of its area, in the Carpathian and Bohemian Basins, just exclaves of the species can be found. *S. eurasius* having pest importance in the eastern part of its range occurs with a few, small, isolated, relict stands in the western margin of its area. Central-European populations of *S. eurasius* are vulnerable – regression and extinction were detected at several occurrences during the last decades. We have some knowledge about habitat requirements of the species, but those are not enough for management programs basing on the most important limiting factors of its population size.

For planning successful conservation projects of *S. eurasius* we systematically examined 15 populations and habitats of the species in 2017 and 2018. All sampled stands located in the Carpathian Basin and they represented the local distribution of the species.

At present, in the Carpathian Basin *S. eurasius* does not occur on zonal lowland steppe areas, it can be found just in edaphic steppe slope–rocky grassland habitats of the colline region. Latter habitat type is very frequent in the Carpathian Basin, but *S. eurasius* occurs just in a small part of that. Understanding the current distribution of the species on its area-margin needs not only the revealing of habitat requirements of the species, but also the analysing of the landscape history. Based on the stands occurring in typical locations of the colline region we assume that the species

has been formerly distributed in the zonal steppe areas of this region, but it disappeared from there caused by the intensive agriculture.

According to our preliminary results presence of *S. eurasius* is typical in dry grasslands being rich in continental steppe plants and characterised by south or south-western exposure and 5–10° angle of repose. Bedrock seems to be unimportant in colonization of the species, its robust populations occur both on basic (limestone, dolomite) and acidic (rhyolite, andesite) bedrocks. In the studied habitats shallow (4–5 cm), medium rich in mould (17–24%) and relative poor in lime (~5–7%) soils were detected in which structure the fine fractions (small sand and silt) had large proportion (50–60% and 15–30%). Cover of the stone surfaces and bare ground were high (6–17% and 5–15%) in all studied habitats of *S. eurasius*. Accompanying Orthopteran assemblages of *S. eurasius* were dominated by thermophilic and moderately-thermophilic species according to ecotype forms and by graminicole species based on life forms. Density of the studied populations showed high deviation. Based on our observations the density of the species affected mostly by the size and disturbance level of the given habitat patch. In further steps of our project we would like to reveal the main drivers of the realized densities and to conceive a species-specific conservation strategy for *S. eurasius* populations occurring on area-margin of the species.

**Key Words:** Orthoptera, locust, relict, steppe vegetation, edaphic steppe slope, soil, management, conservation.

Population Biology & Management

**PRELIMINARY DATA ON SOLITARY POPULATION OF SCHISTOCERCA GREGARIA (FORSKÅL, 1775) IN TUNISIA**

Manel Ben Chouikha <sup>1,2,3\*</sup>, Mohsen Chammem<sup>30</sup>, Khemais Abdellaoui<sup>40</sup>, Haithem Tlili<sup>2,5</sup>, Mouna Mhafidhi<sup>6</sup>, Adel Jammezi<sup>6</sup>, Laure Desutter-Grandcolas<sup>7</sup>, Mohamed Ammar<sup>2</sup>

<sup>1</sup> Department of Biology, Faculty of Sciences of Gabes, University of Gabes, Tunisia;

\* Manelchouikha74@gmail.com

<sup>2</sup> Laboratory of Bioagressors and Integrated Protection in Agriculture, National Institute of Agronomy of Tunisia

<sup>3</sup> Laboratory of Animal Husbandry and Wildlife, Arid regions Institute, Medenine, Tunisia

<sup>4</sup> Department of Biological Sciences and Plant Protection, Higher Agronomic Institute of Chott Mariem, Sousse University, Tunisia

<sup>5</sup> Department of Biological Sciences, Faculty of Science of Tunis, University Tunis El Manar, Tunisia

<sup>6</sup> General Directorate of Plant Health and Agricultural Inputs Control, Ministry of Agriculture Water Resources and Fisheries, Tunisia

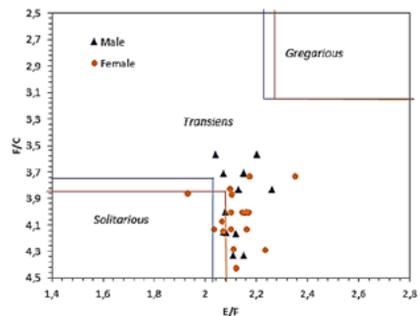
<sup>7</sup> Institute of Systematics, Evolution, Biodiversity, National Museum of Natural History CNRS, Sorbonne University, Paris-France

<sup>0</sup> Co-authors with equal rank

Desert locust *Schistocerca gregaria* is one of the most destructive insect in the world since the old times. Previous work reported that swarms of the 2004 invasion of South Tunisia contained 5% of locusts in the solitary phase. These observations suggest that Tunisian desert could be a natural habitat for the solitary phase of *S. gregaria*, which had never been acknowledged before. The present study aims to verify this hypothesis by periodically prospecting different regions of South Tunisia. We report here for the first time the presence of solitary desert locust populations in Tunisia and we describe some abiotic characteristics of its habitat. From 2016 to 2018, we found *S. gregaria* in 16 different sites widely distributed between TaTaouine, Medenine, Gafsa, Tozeur and Kébili Governorates. A total of 82 individuals were observed among which one larva and 32 adults were collected for morphometric measurements. Our results showed that 71,87% of the insects examined have 7 eye stripes, which characterizes the solitary phase. Plots constructed by E/F and F/C ratios showed that *S. gregaria* populations have a tendency towards the solitary phase.

These results suggest that collected individuals are part of a native population of southern Tunisia,

and that the Tunisian desert could be a permanent habitat for the desert locust. Further investigations are required to delimit its distribution in Tunisia and its ecological niche.



**Figure 1.** E/F and F/C scatter plot of locusts collected in Tunisia from 2016 to 2018.

(E = Length of fore wing, F = Length of hind femur C = Maximum head width)

**Key Words:** Recession area, Permanent habitat, Southern Tunisia, *Schistocerca gregaria*.



# ORAL SESSION D - PART 1

## Biodiversity, Biogeography & Ecology

**Chairman: Claudia Hemp**

University of Wuerzburg, Germany

1. **Holger Braun.** THE TETTIGONIIDAE OF ARGENTINA
2. **Jiajia Dong, Geal J. Keroat, Natallia Vicente, Cahyo Rahmadi, Shengquan Xu, Tony Robillard.** SYSTEMATICS AND BIOGEOGRAPHY OF THE GENUS *CARDIODACTYLUS* (ORTHOPTERA: ENEOPTERINAE: LEBINTHINI) IN THE SOUTH EAST ASIA
3. **Paola Fontana, Markéta Kísova, Petr Kocarek, Roberto Battiston, Filippo Maria Buzzetti.** TOWARDS A CONVINCING AND UPDATED ASSESSMENT OF ITALIAN DERMAPTERA
4. **Mathias Kayalto, Lalla Mina Idrissi Hassani, Michel Lecoq, Cyril Piou.** UPDATE OF DESERT LOCUST GREGARIZATION SITES MAPPING
5. **Itzel Lemus, Roger Guevara, Zenon Cano-Santana, Wesley Dattilo, Raúl Cueva del Castillo.** DIET CHARACTERIZATION OF *TAENIOPODA AURICORNIS* (ORTHOPTERA ROMALEIDAE) THROUGH ITS ONTOGENY, USING DNA BARCODE, IN A SABAL PALMETTO WOODLAND IN MEXICO
6. **Franz Löffler, Dominik Poniatowski, Thomas Fartmann.** EXTINCTION DEBT OF GRASSLAND SPECIALISTS IN A CENTRAL EUROPEAN BIODIVERSITY HOTSPOT
7. **Michael G. Sergeev.** THE MIGRATORY LOCUST *LOCUSTA MIGRATORIA* NEAR THE NORTHERN BOUNDARY OF ITS RANGE: COULD ITS UPSURGES DEVELOP IN SOUTH SIBERIA?
8. **Khadija Abbassi.** DESERT LOCUST AND CLIMATIC PHENOMENA
9. **Riffat Sultana.** PREVALENCE OF OEDIPODINAE (ACRIDIDAE: ORTHOPTERA) FROM THAR DESERT SINDH PAKISTAN
10. **Alain Christel Wandji, Sévilor Kekeunou, Alain Simeu Noutchom, Marcelle Mbadjoun Nzike.** INFLUENCE OF FORESTS ON THE STRUCTURE OF GRASSHOPPERS COMMUNITIES IN SOME AGRO-ECOLOGICAL ZONES OF CAMEROON.



## ORAL SESSION D - PART 2

### Biodiversity, Biogeography & Ecology

**Chairman: Axel Hochkirch**

Trier University & IUCN SSC Grasshopper Specialist Group

11. **Aileen Thompson, Michael Samways and Corinna Bazelet.** BIOSPHERE RESERVE ZONES ARE EQUAL IN TERMS OF KATYDID ECOACOUSTICS
12. **Robert Vlk, Stanislav Rada, Gunther Wöss, Manuel Denner.** RESULTS OF THREE YEARS OF RESEARCH ON HYBRIDISATION OF CHORTHIPPUS ALBOMARGINATUS WITH C. OSCEI IN THE CZECH REPUBLIC AND AUSTRIA
13. **Jorge Humberto Medina-Duran, Rosauro Mayén-Estrada, Ricardo Marino-Pérez, Hojun Song.** NOTES ON THE MORPHOLOGY AND PHYLOGENETIC POSITION OF TWO NEW SPECIES PARASITIZING THE GUT OF THE MEXICAN LUBBER GRASSHOPPER TAENIOPODA CENTURIO
14. **Charly Oumarou Ngoute, Sévilor Kekeunou, Armand Richard Nzoko-Fiemapong, Michel Lecoq, Charles Félix Bilong Bilong.** EFFECT OF ANTHROPOGENIC PRESSURES ON GRASSHOPPER SPECIES DIVERSITY (ORTHOPTERA: ACRIDIDEA) FROM THE FORESTS AND FALLOWS OF THREE LOCALITIES OF SOUTHERN CAMEROON
15. **Martin Huseman, Axel Hochkirch.** BIOGEOGRAPHIC PATTERNS OF BAND-WINGED GRASSHOPPERS IN THE MEDITERRANEAN
16. **Michael G. Sergeev, Sergey Yu. Storozhenko, Alexander A. Benediktov, Natalya S. Baturina, Vladimir V. Molodtsov, Liudmila B. Pshenitsyna.** ORTHOPTEROID INSECTS NEAR THE CENTER OF ASIA-DIVERSITY, DISTRIBUTION AND ECOSYSTEM SIGNIFICANCE
17. **Ahmed Ali Samejo, Riffat Sultana.** FACTORS AFFECTING SEASONAL DISPLACEMENT OF SCHISTOCERCA GREGARIA BETWEEN THAR AND BALUCHISTAN, PAKISTAN
18. **Tarig A. Elballa, Abdalla M. Abdalla, Elrashied E. Elkhidir.** PHENOLOGY AND HABITAT OF ANACRIDIDIUM MELANORHODON MELANORHODON IN WEST KORDOFAN STATE SUDAN
19. **Alain Simeu Noutchom, Sévilor Kekeunou, Nadège Brigitte Mbezele Messi, Alain Christel Wandji, Marcelle Mbadjoun Nzike.** MORPHOLOGICAL CHARACTERISTICS OF GRYLLOALPA MICROPTERA CHOPARD, 1939 (ORTHOPTERA: GRYLLOALPIDAE) FROM THE WEST AND SOUTH WESTERN PART OF CAMEROON
20. **Waheed Ali Panhwar, Riffat Sultana, Muhammad Saeed Wagan.** TETTIGONIIDAE (ORTHOPTERA) OF PAKISTAN.

## Biodiversity, Biogeography & Ecology THE TETTIGONIIDAE OF ARGENTINA

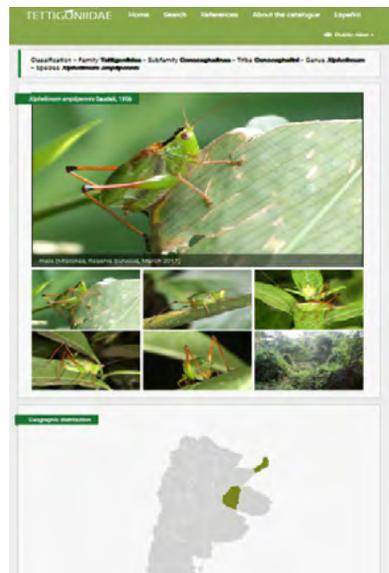
Holger Braun

Museo de La Plata, Argentina; braun@fcnym.unlp.edu.ar

In Argentina live at least 80 to 90 species of katydids, disregarding some doubtful old records. The group received little attention for more than half a century, and only recently more is becoming known about distribution, habitat and ecology, the calling songs, as well as the correct classification of some species. Fieldwork in the Alto Paraná Atlantic Forest in Misiones (2011, 2012, 2017) and in the Yungas in Jujuy (2016, 2017) revealed the presence of species previously only known from Bolivia and Brazil. In the woods close to the famous Iguazú Waterfalls were found little walking leaves belonging to *Typophyllum inflatum* (Pterochrozinae), a species long ago described from Bolivia and never reported again. These camouflage specialists are impossible to locate during the day, but at night the males produce a conspicuous low-ultrasound song which reveals their presence. In forest clearings in the same area lives *Xiphelimum amplipennis* (Conocephalinae), whose males are distinguished by an extraordinary sound generator. They produce day and night a very broad-banded song, from audio to more than 60 kHz, which probably serves the females for distance ranging.

The second extensively investigated area is situated in the Yungas, which are a type of mountain forest on the eastern slope of the An-des, reaching from Peru and across Bolivia to northwestern Argentina, hoping to discover there a species of *Typophyllum* too. Instead other interesting katydids were found. Among them a new species of Anisophya (Phaneropterinae) with a remarkable color dimorphism and males that produce a very continuous ultrasound calling

song, which is extraordinary for the subfamily. The females seem to respond with short calls. These and some other species will be very briefly presented. To the increasing knowledge of the katydids of Argentina are contributing in recent years naturalists and nature photographers who share photos on social media with ID requests, including the Facebook group of the Orthopterists' Society. Currently an illustrated online catalog of the Tettigoniidae of Argentina and Uruguay is being compiled (see picture below).



**Key Words:** bioacoustics, bushcrickets, Iguazú, internet catalog, katydids, Yungas;

## Biodiversity, Biogeography & Ecology

# SYSTEMATICS AND BIOGEOGRAPHY OF THE GENUS *CARDIODACTYLUS* (ORTHOPTERA: ENEOPTERINAE: LEBINTHINI) IN THE SOUTHEAST ASIA

Jiajia Dong<sup>1,2</sup>, Geal J. Kergoat<sup>3</sup>, Natallia Vicente<sup>4</sup>, Cahyo Rahmadi<sup>5</sup>, Shengquan Xu<sup>2</sup>,  
Tony Robillard<sup>1</sup>

<sup>1</sup> Institut de Systématique, Evolution et Biodiversité (ISYEB), Muséum national d'Histoire naturelle, UMR 7205 CNRS, Sorbonne Université, EPHE, 57 rue Cuvier, Paris, France ; Jia\_jia\_dong@hotmail.com

<sup>2</sup> College of Life Science, Shaanxi Normal University, Xi'an, PR China

<sup>3</sup> CBGP, INRA, CIRAD, IRD, Montpellier SupAgro, Univ. Montpellier, Montpellier, France

<sup>4</sup> Universidade Federal de Viçosa, Programa de pós-graduação em Ecologia, Av. PH Rolfs s/n, Viçosa, Brazil

<sup>5</sup> Division of Zoology, RC-Biology, Cibinong Science Center – Indonesian Institute of Sciences (LIPI), Cibinong Science Center, Cibinong, Indonesia

Among the crickets of the subfamily Eneopterinae, *Cardiodactylus* Saussure, 1878 (Orthoptera: Eneopterinae: Lebinthini) is the most speciose and widely distributed genus. It consists of 82 species organized in two species groups (Noveaguineae and Efordi species groups). The species distributions encompass hundreds of islands and territories ranging from the coasts of Southeast Asia to the Samoan islands. *Cardiodactylus* species show contrastive distribution patterns, some being highly endemic while others are distributed in the whole Western Pacific region. This diversity coupled with the rich geological context of the Southeast Asian and Pacific regions, offer great opportunities to address biogeographical questions and investigate the dynamics of diversification in islands.

Despite recent efforts to improve the taxonomical knowledge of *Cardiodactylus*, their diversity is such high that many new species still continue to be discovered. In a first time, taxonomic studies based on morphological, molecular and acoustic data led to the description of five new species from Eastern New Guinea and to the redescription of two species.

In a second time, the molecular phylogeny of *Cardiodactylus* was reconstructed. The results support the monophyly of the genus, of the tested species, and of the *Novaeguineae* species group. The

*Efordi* species group is clearly found paraphyletic, which tends to confirm the presence of a third species group, as suggested by the taxonomical study. According to the historical biogeographic analysis, the origin of *Cardiodactylus* was recovered in the Western Pacific during the Mid-Eocene (ca. 42 Ma). Through the transportation zone of New Guinea, *Cardiodactylus* colonized Southeast Asia from East to West through four independent passageways: Sulawesi, the Philippines, Java and the Lesser Sunda Islands. This work showed that the high diversity of Southeast Asian *Cardiodactylus* took place during the Miocene, as a result of accumulation of in situ diversification and immigration events.

In a third time, a protocol and sets of primers were designed to amplify mitogenomes in crickets. The method was exemplified by amplifying the mitogenome of the species *Cardiodactylus muiri* Otte, 2007 with a long-PCR plus NGS approach. The purpose of this work is to obtain more informative molecular data with relatively low-cost but high taxonomic coverage for future phylogenetic reconstructions.

**Key Words:** Crickets, Historical biogeography, Mitogenome, Phylogeny, Southeast Asia, Systematics, Taxonomy

## Biodiversity, Biogeography & Ecology

# TOWARDS A CONVINCING AND UPDATED ASSESSMENT OF ITALIAN DERMAPTERA

Paolo Fontana<sup>1</sup>, Markéta Kirstová<sup>2</sup>, Petr Kočárek<sup>2</sup>, Roberto Battiston<sup>3</sup>,  
Filippo Maria Buzzetti<sup>4</sup>

<sup>1</sup> Fondazione Edmund Mach, San Michele all'Adige (Trento), Italy; World Biodiversity Association (Verona), Italy; paolo\_api.fontana@fmach.it

<sup>2</sup> Department of Biology and Ecology, University of Ostrava, Ostrava, Czech Republic

<sup>3</sup> Musei del Canal di Brenta, Valstagna, Italy

<sup>4</sup> Museo Civico di Rovereto, Rovereto, Italy

Dermoptera are a well-studied group of insects in Italy since long time. Many Italian entomologists contributed to the knowledge of worldwide as well European Dermoptera: Franco Andrea Bonelli (1784-1830), Carlo Gené (1836-1890), Alfredo Borelli (1857-1943), Felice Capra (1896-1991) and Antonio Galvagni (1924-2015) in the past and nowadays Augusto Vigna Taglianti and Paolo Fontana. Dermoptera are in general well-known in Italy both from a taxonomic point of view as well for what is regarding their distribution and ecology. The Checklist of the Italian Dermoptera (<http://www.faunaitalia.it/checklist/>), compiled and updated by Augusto Vigna Taglianti, numbers 4 Families (Anisolabididae, Labiduridae, Labiidae and Forficulidae), 11 genera and 26 species (8 of them strictly endemic to Italy) plus one (*Forficula smyrnensis* Audinet-Serville, 1839), recently recorded for Italy and probably introduced (Tirello et al., in press).

The Italian Dermoptera up to date known are then the following species (endemic species are underlined):

*Anisolabis maritima* (Bonelli in Gené, 1832)  
*Euborellia annulipes* (Lucas, 1847)  
*Euborellia moesta* (Gené, 1837)  
*Euborellia stali* (Dohrn, 1864)  
*Nala lividipes* (Dufour, 1820)  
*Labidura riparia* (Pallas, 1773)  
*Labia minor* (Linnaeus, 1758)  
*Anechura bipunctata* (Fabricius, 1781)  
*Chelidura aptera* (Megerle in Charpentier, 1825)  
*Chelidurella acanthopygia* (Gené, 1832)  
*Chelidurella caprai* Vigna Taglianti, 1993  
*Chelidurella mutica* (Krauss, 1886)  
*Chelidurella poggii* Capra, 1982

*Chelidurella thaleri* Harz, 1980  
*Chelidurella vignai* Galvagni, 1995  
*Chelidurella fontanai* Galvagni, 1996  
*Pseudochelidura orsinii* (Gené, 1833)  
*Pseudochelidura galvagnii* Vigna Taglianti, 1999  
*Apterygida albipennis* (Megerle in Charpentier, 1825)  
*Forficula apennina* Costa, 1881  
*Forficula auricularia* Linnaeus, 1758  
*Forficula decipiens* Gené, 1832  
*Forficula obtusangula* Krauss, 1904  
*Forficula pubescens* Gené, 1837  
*Forficula silana* Costa, 1881  
*Forficula smyrnensis* Audinet-Serville, 1839

The genus *Chelidurella* Verhoeff, 1902 have been revised by Antonio Galvagni (1997) who confirmed the validity of the genus and the presence of 7 species in Italy. The work of Galvagni, based on male morphology, have been recently mostly confirmed by morphological as well molecular approaches in study conducted by Kirstová, Kundrata and Kočárek (in press). The same research confirmed the validity of the genus *Mesochelidura* Verhoeff, 1902 considered synonym of *Chelidura* Latreille, 1825 by many authors as well as in the Fauna Europaea. After the resolution of the problems within the genus *Chelidurella*, the genus *Chelidura* remains to be revised. The main problem for such a revision is given by the type locality of the type species of the genus, *Chelidura aptera*, which is simply and tragically "Europe". Also the study of this genus, should be managed with a molecular approach too.

**Key Words:** Dermoptera, Italian Fauna, Checklist, *Chelidurella*, *Chelidur*.

## Biodiversity, Biogeography & Ecology

# UPDATE OF DESERT LOCUST GREGARIZATION SITES MAPPING

Mathias Kayalto<sup>1,2,3</sup>, Lalla Mina Idrissi Hassani<sup>1</sup>, Michel Lecoq<sup>3</sup>, Cyril Piou<sup>1,3</sup>

<sup>1</sup> Ibn Zohr University, Agadir, Morocco; kayaltomathias@gmail.com

<sup>2</sup> National Anti-Locust Agency, Ministry of Production of Irrigation and Agricultural Equipment, Chad

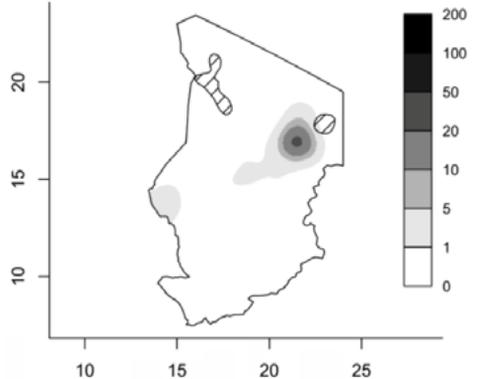
<sup>3</sup> CIRAD, UMR CBGP, F-34398 Montpellier, France

The Desert Locust is a major pest of crops and pastures. The most effective control strategy remains the preventive one. It aims to prevent invasions/upsurges by early localization and elimination of the primary outbreaking populations at gregarization sites. These sites are scattered in various parts of West, Central and Eastern Africa, the Middle East and South-West Asia. Chad, belonging to the western region, hosts some gregarization sites and is also an important route for swarms to travel from the East (Sudan, Eritrea, Somalia and Ethiopia) or the West (Niger, Mali and Mauritania). Empirical maps of Desert Locust gregarization sites in Chad were made based on reports of swarms and hopper bands during invasions/upsurges periods between 1926 and 1976, when the Tibesti region was reported as a gregarization area. Chad, like other Sahelian countries, has experienced significant climatic changes in recent decades that could have influenced the functioning and location of gregarization sites. The objective of this study is to update our knowledge on areas favorable to Desert Locust breeding and gregarization in Chad using locust information from 1965 to 1971 (only old data remaining available to date) and new data collected from 1987 to 2017 by different locust survey teams. We used a spatial smoothing method to map sites suitable for gregarization. Our study shows that there are two geographical areas where gregarization events have been recorded in our study period: i) the Kanem - Lac Chad natural region (on the West), ii) the Ennedi region (main gregarization area, on the East).

These areas are added - as gregarization areas - to

the Tibesti Massif (in the far North-West) that had been identified by previous works but where little exploration/surveys were undertaken in recent years. In addition, monthly maps showing the Desert locust records frequency per square degree during the remission periods were elaborated and may be used for planning preventive control campaigns by the National Anti-Locust Control Agency (ANLA).

**Figure1.** Identification of gregarization sites in Chad from



survey data of 1965-1971 and 1987-2017 periods. The gray scale corresponds to the density of gregarization records per square degree. Hatched areas are gregarization sites identified in the literature from data previous to 1987.

**Key Words:** Desert Locust, gregarization sites, survey, Chad, preventive control, spatial smoothing.

## Biodiversity, Biogeography & Ecology

# DIET CHARACTERIZATION OF TAENIOPODA AURICORNIS (ORTHOPTERA: ROMALEIDAE) THROUGH ITS ONTOGENY, USING DNA BARCODES, IN A SABAL PALMETTO WOODLAND IN MEXICO

Itzel Lemus<sup>1</sup>, Roger Guevara<sup>2</sup>, Zenón Cano-Santana<sup>3</sup>, Wesley Dáttilo<sup>4</sup>, Raúl Cueva del Castillo<sup>5</sup>

<sup>1</sup> Instituto de Ecología A.C., Xalapa, México; itzel.lemus.dguez@gmail.com

<sup>2</sup> Instituto de Ecología A.C., Xalapa, México

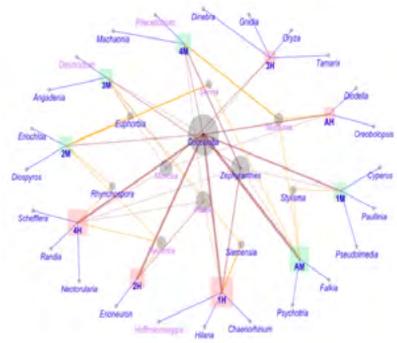
<sup>3</sup> Facultad de Ciencias, Universidad Nacional Autónoma de México, Ciudad de México, México

<sup>4</sup> Instituto de Ecología A.C., Xalapa, México

<sup>5</sup> Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Ciudad de México, México

Knowledge of the diet of generalist herbivores is important because they represent a large proportion of the biomass of herbivores in ecosystems. Generalist herbivores can easily become pests of great economic importance and have the potential to modify the composition of the plant communities in which they are distributed. In Mexico, *Taeniopoda auricornis* (Orthoptera: Romaleidae) is an insect that is used as food and is considered a crop pest. In this work, the diet of *T. auricornis* was determined through its ontogeny and according to its sex, analysing the DNA of the tissue consumed in a sabal palmetto woodland in the southeast of Mexico. Additionally, the influence of some attributes of the plants and the plant community that could determine the diet choice of this herbivore were analysed. The results showed that *T. auricornis* is a generalist herbivore. The individuals of *T. auricornis* were found settled on eight species of plants in total, in addition to some records of individuals found in the pastureland; however, the DNA sequences showed that *T. auricornis* consumed plants belonging to 35 genera (17 families) in the study area. The most consumed plants were *Coccoloba* sp. (33 %), *Zephyrantes* sp. (10 %) and five genera of the Fabaceae family. The nutritional attributes (water content, chlorophyll content and specific foliar area) were not important in the choice of *T. auricornis* diet, but they were relevant in their choice of settlement site. The composition of the diet did not vary between the different stages of development or between sexes. The results obtained imply that, although *T. auricornis* is a generalist herbivore throughout its life cycle,

the nucleus of its diet is composed of only four genera of plants, each with specific characteristics important in the development of this species.



**Figure1.** Interaction network of plants consumed by stages of development of *Taeniopoda auricornis* in a sabal palmetto woodland in Mexico. Squares represent the nodes of the stages of the life cycle: nymphs from first (1) to fourth (4) stage and adults (A) by sex: females (H) and males (M); and the circles represent the nodes of the plants. The size of the nodes indicates the number of nodes to which they are linked (degree), the thickness of the links indicate the frequency of the interactions, the connections of the network nucleus are in red, connections of second order are in orange and connections of interactions that occurred only once are in blue. The genera of Fabaceae are shown in violet color.

**Key Words:** grasshopper, Sabal mexicana, polyphagia, DNA barcoding, gut content, lifecycle, host plant utilization.

## Biodiversity, Biogeography & Ecology

# EXTINCTION DEBT OF GRASSLAND SPECIALISTS IN A CENTRAL EUROPEAN BIODIVERSITY HOTSPOT

Franz Löffler<sup>1,\*</sup>, Dominik Poniatoski<sup>1</sup>, Thomas Fartmann<sup>1,2</sup>

<sup>1</sup> Department of Biodiversity and Landscape Ecology, Osnabrück University, Osnabrück, Germany;

\* [franz.loeffler@uos.de](mailto:franz.loeffler@uos.de)

<sup>2</sup> Institute of Biodiversity and Landscape Ecology (IBL), Münster, Germany

Due to the transition from traditional land use to modern agriculture throughout Europe, semi-natural grasslands are subject to severe environmental changes. Both agricultural intensification and abandonment have caused fragmentation of semi-natural grasslands in Europe with adverse effects on biodiversity. However, species extinction can possibly occur with a substantial delay to habitat deterioration. Meanwhile, there is increasing evidence that such time-delayed extinctions represent an essential but still less-considered challenge in the conservation of grassland biodiversity. In this study, we analyzed the effects of past and present landscape conditions on Orthoptera, butterfly and vascular plant specialists in calcareous grasslands in one of the German biodiversity hotspots.

Patch area as well as patch connectivity significantly decreased from 1970 to 2015. However, this decrease was most dramatic between 1970 and 1990; since then further habitat fragmentation is proceeding at a much lower rate as a result of intensified conservation measures. Due to regular management, the studied patches were generally characterized by a high habitat quality and were still large and well-connected compared to most other regions in Central Europe. Whereas Orthoptera specialist species richness was not affected by patch area, the number of butterfly and vascular plant specialists significantly increased with patch area but was more strongly related to past fragment size.

Moreover, the number of specialists was better explained by past than present habitat connectivity across all studied groups.

Our results clearly suggest that habitat specialists can persist in calcareous grasslands for several decades, despite increasing pressure of habitat fragmentation. In general, past landscape conditions were more strongly correlated to today's specialist species richness indicating the existence of an extinction debt in all species groups. Contrary to our expectations, this was also true for butterflies which are generally known to be relatively mobile and short-lived. However, due to regular management and still sufficient area and connectivity of the patches, even organisms that are more sensitive to fragmentation may persist in such well-connected landscapes. However, current patch area and connectivity were still important drivers of butterfly and plant diversity. In contrast, the number of Orthoptera specialists within a patch seems to depend mainly on other factors such as habitat quality. Consequently, conservationists should primarily focus on the maintenance of habitat quality in calcareous grasslands, as well as the restoration of functional habitat networks to counteract future biodiversity loss.

**Key Words:** butterfly, habitat management, land-use change, Orthoptera conservation, species-area relationship, vascular plant.



## Biodiversity, Biogeography & Ecology

# THE MIGRATORY LOCUST *LOCUSTA MIGRATORIA* NEAR THE NORTHERN BOUNDARY OF ITS RANGE: COULD ITS UPSURGES DEVELOP IN SOUTH SIBERIA?

Michael G. Sergeev

*Institute of Systematics and Ecology of Animals, Novosibirsk, Russia; mgs@fen.nsu.ru, mgsergeev@aol.com  
Novosibirsk State University, Novosibirsk, Russia*

The Migratory locust is one of the most widely distributed species of Orthoptera. Its range occupies Eurasia (except the North), Africa, Australia and many islands of Atlantic, Indian and Pacific Oceans. However, a question arises about the northern boundary of the species distribution, because locusts can actively migrate northbound. This results in species findings and observations (including of small swarms) up to the northern parts of the British Isles [Waloff, 1940], the latitude of 63°N in European Russia [Uvarov, 1925; Filipjev, 1926; Bey-Bienko, 1932], and 59° N in West Siberia [Berezhkov, 1956]. Predtechensky and his coauthors [1935] noted the full life cycle of the solitary Migratory locust may be realized southward the latitudes of 55–56° N.

In the southern part of West Siberia, there are scarce populations of the Migratory locust. They usually occur in typical habitats: the flood-plains with reed beds. As a rule, larvae and fresh adults may be found on such plots. Nowadays the solitary populations of the species are found across the steppes and forest-steppes of West Siberia [Sergeev, 2017].

In the Altay-Sayan Mts. and East Siberia there are a few known localities of the Migratory locust [Sergeev, 2017]. However, in 2017 its dense population has been found in Tuva, near hyperhaline Shara Lake [Sergeev, 2017, 2018]. The newly discovered population inhabited several adjacent habitats: the local dry meadows, some meadows with short mesophilous grasses and halophytic meadows. The Migratory locust was very abundant on the lake terraces: its density was up to 1 per square meter.

The main traits were typical for the solitary form. However, some traits of adults indicated that the population could be characterized by some level of gregarisation [Nikulin, 1968]. Besides, it is worth noting that there were no locusts in the local reed beds.

This means that near the northern boundary of its range the Migratory locust can settle some new and unusual types of habitats. The local populations may be very abundant and gregarious, at least partly. The comparison between the maps of the species range boundaries and of so-called growing degree units (for 10 °C) in North Eurasia shows that opportunities for both full development of locusts and existence of disperse and local populations are limited by the level of growing degree units more than 1650–1700. If one takes into account that for last decades in South Siberia, especially in the Altay-Sayan Mts., the trend of climatic changes is very significant, the tendency to possible increasing of both general number of local populations of the Migratory locust and its common abundance is evident. This will result, perhaps, in some serious problems for plant protection systems.

These studies were supported by the Russian Foundation for Basic Researches (16-04-00706), the joint programme of the RFBR and the Government of Novosibirsk Region (18-416-540001), and the Federal Fundamental Scientific Research Programme for 2013–2020 (No. AAAA-A16-116121410123-1). Some data used in the study were provided by the Institute of Systematics and Ecology of Animals, collection "Siberian Zoological Museum", developed within project 0311-2017-0016.

**Key Words:** *Locusta migratoria*, Migratory locust, South Siberia, population, outbreak.



## Biodiversity, Biogeography & Ecology

# DESERT LOCUST AND CLIMATIC PHENOMENA

*Khadija Abbassi*

*Rabat, Maroc; abbassi\_khad@yahoo.fr*

The desert locust (*Schistocerca gregaria*, Forskål, 1775) invasion is a natural phenomenon, cyclic, complex and unpredictable. It is often considered as a divine sign mentioned in the Bible and the Quran. It presents a major obstacle for economic development for 30 countries of the recession area, and of around 65 countries that can be devastated during the plagues. Furthermore, this study of the Desert locust manifestations characteristics from 1966 to 2018, revealed that the initial phase of several outbreaks was preceded of heavy rainfall and floods, associated with unusual tropical cyclones over southern Arabian peninsula, African Horn, and the border India-Pakistan during May-June and October-November. In this latter period, El Niño coincide with tropical cyclones in the Central Region producing heavy rains preceding Desert locust manifestations. In June-July, monsoon can produce heavy summer rains in Sahelian countries, especially Mauritania, Sudan, and the African Horn. These heavy rains generate favourable ecological conditions for Desert locust breeding. Therefore, the evolution of outbreaks into upsurge or plague depends on a good spatio-temporal distribution of intensive rains in complementary areas for the Desert locust breeding, especially abundant winter rains ending a drought period in Desert locust habitats. During this period, these climatic phenomena have reached extreme intensities. The strongest tropical cyclones attained the 4 and 5 categories. Storm force winds (150 – 280 km/h), heavy rainfall (125-610 mm a month) and heavy winter rains have caused heavy floods, human losses, and environmental and socio-economic disasters. It's important to notice certain observations.

(1) The importance of the Desert locust Western Region, which have generated an upsurges in 1993/1995 and 2003/2005 without any contribution of the Central and Eastern Regions. (2) The evolution of the 2003/2004 upsurge towards a large-scale invasion which attain its peak in 2004/2005 and decline rapidly as a result of unfavourable ecological conditions and intense control operations. (3) Other important observations concern the Central Region where rarely tropical cyclone formed in the Gulf of Aden between Yemen and northern Somalia. The Arabian Sea ended stronger tropical cyclones. (4) In addition, environmental changes resulting from the agricultural development in the Sahel countries to ensure food security for their human populations, may affect the natural ecosystems in the Desert locust habitat. Otherwise, during this period a continuous Desert locust intensives activities developed in all regions of the recession area.

The Desert locust invasions are closely related to climatic phenomenons. It's a bio-indicator of the natural climatic changes of our planet. However, this locust is endowed with a phase polymorphism, a very elaborated adaptive strategy for extreme environmental and climatic situations to exploit any ecologically favourable sites in the recession area. He has faced all the climate upheavals that have affected the planet. It's necessary to survey Desert locust activity which can be a good signal to reveal climatic disturbances.

**Key Words:** Desert Locust, Bioclimatic indicator, Disturbances climatic

Biodiversity, Biogeography & Ecology

**PREVALENCE OF OEDIPODINAE (ACRIDIDAE: ORTHOPTERA) FROM THAR DESERT SINDH PAKISTAN**

Riffat Sultana

Department of Zoology, University of Sindh, Jamshoro, Sindh, Pakistan; riffat.sultana@usindh.edu.pk

Thar Desert is known as the largest desert of the world. It is occupied by numbers of diversified fauna of Orthoptera species. During the present survey fair numbers of orthoptera species were collected and sorted out into different generic categories however, in this manuscript incidence of Subfamily Oedipodinae along with its different color forms were presented. Oedipodinae or Band winged are graminivorous in nature cause massive loss to *Zea mays*, *Abelmoschus esculentus*, *Medicago sativa*, *Hordeum vulgare*, *Pennisetum glaucum*, *Sorghum vulgare*, *Citrullus vulgaris* and *Cynodon dactylon*. Oedipodinae sampling were identified as *Hilethera aeolopoides* (Uvarov, 1922), *Aiolopus thalassinus thalassinus* (Fabricius, 1781), *A. thalassinus tamulus* (Fabricius, 1798) *Acrotylus humberianus* Saussure, 1884, *A. longipes longipes* (Charpentier, 1845), *A. longipes subfasciatus* Bey-Bienko, 1948, *Trilophidia annulata* (Thunberg, 1815), *Sphingonotus (Sphingonotus) rubescens rubescens* (Walker, 1870), *S. (Sphingonotus) savignyi* Saussure, 1884, *Locusta migratoria* (Linnaeus, 1758) and *Oedaleus senegalensis* (Krauss, 1877). Beside this, Phallic Complex and ecological differentiate amongst these species were also compared. This research was financially supported by Higher Education Commission, Islamabad, Pakistan (Project No. 6737 SINDH/ NRP/ R&D/ HEC/ 2015).

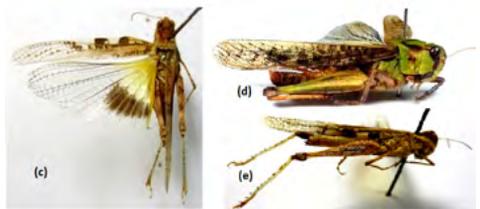


Figure 1: Dorsal view of (a) *H. aeolopoides* (b) *O. senegalensis* (c) *A. humberianus* and Lateral view of (d) *L. migratoria* (e) *A. longipes longipes*

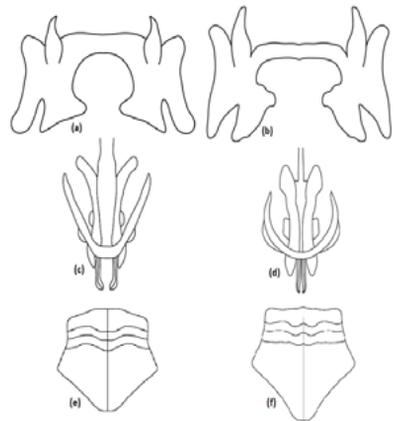
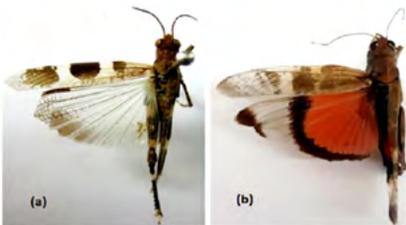


Figure2: (a) Epiphallus *H. aeolopoides* (b) Epiphallus *A. humberianus*, (c) Endophallus *H. aeolopoides* (d) Endophallus *A. humberianus* (e-f) Pronotum *T. annulata* ♂♀



**Key Words:** Oedipodinae, Thar Desert, Incidence, Ecology, Phallic Complex.



## Biodiversity, Biogeography & Ecology

# INFLUENCE OF FORESTS ON THE STRUCTURE OF GRASSHOPPERS COMMUNITIES IN SOME AGRO-ECOLOGICAL ZONES OF CAMEROON

Alain Christel Wandji<sup>1</sup>, Sévilor Kekeunou<sup>1</sup>, Alain Simeu Noutchoum<sup>1</sup>, Marcelle Mbadjoun Nzike<sup>1</sup>

<sup>1</sup> Zoology Laboratory, Faculty of Science, University of Yaounde I, Yaounde, Cameroon;  
wandjichristel@gmail.com

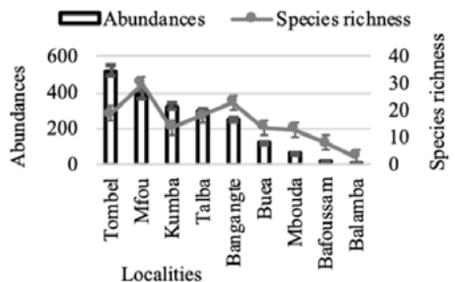
To date, habitat loss caused by Anthropogenic activities and climate changes are obvious threats to grasshoppers (Hochkirch et al., 2016). Consequently, many grasshopper's species never indexed before, with restricted distribution areas and specific habitats, are seriously threatened (Barataud, 2005). Thus, immediate measures should be taken in order to improve their status and tackle in particular the degradation of their habitats. The goal of this study is to evaluate the effects of habitat conversion on grasshopper population in some agro-ecological zones of Cameroon in order to predict future trends in the distribution and abundance of this taxa.

