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METALEPTEA

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14th INTERNATIONAL CONGRESS OF ORTHOPTEROLOGY
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Abstract Book 2023

Mérida, Mexico 2023
October 16-19th

FOREWORD

Dear participants and collaborators,

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

The beginning of the organization of this congress was under extraordinary circumstances: the pandemic caused this event to be delayed by one year, its planning was under an uncertain scenario, massive events were suspended, and the vaccination process was about to begin. However, even under these circumstances, we were delighted to celebrate the 14th International Congress of Orthopterology for the first time in Mexico, in the heart of the Mayan culture: in the City of Mérida in the State of Yucatan.

The scientific program consisted of five plenary speakers, 10 symposia, five sections of oral presentations, 15 posters, two workshops, and three meetings. 176 people attended ICO 2023 from 29 countries. Mexico, being the host, was the one with the most people attending. Unfortunately, for various reasons, such as visa or health problems, several speakers canceled their participation at the last minute, so they had to send their presentation via video.

On Friday 20th, there was a visit to the Municipality of Buctzotz where the nymphs of the Central American locust were observed, drone control operations were demonstrated, insects were collected in grasses, and a free lunch was provided at the invitation of the owner of the ranch.

The main organizing institution for this congress was the Yucatan Plant Health (CESVY), which was supported by different national and international organizations and institutions. We would like to thank the financial support of the Governing Board of the Orthopterists' Society, OIRSA head office in El Salvador, OIRSA Mexico, SENASICA México, Government of Yucatan (SEDER), FAO Mesoamerica, and the Mexican aerial application company "Helimaz S.A de C.V." Everyone contributed to achieving this successful congress.

I would also like to thank regional organizations such as OIRSA, COSAVE, CLCPRO, FAO, GICSV, institutions such as GLI, research centers such as CIRAD, and all the universities and phytosanitary protection agencies that attended this important event. A special recognition was given to the National Plant Health Organizations in Mexico from the 32 states that make up Mexico, and representatives from 16 states attended this congress.

President ICO 2023, Mario A. Poot-Pech, Ph.D.

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PLENARY SESSIONS

PLENARY SESSIONS 1

CURRENT RESEARCH ON THE CENTRAL AMERICAN LOCUST IN NORTHERN MEXICO

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The Central American locust (CAL), *Schistocerca piceifrons piceifrons* (Walker, 1870), is a tropical pest that causes damage to agriculture from Mexico to Central America. Throughout its range, the CAL breeds in what are known as permanent breeding areas (PBA) of which eight have been identified. One of these is located in the Huasteca Region in northern Mexico. This PBA comprises four states on the coastal plain of the Gulf of Mexico (south Tamaulipas, east of San Luis Potosí, north of Veracruz, and the northeastern of the State of Hidalgo). Typically, CAL populations breed and migrate within this region. However, in the last four years (2020-2023) numerous bands and swarms of the CAL were reported in the central-west region of Tamaulipas and southern Nuevo León. To have a better understanding on the ecology of the CAL in northeastern Mexico and possible CAL scenarios under climate change, research is conducted aiming to: again, insight on environmental factors that are favoring migration and establishment of populations in new areas; b) potential use of the CAL in biotechnological industries.

A reproduction program of the CAL was established under semi-controlled conditions; at high temperature (35±2°C), and low RH (45±2%) the CAL populations are reproducing continuously; that is, it does not enter a pre-reproductive diapause period.

Thus, under the current climate change scenario, in addition to extending its geo-graphical distribution, as it is occurring, the CAL may increase the number of generations per year. Regarding the impact of climate change on the generation of new permanent breeding areas, climatic characteristics of the PBA vs., climatic conditions in localities where gregarious populations were reported in 2020-2023 are analyzed. So far, climatic data from Tamaulipas and Veracruz have been analyzed. Ten years geographical records of the CAL were obtained from SICAFI-SENASICA. Polygons on CAL occurrence in the PBA and potential breeding areas were delimitated; the ArcMap 10.2 software was used for this purpose. A buffer or circular radius of 5 km around each of the CAL record points was generated. Climatic da-ta on the delimited polygons were provided by the National Water Commission (CONAGUA). Lin-ear discriminant function analysis was used to find significant differences between climatic variables of the PBA vs., potential breeding areas. Tamaulipas showed nine potential breeding areas, while five were found in the state of Veracruz. In Tamaulipas eight of the potential breeding areas are climatically different of the PBA; variables that most contribute to this result are the number of days with frosts and the minimum monthly temperature. In contrast, in Veracruz, four of the potential areas were

climatologically similar to the PBA; variables that account most for similarity are the average and maximum monthly temperature. Results indicate that there are populations of the CAL established and breeding in areas that are climatologically different from the PBA; therefore, the CAL may be exploiting other re-sources/variables, than those analyzed in this work, that favor their reproduction and establishment. The CAL now reproduces massively in areas close to a large dam in Tamaulipas central west region. Climatic factors and inconsistencies in the monitoring and combat of populations in its PBA in the Huasteca region, favored migration and expansion of its distribution. Additional work considers the CAL bioactive compounds and nutritional contents, envisioning its potential use in biotechnological industries.

Key Words: Climate Change, Locus Populations, Distribution, Breeding areas.

Plenary sessions 2

APPLYING NEW SCIENCE TO OLD PROBLEMS WITH AUSTRALIAN GRASS-HOPPERS

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GRASSHOPPERS have been used to tackle fundamental problems in ecology and evolution. Between 1930 and 1980 Australia was a swarm of activity in this respect, with grasshoppers being used to ask such questions as: How does climate and weather constrain distribution and abundance? How does parthenogenesis evolve? How do species form? How does genetic variation change across landscapes? In this talk I will provide a historical perspective of the Australian scientists who asked these questions with grasshoppers, including MJD White, KHL Key, LC Birch & HG Andrewartha. I will show how our recent research has allowed us to take significant leaps forward in answering these questions, using new methods and technologies and springboarding from the enormous efforts of these past researchers.

Plenary sessions 3

SOUNDS OF LOVE FOR TINNY LISTENERS: THE BIOPHYSICS OF SOUND PRODUCTION AND HEARING IN ENSIFERA

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This Many animal species, from the tiniest insects to the largest marine mammals, use sound to communicate. *Ensifera* (Orthoptera) are amongst the earliest terrestrial arthropods to develop acoustic communication. Males of crickets, grigs and katydids are known to produce matting calls by tegminal stridulation (the rubbing together of specialized structures on the forewings). The general biomechanics and bioacoustics of this system are relatively well understood in modern crickets and bush crickets. While most species of crickets and grigs use human-audible frequencies (e.g., 2-20 kHz) for communication, a large number of species of katydids communicate with signals in the ultrasonic frequency range (20-150 kHz). The lineages leading to katydids and crickets diverged by the Permian, some 270 mya. What did these insect's calls sound like? Did they have specialized ears?

Acoustic signaling has evolved separately many times, but a key feature shared by all advanced hearing systems is the ability to simultaneously detect tones of different frequencies, enabling the listener to discriminate complex sound signals out of confusing background noise. In mammals, this 'frequency analysis' is performed within the cochlea, a spiral tube in the inner ear, which in humans has an uncoiled length of around 3 cm and hosts some 18,000 sensory cells. The position of the mammalian cochlea within the skull means that measuring their inner-ear function is a highly invasive process – my lab is pioneering research into the insect equivalent. Male katydid attracts mates by "singing" at high frequencies by rubbing their wings together; this signal can be heard and recognized by females great distances away. Katydid ears are located on their forelegs and are unique among arthropods because (just like their mammalian equivalent) they exhibit outer, middle, and inner ear components. Katydid can detect ultrasound using a tiny uncoiled 'cochlea' of around 1mm and with fewer than 100 sensory cells, this inner ear is unique among Arthropoda, and remarkably, it can be accessed non-invasively, providing an exceptional opportunity to measure complex hearing processes in real time. This characteristic will allow us to perform measurements and manipulations of hearing processes that are impossible in the mammalian inner ear, in turn opening up new avenues for research into miniature, bio-inspired sensors.

This lecture will de-scribe a life journey through the fascinating world of insect acoustic communication, a childhood curiosity which drove me to travel the world and discover many new species and their unique singing and hearing organs

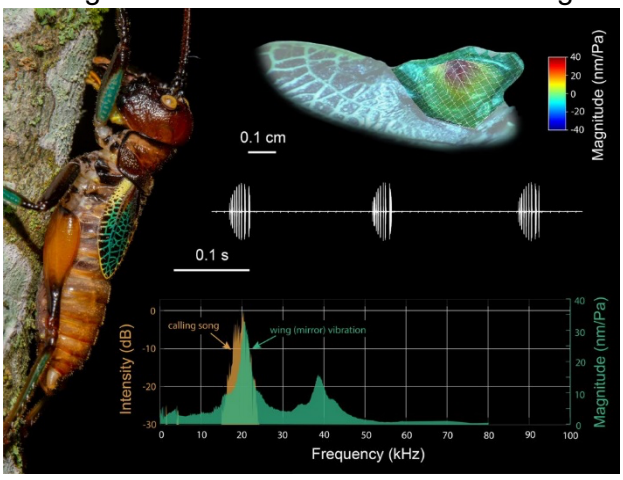

Figure 1. Male of a new genus and species of Pseudophyllinae katydid, from the cloud forest of Central Cordillera, Colombia.

Key Words: Bioacoustics, Hearing, Ultrasound, Havana Syndrome, Laser Doppler

Plenary sessions 4

THE ORIGINS OF NOVELTY IN COMMUNICATION BETWEEN THE SEXES – *Teleogryllus oceanicus*

Robin Tinghitella[1], Dale Broder[2], David Zonana[3], Jay Gallagher[4] & Aaron Wikle[5]
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The diversity of signaling traits within and across taxa is vast and striking, prompting us to consider how novelty evolves in the context of animal communication. New communication features could first arise in signalers or receivers, but the microevolutionary processes that result in novel signal or receiver traits remain relatively unknown because observing the contemporary evolution of new traits is so very rare. Further, how new sexual signals, the focus of this talk, arise, persist, and spread is difficult to envision because signals and receiver responses frequently coevolve, and new signal features could disrupt existing communication systems. How then do novel sexual signals come to be? In this talk I will highlight recent work demonstrating how opposing selection pressures and the decoupling of form and function facilitated the evolution of new male mating songs in introduced island populations of the field cricket, *Teleogryllus oceanicus*.

Over the last 20 years a silent male morph and at least four other male morphs that produce attenuated calling and courtship songs have evolved in Hawaiian *T. oceanicus*. The novel singing morphs each produce their song using uniquely modified wing structures (Fig. 1), and each morph is variably protected from an acoustically orienting deadly natural enemy. Collectively, our work reveals how strong natural selection against conspicuous signals can facilitate the evolution of novelty in animal communication, particularly when coupled with the restructuring of morphology and relative lax mating requirements.