Grasshoppers were sampled using sweep net method. The results show that in all forests, 1992 individuals belonging to 59 species were collected. Among these species, *Holopercna gerstaeckerii* was the most abundant species (449 individuals) and *Amphicremna scalata*, *Cyrtacanthacris aeruginosa*, *Eupropacris coerulea*, *Heteracris coerulescens*, *Pterotiltus* sp.3, and *Stenocroblylus festivus* were the least abundant species (only one individual each). *Abisares viridipennis*, *Heteracris annulosa*, and *Oxyccatantops spissus* are species that have been widely distributed in different localities, 23 species have been restricted to one site and the rest of the species have 2, 3, 4 and 5 sites in common. The forests of the locality of Balamba, which in reality are small forest fragments located in the savanna zone, have been the least diversified (3 species) and the least abundant (6 individuals). The forests of the locality of Mfou (30 species) were the most diversified whereas those of the locality of Tombel (524 individuals) had the

greatest number of individuals.

Comparison of abundances ( $\chi^2 = 78.93$ ,  $df = 8$ ,  $P < 0.0001$ ) and species richness ( $\chi^2 = 55.10$ ,  $df = 8$ ,  $P < 0.0001$ ) showed highly significant differences between the different localities. Based on the calculation of the indices, the grasshoppers' fauna of the Bangangte locality is the most diversified ( $H' = 2.38$ ), while the least diversified ( $H' = 0.87$ ) is that of the locality of Balamba. The Piélou Equitability Index for its part shows a better distribution of species in the locality of Bafoussam ( $J = 0.93$ ) compared to the locality of Talba ( $J = 0.58$ ) where the species are the least distributed from all localities.

At the end of this study, we can say that the degradation of the forest cover results in the substitution of the typical forest species by the



species of the open environments.

**Figure 1:** Abundance and species richness in the forests of the different localities.

**Key Words:** Grasshoppers, diversity, forests, degradation, localities.



## Biodiversity, Biogeography & Ecology

# BIOSPHERE RESERVE ZONES ARE EQUAL IN TERMS OF KATYDID ECOACOUSTICS

Aileen Thompson<sup>1</sup>, Michael Samways<sup>1</sup>, Corinna Bazelet<sup>1</sup>

<sup>1</sup> Department of Conservation Ecology and Entomology, Stellenbosch University, Matieland 7602, South Africa; acthompson@sun.ac.za

Globally, biosphere reserves (BR's) are an important management strategy to conserve biodiversity across a gradient of human disturbance. Yet there exists very little empirical research investigating the effectiveness of BR's in maintaining and conserving biodiversity.

Katydid species are highly charismatic, with the males often producing species-specific calls, are thought to be possible indicators of habitat quality. The aim of this study is therefore to compare the song diversity and abundances of katydid species across the three zones of the Kogelberg BR by using various acoustic monitoring techniques such as songmeters, active searches and spot counts. An Acoustic Activity Index was used to determine katydid song abundances from recordings.

Only eight katydid species were recorded and identified across the four sampling sessions between November 2015 and April 2016. This lower-than-expected number of species is further supported by the fact that the species accumulation curve reaches an asymptote of only 8.

Although katydid diversity and abundance were similar across the three zones of the Kogelberg BR, habitat quality had a greater effect on abundance than on species richness. No single katydid species was identified as an indicator of habitat quality but rather the entire assemblage is responsive to habitat quality.

The Kogelberg BR is situated in the Cape Floristic Region, a global biodiversity hotspot, and a low diversity of katydid species was not expected. It is likely that a long history of fire and extreme weather events have resulted in the lower than expected diversity, as is the case with some other vegetation dependent taxa in the region. While we expect lower biodiversity away from the core zone of a BR, katydid diversity is maintained equally well in the three zones, and does not seem to be adversely affected by human activity.

**Key Words:** Tettigoniidae, Orthoptera, insect song, soundscaping, assessment, UNESCO, biodiversity hotspot, biodiversity monitoring.

## Biodiversity, Biogeography & Ecology

# RESULTS OF THREE YEARS OF RESEARCH ON HYBRIDISATION OF CHORTHIPPUS ALBOMARGINATUS WITH C. OSCHEI IN THE CZECH REPUBLIC AND AUSTRIA

Robert Vlk<sup>1</sup>, Stanislav Rada<sup>2</sup>, Günther Wöss<sup>3</sup>, Manuel Denner<sup>4</sup>

<sup>1</sup> Faculty of Education, Masaryk University, Brno, Czech Republic; vlk@ped.muni.cz (presenting author)

<sup>2</sup> Faculty of Science, Palacký University, Olomouc, Czech Republic

<sup>3</sup> Denisgasse 35/26, Wien, Austria

<sup>4</sup> Ingenieurbüro für Landschaftplanung, Hörersdorf, Austria

The Carpathian Dancing Grasshopper (*Chorthippus oschei*) is a sibling species of our common Lesser Marsh Grasshopper (*C. albomarginatus*) producing together interspecific hybrids inside the connection zone of their areas of distribution. Into Central Europe, extends a subspecies *C. oschei pusztaensis*, whose continuous area of distribution lies southeast of the territory of the Czech Republic and Austria (H, RO, MD and UA). The Carpathian Dancing Grasshopper has never been recorded in the Czech Republic, however due to the ongoing spread in Lower Austria it was included into the Atlas of the Orthoptera of the CR (Kočárek et al., 2013) amongst species with an expected occurrence.

On 9.vii.2016 one male of the Carpathian Dancing Grasshopper was accidentally captured at the locality of Děvín (Pálava LPA). Due to the altitude (about 530 m) and the steppe character of mainly inappropriate dry locality, this individual has to be considered to be a migrant (vagrant). This unexpected finding has encouraged the authors to survey appropriate sites in the region of South Moravia to find reproducing population of the Carpathian Dancing Grasshopper. During the period of 2. viii.-18. ix.2016, at 9 localities, we collected altogether 31 males (and 20 females) of the Lesser Marsh Grasshopper with some characters of the Carpathian Dancing Grasshopper. Analysis of the key character, i.e. the number of pegs on the stridulatory file (on the inner side of the hind femora), was

performed using a microscope with the attached digital camera. In the same period, at the locality Moravičany (Litovelské Pomoraví LPA – northern Moravia) a comparative sample of 33 males of the Lesser Marsh Grasshopper was collected, in which the number of pegs was determined in the same way.

While for the Lesser Marsh Grasshopper 104–122 pegs are indicated, we have several males from Moravičany with higher numbers (max. 137, avg. 118.4). In south-moravian populations, the number of pegs (up to 145, avg. 125.0) range is between the numbers reported for the Lesser Marsh Grasshopper (see above) and the Carpathian Dancing Grasshopper (165–186), so they represent (from 61.5%) hybrids. These findings demonstrated that the hybrid zone within a few years had moved from Austria to South Moravia and its northern border could intervene significantly further. Very similar results were obtained by evaluation of individuals captured on similar sites in the season 2017 (24 males), whereas the occurrence of hybrids was confirmed more northerly than in the season 2016. In the season 2018, the research on hybrid individuals was focused also outside the territory of Moravia, namely in Austria and South Bohemia.

**Key Words:** Caelifera, Acrididae, Gomphocerinae, *Chorthippus oschei*, *Chorthippus albomarginatus*, hybridisation, Czech Republic, Austria.

## Biodiversity, Biogeography & Ecology

# NOTES ON THE MORPHOLOGY AND PHYLOGENETIC POSITION OF TWO NEW GREGARINE SPECIES PARASITIZING THE GUT OF THE MEXICAN LUBBER GRASSHOPPER *TAENIOPODA CENTURIO*

Jorge Humberto Medina-Durán<sup>1,3\*</sup>, Rosaura Mayén-Estrada<sup>1</sup>, Ricardo Mariño-Pérez<sup>2</sup>, Hojun Song<sup>2</sup>

<sup>1</sup> Laboratorio de Protozoología, Departamento de Biología Comparada, Facultad de Ciencias, Universidad Nacional Autónoma de México. Mexico City, Mexico

<sup>2</sup> Department of Entomology, Texas A&M University, College Station, Texas, USA

<sup>3</sup> Posgrado en Ciencias Biológicas, Universidad Nacional Autónoma de México, Ciudad de México, Mexico;

\* jorgemedina@ciencias.unam.mx

Eugregarines are common unicellular eukaryote parasites belonging to the phylum Apicomplexa that can be found parasitizing the digestive tract of insects. Although it is thought that they can be one of the most diverse groups of eukaryotes, the studies on gregarine diversity are uncommon, and for example, these parasites have been described from less than 1% of the total insect diversity. In orthopterans, the reports of eugregarines are scarce and most of them are based on the morphology of the cells and line drawings, leading to a gap in their ultrastructural and phylogenetic placement. As an attempt to contribute to the knowledge of the diversity of eugregarines in orthopterans, we have carried out a survey of the eugregarines that parasitize the digestive tract of the Mexican lubber grasshopper *Taeniopoda centurio*, which is a common species in the northeastern mountain ranges of Mexico, and in some areas, it may even become a plague.

The main objective of this work is to provide morphological, ultrastructural and phylogenetic positions based on SSU rDNA gene about two eugregarine species, *Amoebogregarina* sp. and *Quadruspinospora* sp. found parasitizing the gut of *T. centurio*. Although both eugregarine species parasitize the same host, they are morphologically very dissimilar in all their life cycle stages and their ultrastructure. The phylogenetic analysis showed that the two species are phylogenetically distant from each other and are placed in two different superfamilies. Our findings showed that a single insect host can harbor more than one, Phylogeny- etically distant eugregarine species. Also, we showed the first record of *Amoebogregarina* sp. in Mexico and the first record of *Quadruspinospora* sp. in the New World.

**Key Words:** Romaleidae, parasites, Apicomplexa, Mexico, Hidalgo State, phylogeny, protists.

Biodiversity, Biogeography & Ecology

**EFFECT OF ANTHROPOGENIC PRESSURES ON GRASSHOPPER SPECIES DIVERSITY (ORTHOPTERA: ACRIDIDEA) FROM THE FORESTS AND FALLOWS OF THREE LOCALITIES OF SOUTHERN CAMEROON**

Charly Oumarou-Ngoute<sup>1</sup>, Sévilor Kekeunou<sup>1</sup>, Michel Lecoq<sup>2</sup>, Armand Richard Nzoko-Fiemapong<sup>1</sup>, Charles Félix Bilong Bilong<sup>1</sup>

<sup>1</sup> Department of Animal Biology and Physiology, Faculty of Science, University of Yaoundé 1, Cameroon; coumaroungoute@yahoo.fr

<sup>2</sup> CIRAD, Montpellier, France

Grasshoppers are highly diverse in tropical rainforest, and are considered to be of both ecological and conservation importance. Despite these considerations, the populations' dynamics of Central African grasshoppers and the structure of their communities remain poorly studied. We here report on the impact of human activities on the diversity of grasshoppers' species from 3 localities of southern Cameroon: Ongot - more anthropized forests, Zamakoe - moderately anthropized forests and Ngutadjap - less anthropized forests.

Data were collected using sweep nets, quadrates and pitfalls. We analyzed how pressure from human activities affect the different species compositions using five statistical methods: eight non-parametric estimators for specific richness; abundance; abundance distribution model;  $\alpha$  diversity index; and  $\beta$  diversity index.

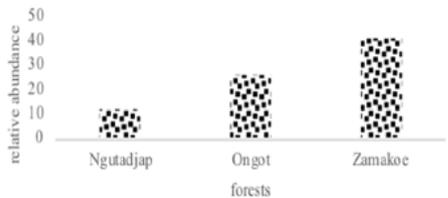
The results showed that abundance and specific diversity of grasshoppers increase with the anthropogenic pressure on the forests and the fallows (Table1). In the forests and fallows studied the abundance distribution models were respectively Log-series and Log-normal. The  $\beta$  diversity index shows more likeness between the two grasshopper communities of the higher anthropized forests, in comparison with the grasshopper community of the less anthropized forests. *Zonocerus variegatus* (15.37 ± 3.05%) and *Mazaea granulosa* (79.15 ± 3.1%) – were overall the most abundant grasshopper species respectively in fallows and forests. *Mazaea granulosa*, for which abundance significantly depends on the rate of deforestation between the three sites (Figure1) – it is revealed as a good bioindicator of the levels of

anthropogenic disturbance of natural forests. This work is a contribution to the better understanding of the role of grasshoppers to recognize the levels of forest degradation in southern Cameroon.

**Table 1.** Average relative abundance of grasshoppers.

Sites	Ngutadjap	Ongot	Zamakoe	H	p-value	Total
Forests	16.8±2.3a	35.45±2,8b	47.73±3.0c	23.49	<0.0001	100
Fallows	28.98±1.7a	39.76±1.4b	31.25±2.03a	15.45	0.0004	100
All	27.45±1.5a	39.14±1.2b	33.3±2.2c	17.69	0.0001	100

**Legend:** n = 12 (number of months of observation); H: Kruskal Wallis test value; P-value: Probability; the letters a, b and c represent the results of the statistical comparisons (by the Wilcoxon W test) of the abundance between the sites. The same letters reflect a non-significant difference for an error risk of  $\alpha = 0.05$ .



**Figure 1.** *Mazaea granulosa*'s relative abundance in the forests.

**Key Words:** Biodiversity, grasshopper' communities, abundance, degradation rate, bioindicator, tropical rainforest.



## Biodiversity, Biogeography & Ecology

# BIOGEOGRAPHIC PATTERNS OF BAND-WINGED GRASSHOPPERS (OEDIPODINAE) IN THE MEDITERRANEAN

Martin Huseman<sup>1</sup>, Axel Hochkirch<sup>2</sup>

<sup>1</sup> Center for Natural History, Hamburg University, Martin-Luther-King Platz 3, 20146 Hamburg, Germany; martin.husemann@uni-hamburg.de

<sup>2</sup> Biogeographie, Universität Trier, Universitätsring 15, 54286 Trier, Deutschland

The Mediterranean region has served as the most important refuge for many European taxa and as such represents the cradle of much of the biodiversity which is found in the region today. Biogeographic studies have revealed the origin and migration pathways for many species. They also have unravelled interesting patterns of secondary contact which explain many of the diversity patterns observed today. Within the Mediterranean, the band-winged grasshoppers (Oedipodinae) have one of their diversity centres with large numbers of species, including many endemics. For some of the more widespread species a Mediterranean origins seems likely, but has never been tested in detail. Further, for many Oedipodines, even for well-known genera such as *Oedipoda*, *Oedaleus* and *Acrotylus* barely any genetic data is available.

Therefore, we have started investigating the biogeography of the genera *Sphingonotus*, *Acrotylus* and *Oedipoda* using molecular approaches. The results suggest interesting patterns of colonization history and cryptic diversity, but also that the current taxonomy needs to be updated. While these are only case studies for single genera, the whole sub-family Oedipodinae and even the Acrididae need to be revised in the future also considering molecular data, as patterns of large scale convergence and phenotypic plasticity suggest morphology to be misleading in many taxa of this group. This makes the group as a whole an interesting and important system to study evolutionary drivers of a recent non-adaptive radiation in the future.

**Key Words:** Convergence, Europe, evolution, hotspot, North Africa, Oedipodinae, radiation.

## Biodiversity, Biogeography & Ecology

# ORTHOPTEROID INSECTS NEAR THE CENTER OF ASIA: DIVERSITY, DISTRIBUTION AND ECOSYSTEM SIGNIFICANCE

Michael G. Sergeev<sup>1,2</sup>, Sergey Yu. Storozhenko<sup>3</sup>, Alexander A. Benediktov<sup>4</sup>, Natalya S. Baturina<sup>1,2</sup>, Vladimir V. Molodtsov<sup>1</sup>, Liudmila B. Pshenitsyna<sup>1</sup>

<sup>1</sup> Novosibirsk State University, Novosibirsk, Russia; mgs@fen.nsu.ru, mgsergeev@aol.com

<sup>2</sup> Institute of Systematics and Ecology of Animals, Novosibirsk, Russia.

<sup>3</sup> FSC of the East Asia Terrestrial Biodiversity, Vladivostok, Russia

<sup>4</sup> Moscow State University, Moscow, Russia

Tuva is the mountain region in the central part of Asia. The region is characterized by extremely high diversity of terrestrial and aquatic ecosystems – from the deserts to the mountain tundra and from hyperhaline lakes to cold streams. The terrestrial and amphibiotic orthopteroïd insects are very abundant and diverse in the region. The general patterns of their assemblage structures, their transformations and possible range shifts should be revealed relative to global, regional and local changes.

We analyzed data of our field trips to Tuva and adjacent areas from 1978 until 2018. Besides that, we also used some materials of several expeditions of Novosibirsk State University and the Institute of Systematics and Ecology of Animals, Novosibirsk (1960–1986). Stoneflies have been specially studied from 2012 until 2018. These sets of data include both qualitative collections and quantitative counts. Now the list of Orthopteroidea of Tuva and adjacent areas includes 201 species (known and possible): Blattodea (2 known/2 possible species); Plecoptera (60/11 and 3 species should be checked); Notoptera (1); Dermaptera (1/1); Orthoptera (92/24, 4 species should be checked). All species are also distributed outside the region. There are several endemics of the Altay–Sayn Mts., namely *Grylloblattella sayanensis* (Notoptera), *Zubovskya mongolica*, *Podismopsis altaica*, *Stenobothrus newskii* (Orthoptera). The species mainly associated with the boreal and subboreal parts of the Palaearctic populate the northern part of Tuva. Its arid territories are usually settled by the insects associated with the desert and semi-desert

faunas of Mongolia and China. Several Turanian forms penetrate into the arid intermountain basins. The local fauna also includes some species mainly associated with the Far East. The relatively high level of taxonomic diversity of Orthopteroidea corresponds to the high levels of assemblages' diversity and biomass. In the local steppes, the dry mass of these insects commonly varies between 0,5 and 5 kg per ha. In 2017 and 2018 we have found that the dry orthopteran biomass might be more than 13 kg per ha. This means the terrestrial Orthoptera may consume more than 10 % of NPP in the local dry steppes and semi-deserts (in some cases, up to 66–68 %). Local grasshoppers may feed on almost all grasses, sedges and forbs. They also consume leaves of shrubs and subshrubs. The dry biomass of stoneflies is also significant in local mountain streams (more than 1 kg per ha). Hence, the Orthopteroïd insects are one of the most important groups of consumers in the grassland and stream ecosystems of Tuva. These studies were financially supported by the Russian Foundation for Basic Researches (16-04-00706), the Federal Fundamental Scientific Research Programme for 2013–2020 (No. AAAA-A16-116121410123-1). Some data used in the study were provided by the Institute of Systematics and Ecology of Animals, collection "Siberian Zoological Museum", developed within project 0311-2017-0016.

**Key Words:** Convergence, Europe, evolution, hotspot, North Africa, Oedipodinae, radiation.

Biodiversity, Biogeography & Ecology

**FACTORS AFFECTING SEASONAL DISPLACEMENT OF SCHISTOCERCA GREGARIA BETWEEN THAR AND BALUCHISTAN, PAKISTAN**

Ahmed Ali Samejo<sup>1</sup>, Riffat Sultana<sup>1</sup>

<sup>1</sup>Department of Zoology, University of Sindh, Jamshoro, Pakistan, samejo\_ali7@hotmail.com, riffatumer@hotmail.com

Pakistan has two breeding seasons for desert locust viz: spring breeding in Baluchistan and summer breeding in Thar Desert. Purpose of this study was to investigate the seasonal distribution of desert locust from Thar (Sindh province), and the effects of meteorological factors on the displacement or migration of locust between two permanent breeding areas of Pakistan. During present study many extensive surveys were carried out in different localities of Thar i.e. Nagarparkar, Chachro, Mahandre-jo-par, Khokhrapar and Umerkot to take an observational look over factors affecting the seasonal displacement and outbreak of this species in Thar. Absence or very low population of immature of *S. gregaria* and higher ratio of adults confirmed that adults of desert locust must have been migrated to Thar Desert from Baluchistan province. It was noticed that whenever large population of desert locust appeared in the fields at that time, winds were blown from south to north and wind speed was higher with 7.0-10.5 knots. These downwind displacements always coincided with low atmospheric pressure which was recorded between 996-999 millibars during summer mainly from June to August 2014-17. Further, a correlation between rainfall and population densities was significantly highly positive in 2014, as well as a correlation between temperature and the incidence of desert locust in 2016.

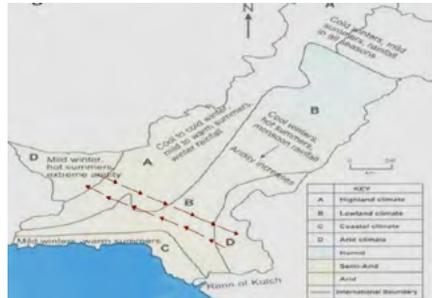


Figure 1. Various climatic zones in Pakistan and migration of desert locust between Thar and Baluchistan

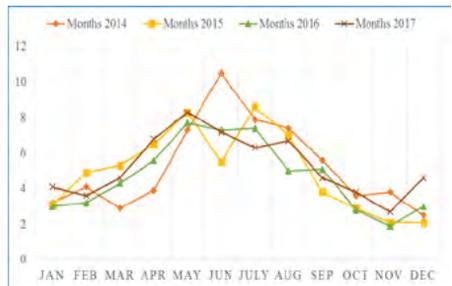


Figure 1. Month-wise record of wind speed regarding seasonal displacement of *S.gregaria* between Thar Desert and Baluchistan during 2014-17.

**Key Words:** Desert locust, seasonal displacement, Thar Desert, wind speed and direction, correlation, atmospheric pressure, population dynamics.



## Biodiversity, Biogeography & Ecology

# PHENOLOGY AND HABITAT OF *ANACRIDIDIUM MELANORHODON* *MELANORHODON* (ORTHOPTERA: ACRIDIDAE) IN WEST KORDOFAN STATE, SUDAN

Tarig A. Elballa<sup>1</sup>, Abdalla M. Abdalla<sup>2</sup>, Elrashied E. Elkhidir<sup>3</sup>

<sup>1</sup> University of West Kordofan, Ennohoud, Sudan

<sup>2</sup> University of Kordofan, 51111 Elobeid PO Box 160, Sudan; khalil2004@hotmail.com

<sup>3</sup> University of Khartoum, Shambat Khartoum North, Sudan

The phenology and habitat of the tree locust, *Anacrididium melanorhodon melanorhodon* (Orthoptera: Acrididae) were studied in West Kordofan (Sudan) during the years 2012/2013 and 2013/2014. This locust is most destructive pest of *Acacia senegal* trees, the main source of gum arabic, a famous natural product of the Sudan. We focused on the ecological niche of this pest, its developmental stages and activities in relation to the environment.

Three sites, 10,000 M<sup>2</sup> each, dominated with natural stands of *A. senegal* trees were randomly chosen at the outskirts of Ennohoud town in Western Kordofan. Each site was checked every five days, from the beginning of May to the end of October, and at ten days intervals from the beginning of November to the end of April throughout the study period.

Parents locust were found to arrive in the study area during June/July (mean numbers of locust per tree growing from 0.0/6.0±1.7 to 21.1±2.3/11.9±1.6 from June to July, respectively in 2012/2013 and 2013/2014). Eggs were laid early in August and hatchlings observed in grasslands and/or on tree understory towards late August. Of the six nymphal instars, the first three were observed mainly in August and September, and the last three in September and October. For the 1st instar, the mean numbers of nymphs per square meter were 22.8±0.6 in August (season 2012/2013), and 1.9±1.1 and 13.1±1.2 in August and September (2013/2014).

While, the mean numbers of nymphs/tree were 16.0±2.4, 29.0±0.5 and 8.6±1.6 in Aug./Sept./Oct.

2012/2013, and 11.9±1.6 and 8.4±1.4 in Sept./Oct. 2013/2014. Sexually immature adults appeared during September and October in 2012/2013 (mean locust numbers/tree = 16.2±2.3 and 14.6±2.2, respectively), while it was in October (17.1±0.3) during the 2013/2014 season. The average overall numbers of locusts for daily activities during the course of our study were as follows: roosting (6.5±2.0 locusts), basking (5.6±1.4), walking (5.5±1.5), feeding (5.7±0.4), copulation (12.8±1.2), egg laying (2.2±2.0), flying (7.1±4.1) and moulting (2.3±0.6). The main activity manifested by parent adult's was copulation (mean number = 11.6±1.4 in July 2012/2013, and 15.5±1.7 / 13.2±1.3 respectively in June and July of the 2013/2014 season). Roosting and basking were the dominant activities during August, while basking and walking were the major activities in September with inter-trees flying reported as the main activity in October. The locust activities were influenced by the prevailed environmental factors and the locust development and phenology was coinciding with the phenology of the tree.

This better understanding of the locust phenology and habitat may enhance the locust management operations. However, an area wide monitoring program targeting local and trans-border migrations of the locust seems indispensable.

**Key Words:** *Anacrididium*, *Acacia senegal*, Phenology, Locust Habitat, Gum arabic, Kordofan, Sudan.

## Biodiversity, Biogeography & Ecology

# MORPHOLOGICAL CHARACTERISTICS OF *GRYLLOTALPA*, 1939 (ORTHOPTERA: GRYLLOTALPIDAE) FROM THE WEST AND SOUTH WESTERN PART OF CAMEROON

Alain Simeu Noutchoum<sup>1</sup>, Sévilor Kekeunou<sup>1</sup>, Nadège Brigitte Mbezele Messi<sup>2</sup>, Alain Christel Wandji<sup>1</sup>, Marcelle Mbadjoun Nzike<sup>1</sup>

<sup>1</sup> Zoology Laboratory, Faculty of Science, University of Yaoundé 1, Yaoundé, Cameroon; simeunou@gmail.com

<sup>2</sup> Higher Teacher Training college of Yaoundé 1, Yaoundé, Cameroon

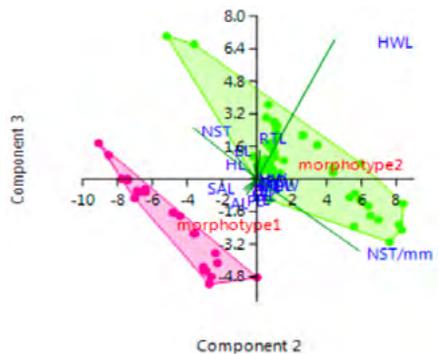
The description of all unknown species is a major taxonomic challenge, especially in insects where many species are to be discovered. *Gryllotalpa microptera* is a Gryllotalpidea Orthoptera whose literature is almost non-existent on specimens of Cameroonian fauna. To contribute to the knowledge of the species of Cameroon, we have morphologically described *Gryllotalpa microptera* Chopard, 1939 in two regions of Cameroon with different vegetative conditions: Southwest (forest zone) and West (savanna with high grassland).

The specimens studied were collected in both regions from the pit falls from March 2017 to March 2018. Descriptions and measurements were made for 82 individuals. 20 parameters inspired by Townsend's work (1983) were measured using a vernier caliper and a triocular magnifier connected to an Amscope.

The results show that compared to species of genus *Gryllotalpa*, *G. microptera* has shorter fore wings than the abdomen, not exceeding 7mm. In this species, there is a fusion of the veins of the right forewing (R1 and Rs); the number of stridulatory teeth varies from 40 to 60. However, the morphometric study reveals two morphotypes linked to the eco-geographical origins (Figure 1). The hind wings were all vestigial in the Southwest individuals and longer than the fore wings in those of the West. In addition, the lengths of body (BL), pronotum (PL), hind tarsus (TL), cerques

(CL), highest dactyl (HDL), right tegmen (RTL), hind wing (HWL), stridulatory file (SFL), the head width (HW), the intercellular distance (IOD), the number of stridulatory teeth (NST) and the number of stridulatory teeth per millimeter (NST / mm) were significantly different between individuals from the two regions.

These two morphotypes are thought to be related to the existence of two ecotypes in the south Cameroon. More studies are continuing to draw stable conclusions about the status of each identified morphotype.



**Figure 1.** Relationship between morphometric characters of *G. microptera* and its origins.

**Key Words:** description, *Gryllotalpa microptera*, morphometrie, ecotype, morphotype comparison, Cameroon.



## Biodiversity, Biogeography & Ecology TETTIGONIIDEA (ORTHOPTERA) OF PAKISTAN

Waheed Ali Panhwar<sup>1</sup>, Riffat Sultana<sup>2</sup>, Muhammad Saeed Wagan<sup>2</sup>

<sup>1</sup> Department of Zoology, Shah Abdul Latif University Khairpur Mirs Sindh Pakistan;  
waheedalipanhwar11@gmail.com

<sup>2</sup> Department of Zoology, University of Sindh Pakistan

Pakistan occupies an important geographic position in old world and represents elements of Ethiopian, Palearctic and Oriental zoogeographical regions. Ethiopian region runs along southern coastal areas of Sindh and eastern Makran in Baluchistan; Palearctic region is continuous with those of Iranian Baluchistan, eastern Afghanistan, north-western and eastern China; the Oriental region is continuous with those of Indian Punjab and Rajasthan. During the present study an extensive survey was carried out during the year 2013-2017 from different provinces of Pakistan. As a result of this survey, fairly large number of samples were captured using tradition insect nets and some by hand picking method. Field survey sites included: agriculture land, forests, orchards, grapevine & berry gardens, hilly, semi desert and desert areas, trees, shrubs, herbs and grasses.

The collected material was sorted out into *Trigonocorypha unicolor*, Stål, 1873, *T. angustata*, Uvarov, 1922, *Trigonocorypha* nr *angustata* Uvarov, 1922, *Phaneroptera spinosa*, Bei-Bienko, 1965, *P. roseata*, Walker, 1869, *P. gracilis* Bei-Bienko, 1954, *Ducetia japonica*, Thunberg, 1815 of sub-family Phaneropterinae, *Calopterus balucha* (Uvarov, 1932), *Glyphonotus sinensis*

Uvarov, 1939, *Eupholidoptera karatolosi* Mofidi & Quicke 2007 of sub-family Tettigoniinae, *Euconocephalus incertus*, Walker 1869, *E. pallidus*, Redtenbacher, 1891, *E. mucro* de Haan, 1842 sub-family Conocephalinae, *Hexacentrus unicolor* Serville, 1831, *H. pusillus* Redtenbacher, 1891 belong to sub-family Hexacentrinae and *Mecopda platyphoea* Walker, 1870, *Afromecopoda monroviana* (Karsch, 1886) of sub-family Mecopodinae, *Decticus verrucivorus* (Linnaeus, 1758), *D. albifrons* (Fabricius, 1775) of sub-family Decticinae were recorded. Beside this, the distribution of all previously recorded species has been greatly extended to the new localities. The identification keys for various species have also been constructed along with brief description and list of host plants was also presented. Current study will form a basis for Tettigoniodea biodiversity in Pakistan.

Research grant received from Pakistan Science Foundation Islamabad under research Project PSF/Res/S-SU/Bio(423) is highly acknowledged.

**Key Words:** Tettigoniodea, pest, phytophagous, survey, geographical zones, biodiversity, identification keys.



# ORAL SESSION E

## Behaviour & Communication

### Chairman: Paolo Fontana

Fondazione Edmund Mach & World Biodiversity Association (Verona), Italy;  
paolo\_api.fontana@fmach.it

1. **Christian Pulver, Daniel A. Veitch, Fernando Montealegre-Z.** DIRECTIONALITY AND TYMPANAL SLIT FUNCTION IN BUSHCRICKETS
2. **Ed Baker, David Chesmore, Katie Davis, Jon Hill, Peter Mayhew.** GETTING HEARD : COMMUNICATION STRATEGIES IN ORTHOPTERA
3. **Jose Luis Benavides-Lopez, Stefan Schöneich, Hannah Ter Hofstede, Tony Robillard.** ACOUSTIC AND VIBRATORY COMMUNICATION IN THE SPECIES PONCA HEBARDI
4. **Paolo Fontana, Filippo Maria Buzzetti, Ricardo Marino-Pérez, Derek A. Woller, Hojun Song.** SOUND EMISSION IN THE NON-SINGING GRASSHOPPER NETROSOMA RUBRICORNE ROBERTS, 1947 (ACRIDIDAE : MELANOPLINAE)
5. **Natasha Mhatre, Robert Malkin, Rittik Deb, Rohini Balakrishnan, Daniel Robert.** TREE CRICKETS OPTIMISE BAFFLE ACOUSTICS
6. **Francisco de Assis Ganeo de Mello.** FEMALE MONOPOLIZATION BY MATING PLUGS IN SOUTH AMERICAN CRICKETS (GRYLLOIDEA)
7. **Oto Kalab, David Musiolek, Peter Hurtik, Pavel Rusnok, Martin Tomis, Petr Kocarek.** ESTIMATION OF THE EFFECT OF TELEMETRY TRANSMITTER WEIGHT ON MOVEMENT ABILITY OF THE CRICKET GRYLLUS ASSIMILIS
8. **Howon Rhee.** CAN TETTIGONIA VIRIDISSIMA MALES DETECT AND DISCRIMINATE DOMINANCE RANK BASED ON ACOUSTIC SIGNALS?
9. **Donovan Tremblay, Susan M. Bertram.** AN EXPERIMENTAL TEST OF THE CONDITION-DEPENDENT HYPOTHESIS USING THE FALL FIELD CRICKET, GRYLLUS PENNSYLVANICUS
10. **Daniel Veitch Emine Celiker, Sarah Aldrige, Fernando Montealegre-Z.** THE BIOPHYSICS OF SOUND PROPAGATION IN THE AUDITORY CANAL OF BUSH-CRICKETS
11. **Martina E. Pocco, Bert Foquet, M. Marta Cigliano, Eliana L. Nieves, Carlos E. Lange, Hojun Song.** PHENOTYPIC PLASTICITY IN THE SOUTH AMERICAN LOCUST SCHISTOCERCA CANCELLATA (ACRIDIDAE)
12. **Sory Cisse, Said Ghaout, Ahmed Mazih, Mohamed Abdallahi Ould Babah Ebbe, H el ene Jourdan-Pineau, Koutara Maeno, Nicolas Lem enager, Cyril Piou.** QUANTITATIVE ANALYSIS OF BEHAVIOR PHASE DIFFERENCE IN LOCUSTS WITH THE EXAMINATION OF SPATIAL DISTRIBUTION PATTERNS
13. **Varvara Vedenina, Nikita Sevastianov.** INCREASING COURTSHIP SONG COMPLEXITY IN A NEWLY DISCOVERED STENOBOTHRUS EURASIUS HYBRID ZONE



## Behaviour & Communication

# DIRECTIONALITY AND TYMPANAL SLIT FUNCTION IN BUSHCRICKETS

Christian Pulver<sup>1</sup>, Daniel A. Veitch<sup>1</sup>, Fernando Montealegre-Z<sup>2</sup>

<sup>1</sup>University of Lincoln, Lincoln, United Kingdom; cpulver@lincoln.ac.uk

<sup>2</sup>Univer2sity of Lincoln, Lincoln, United Kingdom; fmontealegrez@lincoln.ac.uk

Bush-crickets detect sound pressure waves using a system of paired tympana located in each foreleg. Sound vibrations can reach the membrane externally and internally through a tracheal path. These two inputs differ in that the sound travelling in the acoustic trachea passes an acoustic resistor.

Within the trachea, sound propagates at a lower velocity than in air and is passively amplified by several decibels depending on tracheal morphology. Sound waves travelling in free air reach the tympanic membranes first and avoid passive amplification in the process. Without impedance matching, sound waves arrive at the external surface of the tympanum causing low amplitude vibrations.

In certain bush-cricket species, tympanal membranes are covered by cuticular flaps, and are externally accessed through narrow slits and protected by cuticular flaps. It has been previously theorized that these auditory apertures not only protect the tympanic membranes, but also contribute to auditory directionality [1]. Previous studies have shown that cuticular flaps increased auditory thresholds (ultrasonic hearing) and account for directional sensitivity when acoustic spiracle is blocked [1,2].

A mechanistic investigation using non-contact measurements of tympanal vibrations, by means of micro-scanning laser Doppler vibrometry could yield insight of the role of flaps as directionality receivers.

We hypothesized that the oscillation phase of a sound wave would be different in each tympanum with the flaps present and would be the same with the removal of the flaps. To test this hypothesis, we used three laser heads simultaneously, two of them beamed on the anterior and posterior tympanal membranes of the same leg, and a third one on the inner ear (taking advantage of cuticle transparency). Results and methodology are discussed and compared with earlier studies.



**Figure 1.** Frontal view of the katydid *Copiphora vigorosa*. The inset shows a close view of the ear and tympanal slits.

**Key Words:** bioacoustics, ultrasound, tympanal slits, directionality.



## Behaviour & Communication

# GETTING HEARD: COMMUNICATION STRATEGIES IN ORTHOPTERA

*Ed Baker<sup>1</sup>, David Chesmore<sup>1</sup>, Katie Davis<sup>2</sup>, Jon Hill<sup>3</sup>, Peter Mayhew<sup>2</sup>*

<sup>1</sup> Department of Electronic Engineering, University of York, UK; ed.baker@york.ac.uk

<sup>2</sup> Department of Biology, University of York, UK

<sup>3</sup> Department of Environment and Geography, University of York, UK

The songs of Orthoptera have been studied for many years as tools for the delimitation of species. The stereotypical calling songs of male Orthoptera are widely regarded as a major component of the acoustic diversity of ecosystems, from the daytime calls of European grasshoppers to the nocturnal cacophony of tropical forests.

The evolutionary pressure on calling songs to uniquely identify species is a key factor that allows a number of projects to use automated methods to provide species identification and in some cases abundance measurements based on acoustic methods that are both cost effective and non-intrusive.

The Leverhulme funded Automated Acoustic Observatories project is an interdisciplinary project to investigate the evolution of Orthopteran acoustic communication alongside novel methods for automated identification. The project combines knowledge from engineers, evolutionary biologists, insect ecologists and Orthoptera specialists.

One of the goals of this project is to identify what the total information content of the calling song of an Orthopteran can tell us, even if the species cannot be identified to species.

The calling song of a species is constrained by the evolutionary history and morphology of the species, but it can also be expected that the calling song has in part evolved for efficient transmission of information through the acoustic environment that the species inhabits.

This presentation investigates possible analogies between methods for reliable communication through differing environments in the electronic engineering domains (e.g. spread spectrum radio techniques) and the variable features (e.g. amplitude, bandwidth) of Orthopteran song, using acoustic traits that were originally collated for the purposes of automated classification of unrecognised taxa.

**Key Words:** acoustic communication, communication theory, orthoptera.



## Behaviour & Communication

# ACOUSTIC AND VIBRATORY COMMUNICATION IN THE SPECIES PONCA HEBARDI

Jose Luis Benavides-Lopez<sup>1</sup>, Stefan Schöneich<sup>2</sup>, Hannah ter Hofstede<sup>3</sup>, Tony Robillard<sup>1</sup>

<sup>1</sup> Muséum National d'Histoire Naturelle, Département Systématique et Évolution ISYEB, UMR 7205, Paris Cedex 05, France ; jose.benavides-lopez@edu.mnhn.fr

<sup>2</sup> University of Leipzig, Leipzig, Germany

<sup>3</sup> Dartmouth College, Hanover, NH, USA

Most cricket species use calling songs as intraspecific communication signal for mate finding. The males usually produce low-frequency (3-8 kHz) calls and guided by the sound signal females approach the singing male (phonotaxis).

A recent study (ter Hofstede et al. 2015) revealed that crickets of the tribe Lebinthini (Eneopterinae) developed an alternative communication system, involving male high- frequency signals, female vibrational response to male calls, and absence of phonotaxis. This set of behaviors was described for three species of three different genera from Asia and the Pacific islands: *Cardiodactylus muria*, *Agnotecocus obscurus* and *Lebinthus laue*.

In this study, we investigated the acoustic behavior of a species belonging to the Neotropical lineage of the Lebinthini, which is the sister clade of all other genera in this tribe. We conducted experiments with the species *Ponca hebardii* to determine whether the alternative system of communication found in species distributed in Asian-Pacific regions is also found in Neotropical species. We recorded for the first time the calling song of this species (n=4) and used the recordings for playback experiments to test the response of both sexes.

Our results show that the calls of *P. hebardii* are short schemes composed of 10±2 syllables with high dominant frequencies at about 17 kHz, which is consistent with other Lebinthini species. The dominant frequency of the spectrum corresponds to the third harmonic peak.

Playback experiments revealed that female *P. hebardii* exhibit the same type of answer as

Lebinthini species from the Asian-Pacific clade: females produce a vibratory response to male calls and show no phonotactic activity. As in previously studied species, the female vibratory response occurs after a specific time delay of 349±0.49 ms and includes 10 ± 1 oscillation peaks, with a frequency of 106 ± 6 Hz, and a mean vibration duration of 86 ± 5 ms. These values are all consistent with previously studied Lebinthini species.

The results confirm that this alternative communication system is found throughout the Lebinthini tribe (ca. 150 species distributed in Southeast Asia, the Pacific islands and South America). It suggests that this new communication system evolved early by sensory exploitation of female startle behavior. It is probably linked with the origin of the evolutionary diversification of the Lebinthini tribe.

Most interestingly, the playback experiments suggest that *P. hebardii* males also respond to calls of other males, both alternating between calls and similar vibrational response as observed in the females (with very similar time delay of 351 ±0.51 ms). Such acoustic-vibratory duet-like behaviour between males has not been documented in any cricket species before and opens a completely new avenue to investigate the evolution and functionality of intraspecific communication systems in eneopterine crickets.

**Key Words:** eneopterine crickets, intraspecific communication, high-frequency calling song, vibrational reply.



## Behaviour &amp; Communication

## SOUND EMISSION IN THE NON-SINGING GRASSHOPPER *NETROSOMA RUBRICORNE* ROBERTS, 1947 (ACRIDIDAE: MELANOPLINAE)

Paolo Fontana<sup>1</sup>, Filippo Maria Buzzetti<sup>2</sup>, Ricardo Mariño-Pérez<sup>3</sup>, Derek A. Woller<sup>4</sup>, Hojun Song<sup>3</sup>

<sup>1</sup> Fondazione Edmund Mach, San Michele all'Adige (Trento), Italy; World Biodiversity Association (Verona), Italy; paolo\_api.fontana@fmach.it

<sup>2</sup> Fondazione Museo Civico di Rovereto, Borgo Santa Caterina 41, 38068 Rovereto (TN), Italy

<sup>3</sup> The Song Lab, Department of Entomology, Texas A&M University, College Station, Texas, USA

<sup>4</sup> USDA-APHIS-PPQ-S&T-CPHST Phoenix Lab, Phoenix, AZ, USA

The genus *Netrosoma* Scudder, 1897 is currently assigned to the subfamily Melanoplina and the tribe Melanoplini. This genus is endemic to Central America and contains four brachypterous species: *N. fusiforme* Scudder, 1897, *N. nigropleura* Scudder, 1897, *N. rubricorne* Roberts, 1947 (Fig. 1), and *N. xanthops* Roberts, 1947.



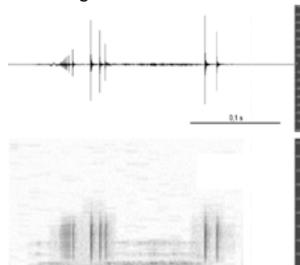
**Figure 1.** *Netrosoma rubricorne* male, Puebla, Acatlán, Mexico, October 2004 (photo P. Fontana).

Melanoplinae are also known as *non-singing grasshoppers*, which is why it is extraordinary that some *Netrosoma* species produce clear and audible chants. The production of these sounds is clearly related to the presence of anatomical structures evidently attributable to those of the singing species of the subfamily Gomphocerinae Fieber, 1853. Sound emissions have been clearly observed and recorded for at least three species: *N. fusiforme*, *N. xanthops*, and *N. rubricorne*. In these species, a pars stridens composed of denticles on the inner side of the posterior femora and of a thickened vein on the extremely reduced elytra are recognizable.

For *N. rubricorne*, a peculiar mating behaviour has also been observed and filmed. During mating, *N. rubricorne* males have been observed hanging

from females (being hooked to them in some way with the apex of the abdomen), similar to what has been observed in species of the genus *Proctolabus* Saussure, 1859 (subfamily Proctolabinae).

Sound emission of males of *N. rubricorne* as well as the peculiar mating behavior are described here for the first time. The sound is a sequence of clicks of various length and intensity. After sound analysis, the sonogram is similar in general structure to that of some species of the family Pamphagidae. The song and stridulatory apparatus of *N. xanthops* are also described. More audio recordings and filming are needed to understand the exact roles of males and females in sound emission and reception, plus the complete sequence of mating behavior, which may be linked in some way. Additionally, molecular analyses are underway to verify the correct phylogenetic position of the genus *Netrosoma*.



**Figure 2.** *Netrosoma rubricorne* sonogram and spectrogram.

**Key Words:** *Netrosoma*, Melanoplinae, Proctolabinae, Bioacoustic, Mating Behaviour, Pars Stridens, Sonogram.

## Behaviour & Communication

# TREE CRICKETS OPTIMISE BAFFLE ACOUSTICS

Natasha Mhatre<sup>1</sup>, Robert Malkin<sup>2</sup>, Rittik Deb<sup>1</sup>, Rohini Balakrishnan<sup>1\*</sup>, Daniel Robert<sup>2</sup>

<sup>1</sup> Centre for Ecological, Sciences, Indian Institute of Science, Bangalore, India; \* brohini@iisc.ac.in

<sup>2</sup> School of Biological Sciences, University of Bristol, Bristol, UK

Male tree crickets produce almost tonal calling songs to attract females from a distance. Females typically use the calling song to recognise conspecifics and to locate potential mates. The louder the song, the further the signal travels and this increases the probability of detection by a conspecific female in the vicinity. Tree crickets are small and produce relatively low frequency calls in the range of 2-4 kHz, which makes them inefficient sound radiators and constrains the loudness of their mate attraction calls. In addition, their small wings worsen the problem by acoustic short-circuiting, that is, cancellation of sound pressure at the edges, which further decreases the amplitude of their calls. Tree crickets have overcome this constraint by producing an acoustic amplifier, a baffle. A baffle consists of a hole cut in a leaf by the cricket, which then sings with its wings placed flat against the leaf surface. Acoustic short-circuiting is avoided when baffling since the compressions and rarefactions are now cleanly separated on either side of the wing by the leaf and do not cancel out. The resultant sound is thus 2-3 times louder than without the baffle. The tree cricket species *Oecanthus henryi* from southern India is found largely on bushes of *Hyptis suaveolens*. This species is interesting because it is not an obligate baffle. Only a small proportion of males in the field could be observed singing from baffles. We investigated whether this behaviour was modulated by leaf size.

We reasoned that larger leaves would result in more sound amplification and should be chosen by males for making baffles. We first measured the distribution of *H. suaveolens* leaf sizes available to males in the wild and then examined baffling probability of wild-caught males by offering them small, medium and large-sized leaves in both no-choice and choice scenarios. In no-choice scenarios, males never produced baffles on small leaves and baffling probability increased with leaf size. In choice experiments, males always preferred to baffle on the larger of two leaves. We modelled the sound radiation efficiency of baffles of different leaf and hole sizes and compared these values with the choices made by the crickets and the sizes of holes they made. We found that tree crickets optimise the acoustics of the baffles they make by choosing leaves of larger size, making holes of appropriate size and in favourable locations on the leaves, towards the centre rather than the periphery. The crickets produced these baffles in one shot and did not appear to use trial-and-error, with one exception, where a cricket made one hole at a suboptimal location, sang from it and then made a second hole at a more central location. Optimisation thus appears to be achieved by an inherited heuristic.

**Key Words:** Tree cricket, baffle, optimisation, *Oecanthus henryi*.



## Behaviour & Communication

# FEMALE MONOPOLIZATION BY MATING PLUGS IN SOUTH AMERICAN CRICKETS (GRYLLOIDEA)

Francisco de Assis Ganeio de Mello

Departamento de Zoologia, Instituto de Biociências, São Paulo State University (UNESP), 18618-689 Botucatu, São Paulo, Brazil, e-mail: gryllus57@gmail.com

Male plays to reproductively monopolize females or try to father the highest number of female offspring are rather common phenomena throughout animals. These paternity-directed strategies may have behavioural, chemical, structural, a combination of more than one of these natures, and even other almost unlikely strategic solutions.

Due to conflicting interests regarding reproductive strategies among the sexes, authors note a similarity between the development of male and female mating systems to an evolutionary arms race, but competition for mates among males is also an important force that may affect the evolution of mating systems in both sexes. If the number of males willing to mate meets a situation in which the number of females prone (or able) to copulate is small, competition among males should be intense.

The strategies of males to monopolize females or, better put, the strategies of the sex that invests the least on reproduction over the one that invests the most (normally the female, but with several reported interesting cases of sex-role reversal) certainly arose by competition for mates among members of the least contributing sex.

Mate guarding, prolonged copulations, and concealment of the partner are examples of behavioral strategies of female monopolization by males.

Marking the female with anti-aphrodisiacal pheromones during copula and marking females' body surface with citral from mandibular glands by *Centris adani* bee males to make her smell like males exemplifies chemical strategies.

The employment of mating plugs to block and/

or damage female genitalia upon her first copulation is not uncommon among animals and is an example of a structural strategy.

An amazing solution to monopolize females was developed by the deep-sea anglerfish. In species belonging to this group, the very small male fix itself outer on the body of a much larger female and their blood vessels merge into a single circulatory system and, being attached to her, he will- not his competitors- fertilize all her ova.

Since the phallic complex of crickets (in fact, in Ensifera, in general) is not an intromittent organ, during copulation the point of contact between the neck of the spermatophore and the small orifice at the tip of the female copulatory papilla is minimal; the spermatophore is not inserted inside the female as in many other groups of insects. Due to this peculiarity, the occurrence of mating plugs in crickets was something that had not been realized until I have described three cases in South America in 2007. In all these cases the females are incapable of removing the plugs and their genitalia become structurally damaged. That means the females are male-made monogamous, while males are potentially polygamous. Albeit sex-ratios are of the 50%-50% type, the effective sex-ratio is much deviated from that since virgin females prone to copulation are much rarer in the populations and competition among males is harsh.

Three cases already published are reviewed and new ones recently discovered, still under study, are presented.

**Key Words:** mating plugs, intra-sexual competition, mating strategies, mate monopolization, paternity assurance, Grylloidea.

## Behaviour & Communication

# ESTIMATION OF THE EFFECT OF TELEMETRY TRANSMITTER WEIGHT ON MOVEMENT ABILITY OF THE CRICKET *GRYLLUS ASSIMILIS*

Oto Kaláb<sup>1</sup>, David Musiolek<sup>1</sup>, Petr Hurtík<sup>2</sup>, Pavel Rusnok<sup>2</sup>, Martin Tomis<sup>3</sup>, Petr Kočárek<sup>1</sup>

<sup>1</sup> Department of Biology and Ecology - University of Ostrava, Ostrava, Czechia; kalab.oto@gmail.com

<sup>2</sup> IRAFM - CEIT4I, Ostrava, Czechia

<sup>3</sup> Department of Telecommunications - VSB-TU Ostrava, Ostrava, Czechia

Radio telemetry tracking is one of the methods used to study animal movement, dispersal and space use. It's based on attachment of active transmitter on the animal's body. Each single transmitter emits unique frequency signal which is detectable with a radio receiver and antenna system. Since the size and weight of transmitters is decreasing, the method was applied in many insect studies. In case of orthopterans it was used only on relatively large species.

The aims of our study are: determine how the weight of the transmitters affects movement ability of a cricket *Gryllus assimilis* (Fabricius, 1775), with use of video records analysis; observe if the effect changed within first three days of continual attachment; and clarify the use of radio telemetry on *G. assimilis* as a model organism for other Orthoptera species.

We prepared 3D printed dummy transmitters based on parameters of the three lightest commercially available transmitters (0.2 g, 0.55 g, 0.75 g) and glued them on pronotum of adult females of *G. assimilis*. Totally, 180 females were divided into 9 groups of 20 individuals. There were 5 control individuals and 5 individuals for each transmitter weight category in each group. Movement of each group was recorded by a 4K camera in 1.2 x 0.8 m arena in a dark room under UV light for 10 minutes repeatedly in three consecutive days. Each individual in a group was tagged by unique mark with UV active color. For each three groups of individuals three different temperature conditions were simulated. For retrieving trajectories from records, we developed original tracking software and algorithm based on F-transform, which is faster and more precise than tested existing tracking algorithms (Hurtik

et al. 2018). Dummy transmitters significantly decreased the walking distance and speed with dependence on temperature. Every milligram of a transmitter weight decreased travelled distance roughly 7 millimetres on average with all temperatures together. Nevertheless, negative effect of lightest transmitter (<30% of crickets weight) was found only on high temperature. Overall, negative effect of heavier transmitters was more significant. The influence was not changing during first three days of attachment with exception of first day in high temperature. Movement speed showed similar patterns as distance response. Preliminary results of spatial interactions show that travelled distance of crickets is longer if their distribution is more separated. The time of closeness of another one cricket has a small positive effect on travelled distance of cricket, but if an individual is approached by two or more other crickets the effect is opposite. We highly recommend consider the effect of transmitter attachment on species of interest before using radio telemetry in research, especially if the study aims to investigate animal movement directly.

We acknowledge support from University of Ostrava students grant (SGS14/PfF/2018) and the Orthopterist's Society by The Theodore J. Cohn Research Fund.

**Reference:** Hurtík, P., Kaláb, O., Musiolek, D., Kočárek, P., Tomis, M. & Číž, D. (2018) Software for visual insect tracking based on F-transform pattern matching. In: IEEE Second International Conference on Data Stream Mining & Processing 2018; New Jersey: IEEE, 2018. s. 528-533.

**Key Words:** radio telemetry, tracking software, laboratory experiment, locomotion



## Behaviour & Communication

# CAN TETTIGONIA VIRIDISSIMA MALES DETECT AND DISCRIMINATE DOMINANCE RANK BASED ON ACOUSTIC SIGNALS?

Howon Rhee

Department of Evolutionary Biology (supervised by Pf.Dr. Klaus Reinhold), Faculty of Biology, University Bielefeld, Morgenbreede 45 D-33615, Bielefeld, Germany; howon.rhee@uni-bielefeld.de

*Tettigonia viridissima* is an aggressive and long-winged bush-cricket in Europe. Only males produce sounds with their wings for attracting females and competing between different individuals. The song of the species consists of a pair of syllables, which is crucial to detect conspecifics. They have strong mandibles, which are used for feeding and for biting predators and competitors during physical contests. Males are clumped when they produced song but they tended to do so with relative distance from competitors within the clumped population. If a distance is too close, males tend to change the song trait differently and/or attack competitors, which is lethal for them. Therefore, it is implied that there would be some hidden information behind the context of songs during this contest. Most likely, a male produces the specific sound showing higher physical dominance than the others so that the physical contests will decrease based on this signal. Moreover, this will show evidence that there is personality variation between individuals within species during the contest. Therefore, in this project we tested the ability for song detection and discrimination of the species in summer, 2018.

In the experiment, all individuals were reared in an individual beaker, isolated and in a fixed temperature ( $27 \pm 2^\circ\text{C}$ ) and the contests and behaviour between two individuals were tested with a video recording digital camera, Avisoft recorder, behaviour notes and the two-isolated large net cage.

The individuals that produced the sound more actively during the experiment were treated as more dominant individuals and vice versa.

There was no significant difference between the mean carrier frequency and the syllable rate of more dominant individuals, and less dominant individuals within pairs of trials. Moreover, there was no correlation between wing traits (wing length, mirror length and mirror width) and individual song traits (the mean carrier frequency and syllable rate).

Consequently, I could not find the relationship between behaviour traits and morphological traits. Therefore, I think more likely the contests of the males are based on the payoff asymmetry hypothesis rather than resource holding potential based on the ability of each individual. If it is the case, global warming could affect the acoustic contests based on migration behaviour because if the temperature is high, individuals of the species have a better ability to fly and are more activity than a low temperature condition. Thus, the temperature change relating to global warming gives the chance to affect dominance rankings based on acoustic signals, and the relationship between intruders and residents should be studied in the future.

**Key Words:** *Tettigonia viridissima*, Behavioural ecology, Cognitive science, Acoustic contest, Syllable rate, Carrier frequency, Dominance hierarchy.

## Behaviour & Communication

# AN EXPERIMENTAL TEST OF THE CONDITION-DEPENDENT HYPOTHESIS USING THE FALL FIELD CRICKET, *GRYLLUS PENNSYLVANICUS*

Donovan Tremblay<sup>1</sup>, Susan M. Bertram<sup>2</sup>

<sup>1</sup> Carleton University, Ottawa, Ontario; donovantremblay@gmail.carleton.ca

<sup>2</sup> Carleton University, Ottawa, Ontario

Although there is strong theoretical support for sexual selection's viability-based indicator models, strong empirical support is limited. Many researchers have assumed that viability-based indicator models predict positive correlations between male secondary sexual traits and survival. However, when more elaborate secondary sexual traits result in high mating success (fitness) benefits, high quality males can evolve elaborate traits to the point that they suffer increased mortality, resulting in negative correlations. Experimental manipulations are therefore required to reveal the underlying relationships. Secondary sexual trait manipulations reveal attraction, viability and survival effects. Unfortunately, these manipulations can also alter male quality, resulting in inaccurate estimates of the costs of secondary sexual traits that arise from correlated developmental and life-history constraints.

In her PhD research, Allison Cotton avoided these pitfalls by adding a weight stressor, unrelated to the sexually selected traits, to stalk-eyed flies and then tested how ornamentation and the weight stressor influenced survivability. She found that while the weighted stressors negatively impacted survival, males that had more exaggerated ornaments survived relatively longer than males with less exaggerated ornaments. Cotton's study provides the strongest empirical support yet for viability-based indicator models.

We built on Cotton's experimental framework, using fall field crickets as our model organism. We added a stressor unrelated to sexual traits (Fig 1) to test the viability-based indicator models' prediction that stressed males should exhibit a positive correlation between sexually selected traits and survival. We predicted that individuals burdened with a weight stressor would die sooner than control (non-weighted) individuals.

We also predicted that weight stressed males with elaborate secondary sexual traits (larger males and males that signal more often and louder) would live longer and continue to signal more elaborately than less endowed weight stressed males. Further, we predicted that weight stressed females would show decreased survival but no reduction in fecundity.

To ensure extensive life history trait variation in our study population, we manipulated the dietary macronutrients. We fed half the crickets a carbohydrate rich diet and the other half a protein rich diet (1:3 versus 3:1 carbohydrates: protein). We predicted that individuals fed a high protein diet (1:3) would have increased body size and decreased longevity, and females would have increased fecundity. We also predicted that males fed a high carbohydrate diet (3:1) would increase their signaling behaviours despite having potentially less exaggerated secondary sexual traits, and that both males and females would experience increased longevity.

Our preliminary findings will be presented.



**Figure 1.** Fall field cricket, *Gryllus pennsylvanicus*, with a 20% weight stressor glued to its thorax.

**Key Words:** Condition-Dependent Hypothesis, Ornamentation, Nutrition, Survival, Fecundity.

## Behaviour & Communication

# THE BIOPHYSICS OF SOUND PROPAGATION IN THE AUDITORY CANAL OF BUSH-CRICKETS

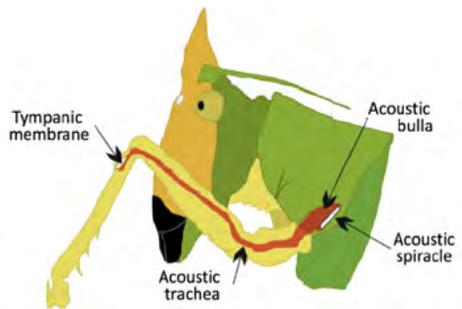
Daniel Veitch<sup>1</sup>, Emine Celiker<sup>1</sup>, Sarah Aldridge<sup>1</sup>, Fernando Montealegre-Z<sup>1</sup>

<sup>1</sup>University of Lincoln, Lincoln, United Kingdom; DVeitch@lincoln.ac.uk

Bush-crickets communicate acoustically and have ears to detect conspecific signals as well as those emitted by predators (e.g. bats). The ears are situated in their forelegs and have at least two paths for sound detection, with the tympanic membranes receiving sound both externally as well as internally via an auditory canal (the acoustic trachea, AT). The AT is a tube derived from the respiratory system of the insect, and runs from an opening in the thorax (the acoustic spiracle) through the leg to the ear. It has been shown that the AT reduces the velocity of sound propagation [1,2]. In the neotropical bushcricket *Copiphora gorgonensis* sound velocity is reduced by about 25% (from 343 m/s in free field air to 255 m/s) [2]. This causes the signal travelling through the AT to arrive at the internal surface of the tympanum a few micro-seconds later than the same signal arriving on the external surface. The resulting interaction of the waves makes the ear directionally sensitive and allows the insect to accurately localise the source of an acoustic stimulus. The mechanism that causes the observed reduction in sound velocity remains undetermined and speculative [3]. By understanding this process, we will be able to more accurately inform models on both directional ears and sound detection.

In this particular study, we test the hypothesis that tracheal sound velocity is affected by the gas composition within the AT, but that the natural composition of gases of the AT is not the underlying cause of the reduction in sound velocity. Using micro-scanning laser Doppler vibrometry we measure the time taken for a signal to travel through the AT to the tympanum, and calculate sound velocity by combining these measurements with dimension measurements generated from micro-computer tomography. Sound velocity was measured within the AT in both

live and dead insects, whilst actively changing the gas composition (air, CO<sub>2</sub> and He) within the AT. Using 3D geometries of the hearing system, we then produced numerical models to corroborate the physical reality (measured in the experiments) or to infer undetected processes.



**Figure 1.** Side view of thorax and head of *Copiphora gorgonensis* showing the acoustic trachea (red) situated within the foreleg.

### References:

1. Michelsen, A., Heller, K. G., Stumpner, A. & Rohrseitz, K. A New Biophysical Method to Determine the Gain of the Acoustic Trachea in Bush-Crickets. *J. Comp. Physiol. A Sens. Neural Behav. Physiol.* 175, 145-151 (1994).
2. Jonsson, T., Montealegre-Z, F., Soulsbury, C. D., Robson Brown, K. A. & Robert, D. Auditory mechanics in a bush-cricket: direct evidence of dual sound inputs in the pressure difference receiver. *J. Royal Soc. Interface* 13 (2016).
3. Michelsen, A. & Larsen, O. N. Pressure difference receiving ears. *Bioinspiration & Biomimetics* 3 (2008).

**Key Words:** Condition-Dependent Hypothesis, Ornamentation, Nutrition, Survival, Fecundity.



## Behaviour & Communication

# PHENOTYPIC PLASTICITY IN THE SOUTH AMERICAN LOCUST, *SCHISTOCERCA CANCELLATA* (ACRIDIDAE)

Martina E. Pocco<sup>1,2</sup>, Bert Foquet<sup>3</sup>, M. Marta Cigliano<sup>1,2</sup>, Eliana L. Nieves<sup>1</sup>, Carlos E. Lange<sup>1,4</sup>,  
Hojun Song<sup>3</sup>

<sup>1</sup> Centro de Estudios Parasitológicos y de Vectores (CEPAVE), CONICET-UNLP, La Plata, Argentina;  
martinapocco@fcnym.unlp.edu.ar

<sup>2</sup> División Entomología, Museo de La Plata, La Plata, Argentina

<sup>3</sup> Department of Entomology, Texas A&M University, College Station, USA

<sup>4</sup> Comisión de Investigaciones Científicas de la provincia de Buenos Aires (CICPBA), Argentina

Historically, *Schistocerca cancellata* has been considered the most serious agricultural pest in Argentina. An outbreak of a magnitude not recorded since 1954 started in 2014-15 in northern Argentina and areas of neighboring Paraguay and Bolivia. The objective of this study is to contribute to the knowledge of the expression of density-dependent phenotypic plasticity by explicitly quantifying density-dependent reaction norms in behavior, coloration, and morphology. Gregarious nymphs and adults of *S. cancellata* were collected in Catamarca province, Argentina in March 2016. Locusts were reared under isolated and crowded conditions for at least three generations before this study. Each treatment was placed in separate rooms at 30°C, 14 L: 10D photoperiod and 40% RH. Characterization of each isolated and crowded nymphal instar and adult stage was performed, and mean duration of stages (nymphal instars and adult stage) was recorded for both density conditions. To quantify behavioral reaction norms, the behavioral assay arena designed by Roessingh et al. (1993) was used in this study. We generated data for 52 isolated and 56 crowded final-instar nymphs (two days after molting). The behavior of each nymph was recorded for 10 minutes using a video camera. Behavioral data (activity and position-related variables) were acquired for each insect using the software EthoVision (Noldus). To quantify color reaction norms, high-resolution digital images of each specimen (lateral and dorsal views of head and pronotum, lateral view of wing pad and hind femur) were taken. From

the captured images, two attributes of color were measured in ImageJ64: background color and black patterns.

To quantify morphology, the linear length of the pronotum and hind femur was measured from the images using ImageJ64. In addition, the number of hairs located on the outer surface of the hind femur of each specimen was counted under a stereomicroscope. The effect of density in each of the variables (behavior, color and morphology) was tested (ANOVA/Kruskal Wallis) in R (3.4.2.). The nymphs reared in crowded conditions were significantly more active than the isolated nymphs. In terms of background color and amount of black patterns, we found clear differences between the two density treatments. We also found that rearing density had clear effects on body size depending on sex: crowded female nymphs were significantly smaller than isolated ones, while crowded male nymphs were significantly larger than isolated ones. Finally, isolated nymphs had about 50% more hairs on the outer face of the hind femora than crowded nymphs, in both sexes. This study provides conclusive evidence on presence of density-dependent phenotypic plasticity in behavior, color and morphology in the South American locust, *Schistocerca cancellata*. We discuss and compare our findings with studies conducted on other locust species.

**Key Words:** Locust, Phase Polyphenism, Behavior, Color, Morphology.



## Behaviour & Communication

# QUANTITATIVE ANALYSIS OF BEHAVIOR PHASE DIFFERENCE IN LOCUSTS WITH THE EXAMINATION OF SPATIAL DISTRIBUTION PATTERNS

Sory Cisse<sup>1</sup>, Saïd Ghaout<sup>2</sup>, Ahmed Mazih<sup>3</sup>, Mohamed Abdallahi Ould Babah Ebbe<sup>4</sup> Hélène Jourdan-Pineau<sup>5</sup>, Koutaro Ould Maeno<sup>4</sup>, Nicolas Leménager<sup>5</sup> & Cyril Piou<sup>5,2</sup>

<sup>1</sup> Centre National de Lutte contre le Criquet pèlerin, BP E-4281, Rue 313, Porte 261, Quartier du fleuve, Bamako, Mali sorycisse01@yahoo.fr ,

<sup>2</sup> Centre de Lutte Antiacridienne, Aït- Melloul, BP 125 Inezgane, Agadir, Morocco,

<sup>3</sup> Institut Agronomique et Veterinaire Hassan II, Departement de Phytierie, BP 18/S, 80 000 Agadir, Morocco,

<sup>4</sup> Centre National de Lutte Antiacridienne, BP 665, Nouakchott, Mauritania

<sup>5</sup> CIRAD, UMR CBGP, F-34398 Montpellier, France

The use of cameras to analyze locust activity, attraction / repulsion is an innovation that is increasingly used in behavioral studies. It allows to simultaneously collect information without interacting with the locusts and to observe more discrete behaviors which are not visually noticeable. Although the technique is complementary to the one focused on the analysis of the individual response to a group of stimuli, it offers an improvement in the observation methods of groups of individuals through the application of spatial statistics.

In our present study, we did laboratory analysis of locust spatial distribution patterns in a circular arena for characterizing phase status. With spatial statistics, we examined the temporal variations of nearest neighbor distances as a criterion of attraction / repulsion between individuals raised either in isolation or in groups in order to induce phase behavior. Also, the successive changes of position of the individuals because of their activity in the circular arena were interpreted as criterion of differentiation between solitary and gregarious locust phases.

Tests were carried out, first with the sequences of photographs taken at regular intervals on 3rd instar hoppers of Desert Locust, *Schistocerca gregaria*, and secondly with the help of video tracking on 3rd instar hoppers of the Migratory Locust, *Locusta migratoria*. Making inferences on the underlying process that generates the temporal variations of the positions of the hoppers in the arena, we found that there was a larger nearest neighbor distance between isolated-reared hoppers (indicating repulsion) in contrast to crowd-reared hoppers, which showed an attraction with their conspecifics. From the analysis of walked distances in both tests, we found a greater activity of crowd-reared hoppers compared to isolated-reared hoppers. This method of quantitative analysis of locust phase differences appears to be more effective in saving time and providing more insight into as yet unclear aspects of behavioral phase studies.

**Key Words:** *Schistocerca gregaria*, *Locusta migratoria migratoria*; Phase polyphenism; attraction; repulsion; activity; Orthoptera, Acrididae.

## Behaviour & Communication

# INCREASING COURTSHIP SONG COMPLEXITY IN A NEWLY DISCOVERED STENOBOTHRUS EURASIUS HYBRID ZONE

Varvara Vedenina<sup>1</sup>, Nikita Sevastianov<sup>1</sup>

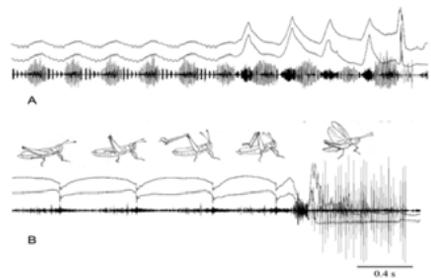
<sup>1</sup> Institute for Information Transmission Problems, Russian Academy of Sciences, Moscow, Russia; vedenin@iitp.ru

Acoustic communication in gomphocerine grasshoppers is extremely developed in terms of stridulatory apparatus structure, the number of sound elements, and mating strategies. A previous analysis of elaborate courtship songs of the *Stenobothrus eurasius* group from Ukraine, Russia and Kazakhstan revealed two different mechanisms of sound generation: hind-leg stridulation that is typical for gomphocerine grasshoppers, and wing clapping that was rarely found so far in this subfamily. *S. e. eurasius* uses only common hind-leg stridulation, whereas *S. e. hyalosuperficies* uses both mechanisms for sound generation. The courtship song of *S. e. eurasius* starts with groups of 3-5 soft pulses, which are gradually transformed into complex syllables; the first half of each syllable is produced by faster vibrations during the leg up-stroke, whereas the second half of each syllable – by slower vibrations during the leg down-stroke (Fig. 1A). In the developed courtship, the vibrating up-stroke of a syllable is replaced by an abrupt, high-amplitude up-movement of the hind legs.

The courtship song of *S. e. hyalosuperficies* starts with the low-amplitude leg movements similar to those in the nominal subspecies. However, the next element is produced by the high-amplitude leg strokes, which are accompanied by conspicuous movements of antennae and tibiae (Fig. 1B). Further, the leg strokes alternate with a loud sound generated by wing beats. In Orenburg region of Russia, we found a hybrid zone between *S. e. eurasius* and *S. e. hyalosuperficies*. The courtship songs of all hybrid specimens (N=13) included complex leg-movement pattern of *S. e. eurasius*, but the songs of only half of specimens included wing clapping.

The high-amplitude leg strokes were found to be intermediate between the parental subspecies in about half of hybrid specimens, whereas these

strokes were found to be parental-like in other specimens. This could indicate a homology between high-amplitude leg strokes in two subspecies. In most hybrid songs, some parental elements were more or less independently superimposed on each other. Thus, the hybrid song pattern exhibited an increased degree of complexity compared to both parental songs. These new elements might offer a potential material for sexual selection. Song analysis of the hybrids also showed a dominance of some features of *S. e. eurasius*. In particular, all hybrids alternated faster vibrations produced during the leg up-stroke and slower vibrations emitted during the leg down-stroke. We, therefore, suggest this complex pattern to be an ancestral feature in the *S. eurasius* group, whereas sound generation via wing clapping could represent a divergent form.



**Figure 1.** Courtship songs of *S. e. eurasius* (A) and *S. e. hyalosuperficies* (B). Drawings show the positions of tibiae, antennae and wings at the corresponding moments of the song in *S. e. hyalosuperficies*.

**Key Words:** grasshopper, courtship, stridulation, leg-movement pattern, sexual selection.

**13<sup>TH</sup>** INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



13<sup>TH</sup>

INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



# POSTER SESSIONS





INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



## POSTER SESSIONS A

Systematics & Molecular Biology





## Systematics & Molecular Biology

# MITOGENOM OF PSORODONOTUS VENOSUS AND ANTERASTES BABADAGHI (ORTHOPTERA, TETTIGONIIDAE): COMPARATIVE ANALYSES INDICATE A HIGHLY CONSERVED GENOME

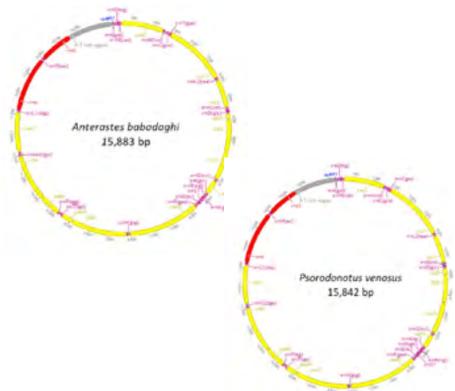
Uğur Karşı<sup>1</sup>, Battal Ciplak<sup>1</sup>

<sup>1</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey

<sup>1</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey; [ciplak@akdeniz.edu.tr](mailto:ciplak@akdeniz.edu.tr)

DNA sequences of the mitochondrial genome are essential data sources in phylogenetic and especially phylogeography studies, since still it is the only reliable tool for molecular clock estimation. Orthoptera is one of the most species rich orders of Insecta and mitochondrial genome of several species have been studied especially during last 2-3 years. However, still there several sublineages of Orthoptera have not been examined. This study aims to present data on mitochondrial genome of *Psorodonotus venosus* ve *Anterastes babadaghi* belonging to Platycleidini, Tettigoniinae (Orthoptera, Tettigoniidae) obtained via next generation sequencing and evaluated by bioinformatics approaches. Five specimens per species are studied. We found that total mitogenome of *Psorodonotus venosus* is 15836-1845 bp and that of *Anterastes babadaghi* is 15882-15883 bp. As in the most of the other eukaryotes the mitochondrial genome of these two species consists of 22 tRNA genes, 2 rRNA genes, 13 protein coding genes and the A+T rich control region. These 37 genes ordered as in pancrustacean mitochondrial genome, which also considered as the ancestral gene arrangement of Hexapoda in both species. The AT/GC content of the protein coding genes is % 68/32 and % 70/30 in *Psorodonotus venosus* and *Anterastes babadaghi* respectively. The length of seven non-coding intergenic spacers varies between 1-16 bp and that of 12 overlapping regions between 1-8 bp in *P. venosus*. There are 11 intergenic spacers lengths of which vary between 1-16 bp and 13 overlapping regions varying between 1-8 in length in *A. babadaghi*. The A+T control region is 1079 and 1100 in *P. venosus* and *A. babadaghi*. The Data of this study indicates following results: (i) mitogenome of both species

exhibit characteristics of multicellular organisms in several aspects, (ii) the gene location of mitochondrial genome of these two species, representing Platycleidini, Tettigoniinae, indicate that no gene arrangement has occurred in evolutionary history of lineage, (iv) Both species have AT rich genome as in other orthopterans, and (v) the tRNA genes in Tettigoniinae exhibit some subfamily specific aspects such as the length and anti-codon of the genes and their overlapping or having non-coding bases with the adjacent genes, and (vi) similarly the length, the initial and stop codons of the genes and their overlapping or having non-coding bases with the adjacent genes in protein coding genes also exhibit subfamily specific patterns.



**Funding:** This study was supported as a project by Akdeniz University, Research Fund (Project No: FYL-2017-2462).

**Key Words:** Tettigoniidae, Platycleidini, *Psorodonotus venosus*, *Anterastes babadaghi*, mitogenome.

## Systematics & Molecular Biology

# SECONDARY STRUCTURE OF ITS2 IN ANTERASTES SPECIES: A COMPARATIVE ANALYSES REVEALED A HIGHLY CONSERVED ITS2

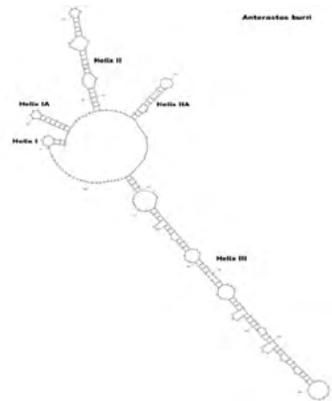
Onur Uluar<sup>1</sup>, Battal Cıplak<sup>2</sup>

<sup>1</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey

<sup>2</sup> Department of Biology, Faculty of Science, Akdeniz University Antalya, Turkey; ciplak@akdeniz.edu.tr

The tools to define biodiversity have changed through time. DNA sequences widely have been used to define biodiversity as they provide objective data and are suitable for computerization. Transcripts and secondary structures of the internally transcribed spacer 2 (ITS2) are using as a species barcode marker in many lineages such as Fungi and Plantae. However, its utility as a barcode marker for animals waits to be tested. The characteristics of the secondary structure (structural characteristics, length polymorphism and compensatory base changes - CBCs) of ITS2 offer unique characters to reveal the species boundaries. The aim of the present study is the characterization of ITS2 secondary structure in the genus *Anterastes* and some representatives from other genera of Tettigoniinae. To reveal the ITS2 secondary structure, we mainly focused to species of the genus *Anterastes*. Additionally, to see the intrageneric conservativeness we studied a few species from other genera. The secondary structures of the ITS2 transcripts were constructed using the appropriate softwares. The helices of secondary structure were identified according to the universal characteristics assumed for ITS2. In the total, the secondary structure of ITS2 was constructed for 19 species (15 in *Anterastes* and 4 in other genera). The total length of ITS2 varies between 267-279 base pairs. Two type of secondary structures were observed. The first consists of three main helices as Helix I+IA, Helix II+IIA and Helix III and observed in 13 species of *Anterastes* plus a species of Pholidoptera. Lengths of these helices are 11+18, 47+25-28 and 135-147 base pairs respectively. The second type secondary structure consists of four main helices as Helix I+IA, Helix II+IIA, Helix

III and Helix IV, and observed in two species of *Anterastes* plus one species per Eupholidoptera, Parapholidoptera and Platycleis. Their lengths are found to be 11+18, 47+ 25-28, 135-147 and 11-22 respectively. The following conclusions have arrived in the light of these results: (i) The secondary structure of ITS2 sequences has some departures from other eukaryotes. The four-helices secondary structure is typical for eukaryotes, but not observed in most of the *Anterastes* and a species of Pholidoptera. (ii) Each



helices is highly conserved and variations are in the regions outside the main body of helices, (iii) the presence of Helix IA between Helix I and Helix II is unique among eukaryotes, (iv) and that of Helix IIA between Helix II and Helix III is unique among Orthoptera. (v) ITS2 does not seem productive to be barcode marker in *Anterastes*.

**Key Words:** ITS2, secondary structure, *Anterastes*, Tettigoniinae, Orthoptera.

## Systematics & Molecular Biology

# MOLECULAR AND MORPHOLOGICAL IDENTIFICATION OF EDIBLE GRASSHOPPERS IN KENYA AND UGANDA

Alfonse Leonard Mutibha<sup>1,2</sup>, Fathiya M. Khamis<sup>1</sup>, Samuel Kyamanywa<sup>2</sup>, Sunday Ekesi<sup>1</sup>, Chrysantus Tanga Mbi<sup>1</sup>, James P. Egonyu<sup>2</sup>, Sevgan Subramanian<sup>1</sup>

<sup>1</sup> International Centre of Insect Physiology and Ecology, P.O. Box 30772-00100 Nairobi, Kenya; [amutibha@icipe.org](mailto:amutibha@icipe.org)

<sup>2</sup> Makerere University, Kampala, Uganda

Grasshoppers are important cultural food among communities in Kenya and Uganda. They are a good source of protein, fats, vital minerals and vitamins. Despite their traditional importance as food, the available edible grasshoppers' species in Kenya and Uganda are not well documented. The information on the grasshoppers' species are important for optimization of mass-rearing protocols. In this regard, we undertook a molecular and morphological identification of available edible grasshoppers' species in Kenya and Uganda. Adult insects were collected at different locations in Murang'a and Kilifi, Kenya and Kampala, Masaka, Mbarara, Kabale and Hoima, Uganda; preserved in absolute ethanol until further analysis. Morphological identification was done using Kenya Museum collection references. Further extraction of DNA was done using the ISOLATE II Genomic DNA Kit from BIONLINE Company as per manufacturer's instructions. Primers used for PCR were LepF1 forward: (ATTCAACCAATCATAAAGATATTGG)

and LepR1 Reverse: (TAAACTTCTGGATGTCCAAAAATCA) for long horned grasshoppers and Cytb-J-1-933 (Fwd) (TCTTTTTGAGGAGCWACWGTWATTAC) and Cytb-N-11367 (Rev) (AATTGAACGTAAAATWGTRTAAGCAA) for short

horned grasshoppers. PCR products were purified and sequenced using Applied Biosystems 3730XL sequencer. Consensus sequences were generated using BioEdit software and the identity of plants established using Basic Local Alignment Search Tool (BLAST) in the Genbank. Morphological identification was done using Kenya Museum collection references.