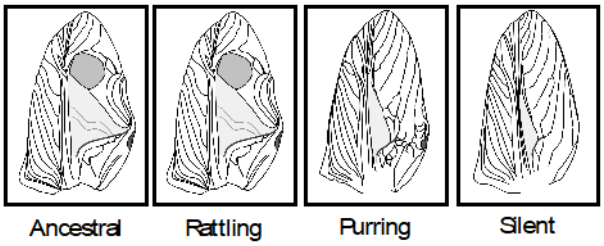

Figure 1. Wings of novel morphs of *T. oceanicus* including the rattling, purring, and silent types depicted here have unique morphologies that generate differently attenuated songs (or no song) during stridulation.

Key Words: ICO2023, Merida, Field Cricket, Communication, Novelty

Plenary sessions 5

BEHAVIORAL RESPONSES TO EAVESDROPPING PREDATORS IN THE ORTHOPTERA AND A NOVEL ANTI-PREDATOR BEHAVIOR IN AFRICAN KATYDIDS

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Eavesdropping parasitoids and predators are a constant threat to those Orthoptera that employ long-range airborne acoustic signaling in their courtship or territorial behavior. Parasitoid flies (Tachinidae) use acoustic cues to locate their orthopteran hosts and had even been able to exert a rapid adaptive pressure on recently arrived field cricket populations in Hawaii, leading to convergent loss of sound production in two allopatric populations. A complete loss of stridulation in male katydids have evolved independently in at least five lineages of these insects, suggesting a strong pressure from parasitoids or predators over the course of the katydids' evolutionary history. Geckos, toads, small mammalian carnivores, and some birds appear to be attracted to the sound of singing crickets and katydids. For nocturnal acoustic insects the greatest threat comes from gleaning bats, resulting in several defensive responses, both preventive and reactive. Calling from dense, cluttered vegetation is a common predator avoidance strategy in many groups of singing Orthoptera. Cessation of sound production in response to bat echolocation signals appears to be common among both crickets and katydids, albeit not in all environments. Reduction of the calling time is a well documented response to foliage `1gleaning bats in the Neotropical Pseudophyllinae and Phaneropterinae, as is transition to substrate borne signaling. The very high frequency calls (up to 150 kHz) in some Neotropical *Listroscelidinae* may also be an attempt to escape eavesdropping by employing acoustic signaling above the hearing range of most predators, including some bats. It appears that chorusing may also play a role in reducing the risk of individual detection by predators. At the same time there is evidence that in some cases silent females in acoustic species may be at a greater risk of predation due to their movement towards the calling males.

During research on the Orthoptera and bats of Gorongosa National Park in Mozambique, my students and I discovered a new calling behavior in two unrelated African Phaneropterinae that likely represents another example of preventive behavioral modification, allowing males who produce high duty courtship calls to avoid predation by gleaning bats. In two species of genera *Debrona* and *Oxyecous*, the males stridulate in flight and exhibit a pattern of activity that allows them not to overlap in time with gleaning bats. These katydids have modified tibial pinnae that presumably in-crease their ability to detect female responses from a greater distance. These observed be-havioral and morphological adaptations have likely evolved in response to gleaning bats of the family Nycteridae, whose diet consists in a large part of sound producing insects.

Key Words: stridulation, anti-predator behavior, katydids

WORKSHOPS

WORKSHOP 1

Introduction to a new version of Orthoptera Species File and to HopperWiki, a new information repository for global stakeholders.

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The Orthoptera Species File (OSF) constitutes the most complete and updated taxonomic database of living and fossil Orthoptera worldwide. It has been migrated to a new platform, TaxonWorks (TW), which integrates the best features of Species File Software with several new ones designed to help with the multiple tasks of taxonomists and other biodiversity scientists. The main purpose of this workshop is to show the most significant features of this new integrative website as a powerful tool for Orthoptera research, and to discuss the community engagement in it. This workshop will be focused on how to use the software, with emphasis on those main functionalities and tasks that help the taxonomic workflow, such as filtering and reporting functionalities, dynamic functionalities for editorial work, batch loading data, importing DwC archive data into the project, building matrices to create interactive keys, score images and observations, among others. This workshop will be an excellent opportunity to interact and discuss among the orthopterists about the needs and development of new features to improve their taxonomic workflow by using this new platform. The activities of the workshop will include a theoretical introduction to the concepts and features of TW and TaxonPages (the public view of OSF displayed by TaxonWorks), and time to get hands on this new software using some of the main available functionalities for research and editorial work.

Additionally, the Global Locust Initiative (GLI) team will introduce a new project called HopperWiki which they have developed over the last two years by collecting and consolidating key information and resources on the world's most notorious pest grasshoppers and locusts. The GLI has used the classic Wikipedia style software to create an information repository and resource hub that synthesizes original content with existing information from myriad other online sources to provide a free resource.

HopperWiki is a centralized location where the global community can access and contribute to

valuable information on locust and grasshoppers in a digestible format and available in any language google translates. The GLI sees the project as an opportunity for the global locust community to come together to create a shared resource written by a diversity of voices.

This portion of the workshop will start with a live demo and tour of the wiki followed by a discussion on people how they can get involved and contribute to the project.