Morphological identification indicated that specimens from Murang'a were *Acanthacris ruficornis* while those collected in Kilifi were *Cyrtacanthacris tatarica*. All specimens collected from Uganda were morphologically identified as *Ruspolia differens*. The BLAST results confirmed the identify of *Acanthacris ruficornis* (99% similarity), while for *Ruspolia differens* (COI gene) and *Cyrtacanthacris tatarica* (cytochrome b gene) sequences are not yet available in the GenBank. The blast results showed the *Ruspolia nitidula* (97% similarity) which is close related species to *Ruspolia differens*. There is a need for developing mass-rearing protocols for these identified grasshoppers with further information on their ecology and host preferences.

**Key Words:** Edible grasshoppers, *Ruspolia differens*, *Acanthacris ruficornis*, *Cyrtacanthacris tatarica*.



## Systematics & Molecular Biology

# PHYLOGENETIC ANALYSIS OF RECENT DATA OF GOMPHOCERINAE GRASSHOPPERS (ORTHOPTERA: ACRIDIDAE), ESPECIALLY THE GENERA OF THE MAGHREB

Hafayed Rachida<sup>1\*</sup>, Bengueraichi Fatiha<sup>1</sup>, Moussi Abdelhamid<sup>1</sup>

<sup>1</sup> Laboratory Valorization and Conservation of Natural Resources, University of Biskra, Algeria;

\* r.hafayed@univ-biskra.dz amutibha@icipce.org

The Gomphocerinae grasshoppers are one of the most diverse and species-rich taxa of the Acrididae. The slant-faced grasshoppers, species of the subfamily Gomphocerinae, encompass over 1274 described species belonging to 192 genera. In order to re-examine phylogenetic relationships of certain species and genera in the Gomphocerinae subfamily of the Maghreb, a phylogenetic analysis has been reviewed by the analysis of mitochondrial genes available in databases.

This study has allowed us to extract important new data and remarkable observations are useful in further studies and necessary to review the current taxonomy of this subfamily with its different species.

**Key Words:** Gomphocerinae grasshoppers, phylogenetic analysis, mitochondrial genes, Maghreb.



## Systematics & Molecular Biology

# MORPHOLOGICAL CHARACTERIZATION OF SOME MOROCCAN LOCUST SPECIES: MORPHOMETRIC APPROACH

Azzouzi Amal<sup>1</sup>, Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Chater Oumaima<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez. amal.azzouzi@usmba.ac.ma

Locust species are characterized by differences in their distribution. Some species are able to spread over large distances and colonize various environments, while others are limited to very small areas. In the present work, we study the morphological traits of 13 locust species that differ in their ability to move. The results obtained show a relationship that exists between the ability of a species to move and its body size (morphological traits).

A principal component analysis applied to biometric measurements revealed a divergence between species capable of large scale displacements such as *Schistocerca gregaria*, well known for its very high displacement capabilities, and those with low displacements abilities.

**Key Words:** locusts, morphological traits, movement abilities.



## Systematics & Molecular Biology

# EVALUATION OF THREE METHODS FOR TOTAL DNA EXTRACTION FROM GRASSHOPPERS (ORTHOPTERA: ACRIDIDAE)

Fatiha Bengueraichi<sup>1</sup>, Rachida Hafayed<sup>1</sup>, Abdelhamid Moussi<sup>1</sup>

<sup>1</sup> Laboratory Valorization and Conservation of Natural Resources, University of Biskra, Algeria;  
fatiha.bengueraichi@univ-biskra.dz

DNA barcoding is very important in helping to reconstruct phylogenetic trees and to confirm the identity of species, particularly for taxa for which morphological identification is difficult. The first step in DNA analyses is the extraction of nucleic acids from tissues or cells. A variety of methods have been used to isolate DNA molecules from insects, and many commercial kits are available. The most important concern on these methods has been the quantity and quality of DNA as well as cost.

From individual grasshopper, subfamilies Gomphocerinae and Oedipodinae, DNA extractions by the SDS method, CTAB method and REExtract-N-Amp™ Tissue PCR Kit were compared in terms of quantity and quality of extracted DNA and were evaluated by an amplification test of the Cytochrome Oxidase subunit I (COI) gene of the mitochondrial genome. All three methods resulted in acceptable DNA concentrations and absorbance ratios, the SDS

and CTAB methods resulted in higher DNA yield (ng DNA vs. mg tissue) at much lower cost but, in terms of quality, the SDS method showed less degradation than the CTAB method on agarose gels. The REExtract-N-Amp™ Tissue PCR Kit was most time-efficient but was the costliest among the methods tested. DNA samples obtained from all three methods were PCR tested to amplify the mitochondrial COI gene in grasshopper, and the majority of samples showed successful amplification.

This study provides a guide for choosing methods of DNA extraction from grasshopper based on the expected yield and quality of the DNA and the cost. The DNA extracted by the three methods was suitable for further molecular applications such as PCR and sequencing by synthesis.

**Key Words:** DNA barcoding, Grasshoppers, SDS method, CTAB method, REExtract-N-Amp™ Tissue PCR Kit.



## Systematics & Molecular Biology

# METHODOLOGICAL OPTIMIZATION AND STANDARDIZATION OF THE METABARCODING OF INSECTS GUT MICROBIOME

Laure Benoit<sup>1</sup>, Maxime Galan<sup>2</sup>, Sylvain Piry<sup>2</sup>, Marie-Pierre Chapuis<sup>1</sup>

<sup>1</sup> Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), UMR Centre de Biologie pour la Gestion des Populations (CBGP), CS 30016, Montferrier-sur-Lez, France; laure.benoit@cirad.fr

<sup>2</sup> INRA, UMR CBGP, F-34398 Montpellier, France

Metabarcoding analysis of microbiota could help understand how Orthopteran species cope with challenges associated with environmental changes. Since microbial symbionts have a mutually beneficial relationship with its host and play important roles in the immune and physiological systems, they likely impact its ecology and evolution (i.e. plant range, life history, behaviour). In addition, the analysis of the complex pathogenic communities associated with locusts could be useful to discover unexplored pathogens and develop future research on biological control innovation. Yet, current knowledge of Orthopteran-associated microbial communities is limited.

This is partly because recognizing cryptic, diverse, and numerous microorganisms hosted by insects is a difficult task. Despite the design of standard genes for their identification and the latest advances in high throughput sequencing, difficulties persist when we look at the microbiota of insects, including Orthopterans. (1) DNA purification is an essential step in all cultivation-independent approaches to characterize microbial diversity. Indeed, the microbial composition is mainly biased by the efficiency of cell lysis. (2) Another critical step for unbiased representation analysis and high taxonomic resolution is the choice of amplicon and primers. In particular, we showed that Enterobacteriaceae, common in insects, were poorly resolved with some of currently used amplicons. (3) Moreover, in the case of phytophagous insects, it is necessary to avoid the amplification of plant remains contained in the digestive tract.

In this study, we use (1) three mock community standards that contained equal and logarithmic numbers of eight species (ZymoBIOMICS), and equal numbers of twenty other species (ATCC), and (2) six samples representing the six main orders of insects (Orthoptera, Diptera, Hemiptera, Coleoptera, Hymenoptera and Lepidoptera). On these dedicated samples, we first statistically evaluate the most commonly used DNA purification kit (Qiagen DNeasy Blood and Tissue), two microorganisms-specific DNA purification kits (ZymoBIOMICS-96 bashing beads and DNeasy UltraClean 96 Microbial Kit) and two homemade procedures (bashing beads and enzymatic cocktails added to Qiagen DNeasy Blood and Tissue). These methods are compared on the basis of DNA yield, DNA shearing, reproducibility, and most importantly representation of microbial diversity in 16S rRNA gene sequences. Secondly, we are currently evaluating the taxonomic representativity and resolution of different 16S gene primers to avoid plant chloroplast genes amplifications.

Second, we evaluate, using *in silico* analyses, (1) the PCR efficiency (representativity), (2) the taxonomic resolution and (3) the risk to amplify plant chloroplasts of already published primers on various variable regions of the 16S gene (V3, V4, V6, V9) and of the *rpoB* gene. We then test and validate *in vitro* the best primer candidates on the dedicated samples.

**Key Words:** Gut microbiota, Next Generation Sequencing, metabarcoding.



## Systematics & Molecular Biology

# NEW GENUS OF ODONTOGRYLLINI FROM AMAZON RAINFOREST (GRYLLIDAE; LANDREVINAE)

Darlan Rutz Redu<sup>1</sup>, Pedro G. B. Souza Dias<sup>2</sup>, Silvio Shigueo Nihei<sup>3</sup>

<sup>1</sup> University of São Paulo, Department of Zoology, São Paulo, Brazil; darlanredu@gmail.com

<sup>2</sup> National Museum, Federal University of Rio de Janeiro, Department of Entomology, Rio de Janeiro, Brazil

Odontogryllini de Mello, 1992 is a Neotropical tribe of Landrevinae and comprises 5 genera as well as 20 valid species. *Odontogryllus* Saussure, 1877 is the most diverse genus, with 11 described species from Ecuador, Peru, Brazil and Mexico; *Brasilodontus* de Mello, 1992, with 6 species, occurs in the Brazilian Atlantic forest; *Valchica* de Mello, 1992, *Xulavuna* de Mello & Campos, 2014 and *Yarrubura* de Mello & Campos, 2014 are monotypic, the first one from Costa Rica and the last two from Amazonas State, Brazil.

The aim of this work is to describe the new genus of Odontogryllini based on morphological and genital characters from specimens collected in the municipality of Cotriguaçu, northwest region of the Mato Grosso State.

The new genus presents a peculiar modified fore wing, such as occurs in *Xulavuna*, with the dorsal field very reduced and presenting a glandular structure in the median portion, as well as the lateral field larger and occupying a dorsal position.

The male genitalia of the new genus have several characteristics in common with the other genera of the tribe, such as: rami laterally compressed and positioned in parallel, pseudepiphallic

sclerite elongate and semi-tubular, ectophallic sclerite with a pair of very long apodemes, absence of ectophallic arc and endophallic sclerite with apodemes.

Despite the common characteristics, their genitalia can be easily differentiated from all others in the tribe by the form of the ectophallic apodemes, which present a distally bifurcated sclerite. Furthermore, there are other substantial differences in the shape and position of their pseudepiphallic sclerite, pseudepiphallic paramere and endophallic sclerite. Although their external morphology closely resembles *Xulavuna*, because the shape of fore wings, this similarity does not occur in phallic sclerites that are more similar to those of *Odontogryllus*.

The recent descriptions of this new genus, *Xulavuna* and *Yarrubura* from the Amazon rainforest suggest that the number of taxa described in this group of crickets is very underestimated and we believe that their diversity will be increased with further expeditions.

**Key Words:** taxonomy, systematics, biodiversity, Neotropical, South America, cricket.



## Systematics & Molecular Biology

# ANTIBACTERIAL ACTIVITY OF FOUR ESSENTIAL OILS ON BACTERIA ISOLATED FROM THE DESERT LOCUST GUT *SCHISTOCERCA GREGARIA*

Rochdi Mouad<sup>1</sup>, Chater Oumaima<sup>1</sup>, Errachidi Faouzi<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>, Haloti Saidi<sup>1</sup>

Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez. Moad9700@gmail.com

To control desert Locust *Schistocerca gregaria*, we have used medicinal plants to block growth of symbiotic microbial flora in cricket gut. 40 bacterial strains were isolated, purified and enzymatically characterized (cellulase, pectinase, and amylase). After screening, we have selected five performants strains. After, we have tested antibacterial activity of four essential oils namely thyme, lavender, rosemary and sage on selected isolates by using disc diffusion method.

The antibacterial activities obtained show a differential variation depending on essential oil nature. Maximum activity was obtained with thyme (*Thymus vulgaris*) which seems to have a possible capability in locust control.

**Key Words:** Antibacterial activity, antilocust activity, Essential oil, *Schistocerca gregaria*, *Thymus Vulgaris*.



## Systematics & Molecular Biology

# TAXONOMIC STUDY OF LOCUSTS (ACRIDOIDEA, ACRIDOMORPHA) AND EFFECTS OF VEGETATION STRUCTURE ON ORTHOPTERAN ASSEMBLAGES IN THE ADRAR REGION IN ALGERIA

Abderrahmane Soudani<sup>1</sup>, Abdelhamid Moussi<sup>2</sup>

<sup>1</sup> Department of Agronomy, Faculty of exacts sciences and natural and life sciences, Mohamed Khaider University, Biskra, Algeria; [abderrahmanesoudani86@gmail.com](mailto:abderrahmanesoudani86@gmail.com)

<sup>2</sup> Laboratory of genetic, biotechnology and valorization of bio-resources, Mohamed Khaider University, Biskra. Algeria

The region of Adrar is located in the central Sahara of Algeria, where the bioclimatic floor is Saharan with moderate winter. The Agriculture in this area is based on two systems; mainly the oasien type where we find the old system of irrigation which is the Foggara and the large farms characterized by pivots as the mean of irrigation system. Only few studies were realized on the locusts situation in this area and the subject remains almost unknown. For this reason, a qualitative study has been carried out on the locusts which are found in the region of Adrar in different environments: traditional palmerais, modern palmerais, pivots of the cereals, and in natural environments. To carry out this study, excessive visits were carried out seasonally at 23 study stations during a period that lasted from February 2016 to August 2018. The collection of locust individuals is carried out by the sweep net, the capture by hand and the traps lights.

This work allowed the enumeration of 18 locust species. These species are grouped into two families: Pyrgomorphidae and Acrididae. The Acrididae family is subdivided into 05 subfamilies (Acridinae, Cyrtacantacridinae, Eyprepocnemidinae, Gomphocerinae and Oedipodinae) which total 15 species of the global acridofauna identified. While the family of Pyrgomorphidae is presented only by the Pyrgomorphinae subfamily which encompasses two species. Our study of some of these species in 6 different biotopes has shown the emergence of five orthopteran assemblages in relation to the high sensitivity of orthopteran to changes in vegetation structure.

**Key Words:** Algeria Sahara, Adrar, Caelifera, locusts, Diversity, Taxonomy, Inventory, Vegetation structure.

Systematics & Molecular Biology

**ESTABLISHING THE MOLECULAR PHYLOGENY OF ACRIDIDAE GRASSHOPPERS (ORTHOPTERA, CAELIFERA)**

Igor Sukhikh<sup>1</sup>, Kirill Ustyantsev<sup>1</sup>, Alexander Bugrov<sup>2,3</sup>, Michael Sergeev<sup>2,3</sup>, Valeriya Vavilova<sup>1</sup>, Alexander Blinov<sup>1</sup>

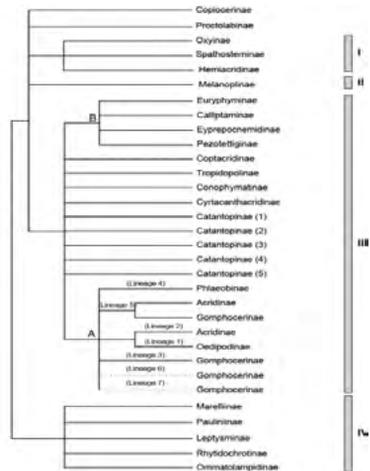
<sup>1</sup> Institute of Institute of Cytology and Genetics SB RAS, Novosibirsk, Russia; igor3419@gmail.com

<sup>2</sup> Novosibirsk State University, Novosibirsk, Russia

<sup>3</sup> Institute of Systematics and Ecology of Animals, SB RAS, Novosibirsk, Russia

Acrididae, with more than 6,500 species, is the largest, cosmopolitan family of short-horned orthopteran insects (Orthoptera, Caelifera). Due to their importance as agricultural pests, Acrididae had long attracted the attention of many taxonomists. However, there is no commonly recognized taxonomic system of this family. Currently, a great number of DNA markers (both mitochondrial and nuclear) is available in NCBI GenBank database for many acridids, including mitochondrial protein-coding genes COI, COII, Cytb and NADH5, as well as nuclear (18S, 28S, including ITS) and mitochondrial (12S, 16S) clusters of ribosomal genes. Using the sequences from this database, with the addition of experimentally obtained data, we address acridid phylogeny focusing first on the subfamily level and continue on the lower taxa levels. In order to establish phylogenetic relationships between Acrididae subfamilies, we compared complete coding mitochondrial and nuclear ITS2 DNA sequences for more than hundred Acrididae grasshoppers. In addition, we analysed three concatenated mitochondrial genes, COI, COII and Cytb. Preliminary results show that all studied acridids fall into three main phylogenetic groups that include 13 subfamilies: (I) Oxyinae, Hemiacridinae, and Spathosterninae; (II) Melanoiplinae; (III) Acridinae, Calliptaminae (=Calopteninae), Catantopinae, Cyrtacanthacridinae, Eyprepocnemidinae, Euryphyminae, Gomphocerinae, Oedipodinae, and Pezotettiginae. Additional comparison of

recent studies to our data reveals a fourth group embracing five more subfamilies: (IV) Marelliinae, Pauliniinae, Leptyminae, Rhytido-chrotinae, and Ommatolampidinae. We also confirm that the family Acrididae is mono-phyletic. Our study provides a basis for further phylogenetic analyses of Acrididae on lower taxonomic levels.



**Figure.1:** Scheme of Acrididae tree. I – IV: phylogenetic groups. A, B: Subgroups of phylogenetic group III.

**Key Words:** ecular phylogeny, mitochondrial DNA, ribosomal DNA, Acrididae.



## Systematics & Molecular Biology

# EFFECTS OF LATITUDE ON THE MOLECULAR EVOLUTION RATE OF THE GRASSHOPPERS (INSECTA: ORTHOPTERA)

Vinícius Wilson<sup>1</sup>, Natália Vicente<sup>1</sup>, Carlos Frankl Sperber<sup>1</sup>

<sup>1</sup> Laboratório de Orthoptera, Departamento de Biologia Geral, Universidade Federal de Viçosa, Av. PH Rolfs s/n. Viçosa, Minas Gerais, Brazil. CEP 36570-900; abexanderconde@gmail.com

One of the best-known species diversity patterns is the latitudinal diversity gradient - a large number of species near the equator and a decrease toward the poles. Several hypotheses have been proposed to explain the great diversity in the tropics, including that animals show an increase in the molecular evolution rate towards low latitudes, which would lead to increased diversity in the tropics. In this work we tested this hypothesis for grasshoppers. For this purpose, we gathered mitochondrial DNA sequences from grasshoppers available in genbank, as well as the geographic distribution of the species found in the Orthoptera Species File. Subsequently, we reconstructed the phylogeny of the Suborder Caelifera using Maximum Likelihood based on three mitochondrial genes: COI, COII and CytB. Only species with a latitudinal range of at most 30 degrees of latitude were included in the phylogeny, since species with very broad distribution are not informative for our aim. From this phylogeny, we selected phylogenetically independent pairs of species, according to the following criteria: the latitudinal midpoint of the species should be separated by at least 10 degrees of latitude; and the latitudinal range can not overlap more than 25%. In addition, we also select a close outgroup for each pair of species. We then estimated the genetic distance of each species from the pairs and its outgroup using pairwise relative rates tests on GTR + G model using PAUP software.

We calculated the contrasts in genetic distance by subtracting the distance of the species from the highest latitude of the pair by the distance of the species of the lowest latitude of the pair. To test the null hypothesis that there is no relationship between the rate of molecular evolution and latitude, we used two non-parametric tests: sign test and Wilcoxon signed rank test. These tests were performed separately for the three mitochondrial genes.

We obtained 25 phylogenetically independent contrasts for COI, 29 for COII and 14 for CytB. Sign tests showed significant results for COI and COII (p-values 0.027 and 0.018, respectively), indicating an increase in molecular evolution rate toward the poles. Wilcoxon signed rank tests did not show significant results for any of the three genes. Unlike our prediction, our results show that there seems to be an increase in the rate of evolution toward the poles. In conclusion, it appears that the molecular evolution rate is not a good hypothesis to explain the latitudinal diversity gradient for grasshoppers. This is the first time an increase in the rate of molecular evolution towards the poles has been detected using a worldwide dataset. Future studies may focus on understanding the causes and whether this is a phenomenon restricted to grasshoppers or is also present in other taxa.

**Key Words:** Caelifera, diversity, independent contrasts, species richness.



## Systematics & Molecular Biology

# GONAD FULL-LENGTH TRANSCRIPTOME OF BAMBOO GRASSHOPPER CERACRIS KIANGSU (ORTHOPTERA: ACRIDIDAE)

Guo-Fang Jiang

Quanzhou Normal University, Quanzhou 362000, PR China, cnjgf1208@163.com

Some grasshoppers are important agricultural pests. This study was aimed at generating the full-length transcriptome of gonads of the bamboo grasshopper *Ceracris kiangsu* using single-molecule real-time (SMRT) sequencing. Two gonads of *C. kiangsu* were harvested for isolating total RNA. The mixed samples were used for SMRT sequencing to generate the full-length transcriptome. Based on the obtained transcriptome data, simple sequence repeat (SSR) analysis, coding sequence prediction, transcript functional annotation, and lncRNA prediction were performed. Total 12.36 Gb of clean reads were generated, including 584,792 reads of insert (ROI) and 453,662 full-length non-chimeric (FLNC) reads. Transcript clustering analysis of FLNC reads identified 262,342 consensus isoforms, including 32,430 high-quality ones. After removing redundant reads, 172,674 transcripts were obtained.

Additionally, 104,315 SSRs and 179,793 coding sequences were identified. Furthermore, 27,705 transcripts were annotated in seven functional databases, 122,308 transcripts were annotated at least one databases, and 51,317 lncRNAs were predicted.

This is the first study to perform SMRT sequencing of the full-length transcriptome of *C. kiangsu*. The obtained transcriptome may facilitate further exploration of the genetic data of *C. kiangsu* and uncover the interactions between this insect and the ecosystem.

**Key Words:** *Ceracris kiangsu*, gonads, full-length transcriptome, single-molecule real-time sequencing, lncRNA, transcripts, simple sequence repeat (SSR).

## POSTER SESSIONS B

### Development & Physiology



## Development & Physiology

# INFLUENCE OF THE TEMPERATURE ON THE NYMPHAL DEVELOPMENT OF *CORNOPS FRENATUM FRENATUM* (MARSCHAL, 1836) (ORTHOPTERA, ACRIDIDAE)

Maiara Beatriz Lima<sup>1</sup>, Marcos Gonçalves Lhano<sup>2</sup>

<sup>1</sup> Universidade Estadual de Feira de Santana (UEFS), Programa de pós- graduação em Ecologia e Evolução (PPGEcoEvol).44036-900.Feira de Santana, BA, Brazil ; maiarab.lima@hotmail.com

<sup>2</sup> Universidade Federal do Recôncavo da Bahia (UFRB), Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB). Programa de Pós-Graduação em Ciências Agrárias. 44380-000. Cruz das Almas, BA, Brazil; marcos@ufrb.edu.br

Environmental factors such as photoperiod, temperature, humidity and food availability have a direct influence on the development of insects and this is essential to establish control plans of the insect pest population. *Cornops frenatum frenatum* is a phytophagous grasshopper, which is gregarious and found in plantations of *Heliconia* spp. L. (Zingiberales, Heliconiaceae), causing great damage to these tropical plants. The present study aimed to determine the influence of temperature on the nymphal development of *C. f. frenatum*. Nymphs of various stages of development were captured, from February 2015 to March 2017, in *Heliconia* plantations located in the Reconcavo region of Bahia and maintained on BOD Incubator (Bio-Oxygen Demand) under constant photoperiod (12/12 hours of photophase/scotophase) and

at different temperatures: 18°C (n= 65), 25°C (n=100) and 30°C (n=65). Monitoring was carried out every 48 hours to verify the occurrence of ecdises, mortality and maintenance of the breeding environment. A higher mortality was observed in specimens maintained at 18°C and 30°C (43 individuals each), and the lower mortality at 25°C (54 individuals). The lowest development time was observed in individuals exposed to 30°C where it took an average of 37.5 days to become adults, whereas at 25°C, it took an average of 82.0 days. Therefore, it was observed that the temperature is an environmental factor that has influence on the nymphal development of *Cornops frenatum frenatum*.

**Key Words:** Biological cycle, Developmental Time, Grasshopper, Insect Development, Instar.



## Development & Physiology

# CLASSICAL AND GEOMETRICAL MORPHOMETRY OF FLIGHT ORGANS IN SOME MOROCCAN LOCUST SPECIES

Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Lazraq Abderrahim<sup>1</sup>, Chater Oumaima<sup>1</sup>, Errachidi Faouzi<sup>1</sup>

<sup>1</sup>Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez

Movement ability is a determining factor in locust species breeding. Morphological traits Variation allows locust populations to move over different distances. By measuring different parts of locust body, we were able to point out a morphometric differences between the species *Dociostaurus maroccanus*, *Dociostaurus dantini*, *Schistocerca gregaria* and *Euchorthippus elegantulus*. Firstly, we noted a morphological distinction at the level of flight organs between migratory species (*D. maroccanus* and *S. gregaria*) and sedentary species (*Dociostaurus dantini* and *Euchorthippus elegantulus*). Secondly, we used geometric morphometry to quantify elytra deformation in studied species. To be done, nine Points-Marker (PM), were considered for morpho-geometric analysis.

The Points-Markers 7 and 8 become more extensive which attributes an elongation of distal part in migratory species. Conversely, in species characterized by small displacements, we noticed proximal translation of Points-Markers 5, 6, 7 and 9 producing a narrowing of elytra at distal part, confirming their sedentary character. However, a relative flattening in *E. elegantulus* of the radial field is attributed to distal part elongation. Differentiation highlighted in this study explains the structure of locust populations in their natural environment.

**Key Words:** Biological cycle, Developmental Time, Grasshopper, Insect Development, Instar.



## Development & Physiology

# REPRODUCTIVE STRATEGIES IN TWO SPECIES OF ACINIBE RAMBUR, 1838: EGG-POD AND EGG FEATURES (ORTHOPTERA, PAMPHAGIDAE)

María-Dolores García<sup>1</sup>, Eulalia Clemente<sup>1</sup>, Nicolás Ubero<sup>1</sup>, Juan-José Presa<sup>1</sup>

<sup>1</sup> Department of Zoology and Physical Anthropology, University of Murcia, Murcia, Spain; mdgarcia@um.es

The egg pod in *Caelifera*, as well as the eggshell surface, show a great variability of morphological patterns, which have been used to solve taxonomical problems, to establish systematic or ecological relationships and to study the population dynamics, mainly in species of economic interest. Since the Pamphagidae are usually of low abundance, their life cycle and development have been overlooked, and the data on the chorionic structure of their eggs are very scarce.

*Acinipe deceptoria* (Bolívar, 1878) and *Acinipe segurensis* (Bolívar, 1908) are sympatric and morphologically close species inhabiting the Southeastern Iberian Peninsula. Their general biology, as well as their population dynamics are practically unknown.

The emergence of two large populations of both species in Southeastern Spain has allowed studying their egg-pods and the egg structure for a better understanding of themselves and their population dynamics. The egg-pods come from populations of Albacete province. Both populations are monospecific, the adults being easily identifiable by morphology. The egg-pods were obtained from adults collected as nymphs and bred in laboratory. The egg-pods were studied under a binocular stereomicroscope provided with a micrometer, and the egg shell was studied using the usual scanning electron microscope (SEM) techniques.

A total of 150 egg-pods of *A. deceptoria* and 100 of *A. segurensis* were studied. Features of egg-pods and chorion of both species fit the general patterns of Pamphagidae species. As usual within

Pamphagidae (Uvarov, 1966), the chorionic sculpture in both species has a geometric

pattern: pentagonal or hexagonal cells with raised ridges which separate the cells. Nevertheless, the egg-pods have some peculiarities. Although their size is similar to that of *Kurtharzia sulcata* or *Eumigus templadoi*, species of also similar size, the number of eggs of the latter is much higher (80-90) than in the former species (15 as a mean). This number is also very much lower than in other Pamphagidae species that have a larger egg-pod. The egg number resembles to that of some species that have egg-pods absolutely different, i.e. *Prionotropis hystrix rhodanica* or *Asiotmethis muricatus*, but, while in *A. deceptoria* and *A. segurensis* they are elongate and more or less curved in the middle, the other egg-pods are almost spherical. Both in *A. deceptoria* and *A. segurensis*, the egg-pod has the bottom rounded and the top collapsed, lacking of an apical lid. The surface is covered by a hard layer of cemented sand grains. The fore third of the pod is occupied by a foam plug. The foaming secretion surrounds and extends into the basal part containing the eggs, forming lamellae between them and firmly holding them together.

**Reference:** Uvarov, B., 1966. *Grasshoppers and locusts. A handbook of general acridology*. Vol. 1. Cambridge University Press.

**Key Words:** *Acinipe segurensis*, *Acinipe deceptoria*, Pamphagidae, egg-pod structure, egg shell features.

## POSTER SESSIONS C

### Population Biology & Management



## Population Biology & Management

# IMPACT OF PESTICIDES USED TO CONTROL DESERT LOCUST ON THE GATHERING ACTIVITY OF WILD BEES ON FLOWERS OF ACACIA AT NIGER

Abdou Mamadou<sup>1</sup>, Ahmed Mazih<sup>2</sup> et Ali Doumma<sup>3</sup>

<sup>1</sup> Centre National de Lutte Antiacridienne, BP 2219, Niamey, Niger ; [abdoumamadou@yahoo.fr](mailto:abdoumamadou@yahoo.fr)

<sup>2</sup> Institut Agronomique et Vétérinaire Hassan II, Département de Phytiairie, BP 18/S, 80 000 Agadir, Maroc

<sup>3</sup> Faculté des Sciences, Université Abdou Moumouni, BP 10 662 Niamey, Niger, BP 10 662

The Desert locust (*Schistocerca gregaria* Forskal 1775) during recrudescence or invasion is an important problem to agriculture in a very large area extending from North Africa to the equator and from the Atlantic to South-West Asia through the Middle East. In the arid and semi-arid areas of Africa and Asia, locusts such as the Desert locust in invasion period, take an active part in the depredation of crops and grazing areas. The Desert locust, especially during periods of invasion, is treated as a national priority in the affected countries. For example, during the last invasion (2003-5), agricultural production in northern Niger was severely affected by invasion that was caused food insecurity. Many strategies were available to control Desert locust. In a period of remission, the control strategy is essentially based on monitoring permanent habitats. In recrudescence period, curative control is advocated, and it is done through the use of pesticides. These pesticides are not without risks to human health and the environment. A large number of publications dealing with the environmental side-effects of locust- control in (semi-) arid and (sub-) tropical environments have been done. Most of these studies were carried out in Africa and Australia; a few studies from North America and Central Asia were also carried. But they have any study carried out in Niger about the side effect of Desert locust control on wild bees, where are "beneficial" key species in the ecological processes. The impact

of chlorpyrifos ethyl (applied at a rate of 225 g a.i./ha) and fenitrothion (at 450 g a.i./ha), two insecticides commonly used to control desert locusts (*Schistocerca gregaria* Forskål), on the gathering activity of wild bees (*Amegilla* sp and *Ceratina* sp) on flowers of Acacia were assessed in Niger during July–December 2010. The wild bee's activity was significantly reduced with chlorpyrifos and fenitrothion compared with unsprayed control plots. The wild bee's activity was most affected 1 to 12 days (Interval I) after treatment and thereafter for a period II (16 to 24 days). The chlorpyrifos was the more toxic insecticide, leading to 88 % and 83 % reduction in gathering activities of wild bees during Intervals I and II, respectively. In period III post treatment (28-60 days), there was a small decline of the bees population in the treated plots; however, the population has weakly maintained in the control plots, especially with *Ceratina* sp and *Amegilla* sp, probably due to their behaviors. Desert locust control must be done strictly in accordance to the FAO guidelines to limit ecological damage to the savannah ecosystems already weakened by climatic and entropic constraints. Field trials in Niger with organophosphorus pesticides concluded that there were adverse impacts on wild bees, potentially beneficial to agriculture.

**Key Words:** desert locust control, chlorpyrifos ethyl, fenitrothion, impact, wild bees, Acacia flowers.



## Population Biology & Management

# SPATIAL UNCERTAINTY AND STRUCTURATION EFFECTS ON PREVENTIVE MANAGEMENT OF LOCUST PLAGUES: A MULTI-AGENT PERSPECTIVE

Pierre-Emmanuel Gay<sup>1</sup>, Michel Lecoq<sup>1</sup>, Cyril Piou<sup>1</sup>

<sup>1</sup> CIRAD, CBGP, Montpellier, France; [cyril.piou@cirad.fr](mailto:cyril.piou@cirad.fr)

CBGP, CIRAD, INRA, IRD, Montpellier SupAgro, Univ Montpellier, Montpellier, France

The spatial structure of locust outbreaks is a major item of planning and success of locust preventive management strategies. Indeed, preventive management relies on where and when survey teams have to be sent to explore and report the biotope situation and the potential locust population development in order to react in time to any upsurge. The spatial concentration of areas favourable to outbreak has been documented in many species. Other spatial limits are the areas where the preventive management fails to collect information, either because of insecurity or remoteness.

We explored these spatial specificities with the help of ALMMAS, a spatially explicit multi-agent system representing a typical preventive management system with 4 levels of agents: locusts moving randomly and causing intermittently outbreaks spatially localized, field teams conducting surveys and controlling locusts, a management centre hiring and funding the field teams, and a budget holder funding the management centre depending on its own perception of the risk. We simulated 1) some areas where field teams have a low access (only through a corridor), 2) some areas where field teams have no access at all and 3) some areas where the probability to observe initial outbreaks is concentrated in hotspots. We explored the effects of number and size of these areas on the proportion of plague times through series of 100-year simulations.

We observed that a strong effort of the budget holder to keep its funding through time might

be annihilated with only 5% of a spatial territory with a restricted access. Logically, we obtained also that the largest the areas without access are, the worse the proportion of plague years is. But interestingly, if these inaccessible areas are divided in several small spots, the plagues are more numerous than with only one equivalent inaccessible area. This is explainable through a border-effect, i.e. more kilometres of frontiers to control when there are several inaccessible areas instead of one.

The concentration of outbreaks in hotspots also increased the probability to observe plagues. Here too, the spatial distribution of only one hotspot was easier to control for the field teams than of several hotspots of identical size. But particularly, an interesting finding was that with only one hotspot, the period of cyclic behaviour of the budget holder between awareness and the reduction of funding was longer than with several smaller hotspots.

These results highlight the need to consider the spatial specificity and accessibility of each locust species when planning the sustainability of anti-locust management systems. The cyclic outbreaks of some locust species, despite the significant budgets in order to establish a preventive management system, may be related to these spatial specificities. Further studies should also focus on the effects of concentrating the attention of surveys in outbreak hotspots.

**Key Words:** multi-agent model, vicious circle, spatial heterogeneity, preventive management.



## Population Biology & Management

# FIRST RECORD OF *ASPERGILLUS ORYZAE* (HYPHOMYCETALES: MONILIACEAE) AS AN ENTOMOPATHOGENIC FUNGUS OF THE LOCUST, *LOCUSTA MIGRATORIA* (ORTHOPTERA: ACRIDIDAE)

Pengfei Zhang<sup>1</sup>, Yinwei You<sup>1,2</sup>, Yuan Song<sup>3</sup>, Youzhi Wang<sup>4</sup>, Long Zhang<sup>1\*</sup>

<sup>1</sup> College of Plant Protection, China Agricultural University, Beijing, China,\* locust@cau.edu.cn

<sup>2</sup> High-tech Research Center, Shandong Academy of Agricultural Sciences, Jinan, China.

<sup>3</sup> Department of Microbiology & Immunology, College of Biological Sciences, China Agricultural University, Beijing, China.

<sup>4</sup> Institute of Microbiology, Chinese Academy of Sciences, Beijing, China.

Plagues caused by *Locusta migratoria* have led to severe damage and great economic losses in both Asian and African countries. The negative side-effects of synthetic insecticides used in locust control stimulated interest in the development of biological control agents. A fungus was isolated from a dead *L. migratoria* collected from northwestern China that was pathogenic to the insect. This entomopathogenic fungus was named *Aspergillus* sp. XJ-1, since the preliminary identification indicated it belongs to the genus *Aspergillus*. A BLAST search of GenBank revealed a 99% similarity between its internal transcribed spacer (ITS) sequence and those of three species, *Aspergillus oryzae*, *Aspergillus flavus* and *Aspergillus parvisclerotigenus*, which are on the same branch of the *Flavi* section of the genus *Aspergillus*. Aflatoxin B1 detection demonstrated

that *Aspergillus* sp. XJ-1 is a non-aflatoxin B1 producer, unlike *A. parvisclerotigenus*. An analysis of morphological features also indicated that *Aspergillus* sp. XJ-1 belonged to section *Flavi* of genus *Aspergillus*, which corroborated the molecular identification. A morphological comparison of *Aspergillus* sp. XJ-1 with *A. oryzae* and *A. flavus* revealed that *Aspergillus* sp. XJ-1 belongs to *A. oryzae*. Its median lethal concentrations were  $3.31 \times 10^8$ ,  $1.72 \times 10^7$ ,  $7.24 \times 10^6$  and conidia/ml after 10, 13 and 15 days post-inoculation, respectively, according to bioassay results. This fungus may have biocontrol potential against locusts.

**Key Words:** *Aspergillus oryzae*; Locust; Pathogenicity; ITS rDNA region; Aflatoxin B1.



## Population Biology & Management

# ORTHOPTERA, THE MAIN ENTOMOLOGICAL PREY OF THE AVIAN SPECIES *CICONIA CICONIA* L., 1758 AND *BUBULCUS IBIS* L., 1758 IN THE EXTREME EAST OF ALGERIA

Linda Bouguessa- Cheriak<sup>1</sup>, Slim Bouguessa<sup>1</sup>

<sup>1</sup> Université de Tébessa, Tébessa, Algérie ; cheriaklinda2005@yahoo.fr

The region of Tébessa which is located in the extreme east of Algeria belongs to the great Algerian steppe known for its important livestock and for the cultivation of cereals. Orthoptera are among the most dangerous enemies of this type of culture and their damage is largely controlled by insectivorous birds such as the white stork and the Cattle egrets. The diversity of the Orthopteran stand, its phenology and its ecology are clearly known through the composition of the diet of these two species that are opportunistic.

The methodology consists in analyzing the rejection pellets of the two birds separately to remove the traces of Orthopteric prey in the form of fragments: mandibles, legs, heads, ovipositors, to determine and then to count them. The study took place between September 2015 and September 2016, it lasted seven months for the white stork (migratory species) and one year for Cattle egrets (sedentary species).

The results obtained revealed the presence of 2032 Orthopteric prey in the white stork diet (divided into five families: Gryllidae, Gryllotalpidae, Tettigoniidae, Acrididae and Pamphagidae), and 1917 prey in the Cattle egrets diet (four families only with the absence of Gryllotalpidae). v

The Acrididae dominate the diet of the two species with respectively 1427 individuals and 1490 specimen, corresponding to 70.22% and 77.72% of all orthopteric prey consumed in each species, followed by Pamphagidae (27.50%) in the diet of *Ciconia ciconia* and Gryllidae (15.33%) that of *Bubulcus ibis*.

The rest of the families are poorly consumed. *Bubulcus ibis* consumes 23 different species, dominated by *Aiolopus thalassinus* (116 individuals), followed by *Oedipoda miniata* (111 individuals), then *Gryllus bimaculatus* and *Acridella nasuta* with 98 and 96 individuals respectively, the other species are little consumed. *Ciconia ciconia* prey account 21 species of which three species are consume in priority: *Pamphagus marmoratus*, *Ailopus thalassinus* and *Oedipoda fuscocincta* with respectively 498, 494 and 471 individuals. The other species are weakly found. The maximum consumption of Orthoptera by *Bubulcus ibis* is noted during the months of August and March, and in July for *Ciconia ciconia*, corresponding to the phenological cycles of the species consumed.

**Key Words:** Orthopteran, prey, *Ciconia ciconia*, *Bubulcus ibis*, diet, Tébessa, Algeria.



## Population Biology & Management

# ORTHOPTERA PESTS OF CEREALS IN THE CONSTANTINE REGION, EASTERN ALGERIA

Imane Guerfi<sup>1</sup>, Naima Benkenana<sup>1</sup>, Chahinez Derrouiche<sup>1</sup>

<sup>1</sup> Laboratoire de Biosystématique et Ecologie des Arthropodes, Université Mentouri, Constantine, route d'Ain-El-Bey, 25000, Cons-tantine, Algérie; imenguerfi92@gmail.com, benkenanan@yahoo.com, chahinez\_25@hotmail.fr

Cereals (mainly durum wheat *Triticum turgidum* subsp. *durum* (Desf.) Husn. 1899) and soft wheat *Triticum aestivum* L. 1753) are strategic crops in Algeria since they are at the base of food security in the country. In the Constantine region, cereals occupy 51.5% of the agricultural area. A biosystematic study on the entomofauna of wheat (durum and soft) has been accomplished during the year 2018 in the station of the Technical Institute of Field Crops (ITGC of EL-Khroub, Constantine). Our investigations in this locality allow us to identify 102 insects belonging to 12 insect orders. The Orthoptera order is represented by four families and eight species: *Ocneridia volximii* (Bolivar, 1878), *Praehippiger pacygaster* (Lucas, 1849), *Dociostaurus marocanus* (Thunb, 1815), *Aiolopus thalassinus thalassinus* (Fabricius, 1781), *Aiolopus strepens* (Latreille, 1804), *Calliptamus barbarus barbarus* (O.G. Costa, 1836), *Pamphagus* sp and *Gryllus* sp.