WORKSHOP 2

INTRODUCTION TO GEOSPATIAL TOOLS TO IMPROVE LOCUST MONITORING

Mario Poot-Pech[1], Claudia Lomas[2], Derek Woller[3], Gabriela Alcalá[1], Daniel Piste[1] and Gonzalo Chí[1].
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Geographic information systems (GIS) are currently an important tool in the analysis of field information on Orthoptera pests. With the information obtained, important short- and long-term decisions can be made regarding the management of locusts or grasshoppers as well as economic aspects.

One of the current uses that is being given is the preparation of risk maps, sites with greater or lesser density of lobster and in this way develop field strategies for efficient use of economic resources and man hours.

In this workshop, exercises were carried out with layers of data from the campaign against locust in the State of Yucatan to analyze spatial and temporal trends, the free software Q GIS was used.

Another aspect that was considered was the support provided by satellite images, since they help find the areas with the greatest risks, that is, reduce the recession area to a risk area with a smaller surface area. Drones are subsequently used to characterize the vegetation, soil, burned areas and precipitation of the study area.

The choice of a drone model is very important since we must consider the objective of the research; what are we going to analyze? vegetation in the recession zone? search for migration swarm? locusts in the outbreak area? There is no reference handbook on this yet, so we must answer these research questions to make a very useful purchase in the long term. Currently in the field, the main use of drones is to spray insecticides or biological products against locusts or grasshoppers.

In summary. Geospatial analysis tools help us detect and reduce potential areas of development of pest Orthoptera. Later, with the use of drones we can analyze the risk area in more detail, finally we send the spraying drones to reduce the risk of acridian formations, especially the gregarious phase.

Key Words: Drone, remote sensing, precision agriculture.

SYMPOSIA

Symposia 1

Impact of Climate change and new approaches on management of the central American locust. Current Orthoptera Research in Latin America.

Organizers: Ludivina Barrientos, Mario Poot and Aurora Rocha

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7. **Carlos Urías, Xavier Euceda and Mario Poot.** THE REGIONAL PREVENTIVE APPROACH OF LOCUST-GRASSHOPPER IN CENTRAL AMERICA.
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9. **Jorge Ariel Torres-Castillo and Ludivina Barrientos-Lozano.** BIOTECHNOLOGICAL POTENTIAL AND REEVALUATION OF PESTS: THE CASE OF THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons piceifrons* (Walker)
10. **Marlon Villela Pinto, Mario Poot-Pech and Veronica Chávez.** DISTRIBUTION AND EFFECT OF CLIMATE CHANGE ON THE CENTRAL AMERICAN LOCUST IN GUATEMALA

THE CENTRAL AMERICAN LOCUST, HISTORY AND MANAGEMENT, AN OVERVIEW

Ludivina Barrientos-Lozano & Aurora Y. Rocha-Sánchez
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The Central American locust (CAL), *Schistocerca piceifrons piceifrons* (Walker, 1870), is one of three true-locust species that occurs in the American Continent. The ancient record of the CAL is found in the Popol Vuh, the Mayan sacred book, demonstrating how it has affected humans for millennia. Climate changes and recurrent locust plagues are believed to have caused the decline of the Mayan civilization in Mesoamerica in the period A.D. 740–930. In Mexico, the CAL was declared a national threat to agriculture since 1824. Serious locust plagues occurred in 1882–1883 when swarms of 20 km2 in size invaded the Yucatán Peninsula and neighboring states in southern Mexico and, since then management actions to sup-press populations and economic damage have been implemented. In the last 20 years, a large amount of information has been generated to improve CAL management. The integration of bioinsecticides and the diversification of chemical products (1999-2010) to the CAL campaign are, perhaps, among the most out-standing. Unfortunately, in some regions the use of bioinsecticides was discontinued, i.e., northern Mexico. Current research focuses on: a) A better understanding of CAL population dynamics in relation to environmental factors (Barrientos-Lozano, et al.). b) Understand the proximate mechanisms of phase change (Song et al.). c) Impact of climate change on its dis-tribution and ecology (Barrientos-Lozano, et al., Poot-pech et al.). d) New technologies in CAL management (Poot-Peach, et al.). e) Additional research is being carried out to study the nutritional contents and bioactive compound levels of CAL, aiming to incorporate this information into its management. The presence of phenolic compounds, alkaloids, tannins, saponins, flavonoids, and quantity of antioxidants against the DPPH (2, 2-diphenyl-1-picrylhydrazyl) and ABTS (2, 2´ -azino-bis, 3-ethylbenzothiazoline-6-sulfonic acid) free radicals was reported. Proximate analysis showed that the CAL has a high protein content (80.26%), low-fat content (6.21%), and fiber content (12.56%) similar to other Orthoptera species. The chitin and chitosan contents of the CAL were 11.88 and 9.11%, respectively, and the recovery percentage of chitosan from chitin was 76.71%. Among the Orthoptera, the protein content of the CAL is among the highest while its chitin and chitosan content is similar to those of other insect species. Results suggest that this locust species is a potential source of bioactive compounds of biotechnological interest for use by pharmaceutical and food industries. A more recent work assessed the digestibility of proteins of the CAL and the content of antioxidants from the peptides resulting from proteolysis. It was found that digestion with trypsin allowed the recovery of 0.68 and 0.055 mM TE/mg of protein, with a digestion time of 1 and 3 h, respectively. This work documents the potential of the CAL as a source of protein for the food industry and provides additional evidence on the potential use of this natural resource.

Key Words: True-locusts, ecology, new management approaches

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THE CAMPAIGN AGAINST THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons piceifrons* (Walker 1870), IN MEXICO: ACHIEVEMENTS AND PROSPECTS

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The Central American Locust (CAL), a pest of economic importance for agriculture in Mexi-co, is now under phytosanitary control. The high populations of this locust affect agriculture with important negative impacts on the availability of basic food crops such as corn, beans, rice, sugar cane, and vegetables, among others. Additional impacts are the loss of native species used as fodder or fiber, medicinal plants, and bee populations. Since 1997, the Ministry of Agriculture through SENASICA (The National Service for Agroalimentary Public Health, Safety and Quality Service) has continuously combated the pest through permanent detection and control campaigns with the active participation of Auxiliary Plant Health Organizations, affected local state governments, and farm growers. The phytosanitary campaign includes surveillance, sampling and control, which are strengthened with training for farm growers and field locust officers, monitoring activities and support for research to improve control practices with the incorporation of advanced technologies for the surveillance and control SENASICA invests more than one million dollars a year to detect locust infestations and their control. The strategy has made it possible to (a) keep the pest under control, (b) in-crease the area covered by the campaign each year, from 589,442 hectares in 2014 to 667,556 in 2023, (c) maintain preventive interventions in the affected states (Hidalgo and Quintana Roo), (d) reduce the number of acridian formations (from 108 in 2014 to 18 in 2022), and (e) reduce total crop loss. No major invasions have been reported during the last 9 years, except for isolated and partial damage in certain regions. Currently, SENASICA has 64 technicians assigned to the national campaign, and has two specific strains of Metarhizium acridum for the biological control of the insect. It also incorporated drones to work in regions with difficult access, updated the density threshold to deploy preventive control actions (from 30 to 15 adult locusts/100m2), coordinates joint phytosanitary actions in gregarious areas and migratory routes, developed a mobile application (App) to record all the actions carried out and created an Early Warning System to identify sites at risk. The training of the teams assigned to the field work is a permanent activity. Several areas for improvement have been identified: (a) changes in the management strategy to adapt it to climate change since the Central American Locust has expanded its distribution range and adapted its life cycle to changes in humidity, (b) improvements in the use of drones to detect and control the outbreaks, (c) strengthening of the Early Warning System, and (d) a training program to prepare the next teams of technicians that guarantee the continuity of the preventive control strategy and the integrated management of the CAL populations.

Key Words: prevention, control, alert

THE SPREADING OF THE CENTRAL AMERICAN LOCUST TO NEW AREAS IN NORTHEASTERN MEXICO

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The Central American Locust (CAL), *Schistocerca piceifrons piceifrons* (Walker, 1870) is an important agricultural pest in Mexico, affecting at least ten countries during outbreaks. An important CAL breeding area is in the "Huasteca Region", located in northeastern Mexico. It includes the east of San Luis Potosí, north of Veracruz and the south of Tamaulipas. In 2021-2022, an outbreak of CAL was reported for the first time in the central region of the state of Tamaulipas. CAL swarms were also reported and controlled in the State of Nuevo León, a neighboring state of Tamaulipas; this was the first report of CAL outbreaks in the north-central part of Tamaulipas and Nuevo León. This work aimed to investigate the migration route, the possible factors that caused the CAL outbreak and the areas of suitable habitat at present and in a 2020-2040 climate change scenario. For the state of Tamaulipas, the data of the CAL populations, such as presence and density, were obtained from the In-formation System of the Phytosanitary Campaigns of the SENASICA (National Service of Health, Food Safety, and Quality) website from 2010 to 2022.The Nuevo León Plant Health Committee (CESAVENL) provided information on the occurrence of CAL populations. Migration Route. The migration route was obtained with the help of the forward wind trajectory with Global Data Assimilation System (GDAS) meteorological data (February-March 2022), Lagrangian Integrated track model of NOAA Hybrid Single Particle (Hysplit) model https://www.ready.noaa.gov/HYSPLIT. php. Factors of CAL outbreak. These were divided into three components: environmental variables (using Principal Component Analysis, PCA), Population Estimated Displacement (PED) in the gregarious area (an indirect form to evaluate displacement because of the insecurity in the region), and CAL management. Current distribution and potential distribution area. It was obtained with MaxEnt using the potential scenarios of Worldclim www.worldclim.org. Results. Migration route. Two possible migration routes were found: one from the Southern to the Central region of Tamaulipas, a distance of approximately 130 km, and from this area towards the Central portion of Nuevo Leon, a distance of around 163 km. Factors of CAL outbreak. In the PCA, a high association of the CAL populations with precipitation in the dry period is observed. Precipitation in recent outbreak years in new areas (2021-2022) was below (81 ± 33.0 mm) normal compared to non-outbreak years (166 mm ± 18.0)In the south Tamaulipas, CAL is found in nine Municipalities and in the central region in eleven Municipalities, which show some degree of PED. The combination of several factors, such as insecurity and its effect on timely response caused the locust outbreak in Tamaulipas. The current estimated area with presence of CAL in Northeastern Mexico, is 2'114,810 ha and under a 2020-2040 climate change scenario it would be 3'654,067 ha, this is an increase of 42.12%.

Key Words: CAL management, Migration, Climate change.