The occurrence frequency of grasshopper species shows that *Ocneridia volximii* (family Pamphagidae) is the most abundant species with 60.52% followed by *Praehippiger pacygaster* (family Tettigoniidae) with 35.96%. The diet of these two species was studied by faeces analysis. The *O. volximii*'s alimentary regime is strictly based on Poaceae (durum and soft wheat) with an occurrence frequency of 100% both for males and females. While *Praehippiger pacygaster* consumes three different plants; Poaceae represent 75% of the diet of males and 50% of that of females.

The monitoring of Orthoptera species inventoried in the field shows that, during our study period (February to July 2018), *O. volximii* has two

generations, whereas the other species only have one generation.

In the present study, species of *Ocneridia volximii* and *Praehippiger pacygaster* were reported as important insect pests of cereals in the Constantine region.

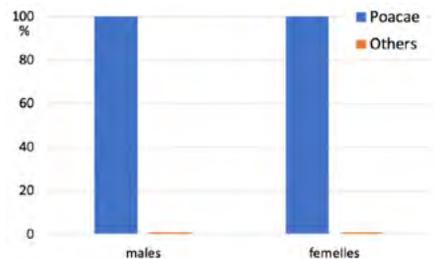


Figure 1. Frequency occurrence of plant tissues in feces of *Ocneridia volximii*.

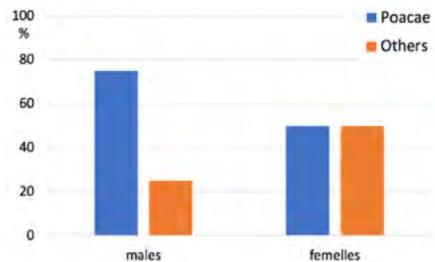


Figure 2. Frequency occurrence of plant tissues in feces of *Praehippiger pacygaster*.

**Key Words:** Orthoptera, Biosystematics, Constantine, Cereals, alimentary regime, Occurrence frequency, *Ocneridia volximii*.



## Population Biology & Management

# EVALUATION OF THE IMPACT OF LARGE SCALE BARRIER TREATMENT OF NOMOLT, (IGR'S, TEFLUBENZURON) ON BENEFIT NON-TARGET FAUNA IN THE SPRING BREEDING AREA OF DESERT LOCUST, MOROCCO.

Abdelghani Bouaichi<sup>1</sup>, Jamal Chihrane<sup>1</sup>, Lahcen Idrissi Raji<sup>1</sup>, Badreddine Elguennouni<sup>1</sup>, Mustapha Zoumthane<sup>1</sup>

<sup>1</sup> Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Maroc ; bouaichi.agadir@gmail.com

An evaluation of the impact of Nomolt (IGR's Teflubenzuron) on large-scale barrier treatment on benefit non-target species was conducted under natural conditions in Massa valley, considered as one of the Desert Locust breeding area during spring in Morocco.

The operational and large scale trial have strengthen the study to be conducted only on two experimental blocks, a treated one with an area of 2400 ha (4.9 x 4.9 km<sup>2</sup>) and the untreated one located at 6 km with a scale of 1000 ha. Totally seven barriers of 4.9 km longer and 700 m distant from each other, were sprayed with Nomolt 50 ULV using two Micronair AU 8115 mounted on vehicles at an average dose of 45.6 g.a.i./ha.

The impact on non-target fauna was evaluated on the basis of population densities by the method of foot transect of 10 m<sup>2</sup> and on the basis of the relative abundance of non-target species by trapping method using "Yellow Trap" and "Pitfall".

Among the orders of insects represented, Lepidoptera and Dipterans are the most abundant. Larvae and adult of the migratory caterpillar; *Vanessa cardui* or *Cynthia cardui*

have been extensively observed during transect. Pieridae (*Pieris spp*) and micro-Lepidoptera of the Tineidae family were captured using yellow Trappe. Dipterans represented by the families of Bombyliidae, Asilidea, Muscidae and Drosophilidea were abundantly caught by the yellow Trappe. Hymenopterans represented by the honeybee, *Apis mellifera*, ants of the genus *Formica* and Sphecidae were taken into account. Beetles represented by two families of Meloidae and Tenebrionidae have been also considered.

Under the present conditions, large scale barrier treatment with Nomolt 50 ULV (IGR's Teflubenzuron) has covered only one to seven of the entire treated area and hence have caused no significant effect on non-target fauna in the study area. These results are in agreement with the fact that Insect Growth Regulators IGR's overall, are known for their selectivity among the stadium of benefit arthropods and have little or no impact on pollinators, predators and arachnids.

**Key Words:** Teflubenzuron, Insect Growth Regulator, impact, side effect, non-target fauna, barrier treatment.



## Population Biology & Management

# EVALUATION OF THE IMPACT OF TWO DOSES OF *METARIZHIUM ACRIDUM* (NOVACRID®) 25 and 50 g CONIDIA / HECTARE ON HOPPERS OF DESERT LOCUST *SCHISTOCERCA GREGARIA* UNDER SEMI-FIELD AND SEMI-CONTROLLED CONDITIONS AT SOUSS-MASSA PARK IN AGADIR; MOROCCO

Abdelghani Bouaichi<sup>1</sup>, Abdellah El Mouden<sup>1</sup>

<sup>1</sup>Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Maroc ; bouaichi.agadir@gmail.com

AExperimentation of a new isolate EVCH077 from *Metarhizium acridum*, registered under the trade name of NOVACRID®, based on a concentration of  $5 \times 10^{10}$  CFU / g dry conidia in a powder formulation was performed under the semi-field and semi-controlled conditions at the Sous-Massa Park in Agadir, Morocco.

Two doses of 25 and 50 g conidia / hectare were assessed in two plots of one hectare each under the same conditions of application according to the technique of Ultra-Low Volume (ULV) on the 4th instar of Desert Locust hoppers issued from breeding in the National Centre for Locust Control. The monitoring of mortalities was carried out over three weeks in exposed cages (semi-field conditions) or under cover (semi-controlled conditions) of solar rays at the rate of 10 larvae per cage conducted in three repetitions. The non-treated hoppers were located upstream of the treatment to avoid any sort of contamination.

The first effect of NOVACRID® applied at a dose of 25 g and 50 g conidia / hectare after treatment appear respectively on the 10th and 12th day after treatment. In terms of biological efficacy, the  $LT_{50}$  is reached at the 12<sup>th</sup> and 14<sup>th</sup> day respectively for the dose of 25 and 50 g conidia / hectare while the  $LT_{90}$  is achieved for the two doses on the 20th day. Overall, the two doses of 25 and 50 g conidia / hectare of NOVACRID® show the same toxic effects. The only difference lies in the maintenance

conditions of the treated hoppers either in semi-field or semi-controlled conditions. This difference is probably endorsed to the effects of Ultraviolet radiation on the spores of *Metarhizium acridum*, which affect their viability.

In conclusion, the isolate EVCH077 of NOVACRID® based on *Metarhizium acridum* seems to have toxic effects similar to the old strain known as GREEN MUSCLE®. In terms of efficiency and cost, NOVACRID® applied at 25 g conidia / hectare seems appropriate for locust control as part of a preventive control strategy in harmony with the required safety standards.



Figure 1. Treated hoppers by *Metarhizium acridum*

**Key Words:** Biopesticide, *Metarhizium acridum*, NOVACRID®, Desert locust, *Schistocerca gregaria*, dose-effect, semi-field condition.

## Population Biology & Management

# A METHOD FOR PREDICTING GRASSHOPPER INFESTATIONS IN UTAH

*Linden Greenhalgh<sup>1</sup>, Larry Jech<sup>2</sup>, Matthew Yost<sup>3</sup>*

<sup>1</sup> *Utah State University, Tooele, Utah, USA; linden.greenhalgh@usu.edu*

<sup>2</sup> *USDA, APHIS, PPQ, CPHST, Phoenix, Arizona, USA*

<sup>3</sup> *Utah State University, Logan, Utah, USA*

Our objective is to develop a reliable method to forecast future grasshopper population density. We are currently analysing 16 years of Utah grasshopper and weather data to see if a relationship exists between grasshopper density and precipitation and high and low temperatures.

We will use grasshopper density counts from multiple counties in Utah for all available years (2002-2017). This data has been accumulated by the United States Department of Agriculture Animal Plant Health Inspection Service (USDA-APHIS) and made available to us for analysis. We will use precipitation and maximum and minimum temperature data from Utah State University's Utah Climate Center.

Our proposed method uses an iterative multivariate analysis based on daily high and low temperature and precipitation.

The calendar starts in August. The iterative interval lasts 21 days (first interval 1 August through 21 August and centers on 10 August). The interval advances seven days and drops seven days and the calculation is performed again; this continues through 52 more iterations.

Being able to predict grasshopper infestations would enable entomologists, farmers, land managers and others to better prepare for and mitigate large outbreaks and the damage they cause. We are working to develop a straightforward procedure that will apply to all areas of Utah as well as other western states.

**Key Words:** Grasshoppers, Weather, Temperature, Prediction Infestations, Method, Utah.

## Population Biology & Management

# A NOVEL BIO-PESTICIDE TO CONTROL LOCUST OUTBREAKS

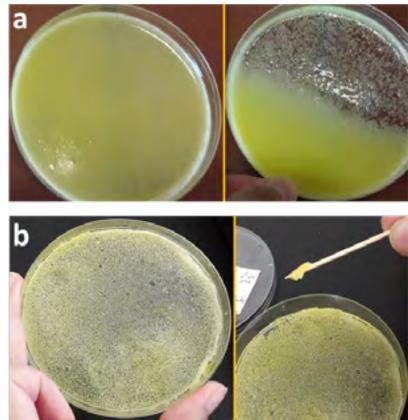
Manfred Hartbauer<sup>1</sup>, Zainab Ali Saad Abdelatti<sup>1,2</sup>

<sup>1</sup> Institute of Biology, University of Graz, Universitätsplatz 2, 8010 Graz, Austria; manfred.hartbauer@uni-graz.at

<sup>2</sup> Department of Zoology, Faculty of Science, South Valley University, 83523 Qena, Egypt.

For thousands of years, large locust swarms have been responsible for severe problems in agriculture. People fight against current outbreaks by using chemical pesticides or an insect fungus known as Green Muscle™. While chemical pesticides may be harmful for humans and non-target species, the sporulation of the fungus takes a long period of time and requires conditions of high humidity that are not always found in those areas where locust outbreaks are common. In our study, we tested the toxicity of linseed oil against locusts and screened for plant essential oils that harm locusts but do not affect mealworm beetles (non-target species). First, we assessed the hardening process of the linseed/ bicarbonate emulsion (56:44 % (v/v)) in a petri dish for one day (Fig. 1). The intention was to coat the locusts with a thin layer of linseed oil that was difficult for the insect to remove. We then combined effective essential oils to develop a formulation that killed two gregarious locust species as a result of a single aerosol treatment. Fumigant toxicity tests performed with two locust species (desert locust *Schistocerca gregaria* and migratory locust *Locusta migratoria*) revealed the moderate toxic effect of the linseed emulsion. In these screening tests we also revealed a synergistic, toxic effect resulting from the combination of several essential oils with the linseed emulsion. Our novel formulation resulted in a desert locust mortality of 90% and a migratory locust mortality of 100% within 30 hours. Interestingly, locusts immediately stopped feeding after contact with this oil emulsion.

Despite their small body size, mealworm beetles did not suffer from the same treatment and were still alive after eighteen days. In addition, spraying this oil mixture on wheat seedlings did not delay their growth. Overall, these results suggest that this oil formulation has a specific, toxic effect on desert and migratory locusts and represents a novel bio-pesticide. Therefore, the University of Graz disclosed our bio-pesticide formulation as a European patent.



**Figure 1.** Hardening of the bio-pesticide emulsion. (a) Emulsion after mixing linseed oil and bicarbonate solution. (b) The emulsion after 24 hours.

**Key Words:** Locust swarms, linseed oil, essential oils, mealworm beetles, pest management, bio-pesticide.

## Population Biology & Management

# HOW DO GRASSHOPPER OUTBREAKS DEVELOP? COMPARING COMMON DATA SITES AND GENERAL SURVEY IN WYOMING

Larry Jech<sup>1</sup>, Derek Woller<sup>1</sup>, Kathleen King<sup>2</sup>

<sup>1</sup> USDA APHIS PPQ CPHST, Phoenix Arizona, USA

<sup>2</sup> USDA APHIS PPQ Cheyenne Wyoming, USA; Kathleen.M.King@aphis.usda.gov

Grasshopper survey, in one form or another, has been conducted in Wyoming U.S.A. since the 1930s. Most of this survey work was general coverage of the state and sometimes returning to areas where grasshoppers or Mormon crickets (Tettigoniidae: *Anabrus simplex*) were a known potential problem. In 1988, permanent survey sites were established in Wyoming, Montana, North Dakota and South Dakota. The purpose of this permanent site survey data was to produce a predictive model for grasshopper development based on climatic zones and also determine changes in species composition.

In 1992, these sites were changed to Common Data Set (CDS) sites and the total number across Wyoming increased from 13 to 223. CDS sites are permanent, predetermined sites that are visited at least once each season and the purpose of the new CDS site survey was part of a regional proposal for grasshopper survey. The CDS survey enabled the application of GIS and modeling technology across the 17 western grasshopper states and supported the population forecasting and decision making required by the APHIS grasshopper Management Program for planning, budgeting, and communicating.

The total number of CDS sites are approximately 10% of what is routinely surveyed in the random 5-mile grid throughout Wyoming's survey area. In Wyoming, these sites are visited during adult grasshopper survey (from July to August) and a collection is always taken for species identification. CDS sites provide historical data on species composition and population densities. Program managers often try to locate these sites in places that represent conditions across their areas of supervision. Over the course of time it may be necessary to add and delete sites from a state's inventory. Surveyors record grasshopper density data as well as species composition data at each site. If surveyors are not qualified to identify

species in the field, a collection is made at each site.

During low grasshopper population years the density of grasshoppers at CDS sites match those at general survey sites across the 5-mile grid. Overall, most sites will have low grasshopper densities. However, as populations increase over several years, the densities at CDS sites may no longer match those at general survey sites. Increased densities at CDS sites may indicate large areas of high densities or outbreaks while general survey sites might show small, localized outbreaks or hot spots, and vice versa. The frequency of zero or low densities would become less as outbreak conditions increase. Generally, it takes several years for a widespread outbreak to occur. Therefore, comparing CDS sites to general survey sites in each Wyoming country will reveal if increasing populations of grasshoppers are in synchrony or if they are going up and down separately across large regions of the state.

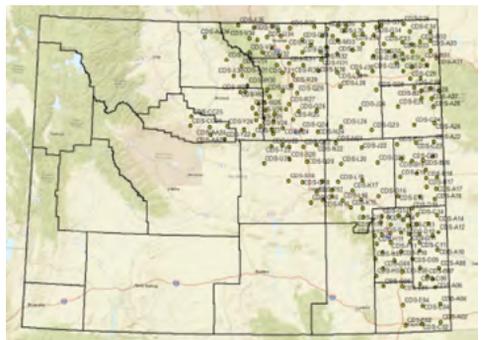


Figure 1. CDS Site Locations in Wyoming.

**Key Words:** Wyoming, grasshopper, outbreak, common data set, APHIS, survey.



## Population Biology & Management

# STUDY OF THE EFFECTS OF VOLATILE SUBSTANCES, FLAVONOIDS, SAPONINS OF ARGANIA SPINOSA LEAVES ON FEEDING BEHAVIOUR OF THE DESERT LOCUST (*SCHISTOCERCA GREGARIA* FORSKÅL, 1775) UNDER LABORATORY CONDITIONS

Aïcha Laadel<sup>1</sup>, Lalla Mina Idrissi-Hassani<sup>2</sup>, Jamal Chihrane<sup>3</sup>, Abdelghani Bouaïchi<sup>4</sup>, Saïd Ghaout<sup>5</sup>, Mohamed Sarehane<sup>6</sup>

<sup>1,3,4,5</sup> Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Maroc ;

aichalaadel@gmail.com

<sup>2</sup> Université Ibn Zohr, Faculté des Sciences, Agadir, Maroc

<sup>6</sup> Institut Agronomique et Vétérinaire Hassan II, Département de Phytatrie, Agadir, Maroc

To control the invasions of the desert locust while having the least negative impact on the environment, various methods can be used including the use of the extracts of plants. This botanical fight can offer a viable alternative to the chemical means. This work is based on preceding studies in which the biological potentialities of the Argan tree was demonstrated.

The present study will address issues raised during the first research on the effect of the volatile substances, dry extracts and saponins and flavonoids of this tree in the south of Morocco on the feeding behaviour of the desert locust.

The effects of the volatile substances and the dry leaves of Argan were tested under the conditions of the laboratory on the fourth stage hoppers and young adults of desert locust.

In light of the results for the behaviour of food intake of fourth-stage larvae placed in an olfactometer in presence of the fresh leaves of Argan, it proved that these leaves have an anti-feeding effect.

The study of the biological potentialities of the desert locust reared under a regime based on the dry leaves of the Argan tree found in 4th larval instar, a daily intake of food, and a decrease of

weight around 44,1 mg, follow-up of an important mortality which reached 79,1% on the last day. This was confirmed by the low

indices of digestibility and efficiency of conversion of digested food.

The same effects were observed at the treated adults which delayed sexual maturity and resulted in females, a blockage of ovarian development.

The results obtained for the extract of saponins and flavonoids (wheat bran pellets soaked at a dose of 50 g/l), showed that the extract of flavonoids caused a decrease of weight, a decrease of the daily intake of food (40 mg  $\pm$  6) compared to controls (62 mg  $\pm$  2) with a high rate of mortality. This last has also been recorded from these treated hoppers.

Based on the results, leaves of Argan tree and secondary substances that they contain, may present a solution for an alternative to control by chemical means preventive measure to fight against the desert locust without ecological damage.

**Key Words:** Desert locust, *Argania spinosa*, plant-locust relationship, volatile substances, anti-palatability.



## Population Biology & Management

# CAPACITIES OF ADULT LOCUST MOVEMENTS UNDER THE EFFECT OF SIMULATIONS SIMULATING PREDATORS

Lazraq Abderrahim<sup>1</sup>, Errabhi Nabil<sup>1</sup>, Zahri Aziz<sup>1</sup>, Chater Oumaima<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>

<sup>1</sup>Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez.abderrahim.lazraq@usmba.ac.ma

The study of the ability of adult locusts to move with four types of stimuli shows that they are relatively more important in males than females and that sexual dimorphism appears to be of great importance in the mobility of these insects. Individuals who are able to make important jumps are those who travel the greatest distances and persist more in the ground.

In addition, those who show low activity against stimuli simulating predators would be less able to escape their enemies.

**Key Words:** locusts, ability to move, jump, stimuli, predators.



## Population Biology & Management

# PECULIARITIES OF LONG-TERM POPULATION DYNAMICS OF THE ITALIAN LOCUST *CALLIPTAMUS ITALICUS* (ACRIDOIDEA) IN THE NORTHERN AND CENTRAL PARTS OF THE KULUNDA STEPPE (SOUTH SIBERIA)

Michael. G. Sergeev<sup>1,2</sup>, Kristina V. Popova<sup>1</sup>, Irina A. Vanjkova<sup>1</sup>, Oxana V. Efremova<sup>1</sup>

<sup>1</sup> Novosibirsk State University, Novosibirsk, Russia; mgs@fen.nsu.ru, mgsergeev@aol.com

<sup>2</sup> Institute of Systematics and Ecology of Animals, Novosibirsk, Russia

The Italian locust is the widely distributed and the most important pest in the steppes and semi-deserts of Eurasia, from the Ukraine to the southern part of West Siberia and Xinjiang. Many of its outbreaks were described for the southeastern part of West Siberia from 1922 until the beginning of the 21st century. The situation became especially serious in the end of the last century. The huge outbreak of the Italian locust in 1999–2002 was determined by both, climatic fluctuations and significant changes in political, economic and social life in the former USSR countries.

The Kulunda steppe is the easternmost part of the steppes of South Europe and Kazakhstan. It is located in the southeastern part of West Siberian Plain between the Ob and Irtysh Rivers. The long-term dynamics of populations of the Italian locust was studied on two model plots: (1) in the northern, meadows steppe near Aleksandrovskiy Village (Novosibirsk Region) and (2) in the dry steppe near the Ust-Volchiha Village (Altay Region). On both plots the average density (insects per square meter) of the Italian locust has varied significantly year by year ("+" – extremely low abundance):

In the meadow steppe, the maximal abundance has been observed in 2000. It has decreased abruptly during two following years, especially in 2002 when summer has been rainy and cold. After that, only scarce colonies with relatively low abundance might be observed. In the dry steppe, the maximal densities have been in 2001, 2002 and 2015. In 2000, 2003–2008 and 2018 some rare colonies with relatively low abundance have been found. Hence, the population dynamics of the Italian locust on two model plots are quite different. This distinction may be determined by general difference in environmental conditions between the northern and central parts of the Kulunda steppe, however, we could not find significant correlations of populations dynamics and main climatic variables, except with monthly precipitation in June (Spearman's rank correlation). We also found no correlations between density of the Italian locust and abundance of blister beetles. Our data show that, in any case, scarce populations of the Italian locust continue to exist constantly in the Kulunda steppe. This means in favourable environmental conditions, these populations may grow and new outbreak may begin in the region.

These studies were financially supported by the joint programme of the Russian Foundation for Basic Researches and the Government of Novosibirsk Region (18-416-540001) and the Federal Fundamental Scientific Research Programme for 2013–2020 (No. AAAA-A16-116121410123-1).

**Key Words:** Acrididae, Italian locust, West Siberia, Kulunda Steppe, population, dynamics.

	Meadow steppe	Dry steppe
2000	21.8	0.5
2001	2.8	1.6
2002	0	1.9
2003	0	+
2004	0.3	0.3
2005	0.3	+
2006	+	0.2
2007	0.3	+
2008	0.5	0
2015	+	1.3
2018	+	0.3

## Population Biology & Management

# FUTURE CLIMATE CHANGE LIKELY TO REDUCE AUSTRALIAN PLAGUE LOCUST (*CHORTOICETES TERMINIFERA*) SEASONAL OUTBREAKS

Bin Wang<sup>1</sup>, Douglas Lawton<sup>2</sup>, Cathy Waters<sup>3</sup>, Edward D. Deveson<sup>4</sup>, Puyu Feng<sup>1,5</sup>, De Li Liu<sup>1,6</sup>

<sup>1</sup>NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, NSW 2650, Australia

<sup>2</sup>School of Life Sciences, Arizona State University, Tempe, AZ 85287, USA; ddlawton@asu.edu

<sup>3</sup>NSW Department of Primary Industries, Orange Agricultural Institute, NSW 2800, Australia

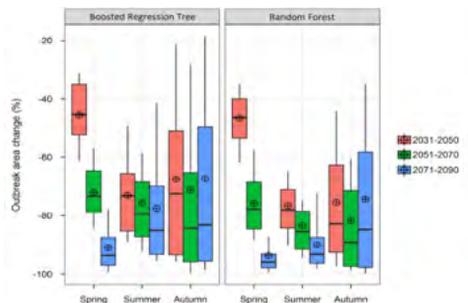
<sup>4</sup>Australian Plague Locust Commission, Australian Government Department of Agriculture, Fisheries and Forestry, GPO Box 858, Canberra, ACT 2601, Australia

<sup>5</sup>School of Life Sciences, Faculty of Science, University of Technology Sydney, PO Box 123, Broadway, Sydney, NSW 2007, Australia

<sup>6</sup>Climate Change Research Centre and ARC Centre of Excellence for Climate Extremes, University of New South Wales, Sydney, NSW 2052, Australia

Climate is a major driver of pest distribution and it is expected that changing climate will alter historic patterns of pest outbreaks. The Australian plague locust (*Chortoicetes terminifera*; APL) is the most economically important locust species in Australia. Understanding its large-scale and long-term dynamics is a prerequisite to develop effective control and preventive management strategies to mitigate damage for crops and pastures. We used a 32-year locust survey data set to identify relationships between climate and spatiotemporal dynamics of seasonal outbreaks and develop species distribution models (SDMs). These models were then projected into a future climate change scenario (RCP8.5) using 34 global climate models (GCMs) to assess how climate change may alter APL specific distribution patterns in eastern Australia. Our results show that two SDMs predicted the spatial distribution of APL outbreak well based on the evaluation criteria. Overall, the model performed better for spring outbreaks than summer and autumn. We ranked the importance of explanatory variables and demonstrated the partial effect of two most importance variables on the spatial distribution of APL outbreak. Spring outbreaks are mainly influenced by precipitation seasonality and mean temperature of coldest quarter. Summer outbreaks are mainly influenced by mean temperature of driest quarter and mean diurnal range. Autumn outbreaks were mainly influenced by high rainfall in the driest quarter and high temperature. Our modelling predicted that APL outbreak areas are likely to decrease regardless of seasons due to changing climate. Multi-GCMs ensemble means showed that the

largest decrease of outbreak areas was in spring (93-94% by 2081-2090). The spatial distribution of future APL outbreaks presented different season-specific patterns. Our selected bioclimatic variables explained 78-98% of outbreak area change. This study represents an important step towards the assessment of the effects of changing climate on a locust species outbreaks and can help inform future priorities for regional mitigation effort in the context of climate change.



**Figure 1.** Projected changes in suitable climatic areas for Australian plague locust outbreaks for three seasons under the RCP8.5 scenario based on two models.

**Key Words:** Australian plague locust, bioclimatic variables, global climate models, species distribution models, outbreak areas.

## Population Biology & Management

# LOCUST AND GRASSHOPPER PREVENTIVE MANAGEMENT

Long Zhang<sup>1</sup>, Michel Lecoq<sup>2</sup>, Alexandre Latchininsky<sup>3</sup>, David Hunter<sup>4</sup>

<sup>1</sup> China Agricultural University, Beijing 100193, China; email: locust@cau.edu.cn

<sup>2</sup> CIRAD, 34398 Montpellier Cedex 5, France

<sup>3</sup> University of Wyoming, Laramie, Wyoming 82071, USA & Food and Agriculture Organization of the UN, 00153 Rome, Italy

<sup>4</sup> Orthopterists' Society, McKellar, ACT 2617, Australia

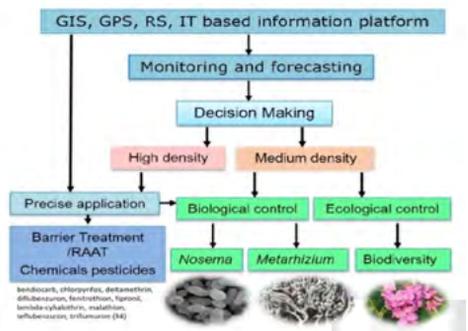
Locusts and grasshoppers (Orthoptera: Acridoidea) are among the most dangerous agricultural pests. Their control is critical to food security worldwide and often requires governmental or international involvement. Although acridid outbreaks are now better controlled and often shorter in duration and reduced in extent, large outbreaks, often promoted by climate change, continue to occur in many parts of the world. While some locust and grasshopper control systems are still curative, the recognition of the damage these pests can cause and the socioeconomic consequences of locust and grasshopper outbreaks have led to an increasing paradigm shift from crop protection to preventive management. Effective preventive management strategy relies on an improved knowledge of the pest biology and ecology and more efficient monitoring and control techniques.

**Reference:** Zhang L., Lecoq M., Latchininsky A., Hunter D., 2019. Locust and grasshopper management. Annual Review of Entomology 64 (1):15-34.



**Figure 1.** Locust (*Locusta migratoria*) swarm migrating over rangeland during August 2011 in Southern Russia (photo I. Latchininskaia).

### Current Preventive Locust Management System



**Figure 2.** Schematic diagram of current preventive locust management system. Locust population density is forecasted and monitored using the information platform that is built with high technologies, such as global position system, remote sensing, geographic information system, and computer science. With this platform, people make decisions for control according to the locust densities. Chemical control may be implemented when locust density is high, and the control action is recommended to perform the barrier treatment where pesticide is sprayed in strips 300–500 m apart by aircraft flying in rangeland or reduced agent and area treatments (RAATs). When locust density is medium, a recommendation is made to implement biological control, such as using *Nosema* (protozoan microbial control agent) and *Metarhizium* (fungal microbial control agent), and ecological control, such as an increase of biodiversity in the locust habitat. The control action can be well timed with the information platform and global positioning system (GPS) navigation. Additional abbreviations: GIS, geographic information system; IT, information technology; RS, remote sense technology.

**Key Words:** Locust, grasshopper, preventive control, pest management.



## Population Biology & Management

# WHAT COMMUNICATION STRATEGY TO MAINTAIN THE COMMITMENT FOR A PREVENTIVE CONTROL OF THE DESERT LOCUST IN MALI?

*Fakaba Diakite*<sup>1</sup>

<sup>1</sup>CNLCPP, Bamako, Mali; diakitfakab@gmail.com

The Desert Locust is a transboundary pest of major importance for all affected countries covering large desert areas; from the Sahel countries to South-West Asia and the Near East, occupied by ethnic groups of various origins and cultures suffering from insufficient financial resources, but trying by all ways to remain in solidarity against this major pest and share a common responsibility for preventing and responding to plagues as they cannot effectively fight the Desert Locust individually.

Also, these areas are sometimes plunged into recurrent insecurity because of political claims or expansions of terrorist networks. In the western region, this state of affairs concerns today mainly Mali.

A contingency plan exists with an institution dedicated exclusively to the fight against this pest, with an operating budget, specialized personnel as well as different materials and equipment. Nevertheless, weariness in the face of prolonged recession had won the spirits even though the reduction of locust plague should be seen as a success of the preventive control strategy. The relevance of a strategic investment in the Desert Locust was constantly questioned and the commitment started to take off. If nothing had been done urgently, there could be a decrease in the budget allocated to the Desert Locust preventive control strategy, a degradation of the motivation of the locust officers and the national partners. The recent national effort to link Desert Locust control to the Plant Protection Service is a good illustration of this assertion.

Fortunately, a major communication campaign was initiated by the National Desert Locust Control

Center, which was supported by the FAO

Desert Locust Control Commission in the Western Region (CLCPRO) and FAO. In addition, the advocacy role of CLCPRO has been crucial in the payment of the contributions to the Trust Fund of the commission and the Regional Locust Risk Management Fund (FRGRA), a guarantee of the success of preventive control against the Desert. The purpose of this contribution is to stimulate reflection on the sustainability of Desert Locust control institutions in the face of prolonged recession of this major pest. To this end, following the experience of Mali, which advocates for all the countries concerned, the adoption of a national strategy of institutional communication in order to constantly remind the importance of preventive control strategy and to share the achievements of the regional management system. In this fight, the role of the CLCPRO is important. For this, a plan of actions of advocacy and sensitization of the Secretariat of the CLCPRO towards the authorities of the different CLCPRO's member States must be continued. In addition, the development of cross-border joint survey program should be encouraged. However, it must be supported by a more ambitious institutional communication scheme both in the countries where these operations are carried out and in the participating countries.

**Key Words:** Desert Locust, Preventive control strategy, Organization, Remission, Mali.



## Population Biology & Management

# BARRIER SPRAYING METHOD WITH THE FUNGUS *METARHIZIUM ACRIDUM* : EXPERIMENTAL EXPOSITION OF DESERT LOCUST NYMPHS TO TREATED VEGETATION

Mohamed Etheimine<sup>1</sup>, Sid'Ahmed Mohamed<sup>2</sup>, Adama Barry<sup>3</sup>, Wim C. Mullié<sup>4</sup>

<sup>1</sup> Desert locust control centre, Nouakchott, Mauritania ; mohamed.atheimine@gmail.com

<sup>2</sup> Desert locust control centre, Nouakchott, Mauritania ; sidmd2002@yahoo.fr

<sup>3</sup> Desert locust control centre, Nouakchott, Mauritania ; fcbreeding10@gmail.com

<sup>4</sup> Fondation Agir pour l'éducation et la santé ; wim\_sen@yahoo.fr

In natural conditions, the secondary pick-up of *Metarhizium acridum* conidia from treated vegetation is considered as the major mode of exposure of target locust. Thus, barrier spraying method presents a new option to reduce the control cost and to protect better the environment. Barrier spray method consists of protecting a large area by spraying barriers along the infested zone. A field trial was conducted using *M. acridum* with the aim to evaluate the efficacy of this method with *M. acridum* against Desert locust nymphs. Collected later instars (L4 - L5) of gregarious Desert locust nymphs were used because the lack of suitable nymph bands during the study period at the experimental field. Nymphs were exposed to contaminated vegetation (barriers) by keeping them in mosquito net cages (60 x 60 x 60 cm). These cages were placed along the barrier width at distances of 15, 25, 40 and 70 m away from the pass of treatment. Nymphs were removed from these cages for monitoring after 6 h and 24 h of exposure to contaminated vegetation.

After 24 h, remained nymphs were transferred to new cages placed in a new barrier to simulate nymphs' displacement from barrier to another and

were kept in cages for 24 h, i.e. 48 h of exposure.

The mortality after 6 and 24 h of exposure was 64 to 85 % and 72 to 88 %, respectively, with 23 to 41 % and 27 to 35 % of sporulated cadavers. The mortality after 48h exposure reached 77 to 97 % with 37 to 97 % of sporulated cadavers. In general, the mortality was higher after 48 h of exposure to the contaminated vegetation in the first 40 m away from the treatment path. Barrier spraying with the fungus *M. acridum* is feasible in Desert locust management. However, for better efficacy, nymphs must cross at least two barriers or stay in contact with contaminate vegetation for 48h. Spraying real nymph bands is recommended to determine under which conditions this technique is more likely to succeed.

**Key Words:** *Metarhizium acridum*, Desert locust, barrier spraying, nymphal bands, treated vegetation, conidial persistence.



## Population Biology & Management

# EPIZOOTICS OF THE ENTOMOPATHOGENIC FUNGUS, ENTOMOPHAGA GRYLLI (ENTOMOPHTHORALES: ENTOMOPHTHORACEAE), IN A GRASSHOPPER POPULATION IN NORTHWEST CHINA

Liwei Zhang<sup>1</sup>, Pengfei Zhang<sup>2</sup>, Long Zhang<sup>1\*</sup>

<sup>1</sup> China Agricultural University, Beijing, China; \*locust@cau.edu.cn

<sup>2</sup> Xingtai University, Xingtai, China

Plagues caused by locusts and grasshoppers have led to severe crop damage and great economic loss in many countries. Nevertheless, populations of these pests are often suppressed by naturally occurring predators and disease. Among such natural control factors, the entomopathogenic fungus, *Entomophaga grylli*, can markedly disrupt the dynamics of grasshopper populations. However, there are few reports of epizootics of this entomopathogenic fungus occurring in consecutive years. Here we report on a consecutive 2-year field survey of *E. grylli* epizootics in Xinjiang, Northwest China. *E. grylli* were observed to infect at least four species of grasshopper, *Calliptamus italicus*, *Gomphocerus sibiricus*, *Chorthippus* sp., and *Stauroderus*.

This is the first record of infection of the last two species by this pathogen. The highest infection rates at the two study sites (Chonghuer and

Jiadengyu, Altay Prefecture) were  $\geq 50\%$ , observed in mid-July 2011, and the lowest rate was  $>16\%$  in early summer. The density of infected grasshoppers was positively correlated with the density of total grasshoppers collected ( $r = 0.981$ ). Therefore, *E. grylli* is an important natural factor regulating the dynamics of grasshopper populations in regions that are not subjected to artificial treatment.

**Key Words:** *Entomophaga grylli*; grasshopper; epizootic; infection; survey.





## Biodiversity, Biogeography & Ecology

# ENDEMISM IN ITALIAN ORTHOPTERA

Bruno Massa<sup>1</sup>, Paolo Fontana<sup>2</sup>

<sup>1</sup> Department of Agricultural, Food and Forest Sciences, University of Palermo, Italy; [bruno.massa@unipa.it](mailto:bruno.massa@unipa.it)

<sup>2</sup> Fondazione Edmund Mach, San Michele all'Adige (Trento), Italy

In Europe the endemism proportion in Orthoptera is generally high; in Italy, according to the most recent contribution to the Italian Orthoptera, overall 144/380 (37.9%) Italian taxa are endemic. The present authors discuss the list of 144 endemic Italian taxa, highlighting the existence of biodiversity 'hot spots' in the Italian Apennines and islands. Most of them are taxa linked to central mountainous systems along the Italian peninsula (Apennines), and isolated on the islands of Sardinia and Sicily; a number of species very probably of trans-Ionian origin gave rise to endemic taxa in different areas of South Italy (not Apennines).

The authors consider endemic those taxa, whose distribution is limited to a geographically distinct and localized territory. Generally the geographic endemic area is considered not larger than 50,000 km<sup>2</sup> (spot-like endemism). To Italian grasshoppers and locusts may apply also the Endemic Bird Area (EBA) proposed for the birds, that is an area holding two or more restricted range species (= with a range covering less than 50,000 Km<sup>2</sup>).

The Italian territory has been divided into main mountainous areas, Alps and Apennines, Sicily and Sardinia. When more than one subspecies was present in the regions, only one taxon was considered. The proportion of endemism was calculated as follows: % endemism = endemic taxa/total number of taxa in the concerned area \* 100, where the % endemism was calculated for each of the above listed areas, endemic taxa of these areas were obtained from available bibliography.

The particular shape of the Italian peninsula has been the subject of biogeographical interest by different authors, mainly concerning the North-South gradient of impoverishment. Italian Peninsula, different from other peninsulas has two separated

tips, one in Apulia and another in Calabria, with very different landscapes and altitudes. This probably contributes to the increase taxonomical diversity. Nevertheless, authors have highlighted that the peninsular effect and related patterns and processes are strongly linked to selected contexts, scales, ecological and taxonomic levels. The case of the Orthoptera is particularly interesting because this order includes species with very different dispersal power, due to their characters (presence/absence of wings, need of peculiar habitats/altitudes, higher or lower thermophily, relations with vegetation structure, etc).

Generally they may be considered allopatric subpopulations, maintained by spatial segregation, that share i) a unique geographic range or habitat, ii) a group of phylogenetically concordant array of phenotypic and genetic characters, iii) a unique natural history relative to other subdivisions of the species, (still) genetically compatible with other subpopulations. Of course, island populations do not have a gene-flow with continental populations, and consequently we could expect that they diverge in isolation; therefore, island populations will diverge at a faster rate than continental ones. We consider that the origin of these taxa is mainly due to a more or less old isolation, which in different times of the biogeographical history separated populations that for a longtime were not able to mix. Thus, high mountains (Alps, Apennines and other isolated reliefs) and islands, have contributed considerably to the endemism proportion in the Italian Orthoptera.

**Key Words:** Teflubenzuron, Insect Growth Regulator, impact, side effect, non-target fauna, barrier treatment.



## Biodiversity, Biogeography & Ecology

# CURRENT STATUS AND HABITAT REQUIREMENTS OF KEELED PLUMP BUSH-CRICKET (*ISOPHYA COSTATA*, BRUNNER VON WATTENWYL, 1878) IN THE AUSTRIAN-SLOVAK BORDER AREA: PRELIMINARY RESULTS

Soňa Nuhličková<sup>1</sup>, Thomas Zuna-Kratky<sup>2</sup>, Ján Svetlík<sup>3</sup>

<sup>1</sup> Comenius University, Faculty of Natural Sciences, Department of Ecology, Bratislava, Slovakia; sona.nuhlickova@uniba.sk

<sup>2</sup> Lange Gasse 58/20, Vienna, Austria

<sup>3</sup> Comenius University, Faculty of Natural Sciences, Department of Zoology, Bratislava, Slovakia

Peripheral populations may be of particular conservation concern, especially when they suffer an elevated risk of extinction, possess low genetic variation and thus could be genetically divergent from core populations. For example, in comparison with core populations, peripheral populations are typically characterized as being less abundant and could react more sensitive to habitat change and degradation at the edge of distribution.

In this paper, we investigate current status and habitat requirements of Keeled Plump Bush Cricket (*Isophya costata*), an endemic species of the Pannonian Basin in Central Europe, which reaches the northern edge of its distribution in the Austrian-Slovak trans-border area. The goal of this study is to clarify the recent population status and habitat preferences of the species, expecting that optimal conditions will be found in highly natural grasslands, reflecting habitats of high ecological value. In 2018, we checked altogether 15 sites of suitable habitat in the trans-border area. However, the occurrence of the target species was confirmed only in two areas. After detailed habitat survey in these two areas, we found that the vegetation structure and the presence of broad-leaved

flowering plants could be important determinants of species habitat requirements.