IMPACT OF CLIMATE CHANGE ON THE GENERATION OF NEW BREEDING AREAS OF THE CENTRAL AMERICAN LOCUST, NORTHEASTERN MEXICO

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The Central American Locust (CAL), *Schistocecrca piceifrons piceifrons* (Walker), extends its distribution from northern Mexico to Costa Rica. One of the eight known permanent breeding areas is in the Huasteca Region, a warm lowland area that occupies the northern part of the tropical and humid coast of the Gulf of Mexico. This breeding area covers the south of Tamaulipas, the east of San Luis Potosí, the north of Veracruz and the east of the State of Hidalgo. CAL populations typically reproduce continuously and migrate within the limits of the Huasteca region. However, in 2020-2022 numerous CAL bands and swarm were reported, for the first time, beyond the northern limits of their breeding range; in the central and central-western regions of Tamaulipas, and the eastern lands of Nuevo León. Field studies confirmed that some of these populations reproduced in lands near Lake Vicente Guerrero, a reservoir located in the central part of Tamaulipas whose water volume has decreased significantly (80%) due to low rainfall in recent years. This work aimed to analyze the climatic characteristics of the permanent breeding area (hereinafter, established), with respect to the climatic conditions in localities where gregarious CAL populations were reported in 2020-2022 (hereinafter, potential). The study area considered, so far, the states of Tamaulipas and Veracruz. The geographical records of the CAL were obtained from the Information System for Phytosanitary Campaigns National Service for Food Health, Safety and Quality (SICAFI-SENASICA). The delimitation of the polygons of the established and potential breeding areas was carried out in the ArcMap 10.2 software, generating a buffer or circular radius of 5 km around each of the geographic coordinates. Subsequently, the climatic data of meteorological stations located within or near the polygons of the previously delimited areas were consulted. The National Water Commission (CONAGUA), an institution that permanently monitors weather stations in Mexico, provided these data. Linear discriminant function analysis was used to find significant differences in the climate of established vs, potential breeding areas. The individual polygons of these areas were considered as groups, and the variables used were the historical averages of monthly temperature (maximum, average and minimum), precipitation, evaporation, and number of days with frosts, number of days with rain ≥ 0.1 mm, and maximum precipitation in 24 hours. The procedure was performed in STATISTICA 8.0 As a result, the state of Tamaulipas presented the largest number of potential breeding areas (9), while in the State of Veracruz five potential breeding areas were found. The established breeding area comprised a single polygon of wide extension, covering the south of Tamaulipas and the north of Veracruz. Regarding the climate analysis, in Tamaulipas only a potential area located in the northeast of the municipality of Aldama, presented a climate similar as that observed in the established area. In contrast, in Veracruz, four of the potential areas were climatologically similar as the one established. Hence, our results indicate that the new areas with gregarious populations of the CAL present adequate climatic conditions for locust reproduction and aggregation.

Key words: Ecology, Climatic variables, Modeling

CHANGES INVASION-REPRODUCTION AREAS OF THE CENTRAL AMERICAN LOCUST IN SCENARIOS OF CLIMATE CHANGE AND GREENHOUSE GASES: TOWARDS THE INNOVATION OF MONITORING AND EARLY WARNING THROUGH REMOTE SENSORS

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By the end of the 21st century, the Earth's temperature is expected to increase between 1.8°C and 4.6°C (IPPC, 2007). Insects are ectothermic; their body temperature is strongly influenced by ambient air temperature, and their life cycles are usually short. Therefore, even small variations in temperature can have a strong impact on its population dynamism (Musolin and Saulich, 2012). Levels in the last 50 years are well above levels in any other recorded period in the planet's history. When a region warms between optimal temperature ranges for development and for long periods, certain pest species are favored: some, which significantly increase their populations, and others, which manage to expand their presence, colonizing new areas. In acridids, the increase in temperature can trigger a variety of responses including change in spacing distribution and earlier hatching. Range changes, based on different climate simulation models, northern hemisphere locust and grasshopper species could expand their ranges beyond the 50 degrees north and south parallel (Olfert 2011). Considering that the soil is the main source of GHG emissions into the atmosphere (Hatano, 2014), due to the soil's ability to act as a "carbon store" and to emit or absorb greenhouse gases (GHG), in addition to driving the flows of heat and water. Soil temperature is key to future climate, as it can provide feedback on climate change (Buchad, 2011). The burning of cattle pastures and sugar cane promote emissions of methane and black carbon that manage to increase the temperature of the soil up to 60°C coupled with gastroenteric methane emissions from livestock, which induces early gregariousness and maximizes the distribution of the species in search of food beyond the niche areas. There is a 90% correspondence between the locust sampling with the high and very high danger zones in the intermediate part of the Tampaón River, which is associated with agricultural activities. The Tampaón River is the ideal ecosystem for reproduction, as well as the environment that develops in its area of influence; humid soils and irrigated and rainfed agriculture (Galindo et al., 2009; figure 1). The areas in bright orange and red are optimal areas for locus mating and oviposition. In the case of the month of October of the year 2020, the soil surface that was in the ranges of 35°C to 37°C was greater.

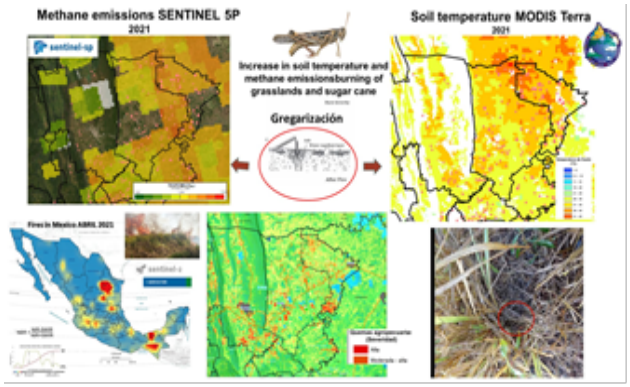

Figure 1. Determination of grassland burn zones that influence gregariousness through MODIS Terra and Sentinel 5P satellite algorithms as well as field radiometry.

Key Words: Central American Locust, Climate Change, Greenhouse Gases, Remote Sensing

LOCUST PHASE POLYPHENISM OF THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons* (Walker, 1870)

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The Central American locust, *Schistocerca piceifrons* (Walker, 1870) is one of the most important migratory pests in Mexico and neighboring Central American countries. It exhibits classic locust phase polyphenism in which solitarious locusts are cryptically colored and shy. In contrast, gregarious locusts are conspicuously colored and gregarious (Fig. 1). While this species has been studied for decades, its locust phase polyphenism has received relatively little attention, compared to other well-known locust species, such as the desert locust *Schistocerca gregaria* and the migratory locust *Locust migratoria*. Over the past several years, we have developed *S. piceifrons* as an alternative model system for locust research, and we have completely characterized the effect of rearing density in behavior, morphology, color, and gene expression in this species. We have produced a high-quality reference genome as well as density-responsive transcriptomes to enable molecular research on this species. We have also conducted a time-course study of phase transition in the lab and a radio telemetry study in the field to understand the intricate details of phase transition and compared with what is known in the desert locust. This presentation thus synthesizes what we have discovered so far on locust phase polyphenism in *S. piceifrons*.

Figure 1. Gregarious (left) and solitarious (right) nymphs of the Central American locust.

Key Words: locust phase polyphenism, behavior, genomics, comparative approach

THE REGIONAL PREVENTIVE APPROACH OF LOCUST-GRASSHOPPER IN CENTRAL AMERICA

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Due to the damage caused by the Central American Locusts (CAL) in Mexico and Central America, in 1947 the International Coordination Committee for Locust Control was created. In 1953, this Committee became OIRSA, which provides technical and financial cooperation to the Ministries and Secretariats of Agriculture and Livestock of its member states, for the protection and development of their agricultural resources. Despite the fact that time has passed, locusts continue to represent a threat to the region, which is why different preventive strategies have been developed to reduce their risk. The components of the CAL preventive Strategies are as follows:

a) Strengthening of capacities. It has been carried out on site and virtually in each member country. New personal officials have been incorporated into the Ministries that require training in identification, survey, and management. During the pandemic, in August 2020, the first virtual locust workshop was held, 1037 people from 21 countries registered, of these 19 were from Latin America, 1 from Israel and 1 from Tunisia.

b) Early warning. OIRSA has a specialized department that analyzes environmental variables, climatic phenomena (El Niño/Southern Oscillation, ENSO), anthropic activities (agricultural burning) that affect locust populations.

c) Early reaction. Coordination between countries is important, so if there is a risk in an area, then they carry out the activities. Cooperation and communications between OIRSA and the Ministries of Agriculture is important to undertake control operations in small areas at an early stage. It is necessary to have a contingency plan that details the processes from identification up to control.

From 2016 to 2023, small outbreaks have been managed preventively in Guatemala, El Salvador, and Nicaragua without significant damage.

Biological control. In 2021, Mexico donated the strain of the *Metarhizium acridium* fungus to be produced and applied against locusts. In this way, locust populations could self-regulate and the environmental impact would be reduced.

Conclusions. Today the Central American Locust continues to be an important pest in the countries of the OIRSA region. Therefore, timely coordination between countries is important, as well as early reaction. The use of biological control agents should be encouraged to reduce the use of conventional chemical insecticides. The pandemic taught us that despite the confinement, phytosanitary activities against locusts must continue.

Key Words: Regional Management, Early Warming, Early Reaction

SUCCESSFUL MANAGEMENT OF THE CENTRAL AMERICAN LOCUST IN YUCATAN WITH *Metarhizium acridium*

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In Mexico, Yucatan is one of the most important states as breeding area for the Central American Locust (CAL). Recent studies have suggested an increase in population density every 2 years and an upsurge every 4 years as swarms migrate towards neighboring States. The management of CAL is through a locust campaign of Federal and State importance, in which the traditional control of the same is carried out with synthetic insecticides. In 1997, studies began to isolate and have an effective and reliable biological product for the management of CAL. Since then, various field evaluations have been carried out in different States of Mexico, including Yucatan, with promising results. Each year in Yucatan usually a small area (30-50 ha) is treated by ground with *Metarhizium acridum*. However, as of 2009, aerial spraying of *M. acridum* against the CAL is carried out over 2000 ha. The objective of this work was to evaluate the effectiveness and persistence of *M. acridum* in the field applied by air in large polygons against CAL. To assess the effectiveness, the population density was evaluated during six weeks, counting the population as gregarious, transiens congregans and solitary. Persistence was evaluated for seven consecutive years in the treated and one untreated polygon. A Chi Square test was performed to evaluate the difference between weeks and treatments. A significant difference was found in the weeks and treatments with P-value of 0.0174 and 0.0334, respectively. In the treated polygon, the population reached adulthood in solitary form and there was no formation of swarms, while in the untreated polygon, the population also reached adulthood but four swarms were formed. In the treated polygon, the population of adult locusts decreased after four weeks of treatment, a change in behavior was observed, such as little food consumption and unpreparedness to migrate. After eight years, in the treated polygon the population has remained low (10-50 locusts in 500 m2), while in the untreated polygon the population has remained high (70-140 locusts in 100 m2). We infer that there has been an autoregulation of *M. acridum* on the CAL, and this occurs in polygons with large treated areas. After the 2009 application, additional applications were made in other polygons in 2010 and 20014 under the system of Reduced Area and Agent Insecticide Treatments (RAAT's) with positive results (population reduction), but no evaluations were carried out. At the end of 2022, 800 ha were treated by helicopter at key sites throughout the CAL development zone, although no systematic assessment has been carried out, quantified CAL populations have been minimal. In the last 14 years, the CAL populations in Yucatan have been decreasing, although not only due to the effect of *M. acridum*, it has undoubtedly played an important role in this reduction.