Our preliminary results indicate that there is a preference of microhabitats rich in *Clematis integrifolia*, which satisfied nutritional and locomotory needs of this relatively heavy insects. Moreover, our survey indicates that the key plant cannot be overgrown with grass or other plant species. In the future, there is the need to consider habitat characteristics of more areas with the occurrence of the target species, including other parameters like humidity and weather conditions. We would also like to study the potential expansion of the species, especially in appropriate habitats at the northern edge of species distribution. Finally, we would like to determine genetic structure of the species metapopulation in trans-border area and compare the genetic diversity and the degree of isolation of the species with countries in its geographical range.

**Key Words:** Keeled Plump Bush-Cricket, *Isophya costata*, distribution, habitat requirements, Austria, Slovakia, trans-border area.



## Biodiversity, Biogeography & Ecology

# POPULATION DYNAMICS AND CHARACTERIZATION OF *ANONCONOTUS ITALOAUSTRIACUS* NADIG, 1987 (ORTHOPTERA, TETTIGONIIDAE) IN NORTH – EAST ITALY

Filippo Maria Buzzetti<sup>1</sup>, Federico Marangoni<sup>1</sup>, Gionata Stancher<sup>1</sup>, Luca Mazzon<sup>2</sup>

<sup>1</sup> Fondazione Museo Civico di Rovereto, Borgo Santa Caterina 41, 38068 Rovereto (TN), Italy;

buzzettifilippo@fondazionemcr.it

<sup>2</sup> Agripolis - Viale dell'università, 16 - Legnaro (Padova), Italy.

The genus *Anonconotus* Camerano, 1878 is endemic of Apennines and Alps, reaching the easternmost point of its distribution in the eastern Alps (Austria and Italy) with the species *A. italoaustriacus*.

The Eastern Alpine Bush-Cricket, *Anonconotus italoaustriacus* Nadig, 1987 is an eualpine heliophilous species typical of prairies. In Italy this species is present with only 3 geographically separated populations, two in Trentino Alto Adige (Monte Sciliar and Monte Elmo, BZ), one in Veneto (Vette Feltrine, BL). Another Italian population (Monte Altissimo, TN) reported by Krauss (1909) is considered extinct. The populations from Trentino Alto Adige and Veneto are confirmed to be present by recent field surveys (last survey in 2018) but their range appears to be very limited, further in the last years the population from Veneto has shown large variability in number of individuals from very abundant to almost absent. These are the only Italian populations remaining of this species and their genetic and biodiversity value is huge. In all the areas occupied by the Italian populations occur human activities: tourism, winter sport and cattle farm. A restriction of the areal during the season (after the cattle grazing starts) has been noted at least in the population of Veneto: in early August, individuals can be found in an area of 40.000 m<sup>2</sup> also on open prairies, while in late August – September they are present in a restricted area, only on low bushes of *Rhododendron* sp. and *Juniperus* sp. where the cattle don't graze. The assumption is therefore that the grazing and the trampling of the cattle affect or at least disturb

the Eastern Alpine Bush-Cricket that is therefore confined in the areas where cattle activity is less intense. Both, the limited and disjunct areas of the three Italian populations, and the presence of human activities in the population area, describe a fragmented and threatened situation. Disappearing of one or more of the target population would be a dramatic loss for the biodiversity in Italy and the genetic diversity of the genus *Anonconotus* in particular. Bioacoustic and molecular analysis are used to characterize the populations. Conservation plan is proposed at least for the Veneto population.



**Key Words:** Biodiversity, Bioacoustic, Population Dynamics, Conservation, Overgrazing.



## Biodiversity, Biogeography & Ecology

# GRASSHOPPER (ORTHOPTERA: CAELIFERA) SPECIES DIVERSITY AT SERRA DA JIBOIA, BAHIA, BRAZIL, A RELICT OF ATLANTIC FOREST

Ana Catia Santos da Silva <sup>1</sup>, Marcos Gonçalves Lhano <sup>1</sup>

<sup>1</sup> Universidade Federal do Recôncavo da Bahia (UFRB), Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB). Programa de Pós-Graduação em Ciências Agrárias. 44380-000. Cruz das Almas, BA, Brazil; katiasantos007@hotmail.com, marcos@ufrb.edu.br

There are few studies on the composition of grasshopper species in the Atlantic Forest biome, and almost scarce in Bahia, Brazil. With the aim to characterize the grasshopper (Orthoptera: Caelifera) assemblage present in the Serra da Jiboia, a relict of Atlantic Forest placed in Bahia, Brazil, fieldworks were carried from May 2016 to May 2017. A total of seven collections were made bimonthly through active searches using entomological net, in each of two sites at this area: Baixa de Areia and Baixa Grande. The samplings carried out in each site, were made during diurnal periods by three simultaneously collectors, with a distance of five meters between each other and with sampling effort of 180 minutes. In order to compare the diversity of the two analyzed areas, the following ecological indexes were used: Simpson and Berger-Parcker Dominance, Shannon\_H and Margalef Diversity together with Pielou Equitability.

A total of 1,939 individuals were collected, corresponding to 1,086 nymphs (56%) and 853 adults (44%), of whom 539 males (63%) and

314 females (37%). We identified 26 species of adult grasshoppers, distributed in 22 genera, 11 subfamilies and six families.

The family Acrididae was the most abundant with 798 adult individuals and 1021 nymphs. The locality of Baixa Grande showed greater diversity by Simpson index (0,8369), Shannon\_H index (2,2) and Margalef (3,552), and also presented the highest species uniformity (0,7017). Baixa de Areia presented higher species dominance (0,4353), analyzed by the Berger-Parcker index.

Thus, we can conclude that Baixa Grande region is richer and more diverse than Baixa de Areia, with a greater number of exclusive species and greater abundance, while Baixa de Areia has a low number of species but with high dominance.

**Key Words:** Biodiversity, Species Composition, Dominance, Equitability.

## Biodiversity, Biogeography & Ecology

# CONTRIBUTION TO THE CHARACTERIZATION OF AREAS WITH HIGH FREQUENCY OCCURRENCES OF DESERT LOCUST *SCHISTOCERCA GREGARIA* (FORSKÅL, 1775) IN MOROCCO USING LOCUST DATABASE AND FLORISTIC INVENTORIES OF 2009

Abdellah Elmouden<sup>1</sup>, Abdelghani Bouaïchi<sup>1</sup>, Ahmed Mazih<sup>2</sup>

<sup>1</sup> Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Morocco ; abdellah.elmouden@gmail.com

<sup>2</sup> Institut Agronomique et Vétérinaire Hassan II, Département Protection des plantes, BP. 18/S 80 000 Agadir, Morocco

The characterization of biotopes through a biogeographic study allows to better know and determine the spatio-temporal dynamics of locust populations from year to year and specially to identify the main ecological specificities of the high frequency areas of occurrence and reproduction of the Desert Locust. The present study aim is to improve the preventive control program in the western region of the Desert Locust invasion area by a better monitoring of the species survival and reproduction.

We analysed data on the recent Desert Locust plagues (1987-1989, 2003-2005) and upsurge (1993-1995) as well as satellite data on vegetation and rainfall, in order to show the biotopes which generally "worked" and can explain the presence or reproduction of this pest species. Areas characterized by high occurrences of presence or breeding activity resulting from the analysis, in the absence of the Desert Locust, were subjected to geomorphological and pedological investigations to allow the physical characterization of plants associations.

The present study has led to the identification and georeferencing of several areas that have repeatedly hosted large Desert Locust swarms or larvae.

The definition and characterization of these zones were carried out within large natural areas: Ziz-Ghriss valley and Hmada of Guir, Upstream of the Drâa valley, mid Drâa and Aval of downstream of Drâa valley. The physical characterization of Desert Locust biotopes at the national level has allowed us to have a clear idea of the ecological potential that each of these biotopes offers. This zoning allows some visibility on the actions that will be carried out in the context of locust control while improving the choice of routes and periods of survey.

The use of new technologies (remote sensing) is one of the means that has greatly contributed to the improvement of locust monitoring and control operations as well as to a better storage of locust data (RAMSES data base). This work would have been completed if, however, all of these satellite data and file data had been coupled to a geographic information system (GIS) in order to produce occurrence maps.

**Key Words:** Desert locust, preventive control, frequency occurrences, characterization, biogeography and vegetation, Morocco.

## Biodiversity, Biogeography & Ecology

# THE ORTHOPTERA FAUNA OF AUSTRIA – AN OVERVIEW

Armin Landmann<sup>1</sup>, ARGE Heuschrecken Österreichs<sup>2</sup>

<sup>1</sup> Institute of Zoology, University of Innsbruck, Innsbruck, Austria; armin.landmann@uibk.ac.at

<sup>2</sup> ARGE Heuschrecken Österreichs, Thomas Zuna-Kratky, Vienna, Austria

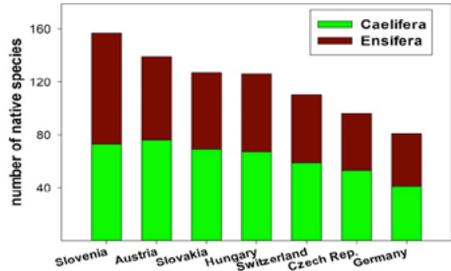
Austria is located at the heart of Central Europe. As consequence the country has part in several biogeographical regions which show pronounced differences in their landscape character and climate. Overall, Austria is a predominantly mountainous country, two thirds of its surface being covered by the Eastern Alps which run west to east through the country.

The dominance of steep altitudinal gradients and the high variability of environmental conditions over short horizontal distances in the Alps must be regarded as the most important factors shaping distributional patterns and species diversity of Orthoptera in Austria. Although just about 28 % of the Austrian landscape is moderately hilly or flat, these regions in the alpine forelands are inhabited by the most diverse, mostly thermophilic lowland fauna with species diversity being highest in the lowest parts (below 200 m a.s.l.) which are part of the Pannonian steppe plain around lake Neusiedl. The species diversity of Austria is also fostered by the direct connection to the Mediterranean and the Balkan fauna regions via Styria and Carinthia.

These favourable settings of Austria are mirrored in the diversity of its Orthoptera fauna. The 139 indigenous Austrian species comprise 63 species of Ensifera and 76 species of Caelifera which belong to five families each. The predominance of Caelifera (Fig. 1) is remarkable and seems to be a general phenomenon for mountainous countries because the more sclerotized grasshoppers in general are better adapted to cold climates. Compared to the neighbouring countries and on a Central European scale, Austria is very species rich in harbouring about 90 % of the species recorded in Central Europe (Fig.1). However, these numbers are also reflecting the good exploration level

which has been reached by joint efforts of Austrian Orthopterologists organised in an "Austrian Orthoptera working group" (= ARGE Heuschrecken Österreichs). This group now can dispose over a huge stock of more than 315.000 records of the 139 extant species. Records mostly are of recent origin (~95 % since 1990), and our data thus allow to draw a representative and actual picture of regional and altitudinal distribution patterns and differences of species diversity as well as of the threat status of selected species.

Figure 1. Compared to its neighbouring countries to the



East, West and North, Austria is very rich in Orthoptera and especially in Caelifera species. Just two Mediterranean neighbours exhibit a more diverse fauna, mainly more Ensifera: Slovenia and Italy (350 species – not shown).

**Key Words:** Austria, landscape and Orthoptera diversity, dominance of Caelifera, altitudinal distribution types.

## Biodiversity, Biogeography & Ecology

# SPECIES RICHNESS OF GRASSHOPPERS (ORTHOPTERA: ACRIDIDEA) IN CERRADO AREAS OF CENTRAL BRAZIL

Wanessa de Lima Batista <sup>1</sup>, Marcos Gonçalves Lhano <sup>1</sup>

<sup>1</sup> Universidade Federal do Recôncavo da Bahia (UFRB), Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB). Programa de Pós-Graduação em Ciências Agrárias. 44380-000. Cruz das Almas, BA, Brazil; wanessa\_biologia@hotmail.com, marcos@ufrb.edu.br

It is estimated that Caelifera presents about 2,400 valid genera and 12,000 species, distributed in two infraorders: Tridactylidea and Acrididea, with the majority of grasshopper species being placed in Acrididea, which currently comprises eight superfamilies. The aim of this study was to characterize the grasshopper (Orthoptera: Acrididea) richness in five areas with dominance of Cerrado biome in the Central Brazil. The fieldwork was carried out from April to May 2014, in the Serra da Bodoquena (MS) (21°07'S 56°43'W), Chapada dos Guimarães (MT) (15°24'S 55°49'0), Chapada dos Parecis (MT) (14°20'S 57°42'W), Chapada dos Veadeiros (GO) (14°08'S 47°37'W) and Dianópolis (TO) (11°26'S 46°53'W). For the sampling, the active search method was performed with the use of entomological net. In each area, samples were made during three consecutive days, by three collectors simultaneously 5-meter distant from each other and with a sampling effort of 90 minutes per site.

We sampled 616 adults and identified 95 species, from the families Acrididae (n=67), Tetrigidae

(n=16), Romaleidae (n=6), Ommexechidae (n=3), Proscopiidae (n=2) and Eumastacidae (n=1). The greatest richness was found in the Serra da Bodoquena, followed by Chapada dos Guimarães, and Dianópolis.

The family Acrididae represented the largest number of the collected individuals (87.7%). Only Acrididae, Romaleidae and Tetrigidae occurred in the five sampled areas while Eumastacidae was collected in only one, probably due to the fact that most species of this group are arboreal and its dietary habits are mainly pteridophytes, whose group is uncommon in the studied areas. *Eutryxalisfilata* (Walker, 1870) and *Rhammatocerusguerrai* Assis-Pujol, 1997 were found in all sampled sites. In this study, we found new occurrence records for 16 species and for one subspecies in the Central-West region.

**Key Words:** Diversity, Ecology, Caelifera.



## Biodiversity, Biogeography & Ecology

# BIODIVERSITY AND BIOECOLOGY OF CAELIFERA (ORTHOPTERA) IN THE TEBESSA REGION NORTH-EAST ALGERIA

*Slim Bouguessa<sup>1</sup>, Linda Bouguessa-Cheriak<sup>1</sup>*

<sup>1</sup> University of Tebessa, Tebessa, Algeria ;bouguessaslim2009@gmail.com

<sup>1</sup> University of Tebessa, Tebessa, Algeria.

Orthoptera represent a central taxon in food webs and are good indicators of both environmental characteristics and habitat disturbances. Being mainly associated with perennial herbaceous habitats, they are threatened in vast grasslands transformed into intensive agricultural areas.

With an area of 13,878 km<sup>2</sup>, Tebessa is located in northeastern Algeria (34°15' to 35°45'N, 7°30' to 8°30'E). It rises about 960 m above sea level and is naturally connected with the country's immense steppe range. 3 stations were chosen according to the vegetation cover and the altitude to carry out this study.

Station 1, El Merdja, is located in the north-east of Tebessa (35°25'60"N, 8°06'00"E). It is limited on the north by Djebel Dyr, and on the south by Djebel Mestiti and Doukkane. This plain is crossed by a groundwater, which gives it a certain humidity. Station 2, Bekkaria, is located at 875 m (35°22'20"N, 8°14'32" E). The station is a forest of Aleppo pines (*Pinus halepensis* Mill. 1768), with an area of 5,200ha, whose upper part is at 970 m. Station 3, Hammamet (Youks baths), has an area of 375 km<sup>2</sup> (35°26'54"N, 7°57'11"E) and is at an altitude of 854 m. It is characterized by different types of reliefs, mountains, hills, and plains.

The plant cover consists of Aleppo pine forests associated with juniper, holm oak and olive trees. Orthopteran collect was made by net, using the techniques of quadrats and transects.

As a result of the surveys carried out in the different study stations, a total of 47 species were captured, belonging to the families Acrididae and Pamphagidae. The Acrididae family is the largest, comprising 8 subfamilies: Acridinae, Calliptaminae, Cyrtacanthacridinae, Eyprepocnemidinae, Gomphocerinae, Oedipodinae, Catantopinae and Pyrgomorphae. The subfamily Oedipodinae is the richest; the subfamilies of Pamphaginae and Gomphocerinae occupy the following rank with 8 species belonging respectively to 4 and 5 genera. The Acridinae have 4 species belonging to 3 genera. The use of ecological indices such as abundance and Shannon for diversity shows that these insects are more interested in the open environment, first in El Merdja then Bekkaria and finally Hammamet. The study of the bio-ecology of *Oedipoda miniata*, common species at the 3 stations, shows important differences between the three environments.

**Key Words:** Inventory, Bioecology, Caelifera, Tebessa, Algeria



Biodiversity, Biogeography & Ecology

**A NEW SPECIES OF GENUS SCHIZODACTYLUS  
(ORTHOPTERA: ENSIFERA: SCHIZODACTYLIDEA:  
SCHIZODACTYLIDAE: SCHIZODACTYLIDINAE) FROM RIVER  
INDUSHYDERABAD (SINDH) PAKISTAN**

Sabir Ali Channa<sup>1</sup>, Muhammad Saeed Wagan<sup>1</sup>, Yawar Saeed Wagan<sup>1</sup>

<sup>1</sup> University of Sindh Jamshoro Pakistan;channasabir61@gmail.com

*Schizodactylusindhensis* sp. nov. is described from river Indus as a new species to science with the addition of *S.indhensis* the total number of known species in this genus become 10 (one species described from fossil).

**Differential diagnosis:** Previous nine species of this genus have been described this new species differs from all the other species in having large size and the hind tibia has four spines on each side whereas in all other species have 3 internal and 4 external spines. Sub genital plate simple, apex broadly rounded and anal plate between paraproct thick ridges like incomplete circle.

Further differences are also reported in the female

Subgenital plate which is more rounded than in *S.monstrosus* and less rounded in *S.minor*. This new species also differ by the shape of tibia, spurs from *S.burmanus* and *S.tuberculatus*. This new species also vary from *S.hesperus* by the shape of spurs of the hind tibia and the shape of Ovipositor which is not strongly curved and has the apex truncate not rounded. However in this genus *S.inexpectatus* was found more differ from others *Schizodactylus* species by the abbreviated wings.

**Key Words:** New species, river Indus, *Schizodactylus*, Ensifera, sub genital plate.



## Biodiversity, Biogeography & Ecology

# BIOECOLOGICAL STUDY OF *PARATETTIX MERIDIONALIS* (TETRIGIDAE) IN CONSTANTINE REGION, EASTERN ALGERIA

Chahinez Derrouiche<sup>1</sup>, Naima Benkenana<sup>1</sup>, Imane Guerfi<sup>1</sup>

<sup>1</sup> Laboratoire de Biosystématique et Ecologie des Arthropodes, Université Frères Mentouri, Constantine 1, route d'Aïn-El-Bey, 25000, Constantine, Algérie; chahinez\_25@hotmail.fr, benkenanan@yahoo.co.nz, imenguerfi92@gmail.com.

The Constantine region is located in the semi-arid bioclimatic stage. The locust and grasshoppers fauna in this region totals the presence of 43 species. They are divided into five families and eleven sub-families. The family Tetrigidae is represented by only one species: *Paratettix meridionalis* (Rambur, 1838). It is a small species, black with white spots. The pronotum is elongated and often covers the abdomen to the apex.

The bioecological study of this species in Chaab Erssas station (36°20'19"N - 6°37'27"E) shows that it prefers humid places. We collected a large number of *P. meridionalis* near to water source.

We performed morphometric analyzes. Surveys and monitoring of this grasshopper during the study period indicate that it has two generations a year.

As part of the alimentary regime study of this species, we identified 16 plants in our study station, divided into four families: *Asteraceae*, *Fabaceae*, *Brassicaceae* and *Poaceae*. Preliminary results from the analysis of faeces of males and females show that it consumes plants that belong to two essential families: *Asteraceae* and *Poaceae*.

The Tetrigidae family is still little known in Algeria. Additional studies are needed and other species remain certainly to be discovered.



Figures 1 and 2. *Paratettix meridionalis* (Rambur, 1838).

**Key Words:** *Paratettix meridionalis*, Constantine, Bioecology, alimentary regime, *Asteraceae*.

## Biodiversity, Biogeography & Ecology

# GRASSHOPPERS OF YELLOWSTONE NATIONAL PARK

Kathleen King<sup>1</sup>, Cindy Legg<sup>2</sup>

<sup>1</sup>USDA APHIS PPQ, Cheyenne, Wyoming, USA; Kathleen.M.King@aphis.usda.gov

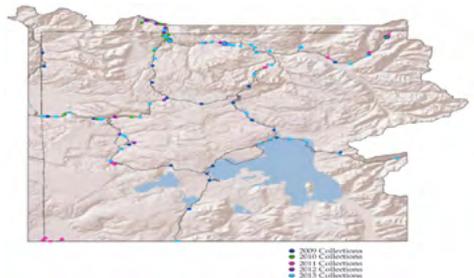
<sup>2</sup> Cooperative Agricultural Pest Survey, University of Wyoming, Laramie, Wyoming, USA

In 1988, the United States Department of Agriculture (USDA APHIS PPQ) and the University of Wyoming (Wyoming, U.S.A.) collaborated on developing a systematic, comprehensive species-based survey of grasshoppers in the state. Since then, over 357,874 grasshoppers have been identified from over 12,665 collection events (not including 2018 data). The resulting database serves as the foundation for information and maps which provide a valuable tool for grasshopper management and biological research. Until 2009, there had been very few specimens collected from Yellowstone National Park (YNP) and documented in this particular database. In 2009, USDA APHIS PPQ conducted 35 grasshopper density surveys throughout areas of YNP with the emphasis on making collections at each survey stop. These collections produced 810 identified grasshoppers from which 36 species of grasshoppers were identified, 11 of which were new records for YNP and one was a new state record. In 2010, 20 grasshopper collections of YNP produced 518 identified grasshoppers from which 28 species of grasshoppers were identified, 3 of which were new records for YNP. In 2011, 16 grasshopper collections of YNP produced 391 identified grasshoppers from which 27 species of grasshoppers were identified, 2 of which were new records for YNP. In 2012, 18 collections of YNP were taken early in the season which produced 243 identified grasshoppers of 22 species, two of which were new records for YNP and was a new state record. In 2013, 46 collections of YNP produced 674 identified grasshoppers from which 39 species of grasshoppers were identified, two of which were new records for YNP. In 2014, 41 collections of YNP produced 674 identified grasshoppers from 28 species of grasshoppers. No new records were caught in 2014 in YNP. Collections were not taken in YNP in 2015, 2016 or 2017. In 2018, 20 collections

of YNP produced 258 identified grasshoppers from which 24 species of grasshoppers were identified. No new records were found.

These data greatly augment the current database and provide a more complete distribution of the collected species. Overall, seven years of collecting grasshoppers in YNP has produced three state records for Wyoming and have also only been found in YNP: *Melanoplus indigenus*, *M. montanus*, and *Trimerotropis diversellus*. The latter species was found on barren mineralized soil associated with fumaroles and geyser basins whereas in other states it is usually found in open woodlands or alkaline depressions.

Each year that YNP collections are made, specimens are pinned, labelled and added to one of three reference collections. Collection #1 is housed in the YNP museum in Mammoth, Wyoming; Collection #2 is housed with the Pfadt Collection at the University of Wyoming; and Collection #3 is housed in Cheyenne,



Wyoming at the USDA APHIS PPQ state office.

**Figures 1.** Grasshopper Collection Sites in Yellowstone National Park (2009–2013).

**Key Words:** Grasshopper, Yellowstone National Park, Wyoming, *Melanoplus*, *Trimerotropis*.

Biodiversity, Biogeography & Ecology  
**MORPHOLOGICAL CHARACTERISTICS AND DISTRIBUTION ABUNDANCE OF PARATETTIX MERIDIONALIS (ORTHOPTERA: TETRIGIDAE) IN SOME LOCALITIES IN CAMEROON**

Marcelle Mbadjoun Nzike<sup>1</sup>, Sévilor Kekeunou<sup>1</sup>, Parfait Carlos Kako Sumegne<sup>2</sup>, Alain Simeu Noutchoum<sup>1</sup>, Alain Christel Wandji<sup>1</sup>

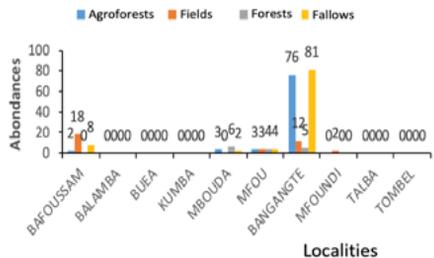
<sup>1</sup> Zoology Laboratory, Faculty of Science, University of Yaoundé I, Yaoundé, Cameroon; marcellenzike@yahoo.fr

<sup>2</sup> Zoology Laboratory, Faculty of Science of Higher Teacher Training College of the University of Yaoundé

*Paratettix meridionalis* (Rambur, 1838) (PM) is a cosmopolitan species. It frequents humid areas in which it feeds on mosses and unicellular algae. In France, laying starts in the spring and continues during the months of May-June. For a better knowledge of this species, its morphological characteristics and abundance have been studied in Cameroon. Regular collects (with net and pitfalls) were conducted once a month in four types of vegetation (forests, fallows, agroforests and crop fields) and 10 localities in the Central, West and Southwest regions. In the laboratory, descriptions and measurements were made on 60 individuals (30 males and 30 females). Our results showed that *P. meridionalis* can be recognized by its usually gray color with two black spots on the pronotum, a head embedded in the pronotum up to the eyes, a long pronotum extending well beyond the end of the posterior femur. PM was more abundant in Bangangté, less in Bafoussam, Mbouda, Mfou and in Mfoundi; totally absent in the localities of Balamba, Buea, Kumba, Talba and Tombel. PM was more abundant in fallows and agro-forests, in low numbers in Bangangté and absent in Bafoussam; it was in average numbers in the fields, fallow lands and agro-forests of Bafoussam. In Mbouda, PM has been abundant in forests and agro-forests, low in fallows and zero in the fields. In Mfou, PM was present in all four vegetation types with a low abundance. In the Mfoundi, it was collected only in the fields. In the localities of Buea, Kumba and Tombel PM was totally absent.

We noted a very marked sexual dimorphism in this species; the female was larger than the male.

The length of the body was respectively  $9.73 \pm 0.16$  mm in the male and  $10.13 \pm 0.25$  mm in the female. The pronotum length and pronotum width were  $9.03 \pm 0.15$  and  $2.60 \pm 0.24$  mm in the male and  $9.73 \pm 0.14$  and  $2.53 \pm 0.03$  respectively in the female. The elytron length is  $1.30 \pm 0.03$  mm in the male and  $1.48 \pm 0.03$  mm in the female. The length of the median femur and its width were respectively  $2.14 \pm 0.06$  and  $0.53 \pm 0.02$  mm in the male and  $2.40 \pm 0.07$  and  $0.54 \pm 0.01$  mm in the female. It is the same for the hind leg whose length was  $5.19 \pm 0.08$  mm in the male and  $5.82 \pm 0.08$  mm in the female. This sexual dimorphism noted in favor of the female could be explained by the fact that females of *P. meridionalis* would store more energy than males to ensure efficient reproduction.



Figures 1. Abundance of *P. meridionalis* in some localities of Cameroon.

**Key Words:** *Paratettix meridionalis*, morphology, sexual dimorphism, localities, abundance

## Biodiversity, Biogeography & Ecology

# A NEW SYMBIONT ASSOCIATED WITH THE SOUTH AMERICAN LOCUST *SCHISTOCERCA CANCELLATA*

Santiago Plischuk<sup>1</sup>, Martina E. Pocco<sup>1,2</sup>, Silvina Quintana<sup>3</sup>, María L. de Wysiecki<sup>1,4</sup>, Carlos E. Lange<sup>1,5</sup>

<sup>1</sup> Z1 Centro de Estudios Parasitológicos y de Vectores (CEPAVE) CONICET-UNLP. Boulevard 120 e/ 60 y 64, (1900) La Plata, Argentina;  
martinapocco@fncym.unlp.edu.ar

<sup>2</sup> División Entomología, Museo de La Plata, La Plata, Argentina

<sup>3</sup> Centro de Investigación de Abejas Sociales (CIAS), Mar del Plata, Argentina

<sup>4</sup> Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina

<sup>5</sup> Comisión de Investigaciones Científicas de la provincia de Buenos Aires (CICPBA), Argentina

After several decades of recession, an outbreak of historical magnitude of the South American locust *Schistocerca cancellata* has recently occurred in parts of Argentina, Paraguay, and Bolivia. Gregarious-phase older nymphs and adults were collected in fields near San Pedro, Jujuy province, in northwestern Argentina. The locusts were taken to the laboratory where they were sacrificed in order to scrutinize them for parasites and pathogens. All individuals were examined by ventral, longitudinal dissection under a stereo zoom microscope. Several adults and last-instar nymphs harbored gregarine-like microorganisms in their digestive tract, which were extracted and stored in absolute ethyl alcohol for DNA extraction. Using three different primer sets, DNA fragments were amplified, purified, and directly sequenced (ABI 3500 Genetic Analyzer, Applied Biosystems). The sequences similarities were determined by the Basic Local Alignment Search Tool (BLAST, NCBI). Morphological observations of the different developmental stages of the symbiont were carried out using a compound microscope. Measurements were taken using Micrometrics® SE Premium 4.0. Its presence was corroborated in the midgut as well as the gastric caeca. Sporozoites, trophozoites, gamonts, gametocysts, and oocysts were individualized. Both the diversity of the stages and their morphology were characteristic of a septate eugregarine. Trophozoites presented a globular epimerite (mean diameter = 24 µm) and averaged

176.8 µm long; the mean length of gamonts was 265.4 µm, protomerites measuring 67.2 µm x 90.4 µm, and deutomerites 198.2 µm x 129.8 µm on average. Syzygy was in all cases frontal-caudal being primate and satellite of similar size but showing slight differences in the anterior end. Both immature and mature gametocysts were observed in the posterior portion of the gut and feces. Gametocysts were spherical structures of 459 µm mean diameter. Two-three days after being passed out with the feces about 30 equidistant basal discs (20.7 µm of average diameter) were observable on the surface of gametocysts. Two days after (under rearing room conditions, i.e.: 30 oC; 40% R. H.; 14 L: 10 D photoperiod) chains of oocysts were ejected from basal discs. Oocysts were doliform, measuring on average 7.4 µm x 4.5 µm. Considering that I) features of the few septate eugregarines described in South America associated with Acrididae members are far from being in agreement with those described here, II) morphological characters fit with those described for genus *Gregarina*, and III) after sequencing, BLAST locates it within that genus but without a clear association, the possibility that the septate eugregarine found in *S. cancellata* would be a new, undescribed *Gregarina* species appears highly likely.

**Key Words:** Acrididae, Apicomplexa, Argentina, Eugregarine.



## Biodiversity, Biogeography & Ecology

# STUDY OF DESERT LOCUST DYNAMICS AND BIOECOLOGY: CASE OF THE 2013 LOCUST OUTBREAK IN ALGERIA

*Hamid Bensaad<sup>1</sup>, Bahia Doumandji-Mitiche<sup>2</sup>*

<sup>1</sup> National Institute of Plant Protection (INPV): BP. 80 El Harrach, Algiers; hamidbensaad@gmail.com

<sup>2</sup> National School of Agronomy (ENSA): Avenue Hassen Badi El Harrach, Algiers; b.doumandji@ensa.dz

The Desert Locust is one of the most dangerous species because of the damage it causes to crops during invasions. This transboundary pest, which can invade an area stretching from the Atlantic coast of Africa to the Indo-Pakistan border and from the Mediterranean to the Equator, is a food security problem with major socio-economic repercussions. The knowledge currently available on the bioecology, dynamics and behavior of locust populations, the field experiences accumulated by the countries concerned, the means offered by new technologies such as GIS, databases and geolocation devices, allow currently to scientifically and effectively conduct the Desert Locust preventive control strategy during the various locust situations.

Algeria in 2013 was confronted with a locust outbreak in the southwestern region (Bechar, Naâma and El Bayadh). This particular locust activity was the subject of a detailed analysis and as a result, all the digital information stored in the Locust database "RAMSES Version 3" was processed.

The data analyzed concern the ecological factors that favored locust installation and breeding in these areas and aspects related to its biology under natural conditions. The abiotic factors selected for this purpose are rainfall, temperature and vegetation covers.

The results obtained showed that the locust facility, particularly in Bechar in 2013, is dependent

on the autumn rains of the previous year which affected the main wadis of these regions and which generated a dense vegetation cover.

The monitoring of locust development under natural conditions by analysis of the 2013 database showed that the average duration of egg incubation in the two regions varied between 28 and 34 days. In the same areas, the mean larval development time varied between 30 and 38 days. For each larval stage, the duration of early stage development varies between 3 and 4 days for stages L1 and L2, 6 to 7 days for stages L3 and L4 and 12 to 14 days for stage L5.

Regarding fluctuations in locust levels, two main activities were noted; a first activity of adults assessed as important occurring during the months of March and April marked by significant aggregations related to the activity of spawning and concentration at the time of feeding in the green areas. Another small locust activity from late May to early July, related to the emergence of fledgling populations of the new generation. For larvae, variation in population levels is characterized by a single fluctuation occurring during the months of April and May.

**Key Words:** Desert Locust, Swarm, Invasion, GIS, resurgence, RAMSES.



## Biodiversity, Biogeography & Ecology

# MORPHOMETRIC VARIATION AMONG MALE POPULATIONS OF *OMALOTETTIX OBLIQUUS* (THUNBERG, 1824) (ACRIDIDAE: OMMATOLAMPIDINAE) FROM THE ATLANTIC FOREST AND PANTANAL, BRAZIL

Aline Santos dos Santos<sup>1</sup>, Lorena Andrade Nunes<sup>2</sup>, Marcos Gonçalves Lhano<sup>1</sup>

<sup>1</sup> Universidade Federal do Recôncavo da Bahia (UFRB), Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB). Programa de Pós-Graduação em Ciências Agrárias. 44380-000. Cruz das Almas, BA, Brazil. aline.santos58@yahoo.com.br; marcos@ufrb.edu.br

<sup>2</sup> Universidade Estadual do Sudoeste da Bahia (UESB), Programa de Pós-Graduação em Enfermagem e Saúde. 45208-091, Jequié, BA, Brazil. lorenunes2@gmail.com

In the subfamily Ommatolampinae (Amedegnato, 1974), *Omalotettix* and its related genus *Abracris* includes the most wide-ranging species of the Neotropical region. However, it's not easy to recognize *Omalotettix* from *Abracris* by its external morphology, as observed by Roberts and Carbonell in 1981. Besides that, many species widely distributed geographically, tend to present both geographic variations and polymorphism, which can lead to incorrect identifications. Therefore, the geometric morphometry can help to solve this taxonomical problem, because this technique aims to describe and represent the geometry of the studied forms. The aim of this study has been to identify changes in pronotum shape and size among populations of *O. obliquus* (Thunberg, 1824), widespread in South America, collected in Atlantic Forest and Pantanal biomes, Brazil. The pronotum of these individuals have been photographed in a left lateral view and the measurements and analyzes have been performed using TPS series programs, MorphoJ and Past v. 2.16. Fifty-eight male specimens from both

populations have been studied. MANOVA has showed significant differences ( $p < 0.005$ ) for form and size of the pronotum among the biomes. In the Principal Components Analyzes has been verified that the first four components explained 68.82% of the total variation of the pronotum form among the individuals. Comparing this structure in the different Atlantic

Forest and Pantanal domains, it has been observed that the greatest variations occurred in the dorsal and ventral regions of the pronotum, and this has been statistically larger in the Pantanal biome than in the Atlantic Forest biome. Cross-validation test has showed that 79.3% of the individuals from Pantanal and 58.6% from Atlantic Forest biome have been correctly assigned to their group. We concluded that the shape and size of the pronotum of these individuals vary according to the biome they inhabit.

**Key Words:** Geometric morphometrics, Polymorphism, Pronotum, Shape, Size.



## Biodiversity, Biogeography & Ecology

# BIOGEOGRAPHY AND LATITUDINAL DIVERSITY GRADIENTS IN RHAPHIDOPHORIDAE (CAVE CRICKETS)

*Joseph Young Sweeney*

Academy of Natural Sciences Philadelphia, 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103;  
*jys43@drexel.edu*

---

Latitudinal Diversity Gradients (LDG) has been researched and debated for at least two centuries and is the most recognizable large-scale biological pattern on earth (Jablonski 2017). Most Rhabdiphoridae are flightless and belong to an ancient lineage diverging from the Tettigoniidae family approximately 175 million years ago (Song 2015) making the family well suited for a LDG analysis. This analysis tests for latitudinal gradients in Rhabdiphoridae across Northern Mexico, North America and Southern Canada. Using existing published distribution records from 1936 to 2018 and unpublished museum records

latitudinal diversity within Rhabdiphoridae is analyzed in reference to the spatial heterogeneity hypothesis and niche partitioning. Since the data sets span many decades the effects of time and subsequent environmental changes will also be discussed.

**Key Words:** Biogeography, *Ceuthophilus*, *Diestrammena*, Latitudinal Diversity Gradient (LDG), Orthoptera, Rhabdiphoridae, Speciation, Tachycines.



## Biodiversity, Biogeography & Ecology

# A REVIEW OF THE GENUS *OXYPTERNA* RAMME (1952) (OCHRILIDINI: GOMPHOCERINAE: ACRIDIDAE: ORTHOPTERA) FROM PAKISTAN

Muhammad Saeed Wagan

Department of Zoology, University of Sindh Jamshoro Pakistan; mswagan@hotmail.com

The genus *Oxypterna* was described by Ramme (1952) from a single female as *O. afghana*. Later it was revised by Uvarov (1954) from a single male from Iran. Moeed (1966, 1971, and 1976) erected three new species namely, *O. akbari*, *O. scapularis* and *O. isoformis*, from small number of specimens collected from Miani forest, Hyderabad. *O. abkari* (1976) was described from 2 males and 1 female whereas *O. scapularis* from 2 males while *O. isoformis* from single female. My study is based on the external morphology as well as the genitalic structures of both male and female. It relies on a fairly large number of

specimens collected from the various districts of Sindh (Province), as well as a few specimens from Balochistan and Punjab Provinces of Pakistan. I confirmed the presence of these species. The female of *O. scapularis* and male of *O. isoformis* are described for the first time. Besides, *O. afghana* is also recorded from Pakistan. These species are re-described and illustrated, and a taxonomic key for their separation is also provided.

**Key Words:** Acrididae, *Oxypterna*, Genitalia Key, Distribution, Pakistan.



## Biodiversity, Biogeography & Ecology

# STUDY OF THE BIOLOGICAL ACTIVITY OF ARGAN (*ARGANIA SPINOSA*) AND EUCALYPTUS (*EUCALYPTUS GOMPHOCEPHALA*) ON LARVAE AND ADULTS OF THE DESERT LOCUST (*SCHISTOCERCA GREGARIA* FORSKÅL, 1775) UNDER LABORATORY CONDITIONS

Mustapha Zoumhane<sup>1</sup>, Lalla Mina Idrissi-Hassani<sup>2</sup>, Jamal Chihrane<sup>3</sup>, Abdelghani Bouaïchi<sup>4</sup>, Saïd Ghaout<sup>5</sup>, Ahmed Mazih<sup>6</sup>

<sup>1,3,4,5</sup> Centre National de Lutte Antiacridienne, B.P 125, 86 343, Inezgane, Maroc; zoumhane83@gmail.com

<sup>2</sup> Université Ibn Zohr, Faculté des Sciences, Agadir, Maroc

<sup>6</sup> Institut Agronomique et Vétérinaire Hassan II, Département de Phytologie, Agadir, Maroc

The desert locust *Schistocerca gregaria* is a pest which has a great importance throughout the world. Chemical control against its invasions is very expensive for the concerned countries and it causes other effects undesirable for the environment. This encourages the search for cheaper alternatives and especially not harmful to the environment. Within this context, this work was conducted to study the relationship between Argan (*Argania spinosa*) and Eucalyptus (*Eucalyptus gomphocephala*) and the desert locust.

The biological effects of leaves and ethanolic extracts of the leaves of Argania and Eucalyptus were tested under laboratory conditions on hoppers and adults of desert locust. Hoppers of the 4th stage with the same age were isolated from the breeding and introduced individually in boxes. These hoppers received plant samples to study after a period of 12 hours without eating. For adults, young females were selected and transferred after fledging by group of 20 in standard cages. Three lots were prepared. Ten males were introduced in each cage. After ten days, dissections were performed to study the effect of plants tested on the reproduction of the Locust.

The influence of Argan and Eucalyptus based diet, on body growth and reproduction is obvious. With 4th larval instar, leaves of both plants have significant effects on daily intake of food, weight and survival of the treated hoppers to the control. The calculation of the indices of digestibility and efficiency of conversion of digested food, have shown the link between the

observed effects and consumption of both plants. Leaves of the two plants induced on treated adults several effects: decrease of food intake, loss of weight, decrease of survival, absence of sexual maturity and most importantly a blockage of ovarian development in females treated. The results also showed that extracts of leaves applied at 4 doses (5, 10, 25 and 50 g/l) induce a decrease of daily intake of food, a decrease of weight, an increase of mortality rate and a delay of larval development with regard to the control. The minimum doses which have an efficient effect are 10 g/l and 25 g/l for the extracts of the Argan and the Eucalyptus respectively. The both plants and especially the Argan, showed a repulsive and/or toxic power towards locusts, which is due to the richness of plants in secondary metabolites known by their active power. The study of the effects of two types of molecules secondary metabolites of tested plants, quercitrin (flavonoid) and coumarin (volatile Component) showed a significative reduction of consumption, revealing their repulsive and toxic power facing desert locust hoppers.

The whole results reveal that the both studied plants, in particular the Argan, have potential insecticide ability. The identification of the active substances of this plant can give an alternative of control against desert locust with suitable harmony facing the environment.

**Key Words:** Desert locust, *Argania spinosa*, *Eucalyptus gomphocephala*, plant-locust relationship, antifeeding, toxicity.



## Biodiversity, Biogeography & Ecology

# FOREST ROADS AS A CRUCIAL TOOL FOR CHORTHIPPUS PULLUS CONSERVATION IN HIGHLY FORESTED AREAS

Jaroslav Holuša<sup>1</sup>, Jana Tragnerová<sup>1</sup>, Jakub Horák<sup>1</sup>

<sup>1</sup> Faculty of Forestry and Wood Technology, Czech University of Life Sciences, Praha, Czech Republic;  
holusaj@seznam.cz

The habitat preferences of *Ch. pullus* have been studied in the National Park České Švýcarsko (Central Europe). This sandy country with deep valleys is nowadays covered mainly by spruce forests. Originally *Ch. pullus* lived on gravel banks of rivers. This habitat has disappeared therefore sandy crosses of forest roads have become permanent sources of *Ch. pullus* occurrence. Forest clearings are also very often inhabited but they represent only temporary habitats due to the overgrowth of trees.

For this reason we set a hypothesis that the size of sandy areas on crossroads correlates with grasshoppers abundance supported by forest clearings in nearby.

The grasshoppers were counted during ten-minute periods on more than one hundred locations (crossroads or forest depots) in mid July 2017. The type of habitat (gravel, sand, litter of needles) and the presence of nearby habitats (clearings, forests younger than 50 years, older than fifty years, mature open and close forests) and all other orthopteran species were also recorded.

The results have shown a tendency of increase in the number of *Ch. pullus* with the size of sand or gravel area for both males and females. The size of largest area was 15 ares. The minimum size of sandy area was 1 are due to the demands of *Ch. pullus* for egg laying. There was no impact of surrounding habitats on grasshoppers' abundance which are supposed to be used for migration of the species from sources represented by sandy crossings of forest roads. The number of other orthopteran species has increased with *Ch. pullus* abundance which is a result of the size and diversity of the habitat.

Ten very abundant orthopteran species represented by euryoecious mesophilic species living in grass, shrubs and tree crowns have been found.

The conservation of pure sandy areas depends on the intensity of forest management and using of roads for logging of wood.

**Key Words:** *Chorthippus pullus*, habitat, spruce forests, Central Europe.



## Biodiversity, Biogeography & Ecology

# GEOGRAPHICAL DISTRIBUTION OF LOCUST SPECIES IN THE MIDDLE ATLAS (MOROCCO)

Benjelloun Meryem<sup>1</sup>, Al Figuigui Jamila<sup>1</sup>, Essakhi Driss<sup>1</sup>, Zahri Aziz<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez. [meryem.benjelloun@usmba.ac.ma](mailto:meryem.benjelloun@usmba.ac.ma).

Locusts are characterized by a wide geographical distribution of which there are a multitude of biotopes in which they have been able to adapt and ensure an ecological balance. The ability to colonize new environments is linked to a high ecological tolerance.

This work aims to make a contribution to the study of the distribution and diversity of locust species in the central Middle Atlas region.

The results showed that the distribution of these species is influenced by many factors including

temperature, altitude, soil and vegetation.

According to their ecological preference, locusts can be classified as geophilic (living on the ground), phytophilous (in vegetation), herbicultural (on low plants) or arboreal (in trees). These species concentrate preferentially in the herbaceous layer.

**Key Words:** locust, geographical distribution, biotope, Middle Atlas, altitude.



## Biodiversity, Biogeography & Ecology

# STUDY ON THE PYGMY GRASSHOPPERS (TETRIGIDEA: ORTHOPTERA) FROM THAR DESERT, SINDH, PAKISTAN

Mohan Lal<sup>1</sup>, Riffat Sultana<sup>1</sup>

<sup>1</sup>Department of Zoology, University of Sindh, Jamshoro, Sindh, Pakistan;  
mohantal5521@gmail.com ; riffat.sultana@usindh.edu.pk

In result of present survey 02 species of i-e *Hedotettix gracilis* (Haan, 1843) and *Paratettix cingalensis* (Walker, 1871) of subfamily Tetriginae were captured from various ecological regions of Thar Desert, Sindh, Pakistan by using Standard Entomological Method.

Detailed taxonomic description for both species constructed in order to know their actual identification as well as pest status in Thar Desert was investigated. Sampling was done from Nagarparkar, Mithi, Chachro, Islamkot and Umerkot . Besides, it was also noticed that antennae in these species thin, filiform with 14-15 segmented and pronotum extended backwardly. Specimens were collected from *Cynodon dactylon* near the Barley (*Hordeum vulgare*), Pearl millet (*Pennisetum glaucum*) and Jowar (*Sorghum vulgare*) fields. This research was financially supported by Higher Education Commission, Islamabad, Pakistan. (Project No. 6737 SINDH/ NRPU/ R&D/ HEC/ 2015).



(a)

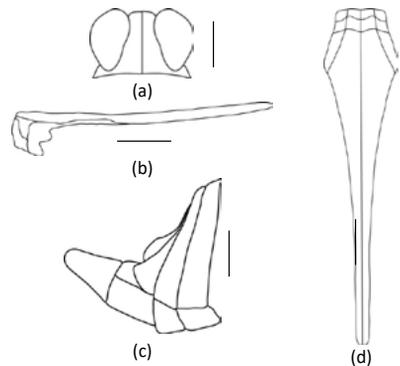


(b)



(c)

**Figure 1.** Lateral view of (a) *H. gracilis*♂. (b) *P. cingalensis* ♂ (c) *P. cingalensis* ♀



**Figure 2.** *P. cingalensis*♂ (a) Dorsal side of Head (b) Lateral side of Pronotum (c) Lateral side of Cerci (d) Dorsal side of Pronotum (BarLine: 2mm)

**Key Words:** Pygmy grasshoppers, Thar Desert, *Hedotettix gracilis*, *Paratettix cingalensis*

Biodiversity, Biogeography & Ecology

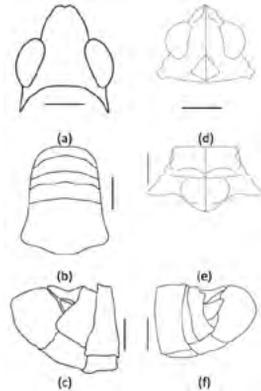
**COMPARATIVE STUDY ON THE "SURFACE" AND "AKK" GRASSHOPPERS (PYRGOMORPHIDAE: ORTHOPTERA) FROM SINDH, PAKISTAN**

Samiullah Soomro<sup>1</sup>, Riffat Sultana<sup>1</sup>

<sup>1</sup>Department of Zoology, University of Sindh, Jamshoro, Sindh, Pakistan; samiullah.soomro@scholars.usindh.edu.pk - riffat.sultana@usindh.edu.pk

Studies were conducted to compare two species of grasshoppers from the family Pyrgomorphidae: *Chrotogonus (Chrotogonus) homalodemus homalodemus* (Blanchard, 1836), commonly called "Surface grasshopper", and *Poecilotherus pictus* (Fabricius, 1775), commonly called "Akk grasshopper". *Chrotogonus homalodemus* is mostly found on open surfaces and moist clay soils (they are looking mud in color) but also, sometimes, in grasses (mainly *Cynodon dactylon*), barley (*Hordeum vulgare*), bajra (*Pennisetum glaucum*) and jowar (*Sorghum vulgare*). *Poecilotherus pictus* is a large and most brightly colored species, hence regarded as a "gaudy grasshopper". Its association was observed with *Calotropis procera* (Apocynaceae), but it also sometimes damage the water melon (*Citrullus vulgaris*), booro, a small species of sugarcane (*Saccharum bengalense*), and lucerne (*Medicago sativa*). Beside, in Sindh Province, it also causes damage to rice, sugarcane, wheat, maize, cow pea, okra (gombo), brinjal (eggplant), castor, citrus, papaya, alfalfa, corn, cotton and fodder crops.

**Figure 1.** Lateral view of *P. pictus*♂ (a) and *C. (Chrotogonus) homalodemus homalodemus* ♂(b).



**Figure 2.** *P. pictus*♂ (a) Dorsal side of head (b) Dorsal side of pronotum (c) Lateral side of cerci. *C. (Chrotogonus) homalodemus homalodemus* ♂(d) Dorsal side of head (e) Dorsal side of pronotum (f) Lateral side of cerci (Bar Line: 2mm).

This research was financially facilitated by Higher Education Commission, Islamabad, Pakistan (Project No. 6737 SINDH/ NRPU/ R&D/ HEC/ 2015).

**Key Words:** Comparison, Surface grasshoppers, Akk grasshoppers, Sindh.





## Biodiversity, Biogeography & Ecology

# INSECTS AND SPIDERS IN THE FALL DIET OF PLAINS SHARP TAILED GROUSE

Sejer Meyhoff<sup>1</sup>, Scott Bazinet<sup>1</sup>, Dan Johnson<sup>1</sup>

<sup>1</sup> University of Lethbridge, Lethbridge, Alberta, Canada; dan.johnson@uleth.ca

Sharp-tailed grouse (*Tympanuchus phasianellus jamesi*) are known to subsist mostly on vegetation, supplemented by insects at certain times of the year. Knowledge of the species, phenology, and densities of insects available for capture could be important for growth and survival of grouse, with variability within seasons or year-to-year. We obtained crops from grouse harvested by licensed hunting in southern Alberta during October, and separated, identified, and determined the proportions and relative abundance of food types captured by grouse. The research is part of a 2-year study of the relative importance of insects in the diet, combined with monitoring and forecasts

of changes in the availability and abundance of grassland insects, and use of stable isotope analysis of feathers. Results showed that certain types of vegetation were over-represented, and that grouse were adept at hunting for grasshopper species like Dawson's grasshopper (*Melanoplus dawsoni*) in fescue grassland in the fall. This grasshopper is formed a significant part of the diet of the grouse. Changes in climate, weather variability, increasing pressure from agricultural development, and insect pest control have effects on the distribution, abundance, and biodiversity of insect species on grassland landscapes.



## POSTER SESSIONS E

### Behaviour & Communication

## Behaviour and communication

# ACOUSTIC & MORPHOLOGICAL VARIATION BETWEEN ANCIENT SOUTH AFRICAN ENDEMIC BLADDER GRASSHOPPERS SPECIES

Mikhaila Gordon

University of the Western Cape, Cape Town, South Africa; [mlgordon90@gmail.com](mailto:mlgordon90@gmail.com)

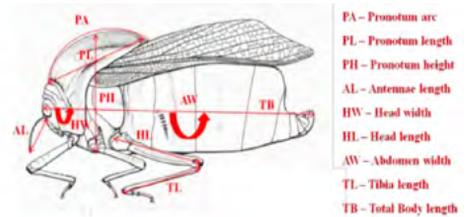
In 1965, the bladder grasshopper genus *Bullacris* was taxonomically reviewed in by Dirsh in which he described each of the seven known species based solely on morphological similarities and differences. Bladder grasshoppers are sexually dimorphic, with males having an inflated abdomen and the ability of flight, whereas the females lack the inflated abdomen and are micropterous. Communication between males and females are done by reciprocal duet-ting and this is responsible for mate location. Despite acoustics being a vital part of bladder grasshopper biology and reproduction success, the male advertisement calls of *Bullacris* males have not yet been compared across species. Therefore it is the aim of this chapter to compare and distinguish between the acoustic calls of *Bullacris* males as well as to differentiate between morphological characteristics between both male and female individuals from each of the known species.

Distribution maps show that species are mainly found along the coast of South Africa, occupying different habitat types. Morphological results have shown that each species is morphologically distinct, with the possible exception of females of *B. discolor* and *B. serrata* which clustered together, which is in accordance with Dirsh (1965). *Bullacris membracioides* is found to have the largest male and female individuals, whereas *B. unicolor* has the smallest male and female individuals. According to Spearman's correlations, there is no significant relationship between total body length and carrier frequencies of males, however, there is a strong relationship between abdomen width and carrier frequency.

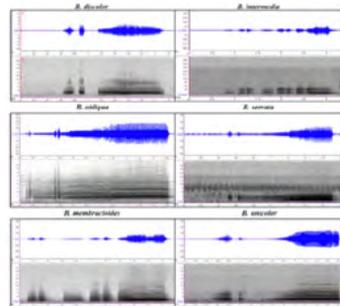
Results for acoustic call properties also indicate that each species is unique in terms of the sound signal produced. However, DFA analyses indicate that *B. unicolor*, *B. serrata* and *B. discolor* share some similarities in acoustic signals, whereas *B.*

*obliqua* has a much more distinct call from the rest.

In conclusion, results have shown that each species differs both morphologically and acoustically, thus broadly supporting the current classification by Dirsh (1965), however, there is some overlap between characteristics.



**Figure 1.** Diagram of a male *B. membracioides* (Dirsh, 1965), showing the nine linear anatomical measurements taken from females and males. For paired structures, the right hand sides were used for each measurement.



**Figure 2.** Waveform (above) and spectrogram (below) showing the differences between advertisement calls of *Bullacris* male species.

**Key Words:** Morphology, *Bullacris*, Distribution.

## Behaviour and communication

# THE ANATOMY OF THE CRISTA ACUSTICA OF VARIOUS BUSH-CRICKET SPECIES STUDIED USING MICRO-COMPUTED TOMOGRAPHY

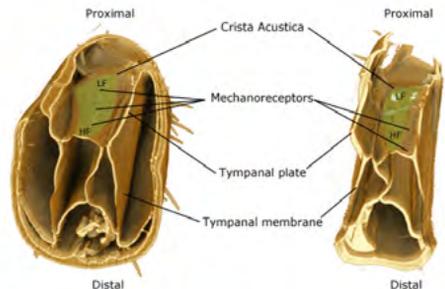
Sarah Aldridge<sup>1</sup>, Emine Celiker<sup>1</sup>, Daniel A. Veitch<sup>1</sup>, Fernando Montealegre-Z<sup>1</sup>

<sup>1</sup> Lincoln University, Lincoln, United Kingdom; [Saldrige@lincoln.ac.uk](mailto:Saldrige@lincoln.ac.uk)

Different from other insects, in bush-crickets the hearing process has evolved to be sophisticated and complex. The ear, located in the forelegs, consists of membranes and fluids that transform acoustic energy into mechanical, which is further interpreted by specialist cells (mechanoreceptors) and converted to electrical impulses for transmission through the nervous system. Unlike other acoustic insects the bushcricket ear is of interest as it exhibits the three major steps for hearing observed in tetrapods: sound capture, impedance conversion, and frequency analysis [1,2]. This hearing process involves a major transformation of energy from air to fluid.

Frequency analysis is achieved in the inner component of the ear by the Crista Acustica (CA), a curved semi-triangular surface sandwiched by two tympanic membranes, containing a row of mechanoreceptors (Fig. 1). These specialised cells traverse the CA, stimulating in response to interactions with the travelling wave [3]. Mechanoreceptors positioned at the distal part of the CA are tuned to high frequencies, and those located proximally respond to low frequencies. The general anatomy of the CA, including number of mechanoreceptors and their linear arrangement seem to vary across species. There are over 7000 species of bush-crickets across the planet, exploiting different acoustic channels and using conspecific signals that vary between elaborated pure tones (extreme narrow frequency band), and large spectral breadth (to something approaching noise). We will conduct an anatomical study of the inner ear of various bushcrickets species with the hypothesis that its structure is associated with the spectral component of the intraspecific signals.

Micro-computer tomography (micro-CT) is a non-destructive method that allows for the internal structure of small features to be analysed in 3D. A number of individuals from a range of species were imaged in this way to produce high resolution representations of the hearing organ. The number of mechanoreceptors and their distance along the CA can be counted and measured for comparison.



**Figure 1.** A comparison between the ear of a *Conocephalus* (left) and a *Phlugis* (right) ear, highlighting the variation in frequency, positioning and number of mechanoreceptors along the CA. HF = high frequency, LF = low frequency.

### References:

- Palghat Udayashankar, A., Kössl, M. & Nowotny, M. Tonotopically arranged traveling waves in the miniature hearing organ of bushcrickets. *Plos One* 7, e31008 (2012).
- Montealegre-Z, F., Jonsson, T., Robson-Brown, K. A., Postles, M. & Robert, D. Convergent evolution between insect and mammalian audition. *Science* 338, 968-971 (2012).
- Palghat Udayashankar, A., Kössl, M. & Nowotny, M. Lateralization of Travelling Wave Response in the Hearing Organ of Bushcrickets. *Plos One* 9, e86090 (2014).

**Key Words:** Frequency analysis, Cochlea, bioacoustics, Ultrasound, Micro-CT.



## Behaviour and communication

# EFFECT OF THREE AROMATIC AND MEDICINAL PLANTS ON THE FEEDING BEHAVIOR OF SCHISTOCERCA GREGARIA FORSKÅL

Bouchama El Ouazna<sup>1</sup>, Chater Oumaima<sup>1</sup>, Zahri Aziz<sup>1</sup>, El Ghadraoui Lahsen<sup>1</sup>, Errachidi Faouzi<sup>1</sup>

<sup>1</sup> Laboratory of Functional Ecology and Environment, Faculty of Science and Technology, University of Sidi Mohamed Ben Abdellah-Fez, Morocco. Route d'Immouzer, BP. 2202, Fez  
elouazna.bouchamma@usmba.ac.ma

The present study studies the feeding behavior of adults of the desert locust "*Schistocerca gregaria*" under the effect of essential oils of aromatic and medicinal plants. The plants tested are *Tanacetum anneum* L., *Thymus vulgaris* and *Artemisia herba alba* Asso. The different parameters studied are: the consumption rate of plants per day, consumption index (IC), digestive utilization coefficient (CUD), digestive conversion efficiency coefficient (ECD). The results obtained on the average variation of weight consumed by adults (controls and treated), show an antiappetant effect of the essential oils used. This effect is estimated

by the determination of gravity indices cited above. The essential oils tested have a significant differential effect on the consumption index of the adults studied.

The effects of the essential oils of the plants used on the trophic behavior of *Schistocerca gregaria* used as an animal model, would allow us to eventually plan the development of locust control products.

**Key Words:** *Schistocerca gregaria*, Essential oils, Food behavior, locust control.



## Behaviour and communication

# PROCESS OF GREGARIZATION AND SOLITARIZATION OF THE CENTRAL AMERICAN LOCUST (*SCHISTOCERCA PICEIFRONS*) IN THE LAB AND IN THE FIELD

Bert Foquet<sup>1\*</sup>, Drew Little<sup>1</sup>, Mario A. Poot Pech<sup>2</sup>, Hojun Song<sup>1</sup>

<sup>1</sup> Department of Entomology, Texas A&M University, College Station, Texas, U. S. A.; bertfoquet@tamu.edu

<sup>2</sup> Yucatan State Plant Protection Committee (Locust Program), Merida, Yucatan, Mexico

Historically, field work on locust collective movement has been rare due to the scarcity of locust outbreaks and the difficulty to work in most outbreak locations. What we know about locust phase polyphenism in the desert locust (*Schistocerca gregaria*) and the migratoria locust (*Locusta migratoria*) has mostly been generated from laboratory studies using locust colonies. While these studies are valuable, it is not clear how well they can be translated into what actually happens in the field because locust outbreaks occur in numbers that are magnitudes higher than what can be manipulated in the lab. The Central American locust, *Schistocerca piceifrons*, provides an exceptionally attractive opportunity to link laboratory research to field research, as outbreaks occur regularly (about once every four years) in Yucatan, Mexico, which is located in a stable, easy-to-reach region. Moreover, the locust populations are very well managed by the local locust control program in Yucatan, and the locust officers have extensive knowledge of this species. In this study, we take full advantage of this unique opportunity to perform an investigation of the process of gregarization and solitarization of locusts, both in the lab and in the field, to assess how laboratory data can be translated to what occurs in nature. First, we performed a laboratory experiment using

a colony of *S. piceifrons* originally established from Yucatan. This experiment established the time-course of behavioral transformation from the gregarious phase to the solitarious phase behavior and vice versa. We found that it would take 2 hours for the solitarious nymphs to gregarize. For gregarious nymphs, a fast partial solitarization happens within 1 hour, but only half of the nymphs become fully solitarious in 48 hours. Subsequently, we set up a field experiment in Yucatan in which the radio-tagged nymphs were tracked using radio telemetry. We performed a reciprocal transplant experiment, in which solitarious nymphs were placed in a gregarious hopper band, and gregarious nymphs were placed in a solitarious population. In both cases, the same number of gregarious or solitarious nymphs, respectively, was released at the same location as a control. All nymphs were followed for 3 days in hopper bands and 2 days in solitarious populations using radiotelemetry, and each experiment was repeated three times. We compare and contrast the results of the lab and field experiment, and discuss their similarities and discrepancies.

**Key Words:** radio telemetry, nymphal band, Central American locust.

## Behaviour and communication

# REPEATED PREDATORY APPROACHES CAUSE THE RICE GRASSHOPPER TO REPEAT THE SAME LOCOMOTION MODE DURING ESCAPE: FLYING OR JUMPING

Tatsuru Kuga<sup>1</sup>, Eiiti Kasuya<sup>2</sup>

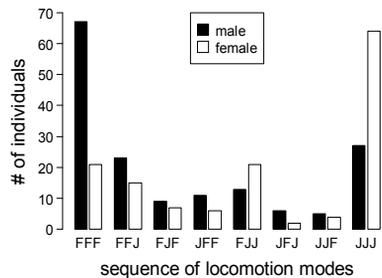
<sup>1</sup> Graduate School of System Life Sciences, Kyushu University, Fukuoka, Japan; tkuga486@gmail.com

<sup>2</sup> Department of Biology, Faculty of Science, Kyushu University, Fukuoka, Japan

Prey that escapes from a predator uses various modes of locomotion, such as walking, running, hopping or swimming. In some observations, individual prey escapes by two or more locomotion modes. Previous studies show that such prey uses different locomotion modes based on the physical conditions of it or the environmental conditions during the escape (e.g., body size or temperature). After the prey escaped, some predators give up the pursuit, while others persist in the pursuit. This repeated pursuit causes the prey to escape again for surviving. We can predict that this prey will change its locomotion modes during the repeated pursuit. One reason for this is that changing these modes increases the unpredictability of the trajectory, which increases the escape success. However, the locomotion modes during repeated escape attempts have rarely been explored. Our study focuses on the shift of the locomotion modes in the Japanese rice grasshopper *Oxya yezoensis*, which escapes by either flying or jumping.

In October and November 2016, we simulated a persistent predator and recorded the locomotion modes of *O. yezoensis* in the field. We approached the wild individuals three times in a row (161 males and 140 females). Their locomotion modes during escape were recorded by two cameras. The results indicated that the grasshoppers escaped by the same locomotion mode repeatedly (Figure 1). Chi-squared tests showed that each of the locomotion modes during three consecutive escape attempts was not decided independently. Moreover, we tested statistically whether specific conditions of the grasshoppers or the environment caused these results or not. In the tests, we divided the data according to two factors and checked the consecutiveness of the same mode in each subset. One of the two factors was sex (male/female). The other was grass height (high/Low),

experimental period (first half/second half) or any one of the following: temperature, humidity, body length or body weight (more/less than median). In the results, some factors changed the ratio between flying and jumping in each escape attempt. Regardless of the effects of these factors, the observed probabilities of using the same locomotion mode as before were always higher than the probabilities expected under random use of the modes. In conclusion, *O. yezoensis* escaping from a persistent predator tends to repeat the same locomotion mode in any physical and environmental conditions. This is opposite to the first hypothesis of changing locomotion modes and provides a new insight into the escape tactics of prey.



**Figure 1.** The sequence of the locomotion modes of *O. yezoensis* in three consecutive escape attempts.

F means flying and J means jumping. Each trigram on the x axis shows each locomotion mode in order of occurrence. For example, when the grasshopper escaped by flying first, jumping second, and flying third, its sequence of the locomotion modes is FJF.

**Key Words:** escape behaviour, locomotion mode, flying, jumping, repeated approach, rice grasshopper, *Oxya yezoensis*.



## Behaviour and communication

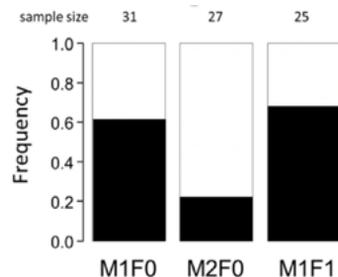
# SOCIAL ISOLATION FACILITATES MALE AGGRESSIVENESS TO FEMALES IN THE CRICKET

Takashi Kuriwada

Kagoshima University, Kagoshima, Japan; kuriwada@edu.kagoshima-u.ac.jp

Social isolation often facilitates aggressiveness to other individuals in various animal species, even in species that have been considered asocial (i.e., not eusocial or not living in groups). Field cricket *Gryllus bimaculatus* reared in isolation also have higher aggression to other males than those reared in a social environment. In the context of sexual selection, social interaction has mainly focused on male-male competition, especially in sperm competition. However, if social isolation also escalates male aggressiveness to conspecific females, their mating success will be decreased by the high aggressiveness. I examined the effect of social isolation on mating behavior in the field cricket *Gryllus bimaculatus*. To control the social relationships of the males, newly emerged virgin males were assigned as 3 treatment groups: isolated males (M1F0), cohobated with another male (M2F0), and cohobated with a female (M1F1). After the treatments for 7 days, each male was offered the opportunity to mate with a virgin female, and their mating behavior was observed. When males cohobated with another male, male aggressiveness was lower than in the other treatments (Fig: M1F0 vs. M2F0:  $P = 0.011$ , M1F0 vs. M1F1:  $P = 0.84$ , M2F0 vs. M1F1:  $P = 0.0034$ ). Higher male aggressiveness reduced the male mating success ( $P = 0.017$ ). The latency to courtship (i.e., the indicator of male motivation for mating) of aggressive males was longer than that of less aggressive males ( $P < 0.05$ ). The results indicated that higher aggressiveness delayed male courtship to females. On the other hands, latency to copulation (i.e., the indicator of male attractiveness) was positively correlated with male aggressiveness, but the relation was marginal ( $P = 0.058$ ). The present results showed that isolation

from other males increased male aggressiveness toward females. Furthermore, the mating success was also decreased by their higher aggressiveness. More aggressive males exhibited a longer latency to court to females than less aggressive males. This will be because male aggressiveness causes a delay in courtship, aggressive males may have reduced mating success. Furthermore, male attractiveness was decreased with their aggressiveness. These results showed that social isolation, particularly in social relationships among same sex individuals, are a critical factor affecting male mating success. This has important implications for the field of sexual selection. The effect of social experiences should be considered to understand the evolution of reproductive strategy, because social conditions affect mating behavior even in asocial species.



**Figure 1.** Focal males that exhibited (black areas) or not (white areas) aggressive behavior. Isolated (M1F0), male-only (M2F0) and female (M1F1) treatments.

**Key Words:** social behavior, mating behavior, field cricket, sexual selection, contest behavior.

## Behaviour and communication

# ASSESSMENT STRATEGY CHANGES ALONG CONTESTS IN THE NEOTROPICAL CRICKET MELANOTES ORNATA (GRYLLOIDEA: PHALANGOPSIDAE)

Gabriel Lobregat<sup>1</sup>, Thiago Gechel Kloss<sup>2</sup>, Paulo Enrique Cardoso Peixoto<sup>3</sup>, Carlos Frankl Sperber<sup>4</sup>

<sup>1</sup> Programa de Pós-Graduação em Ecologia, Universidade Federal de Viçosa, Viçosa, MG, Brazil

<sup>2</sup> Departamento de Ciências Biológicas, Universidade do Estado de Minas Gerais, Ubá, MG, Brazil

<sup>3</sup> Instituto de Ciências Biológicas, Departamento de Biologia Geral, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil

<sup>4</sup> Departamento de Biologia Geral, Universidade Federal de Viçosa, Viçosa, MG, Brazil, [sperberufv@gmail.com](mailto:sperberufv@gmail.com)

Recognizing how animals decide when to withdraw from their fight is central to understand evolution of fighting behaviour. Game theory models suggest two major types of decision criteria: self-assessment: where individuals withdraw when they achieve a threshold of costs associated to its own fighting ability, which may or may not be affected by injuries, or mutual assessment: where the decision of withdrawing is based on information about relative fighting ability between opponents. Many studies failed to find conclusive support for one exclusive assessment strategy, and it has been suggested that individuals may change their assessment strategy during the fight. In the present work, we addressed this question by evaluating the assessment strategies *Melanotes ornata* male crickets along their contests. We used hind femur length as a proxy of fighting ability, as it was the best attribute explaining contest outcome. Overall fight duration was positively associated to loser femur length and negatively associated to winner femur length, while the probability of fights escalating to physical aggression was negatively related to femur length difference between opponents. When analysing the duration of different contest phases, however, such relationships occurred only at earlier stages of the fight, and no relationship between fighting ability and duration was found for escalated phases. This suggests that *M. ornata* males present mutual assessment in the initial phase of the contest, but switch their assessment strategy when fights

escalate, indicating that a single strategy may not explain adequately how contests are settled. The lack of relationship between duration and fighting ability when fights escalate, suggest that, instead of fighting ability, other asymmetries may be more important to determine fight withdrawal in escalated phases.



**Figure 1.** Males of *Melanotes ornata* in an escalated contest. Individuals position their posterior region towards each other, cross their hind legs and start a series of pushes and kicks with hind legs. Individuals also raise their tegmen and emit intermittent acoustic signals of variable duration (represented by the individual in the right).

**Key Words:** Evolutionary game theory, switching assessment strategies, aggressive behaviour, animal contest, fighting behaviour, Grylloidea, Phalangopsidae.



## Behaviour and communication

# EFFECTS OF SUBSTRATE HUMIDITY ON OVIPOSITION SITE SELECTION AND INCUBATION SUCCESS IN GROUNDHOPPERS *TETRIX SUBULATA* AND *TETRIX TENUICORNIS* (ORTHOPTERA: TETRIGIDAE)

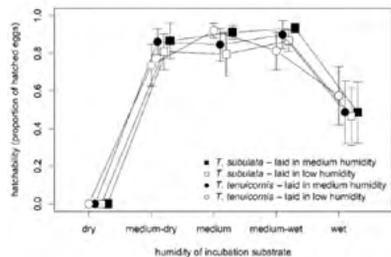
David Musiolek<sup>1,2</sup>, Petr Pyszek<sup>1</sup>, Petr Kočárek<sup>1</sup>

<sup>1</sup> University of Ostrava, Faculty of Science, Department of Biology and Ecology, Chittussiho 10, CZ – 710 00 Ostrava, Czech Republic; musiolek.david@gmail.com

<sup>2</sup> Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Kamýcká 129, CZ – 165 21 Praha 6 – Suchbát, Czech Republic

Groundhoppers of genus *Tetrix* (Orthoptera: Tetrigidae) occupy habitats dominated by mosaic of sparse vegetation, bare ground, and mossy cover. Females often actively search for mossy patches despite moss is not their main food component and it doesn't provide crypsis advantage. The reason of such behaviour is therefore unclear. Females lay egg clutches from spring to summer few millimetres under substrate surface. Eggs absorb water during incubation and hatch 3-4 weeks after oviposition. The mosaic habitat vary in substrate humidity, but mosses are known for their water retention ability. We therefore presume that (1) females search for mossy patches as oviposition sites to reduce egg mortality caused by dehydration; (2) a choice of oviposition substrate has higher fitness consequences for groundhopper species inhabiting relatively dry habitats than for species living in wet habitats. To check these two presumptions, we experimentally tested oviposition substrate choice and eggs hatchability in relation to substrate type and humidity in two common European groundhopper species: hygrophilous *Tetrix subulata* and dry tolerant *T. tenuicornis*. Gravid females were individually kept in plastic cups with cover formed from three equally distributed substrate types: moss, sand, and detritus. We also used two substrate humidity treatments (low and medium). Egg clutches were transferred to other cups for incubation in five levels of substrate humidity: from dry (5±5%) to wet (95±5%). Numbers of hatched and unhatched eggs were counted in each clutch. To test for oviposition substrate type selection, hatchability dependency on laying substrate humidity, incubation substrate humidity, and species identity, standard and

weighed GLMMs with binomial distribution were used. Females significantly discriminated between the three oviposition substrates. Sand and moss were similarly preferred under medium humidity whereas the moss was highly preferred under low humidity. The preferences were similar in both species, but *T. tenuicornis* (drought tolerant) showed more sensitive response to humidity than *T. subulata* (hygrophilous). Egg hatchability showed unimodal trend dependent on incubation substrate humidity (see figure). The results support our hypotheses. Females may search for mossy patches as oviposition sites to enhance their fitness, especially in habitats with fluctuating humidity.



The research was supported by The Theodor J. Cohn Research Grant 2017 (The Orthopterists' Society) and by grant "EVA4.0", No.CZ.02.1.01/0.0/0.0/16\_019/0000803 financed by OP RDE.

**Key Words:** Locust, palp opening response, odorant receptor, inotropic receptor, odorant-binding protein, RNAi, aldehydes.



## Behaviour and communication

# AUDITORY ADAPTATION TO HIGH-FREQUENCY CALLS IN ENEOPTERINE CRICKETS

Stefan Schöneich<sup>1</sup>, Tony Robillard<sup>2</sup>, Hannah M. ter Hofstede<sup>3</sup>

<sup>1</sup> University of Leipzig, Institute for Biology, Talstr. 33, 04103 Leipzig, Germany;

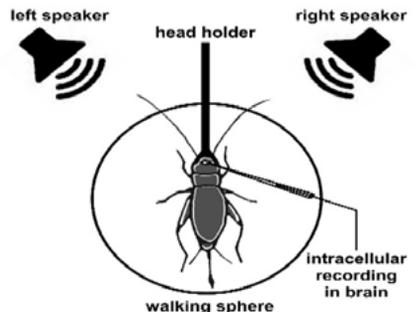
Stefan.Schoeneich@uni-leipzig.de

<sup>2</sup> Muséum national d'Histoire naturelle, Paris, France

<sup>3</sup> Dartmouth College, Hanover, NH, USA

In field crickets (*Gryllus bimaculatus*), the brain receives auditory input from two ascending interneurons; AN1 is sharply tuned to the low-frequency (5 kHz) calling song of the males and controls positive phonotaxis, whereas AN2 triggers negative phonotaxis and is tuned to high-frequency sounds like predatory bat calls. In one group of crickets (Eneopterinae: Lebinthini), however, males produce exceptionally high-frequency calling songs. We recently found that female lebinthines, instead of approaching singing males, produce vibrational responses after male calls, and males then track the source of vibrations to find females [ter Hofstede et al., *Curr Biol* 2015; doi: 10.1016/j.cub.2015.10.064]. In the eneopterine cricket *Cardiodactylus muria*, the dominant frequency of male calls is 14 kHz. Extracellular recordings from the neck connectives in *G. bimaculatus* showed similar activity levels in response to 5 and 14 kHz sound pulses due to AN1 and AN2 activity, respectively. Connective recordings in *C. muria*, however, showed no neural activity in response to 5 kHz and strong activity in response to 14 kHz sound pulses. We assume that either AN1 has been lost in *C. muria* or its frequency tuning has also shifted to that of the AN2. Intracellular recording and staining in the brain were conducted to compare morphologies and the directional- and frequency-tuning of auditory ascending interneurons in the two cricket species. For this, 20 ms pure-tone pulses of systematic frequency (2–20 kHz) and level (35–80 dB SPL) combinations were played by speakers positioned at 45° left and right in front of the cricket, while the animal was standing freely, only tethered at its head, on a walking sphere. In *G. bimaculatus* (N=20), we could unambiguously discriminate between AN1 and AN2 based on their frequency tuning and morphology. AN1 responses

showed highest directionality (spike difference between ipsi- and contralateral sound stimulation) towards soft sound pulses of 45–50 dB at 5 kHz with directionality slightly decreasing at higher intensities, whereas AN2 directionality increased steadily with increasing intensity for 14 and 5 kHz. All ascending auditory interneurons recorded in *C. muria* (N=12) were only sensitive to high-frequency sounds with tuning curves resembling AN2 of *G. bimaculatus*. AN-responses in *C. muria*, however, showed only a small directionality peak just above its response threshold of 55 dB at 14 kHz, and almost no evidence of directionality at other frequencies and intensities. Whereas frequency and amplitude-dependent directionality is seen in *G. bimaculatus*, it appears that AN-directionality has been lost in *C. muria*, perhaps due to the evolution of a new communication system in Lebinthini crickets in which females do not require directional acoustic cues because males find the females based on the vibrational reply.



**Key Words:** Locust, palp opening response, odorant receptor, inotropic receptor, odorant-binding protein, RNAi, aldehydes.



## Behaviour and communication

# TWO OLFATORY PATHWAYS INDEPENDENTLY DETECTING TO ONE ALDEHYDE IN LOCUST MOUTHPART

Liwei Zhang<sup>1</sup>, Hongwei Li<sup>1</sup>, Long Zhang<sup>1\*</sup>

<sup>1</sup> Department of Entomology, China Agricultural University, Beijing 100193, PR China; \*locust@cau.edu.cn

sensing chemical cues is crucial for insects through their olfactory systems to adapt the environments. The receptors employed in insect olfactory system belong to the Odorant Receptor (ORs) and Ionotropic Receptor (IRs) families. In general, ORs and IRs are present in distinct olfactory sensory neurons and function independently. Here, we present evidence that in locust, the abundant host plant odor, Hexanal is detected by both IR- and OR-expressing neurons using the palp opening response (POR) as a simple behavioral paradigm in conjunction with RNA interference (RNAi). Two-color fluorescence *in situ* hybridization showed that OR2 and odorant-binding protein 1 (*OBP1*) were co-localized in palps sensilla basiconica. Whereas, *OBP2a* and *IR8a* were co-localized as well, but in

sensilla chaetica on the palps. Furthermore, both *OR2*- and *OBP1*-knockdowns by RNAi showed that POR responses significantly decreased to Hexanal and E-2-Hexenal, and the same was true for Hexanal with *IR8a*- and *OBP2a*-knockdowns. Interestingly, both the responses of POR of ORco silencing and *IR8a* silencing locusts to Hexenal were significantly reduced, but there was no additive effect when they together were RNAi in one locust. Our results indicate that both OR and IR pathways are involved in the detection of one aldehyde.

**Key Words:** Locust, palp opening response, odorant receptor, ionotropic receptor, odorant-binding protein, RNAi, aldehydes.



## Behaviour and communication

# EXPRESSIONS OF OLFACTORY PROTEINS IN LOCUST OLFACTORY ORGANS AND A PALP ODORANT RECEPTOR INVOLVED IN PLANT ALDEHYDES DETECTION

Hongwei Li<sup>1</sup>, Peng Wang<sup>1</sup>, Liwei Zhang<sup>1</sup>, Xiao Xu<sup>1</sup>, Zewen Cao<sup>1</sup>, Long Zhang<sup>1\*</sup>

<sup>1</sup> China Agricultural University, Beijing 100193, China; \* locust@cau.edu.cn

The main chemosensory organs of locusts consisted of the antennae and the mouthparts (maxillary and labial palps), which are suggested to perform different functions. However, very few are known about the differences of these two organs at molecular level. To understand the differences of locust antennae and palps in olfaction, the electrophysiological response and olfactory gene expression of these two organs were conducted. Our electrophysiological experiments with *Locusta migratoria* showed that the responses of mouth part palps and antennae to odorants are quite different. Only a few odorants, such as (*E,E*)-2,4-hexadienal and (*E,E*)-2,4-heptadienal, elicited stronger electrophysiological responses of both maxillary and labial palps in comparison to the antennae. Additionally, we obtained 114 and 11 putative odorant receptor (OR) gene segments from the antennal and palp transcriptomes, respectively. Two novel odorant binding proteins (OBPs; OBP15 and OBP16) and one novel OR (OR142) were identified for the first time. Out of the 16

OBP genes tested in RT-PCR and qPCR analyses, OBP8 was highly expressed in the nymphal palps. OBP4, OBP10, and OBP16 were only detected in the antennae. The other 11 OBP genes were jointly expressed in both antennae and palps. The relative expression level of OBP6 in male palps was much higher than that of female palps. Furthermore, for the 11 OR genes identified in palp transcriptome, the expression levels of OR12, OR13, OR14, and OR18 in the palps were significantly higher than those in the antennae. The OR12 in palps was demonstrated to be involved in detection of hexanal and E-2-hexenal, as well as (*E,E*)-2,4-heptadienal. Our results provide information on the different olfactory roles of locust antennae and palps at the molecular level.

**Key Words:** Olfactory organs, electrophysiological response, odorant binding protein, odorant receptors, *Locusta migratoria*



## Behaviour and communication

# IDENTIFICATION AND OLFACTOMETRIC BIOASSAY OF SEX-SPECIFIC VOLATILE COMPOUNDS IN ADULT *LOCUSTA MIGRATORIA* (MEYEN) (ORTHOPTERA: ACRIDIDAE)

Jia Li<sup>1</sup>, Xiaoqi Wang<sup>1</sup>, Long Zhang<sup>2</sup>

<sup>1</sup> Plant Protection College, Shenyang Agricultural University, Shenyang, China; academic989@126.com

<sup>2</sup> Key Lab for Biological Control, Ministry of Agriculture, China Agricultural University, Beijing, China

Gregarious locusts use volatile semiochemicals released from their bodies and feces to regulate their biological characteristics, and many of these compounds are sex-specific. The locust *Locusta migratoria* (Orthoptera: Acrididae) is a frequent plague species in China, but very little is known of its olfactory behavioral ecology. In the study, four and six compounds were identified respectively from body and fecal volatiles of gregarious adult *L. migratoria* using a gas chromatograph coupled to a mass spectrometer. 2-Hexanone, butyl acetate and  $\alpha$ -pinene were from the body volatiles of both sexes and 2-heptanone from that of males only. 3-Methyl-1-butanol, cyclohexanol, 2,5-dimethyl-pyrazine, 6-methyl 5-hepten-2-one and 2,6-trimethyl-

2-cyclohexene-1,4-dione were present in the fecal volatiles of both sexes, and 2,2,6-trimethyl-cyclohexanone only in that of females. Olfactometric bioassays indicated that the male-specific 2-heptanone repelled the adult males, but had no effect on females. On the other hand, female-specific 2,2,6-trimethyl-cyclohexanone was found to repel the adult females, but had no effect on males. The two sex-specific compounds may help to improve reproductive efficiency of the locusts.

**Key Words:** Locust, GC-MS, olfactometric bioassay, sex-specific semiochemicals, reproductive efficiency.

## Behaviour and communication

### DOES AGE AFFECT DECISION MAKING IN MALE BUSHCRICKETS?

Antoniya Hubancheva<sup>1,2</sup>, Dragan Chobanov<sup>2</sup>, Holger R. Goelitz<sup>1</sup>

<sup>1</sup> Acoustic and Functional Ecology Group, Max Planck Institute for Ornithology, Seewiesen, Germany  
email address: antonia.hubancheva@gmail.com

<sup>2</sup> Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria

In nature, behavioural decisions can affect drastically animal fitness. Animals often have to trade off important activities such as searching for mating partners for predation avoidance. For instance, male bushcrickets (Orthoptera: Tettigoniidae) attract females by species-specific ultrasonic calls that are exploited by eavesdropping predators such as bats. Therefore, in many bushcricket species males are under strong pressure to constantly trade-off between singing for mate attraction and ceasing the mating song to avoid predation. Moreover, in most bushcricket species the life of the adult forms is short, often limited to only one breeding season. At the beginning of the mating season, males still have a long lifespan and should prioritize predator avoidance over mating effort. Closer towards the end of the breeding season, the male's lifespan is becoming shorter, regardless of their current singing effort. However, little is known about which factors affect the trade-off between singing and song cessation when males hear an attacking bat and if the decision-making process is changing during the lifespan of the animals. Here we hypothesized that with increasing age the bushcricket will accept higher levels of predation risk while singing, effectively prioritizing mating opportunities over survival.

To test our hypothesis we conducted a series of behaviour playback experiments with wild caught male *Tettigonia viridissima* (n=8) in controlled lab conditions. In a large dark flight room, we placed individual bushcrickets within a mesh cage once with and once without singing competitor male present in the room. Then we presented the tested bushcricket with acoustic stimuli: bat echolocation calls with different intensities and repetition rates mimicking higher or lower predation threat levels. We tested the experimental animals twice during the mating season measuring the song cessation duration in response to the different treatments. The first test was conducted at the beginning of the mating season (two weeks after the first singing attempts of the bushcrickets). The experimental animals were tested for a second time one month after the first test.

Our preliminary results suggest that decision making in bushcrickets is affected by the age of the animals.

**Key Words:** Orthoptera, Tettigoniidae, Pseudophyllinae, Nesoecia nigripina, acoustic communication.



## Behaviour and communication

# ACOUSTIC COMMUNICATION IN *NESOECIA NIGRISPINA* (ORTHOPTERA: PSEUDOPHYLLINAE)

Olga Korsunovskaya<sup>1</sup>, Rustem Zhantiev<sup>1</sup>

<sup>1</sup>Moscow Lomonosov State University, Moscow, Russia; korsuno@mail.ru

The males of Mexican katydids *Nesoecianigrispina* (Stal) produce calling songs and protest sounds using the same stridulatory apparatus as in most of the other Ensifera at the base of the elytra. It includes pars stridens on the upper elytron and plectrum on the lower. Calling sounds are 2-pulse series, repeated with a frequency of 2-3 s<sup>-1</sup>. Protest signals in the form of short trills from the same pulse duration males produce with tactile stimulation. The pulse repetition rate is almost three times higher than that of the calling sounds - up to 10<sup>-1</sup>. The frequency spectra of these signals have maxima in the band of 14-15 kHz. However, in addition to the sounds described, both males and females are capable to produce protest signals of the second type with the help of another sound apparatus, namely with the help of the wings. Insects with removed elytra are unable to produce an audible sound. Thus, the sound is produced by the friction of the wings on the elytra, but there are no specialized stridulatory structures on them. In females, in response to tactile stimulation, short clicks are recorded, which they make, apparently, by the mandibles. During courtship, both males and females produce vibration signals at tremulation.

*Investigations were supported by Russian Foundation for Basic Research (grant No -04-19 00104).*

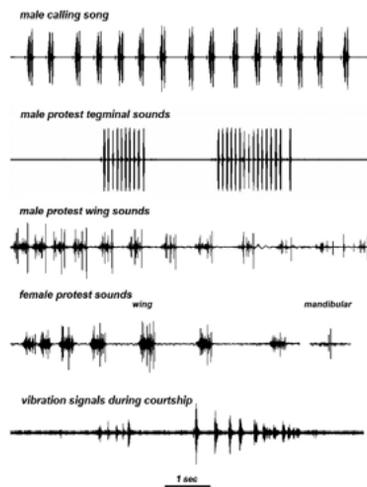


Figure 1. Acoustic signals of *N. nigrispina*

**Key Words:** Orthoptera, Tettigoniidae, Pseudophyllinae, *Nesoecia nigrispina*, acoustic communication.

## Behaviour and communication

# COLOCALIZING MALE SONG AND FEMALE PREFERENCE LOCI FACILITATE RAPID EVOLUTION OF BEHAVIORAL BARRIERS IN THE HAWAIIAN CRICKET LAUPALA

Ming Xu<sup>2</sup>, Kerry L. Shaw<sup>1</sup>

<sup>1</sup> Department of Neurobiology and Behavior, Cornell University Ithaca, NY USA; KLS4@cornell.edu

<sup>2</sup> Department of Neurobiology and Behavior, Cornell University Ithaca, NY USA

The establishment of reproductive barriers is fundamental to the speciation process. Divergent sexual signals can be an important contributor to reproductive barriers. Yet divergence of sexual signaling systems is ultimately a coevolutionary problem: while signal and preference can each diverge between lineages, they must remain coordinated, and therefore, coevolve within a lineage for matings to occur. The genetic mechanism that enables signal-preference coevolution still remains a major evolutionary puzzle. Formal tests of hypotheses for the genetic architecture underlying trait-preference coevolution, namely linkage disequilibrium between unlinked signal and preference loci, pleiotropy of a shared locus, or physical linkage, are challenging to conduct. In the *Laupala* crickets where male song pulse rate and female pulse rate preference have coevolved repeatedly and rapidly, we can test the above three hypotheses due to the simplicity of the acoustic behavior and the ability to conduct crosses between species that have dramatically different songs and preferences. Through selective introgression and quantitative trait loci (QTL) mapping, we estimate the location of the QTL underlying interspecific differences in pulse rate and preference. Remarkably, map estimates of the two loci are only 0.06 cM apart, representing the strongest evidence to date for either pleiotropy or tight physical linkage. This is the second pair of colocalizing pulse rate and preference loci found in the *Laupala* genome, indicating an intriguing role of pleiotropy or tight physical linkage in rapid speciation. Further,

pleiotropy was previously considered unlikely and was dismissed by most models of sexual selection. Our finding suggests the exciting possibility that pleiotropy is a genetic mechanism that promotes coordinated evolution of signals and preference that are the targets of sexual selection.



Figure 1. *Laupala kohalensis* male.



Figure 2. *Laupala kohalensis* female.

**Key Words:** speciation, sexual communication, genetics, evolution, acoustics

## Out of Session

# INSECT AN ACADEMIC ONLINE TRAINING ON INSECTS

Laure Desutter-Grandcolas<sup>1</sup>, André Nel<sup>1</sup>

<sup>1</sup>Institut de Systématique, Evolution et Biodiversité (ISYEB), Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, EPHE, 57 rue Cuvier, CP50, 75231 Paris cedex 05, France. [desutter@mnhn.fr](mailto:desutter@mnhn.fr)

Insects represent 75% of extant animal diversity. They are involved in key biological processes for the functioning and evolution of terrestrial biodiversity and maintain complex relations with humans. Insects also constitute an endless source of model groups to study, in fundamental and applied sciences or for biomimicry. In all these contexts, species identification and knowledge of their biology are crucial.

Species identification requires a basic knowledge of insect morphology and anatomy, since the correspondence between molecular and morphological species is not robustly validated for all species. Despite the importance, this basic knowledge is increasingly rare and the number of scientists specialized in morphology, systematics and biology of insects continues to decline. These global trends result in real shortcomings in the academic world for the teaching and study of the systematics of entire orders of insects. For several years, we have been witnessing a massive loss of skills and expertise. However, new issues appear in the study of insects, with recent advances in molecular and cell biology or through the use of new techniques of analysis and imaging, and these renew comparative studies of anatomy and morphology. Similarly, the integration of fossil data into modern species studies provides a better understanding of the unparalleled megadiversity of insects and a better understanding of its role in ecosystem change as part of global change.

INSECT teaching includes two interactive components for a solid and personalized training: the first concerns a body of knowledge on morphology, anatomy, phylogenetic systematics and evolution of insects, as well as techniques for observing and analyzing their phenotypic

characteristics. The second deals with issues concerning the place of insects in their environment and their evolution in a changing world (including societal applications). INSECT is fundamentally multidisciplinary.

INSECT includes the following modules:

**Module I** : What is an insect ?

**Module II** : Systematics, phylogeny and evolution of insects

**Module III** : Insects, from the field to Museum

**Module IV** : Ecology of insects in a changing world

**Module V** : Insects in their environment

**Module VI** : Of insects and man: societal problems and issues.

In terms of learning, INSECT will allow:

- to acquire basic knowledges on insects (morphology, anatomy, genomics) ;
- to acquire a general frame on insect systematics and evolution ;
- to know how to observe and analyse phenotypic characters ;
- to address analytical techniques and scientific problems according to their general interest for the management and study of local biodiversity;
- to analyse relations between insects and man, based on recent developments ;
- to know the role of naturalist collections and databases on insects.

INSECT was proposed in 2018 to the Master Systematics, Evolution and Paleontology of the Muséum national d'Histoire naturelle, Paris et Sorbonne University.

INSECT will become multilingual.

**Key Words:** Entomology, Teaching, Internet



## LIST OF PARTICIPANTS

LAST NAME	First Name	E-mail	Pages
ABBASSI	Khadija	abbassi_khad@yahoo.fr	162
ABDALLA YAHIA	Abdalla Mohamed	khalil2004@hotmail.com	172
ABDELATTI	Zainab Ali Saad	zainab.abdelatti@edu.uni-graz.at	216
AMMAR	Mohamed	ammam.med@inat.agrinet.tn	114 ; 152
ALDRIDGE	Sarah	saldridge@lincoln.ac.uk	185 ; 255
ANICHINI	Marianna	mary.anichini@gmail.com	47
AXELSEN	JørgenAagaard	jaa@bios.au.dk	39
AYALI	Amir	ayali@tauex.tau.ac.il	40 ; 42
AZZOUZI	Amal	amal.azzouzi@usmba.ac.ma	109 ; 196
BAILEY	Nathan	nwb3@st-andrews.ac.uk	48
BAKER	Edward	ed.baker@york.ac.uk	177
BALAKRISHNAN	Rohini	brohini@iisc.ac.in	180
BAUER	Norbert	bauernorbert1973@gmail.com	76 ; 151
BEN CHOUIKHA	Manel	Manelchouikha74@gmail.com	114 ; 152
BENAVIDES LOPEZ	Jose Luis	jose.benavides-lopez@edu.mnhn.fr	178
BENGUERAICHI	Fatiha	fatiha.bengueraichi@univ-biskra.dz	195 ; 197
BENHALIMA	Thami	thami.benhalima1@gmail.com	9
BENJELLOUN	Meryem	meryem.benjelloun@usmba.ac.ma	112 ; 248
BENKENANA	Naima	benkenanan@yahoo.co.nz	115 ; 214 ; 238
BENOIT	Laure	laure.benoit@cirad.fr	120 ; 197
BENSAAD	Hamid	hamidbensaad@gmail.com	242
BERTRAM	Susan	sue.bertram@carleton.ca	49 ; 139 ; 184
BORISOV	Simeon	borissovsb@gmail.com	22 ; 23
BOUAICHI	Abdelghani	bouaichi.agadir@gmail.com	145 ; 215 ; 216
BOUCHAMA	El Ouazna	elouazna.bouchamma@usmba.ac.ma	110 ; 111 ; 256
BOUGUESSA	Slim	bouguessaslim2009@gmail.com	213 ; 236
BOUGUESSA-CHERIAK	Linda	cheriaklinda2005@yahoo.fr	213 ; 236
BRANSON	David	Dave.Branson@ars.usda.gov	146
BRAUN	Holger	braun@fncym.unlp.edu.ar	155
BREER	Heinz	physiologie@uni-hohenheim.de	94
BRÖDER	Linda	linda.broeder@mailbox.org	30
BUGROV	Alexandre	bugrov04@yahoo.co.uk	64 ; 69 ; 131 ; 202
CASTILLO	Elio Rodrigo	castillo.eliorodrigo@gmail.com	124
CEASE	Arianne	acease@asu.edu	16 ; 74 ; 138 ; 148
CHAPUIS	Marie-Pierre	marie-pierre.chapuis@cirad.fr	82 ; 117 ; 120 ; 198



CHEKE	Robert	r.a.cheke@greenwich.ac.uk	35
CHIHREANE	Jamal	chihreane_61@yahoo.fr	37 ; 215 ; 220 ; 246
CHINTAUAN-MARQUIER	Ioana Cristina	icchintauan.marquier@gmail.com	63 ; 71
CHOBANOV	Dragan	dchobanov@gmail.com	23 ; 66 ; 266
CIGLIANO	Maria Marta	<a href="mailto:cigliano@fcnym.unlp.edu.ar">cigliano@fcnym.unlp.edu.ar</a>	15 ; 25 ; 59 ; 124 ; 186
CIPLAK	Battal	<a href="mailto:ciplakbattal@gmail.com">ciplakbattal@gmail.com</a>	127 ; 130 ; 192 ; 193
CISSE	Sory	<a href="mailto:sorycisse01@yahoo.fr">sorycisse01@yahoo.fr</a>	37 ; 187
CLEMENTE	Eulalia	<a href="mailto:clemente@um.es">clemente@um.es</a>	208
COULDRIDGE	Vanessa	<a href="mailto:vcouldridge@uwc.ac.za">vcouldridge@uwc.ac.za</a>	57
CRESSMAN	Keith	Keith.Cressman@fao.org	34 ; 35 ; 37
CULLEN	Darron	<a href="mailto:darron.cullen@kuleuven.be">darron.cullen@kuleuven.be</a>	50
DANIELCZAK	Anja	<a href="mailto:s6andani@uni-trier.de">s6andani@uni-trier.de</a>	31
DE MELLO	Francisco De Assis Ganeio	<a href="mailto:gryllus57@gmail.com">gryllus57@gmail.com</a>	128 ; 181
DENADAI DE CAMPOS	Lucas	<a href="mailto:lcdenadai@gmail.com">lcdenadai@gmail.com</a>	131
DERROUICHE	Chahinez	<a href="mailto:chahinez_25@hotmail.fr">chahinez_25@hotmail.fr</a>	214 ; 238
DESUTTER-GRANDCOLAS	Laure	<a href="mailto:laure.desutter-grandcolas@mnhn.fr">laure.desutter-grandcolas@mnhn.fr</a>	61 ; 71 ; 114 ; 131 ; 152 ; 269
DEVESON	Ted	<a href="mailto:ted.deveson@agriculture.gov.au">ted.deveson@agriculture.gov.au</a>	33 ; 75 ; 84 ; 223
DEY	Lara-Sophie	<a href="mailto:larasophie.dey@gmail.com">larasophie.dey@gmail.com</a>	133
DIAKITE	Fakaba	<a href="mailto:diakitfakab@gmail.com">diakitfakab@gmail.com</a>	37 ; 225
DONG	Jiajia	<a href="mailto:jia_jia_dong@hotmail.com">jia_jia_dong@hotmail.com</a>	156
DORIA	Maria	<a href="mailto:mariadoria@cmail.carleton.ca">mariadoria@cmail.carleton.ca</a>	139
EBBE	Mohamed Abdellahi	<a href="mailto:maouldbabah@yahoo.fr">maouldbabah@yahoo.fr</a>	37 ; 97 ; 98 ; 103 ; 105 ; 187
EL GHADRAOUI	Lahsen	<a href="mailto:lahsen.elghadraoui@usmba.ac.ma">lahsen.elghadraoui@usmba.ac.ma</a>	107 ; 108 ; 109 ; 110 ; 111 ; 112 ; 113 ; 196 ; 200 ; 221 ; 248 ; 255
ELGUENNOUNI	Badreddine	<a href="mailto:gnbaddr@gmail.com">gnbaddr@gmail.com</a>	215
ELMOUDEN	Abdellah	<a href="mailto:abdellah.elmouden@gmail.com">abdellah.elmouden@gmail.com</a>	145 ; 216 ; 233
ERRABHI	Nabil	nabil.errabhi@usmba.ac.ma	108 ; 109 ; 111 ; 116 ; 196 ; 207 ; 221
ERRACHIDI	Faouzi	<a href="mailto:faouzi.errachidi@usmba.ac.ma">faouzi.errachidi@usmba.ac.ma</a>	110 ; 111 ; 113 ; 116 ; 200 ; 207 ; 255
ETHEIMINE	Mohamed	<a href="mailto:mohamed.atheimine@gmail.com">mohamed.atheimine@gmail.com</a>	98 ; 226
FARTMANN	Thomas	<a href="mailto:t.fartmann@uos.de">t.fartmann@uos.de</a>	160
FONTANA	Paolo	paolo_api.fontana@fmach.it	147 ; 157 ; 175 ; 179 ; 229



GAUFFRE	Bertrand	<a href="mailto:bertrand.gauffre@inra.fr">bertrand.gauffre@inra.fr</a>	118
GHAOUT	Said	<a href="mailto:s.ghaout@gmail.com">s.ghaout@gmail.com</a>	36 ; 37 ; 187 ; 220 ; 246
GORDON	Mikhaila	<a href="mailto:mlgordon90@gmail.com">mlgordon90@gmail.com</a>	57 ; 253
GREENFIELD	Michael	<a href="mailto:michael.greenfield@univ-tours.fr">michael.greenfield@univ-tours.fr</a>	119
GREENHALGH	Linden	<a href="mailto:linden.greenhalgh@usu.edu">linden.greenhalgh@usu.edu</a>	217
GRZYWACZ	Beata	<a href="mailto:grzywacz@isez.pan.krakow.pl">grzywacz@isez.pan.krakow.pl</a>	64 ; 65 ; 66 ; 70
GUERFI	Imane	<a href="mailto:imenguerfi92@gmail.com">imenguerfi92@gmail.com</a>	214 ; 238
HAFAYED	Rachida	<a href="mailto:r.hafayed@univ-biskra.dz">r.hafayed@univ-biskra.dz</a>	195 ; 197
HAMOUNY	Mohamed Lemine	MohamedLemine.Hamouny@fao.org	17 ; 100 ; 105
HAO	Shuguang	<a href="mailto:haosg@ioz.ac.cn">haosg@ioz.ac.cn</a>	78
HARTBAUER	Manfred	<a href="mailto:manfred.hartbauer@uni-graz.at">manfred.hartbauer@uni-graz.at</a>	218
HAWLITSCHKE	Oliver	<a href="mailto:oliver.hawlitschek@gmx.de">oliver.hawlitschek@gmx.de</a>	125
HEDWIG	Berthold	<a href="mailto:bh202@cam.ac.uk">bh202@cam.ac.uk</a>	54 ; 86 ; 87 ; 91 ; 92
HELLER	Klaus-Gerhard	<a href="mailto:heller.volleth@t-online.de">heller.volleth@t-online.de</a>	51 ; 70
HEMP	Claudia	<a href="mailto:claudiahemp@yahoo.com">claudiahemp@yahoo.com</a>	10 ; 51 ; 70 ; 153
HOCHKIRCH	Axel	<a href="mailto:hochkirch@uni-trier.de">hochkirch@uni-trier.de</a>	21 ; 28 ; 29 ; 30 ; 31 ; 133 ; 154 ; 159
HOLUSA	Jaroslav	<a href="mailto:Holusaj@seznam.cz">Holusaj@seznam.cz</a>	247
HOMBERG	Uwe	<a href="mailto:homborg@biologie.uni-marburg.de">homborg@biologie.uni-marburg.de</a>	41
HUBANCHEVA	Antoniya	<a href="mailto:antonia.hubancheva@gmail.com">antonia.hubancheva@gmail.com</a>	266
HUNTER	David	<a href="mailto:davidhunter100@gmail.com">davidhunter100@gmail.com</a>	32 ; 72 ; 73 ; 222
HUSEMAN	Martin	<a href="mailto:martin.husemann@uni-hamburg.de">martin.husemann@uni-hamburg.de</a>	169
IDRISSI HASSANI	Lalla Mina	<a href="mailto:aminaidrissi@uiz.ac.ma">aminaidrissi@uiz.ac.ma</a>	3 ; 158 ; 220 ; 246
JECH	Larry	<a href="mailto:Larry.E.Jech@aphis.usda.gov">Larry.E.Jech@aphis.usda.gov</a>	150 ; 217 ; 219
JIANG	Guo-Fang	<a href="mailto:cnjgf1208@163.com">cnjgf1208@163.com</a>	204
JOHNSON	Dan	<a href="mailto:dan.johnson@uleth.ca">dan.johnson@uleth.ca</a>	85 ; 251
KALAB	Oto	<a href="mailto:kalab.oto@gmail.com">kalab.oto@gmail.com</a>	182
KAYALTO	Mathias	<a href="mailto:kayaltomathias@gmail.com">kayaltomathias@gmail.com</a>	158
KEARNEY	Michael	<a href="mailto:mrke@unimelb.edu.au">mrke@unimelb.edu.au</a>	84
KELLY	Clint	<a href="mailto:kelly_clint@uqam.ca">kelly_clint@uqam.ca</a>	52
KENYERES	Zoltan	<a href="mailto:kenyeres.zol@gmail.com">kenyeres.zol@gmail.com</a>	76 ; 151
KHEMAIS	Abdallaoui	<a href="mailto:kemais_a@yahoo.fr">kemais_a@yahoo.fr</a>	114 ; 137 ; 142 ; 152
KING	Kathleen	<a href="mailto:Kathleen.M.King@aphis.usda.gov">Kathleen.M.King@aphis.usda.gov</a>	219 ; 239
KLEUKERS	Roy	<a href="mailto:Roy.kleukers@naturalis.nl">Roy.kleukers@naturalis.nl</a>	81
KOCAREK	Petr	<a href="mailto:petr.kocarek@osu.cz">petr.kocarek@osu.cz</a>	157 ; 182 ; 261
KOCINSKI	Maciej	<a href="mailto:kocinski@isez.pan.krakow.pl">kocinski@isez.pan.krakow.pl</a>	66
KOORYMAN	Christiaan	<a href="mailto:christiaan.kooryman@elephantvert.ch">christiaan.kooryman@elephantvert.ch</a>	101
KORSUNOVSKAYA	Olga	<a href="mailto:korsuno@mail.ru">korsuno@mail.ru</a>	267



KUGA	Tatsuru	tkuga486@gmail.com	258
KURIWADA	Takashi	<a href="mailto:kuriwada@edu.kagoshima-u.ac.jp">kuriwada@edu.kagoshima-u.ac.jp</a>	259
LAADEL	Aicha	aichalaadel@gmail.com	220
LAL	Mohan	<a href="mailto:mohanlal.harijan@scholars.usindh.edu.pk">mohanlal.harijan@scholars.usindh.edu.pk</a>	249
LANDMANN	Armin	<a href="mailto:armin.landmann@uibk.ac.at">armin.landmann@uibk.ac.at</a>	24 ; 80 ; 234
LANGE	Carlos	<a href="mailto:carlosl@cepave.edu.ar">carlosl@cepave.edu.ar</a>	186 ; 241
LATCHININSKY	Alexandre	<a href="mailto:alexandre.latchininsky@fao.org">alexandre.latchininsky@fao.org</a>	83 ; 224
LAWTON	Douglas	ddlawton@asu.edu	74 ; 148 ; 223 ;
LAZAR	Mohammed	<a href="mailto:lazar.mohammed@gmail.com">lazar.mohammed@gmail.com</a>	37 ; 102
LAZRAQ	Abderrahim	<a href="mailto:abderrahim.lazraq@usmba.ac.ma">abderrahim.lazraq@usmba.ac.ma</a>	108 ; 116 ; 207 ; 221
LECOQ	Michel	mlecoq34@gmail.com	82 ; 102 ; 158 ; 168
LEHMANN	Gerlind	gerlind.lehmann@t-online.de	46 ; 47 ; 53
LEMUS	Itzel	<a href="mailto:itzel.lemus.diguez@gmail.com">itzel.lemus.diguez@gmail.com</a>	159
LHANO	Marcos Gonçalves	<a href="mailto:entomology@gmail.com">entomology@gmail.com</a>	126 ; 135 ; 206 ; 232 ; 235 ; 243
LIMA	Maiara Beatriz	maiarab.lima@hotmail.com	206
LÖFFLER	Franz	franz.loeffler@uos.de	160
LONG	Zhang	locust@cau.edu.cn	86 ; 95 ; 96 ; 106 ; 212 ; 224 ; 227 ; 263 ; 264 ; 265
MAGZOUB	Bashir	yamagzoub2@yahoo.com	13
MAIGA	Idrissa Halidou	<a href="mailto:idrissa.maiga@cilss.int">idrissa.maiga@cilss.int</a>	39 ; 77
MAMADOU	Abdou	<a href="mailto:abdoumamadou@yahoo.fr">abdoumamadou@yahoo.fr</a>	210
MARIÑO-PÉREZ	Ricardo	<a href="mailto:pselliopus@yahoo.com.mx">pselliopus@yahoo.com.mx</a>	26 ; 62 ; 167 ; 179
MASSA	Bruno	bruno.massa@unipa.it	115 ; 229
MBADJOUN NZIKE	Marcelle	<a href="mailto:marcellenzike@yahoo.fr">marcellenzike@yahoo.fr</a>	164 ; 173 ; 240
MEDINA DURAN	Jorge Humberto	<a href="mailto:jorgemedinad@ciencias.unam.mx">jorgemedinad@ciencias.unam.mx</a>	167
MEYHOFF	Sejer		251
MEYNARD	Christine	<a href="mailto:cnmeynard@gmail.com">cnmeynard@gmail.com</a>	82
MHAFDHI	Mouna	<a href="mailto:mounamhafdhi@gmail.com">mounamhafdhi@gmail.com</a>	114 ; 142 ; 152
MIEGE	Yann	yann.miege@elephantvert.ch	101
MILADI	Meriem	<a href="mailto:meriamiladi@gmail.com">meriamiladi@gmail.com</a>	137,142
MONARD	Annie	<a href="mailto:Annie.Monard@fao.org">Annie.Monard@fao.org</a>	104
MONTEALEGRE-Z	Fernando	<a href="mailto:fmontealegrez@lincoln.ac.uk">fmontealegrez@lincoln.ac.uk</a>	176; 185; 255
MUSIOLEK	David	<a href="mailto:musiolek david@gmail.com">musiolek david@gmail.com</a>	182 ; 261
MUTIBHA	Alfonce Leonard	<a href="mailto:amutibha@cipe.org">amutibha@cipe.org</a>	194
NTELEZOS	Athanasios	<a href="mailto:an478@cam.ac.uk">an478@cam.ac.uk</a>	92
NUHLICKOVA	Sona	<a href="mailto:sona.nuhlickova@uniba.sk">sona.nuhlickova@uniba.sk</a>	230
ODE	Baudewijn	<a href="mailto:baudewijnnode@gmail.com">baudewijnnode@gmail.com</a>	28 ; 81
OULD MAENO	Koutaro	<a href="mailto:kmaeno@affrc.go.jp">kmaeno@affrc.go.jp</a>	103 ; 105 ; 187

OUMAROU NGOUTE	Charly	<a href="mailto:coumarougoute@yahoo.fr">coumarougoute@yahoo.fr</a>	168
OVERSON	Rick	<a href="mailto:rickoverson@gmail.com">rickoverson@gmail.com</a>	16 ; 74 ; 138 ; 148
PANHWAR	Waheed Ali	<a href="mailto:waheed.panhwar@salu.edu.pk">waheed.panhwar@salu.edu.pk</a>	174
PIOU	Cyril	<a href="mailto:cyril.piou@cirad.fr">cyril.piou@cirad.fr</a>	32 ; 36 ; 37 ; 38 ; 82 ; 102 ; 144 ; 158 ; 187 ; 211
PLISCHUK	Santiago	<a href="mailto:santiago@cepave.edu.ar">santiago@cepave.edu.ar</a>	241
POCCO	Martina Eugenia	<a href="mailto:martinapocco@gmail.com">martinapocco@gmail.com</a>	186 ; 241
POOT-PECH	Mario	<a href="mailto:mpootpech@gmail.com">mpootpech@gmail.com</a>	79 ; 257
PRESA	Juan-Jose	<a href="mailto:jjpresa@um.es">jjpresa@um.es</a>	208
PULVER	Christian	<a href="mailto:cpulver@lincoln.ac.uk">cpulver@lincoln.ac.uk</a>	176
RHEE	Howon	<a href="mailto:howon.rhee@uni-bielefeld.de">howon.rhee@uni-bielefeld.de</a>	183
RIFFAT	Sultana	<a href="mailto:riffat.sultana@usindh.edu.pk">riffat.sultana@usindh.edu.pk</a>	163 ; 171 ; 174 ; 249 ; 250
ROBILLARD	Tony	<a href="mailto:tony.robillard@mnhn.fr">tony.robillard@mnhn.fr</a>	12 ; 88 ; 128 ; 156 ; 178 ; 262
ROCHDI	Mouad	<a href="mailto:Moad9700@gmail.com">Moad9700@gmail.com</a>	113 ; 200
ROEMER	Heiner	<a href="mailto:heinrich.roemer@uni-graz.at">heinrich.roemer@uni-graz.at</a>	90
ROGERS	Stephen	<a href="mailto:smr34@cam.ac.uk">smr34@cam.ac.uk</a>	43
RUTZ REDÜ	Darlan	<a href="mailto:darlanredu@gmail.com">darlanredu@gmail.com</a>	199
SAMEJO	Ahmed Ali	<a href="mailto:samejo_ali7@hotmail.com">samejo_ali7@hotmail.com</a>	171
SAMWAYS	Michael	<a href="mailto:samways@sun.ac.za">samways@sun.ac.za</a>	165
SARMIENTO PONCE	Edith Julieta	<a href="mailto:js2139@cam.ac.uk">js2139@cam.ac.uk</a>	54
SCATTOLINI	Celeste	<a href="mailto:celestescattolini@yahoo.com.ar">celestescattolini@yahoo.com.ar</a>	25 ; 59
SCHÖNEICH	Stefan	<a href="mailto:Stefan.Schoeneich@uni-leipzig.de">Stefan.Schoeneich@uni-leipzig.de</a>	88 ; 89 ; 178 ; 262
SERGEEV	Michael	<a href="mailto:mgs@fen.nsu.ru">mgs@fen.nsu.ru</a> ; <a href="mailto:mgsergeev@aol.com">mgsergeev@aol.com</a>	161 ; 170 ; 202 ; 222
SEVASTIANOV	Nikita	<a href="mailto:met3254@yandex.ru">met3254@yandex.ru</a>	132 ; 188
SHAH	Abhijeet	<a href="mailto:abhijeet.shah@uni-jena.de">abhijeet.shah@uni-jena.de</a>	67
SHAW	Kerry	<a href="mailto:kls4@cornell.edu">kls4@cornell.edu</a>	11 ; 123 ; 268
SHELOMI	Matan	<a href="mailto:mshelomi@ntu.edu.tw">mshelomi@ntu.edu.tw</a>	68
SID'AHMED	Mohamed	<a href="mailto:sidmd2002@yahoo.fr">sidmd2002@yahoo.fr</a>	98 ; 103 ; 105 ; 226
SIMEU NOUTCHOUM	Alain	<a href="mailto:simeunou@gmail.com">simeunou@gmail.com</a>	164 ; 173 ; 240
SMIEJ	Mohammed Faouzi	<a href="mailto:smiej@crrts.gov.ma">smiej@crrts.gov.ma</a>	36
SOFRANE	Zina	<a href="mailto:sofranezina1@yahoo.fr">sofranezina1@yahoo.fr</a>	129
SONG	Hojun	<a href="mailto:hsong@tamu.edu">hsong@tamu.edu</a>	56 ; 58 ; 62 ; 121 ; 136 ; 167 ; 179 ; 186 ; 257
SOUDANI	Abderrahmane	<a href="mailto:abderrahmanesoudani86@gmail.com">abderrahmanesoudani86@gmail.com</a>	201
SPERBER	Carlos Frankl	<a href="mailto:sperberufv@gmail.com">sperberufv@gmail.com</a>	203 ; 260
SRYGLEY	Robert	<a href="mailto:Robert.Srygley@ars.usda.gov">Robert.Srygley@ars.usda.gov</a>	149
STEVENSON	Paul Anthony	<a href="mailto:stevenson@rz.uni-leipzig.de">stevenson@rz.uni-leipzig.de</a>	44



STRAUSS	Johannes	<a href="mailto:johannes.strauss@physzool.bio.uni-giessen.de">johannes.strauss@physzool.bio.uni-giessen.de</a>	55 ; 60
SUKHIKH	Igor	<a href="mailto:igor3419@gmail.com">igor3419@gmail.com</a>	134 ; 202
SWEENEY	Joseph Yung	<a href="mailto:jys43@crexel.edu">jys43@crexel.edu</a>	244
TANGA	Chrysantus	<a href="mailto:ctanga@icipe.org">ctanga@icipe.org</a>	140 ; 150 ; 194
TATSUTA	Haruki	<a href="mailto:htatsuta@agr.u-ryukyu.ac.jp">htatsuta@agr.u-ryukyu.ac.jp</a>	63 ; 64 ; 65 ; 69
TER HOFSTEDE	Hannah	<a href="mailto:hannah.ter.hofstede@dartmouth.edu">hannah.ter.hofstede@dartmouth.edu</a>	88 ; 178 ; 262
THOMPSON	Aileen	<a href="mailto:acthompson@sun.ac.za">acthompson@sun.ac.za</a>	165
TLILI	Haithem	<a href="mailto:haithem.tlili@fst.utm.tn">haithem.tlili@fst.utm.tn</a>	114 ; 152
TRUMPER	Eduardo	<a href="mailto:trumper.eduardo@inta.gob.ar">trumper.eduardo@inta.gob.ar</a>	38 ; 138
TREMBLAY	Donovan	<a href="mailto:donovantremblay@mail.carleton.ca">donovantremblay@mail.carleton.ca</a>	184
VAHED	Karim	<a href="mailto:k.vahed@derby.ac.uk">k.vahed@derby.ac.uk</a>	27 ; 46
VANDEN BROECK	Jozef	<a href="mailto:jozef.vandenbroeck@kuleuven.be">jozef.vandenbroeck@kuleuven.be</a>	45 ; 50 ; 137 ; 141 ; 142
VEDENINA	Varvara	<a href="mailto:vedenin@iitp.ru">vedenin@iitp.ru</a>	93 ; 132 ; 188
VEITCH	Daniel	<a href="mailto:dveitch@lincoln.ac.uk">dveitch@lincoln.ac.uk</a>	176 ; 185 ; 255
VICENTE	Natallia	<a href="mailto:natalliavicentte@gmail.com">natalliavicentte@gmail.com</a>	128 ; 156 ; 203
VLK	Robert	<a href="mailto:vlk@ped.muni.cz">vlk@ped.muni.cz</a>	166
WAGAN	Muhammad	<a href="mailto:mswagen@hotmail.com">mswagen@hotmail.com</a>	174 ; 237 ; 245
WANDJI	Alain Christel	<a href="mailto:wandjichristel@gmail.com">wandjichristel@gmail.com</a>	164 ; 173 ; 240
WARCZALOWSKA	Elzbieta	<a href="mailto:warczalowska@isez.pan.krakow.pl">warczalowska@isez.pan.krakow.pl</a>	64 ; 69 ; 70
WILSON	Vinicius	<a href="mailto:abexanderconde@gmail.com">abexanderconde@gmail.com</a>	203
WOLLER	Derek	<a href="mailto:derek.a.woller@usda.gov">derek.a.woller@usda.gov</a>	150 ; 179 ; 219
YIN	Xuewei	<a href="mailto:locust@cau.edu.cn">locust@cau.edu.cn</a>	95
YOU	Yinwei	<a href="mailto:locust@cau.edu.cn">locust@cau.edu.cn</a>	96 ; 212
ZHANG	Xinyang	<a href="mailto:zxy1385@outlook.com">zxy1385@outlook.com</a>	91
ZHANG	Liwei	<a href="mailto:locust@cau.edu.cn">locust@cau.edu.cn</a>	227 ; 263 ; 264
ZOUMHANE	Mustapha	<a href="mailto:zoumhane83@gmail.com">zoumhane83@gmail.com</a>	215 ; 246



## LIST OF PARTICIPANTS BY PRESENCE

<b>Daniela MATENAAR</b>	Curator Hessisches Landesmuseum Darmstadt Germany	matenaar@hlmd.de
<b>Hilery WARNER</b>	Data Manager Natural HistoryMuseum. London	hbwarner@gmail.com
<b>Luc WILLEMSE</b>	Head of Entomological Collections Naturalis Leiden Nederland	luc.willemse@naturalis.nl
<b>Catherine CONS-TANT</b>	Ingénieur agronome Bruxelles Belgique	constantcath@gmail.com
<b>Chris ADRIAANSEN</b>	Director Australian Plague Locust Commission Canberra Australia	chris.adriaansen@agriculture. gov.au
<b>Sophie OGAN</b>	PhD Student Biogeography University Trier Germany	ogan@uni-trier.de
<b>Andrew HARVEY</b>	Consultant Cheltenham United Kingdom	andrewharvey1000@aol.com
<b>Rob FELIX</b>	Biologist Naturalis Nijmegen Nederland	robfelix1@gmail.com
<b>Lucien SAVADOGO</b>	CLCPRO Burkina-Faso	sawadogolucien12@gmail.com
<b>Mahamat Tolli ADOUM</b>	CLCPRO Tchad	
<b>Mody GAYE</b>	CLCPRO Sénégal	
<b>John CLAYTON</b>	Microgroup Micronair	john.clayton@micron.co.uk
<b>Tim SANDER</b>	Microgroup Micronair	tsander@micronair.co.uk

13<sup>TH</sup>

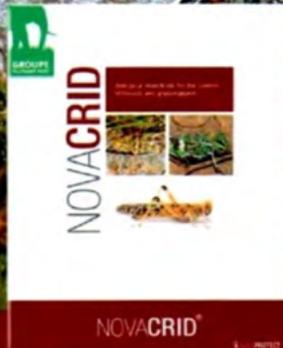
INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



GROUPE  
ÉLÉPHANT VERT

NOVAPROTECT

YOUR NATURAL AND SELECTIVE ALLY  
AGAINST LOCUSTS AND GRASSHOPPERS



BIO-INSECTICIDE

NOVACRID<sup>®</sup>

NOVACRID<sup>®</sup>

13<sup>TH</sup>

INTERNATIONAL  
CONGRESS OF  
ORTHOPTEROLOGY



Locust  
Control



**ULV application for ground and air**

Micron Sprayers Ltd, Bromyard, herefordshire, England UK

Tel: +44 1885 482397 email: sales@micron.co.uk www.micron.co.uk





جامعة ابن زهر  
UNIVERSITÉ IBN ZOHR



كلية العلوم  
FACULTÉ DES SCIENCES



Centre National de la Recherche Scientifique



## CONGRESS SECRETARIAT

Sciences Faculty, University Ibn Zohr  
AGADIR | MOROCCO  
orthoptera2019@uiz.ac.ma

[www.ico2019morocco.com](http://www.ico2019morocco.com)