Key Words: Prevention, Autoregulation, Bioinsecticide.

DISTRIBUTION AND EFFECT OF CLIMATE CHANGE ON THE CENTRAL AMERICAN LOCUST IN GUATEMALA

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Historically, the Central American Locust (CAL), *Schistocerca piceifrons piceifrons* (Walker), was present in Guatemala from the Mayas to colonial times, damaging important agricultural crops.

In recent times, in 2020, we had the largest populations of this pest, with migratory swarms mainly in the Department of El Petén, northern Guatemala. Currently, it is also distributed in two other departments: Jutiapa (southwest) and Retalhuleu (southeast).

Guatemala has high exposure to natural hazards and the effects of climate change, including higher temperatures and a more variable rainfall pattern; these factors increase the risk of food supply and water security.

Recent studies suggest an association between climate change and intense locust outbreaks, so this study analyzes the distribution of CAL in the current scenario and under climate change.

Materials and methods. The current and potential distribution of CAL under a climate change scenario was obtained using the MaxEnt algorithm. The Guatemalan Ministry of Agriculture, Livestock and Food (MAGA) provided information on CAL distribution sites. The variables considered in the analysis are the following: precipitation of the driest month, maximum temperature of warmest month, minimum temperature of the coldest month, precipitation of the rainiest month, mean annual temperature, and annual precipitation; the data was obtained from the worldclim website www.worldclim.org

Results. MaxEnt provided an area under the Curve (AUC) of 0.942. The current distribution of CAL is over an important area of 6,269.16 km2 and under a climate change scenario, 2020-2040, it can be reduced to 2,169.46 km2; that is 65 % less. However, additional CAL populations are expected in the following Departments: Quetzaltenango, Jalapa, Chiquimula, and Baja Verapaz.

The contribution of the variables in the analysis was precipitation of the driest month (33.5 %), maximum Temperature of the warmest month (23.5 %), minimum Temperature of the coldest month (21 %), precipitation of the rainiest month (10.6 %), the average annual temperature (5.9 %) and the annual precipitation (5.5 %).

Conclusions. In Guatemala, there would be a reduction and redistribution of CAL outbreak areas due to the effect of climate change under the scenario 2020-2040.

Key Words: Climatic variables, Outbreak areas, Early Warming.

BIOTECHNOLOGICAL POTENTIAL AND REEVALUATION OF PESTS: THE CASE OF THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons piceifrons* (Walker)

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Conventional control of locusts around the world is mainly based on decreasing the population density through the use of different control techniques. This management strategy leads to the destruction of this natural resource that represents an important source of compounds of interest to the food and biotechnological industry. Recently, the exploration of the Central American Locust (CAL) as a potential source of biochemical compounds showed that this species could provide important metabolites, polymers, enzymes, and nutrient contents. These findings allowed CAL to be revalued as a natural resource and, as such, an alternative management approach may be feasible. A first stage of exploration detected entomochemicals and polymers, highlighting the potential of the CAL as a source of total phenolic content, antioxidant activity, steroidal compounds, tannins, and saponins. The chitosan and chitin contents are 11.88 and 9.11 g, respectively, in 100 g of dry matter; these levels are similar compared to other potential source insects of compounds. The proximate composition of adults showed 65.84% moisture content and 34.15% dry matter, which consisted of 80.26 g of protein, 6.21 g of fat, 3.35 g of ash, and 12.56 g of fiber content; per 100 g of dry matter. These results are an indication that CAL could potentially be useful for innovations in feed development. A second stage focused on the characterization of the intestinal proteolytic enzyme, the most abundant digestive proteolytic enzyme was the catalytic-type trypsin, confirmed by its sensitivity to the chemical inhibitors phenylmethylsulfonyl fluoride and EDTA. This supports the potential use of CAL as a source of enzymes for industrial and food processing. A third stage sought confirmation of protein digestibility and the development of food prototypes. The CAL water-soluble protein fraction was subjected to proteolytic hydrolysis by simulating the monogastric digestive process, using pepsin and trypsin. Both proteinases hydrolyzed total soluble proteins, which was confirmed by polyacrylamide gel electrophoresis. A prototype tortilla supplemented with powdered CAL was developed, in order to increase the fiber, protein, antioxidant and mineral contents compared to a simple corn tortilla. The addition of 1 to 5% powdered CAL did not affect the physical properties of the tortilla, supporting its use for food development, although acceptability and toxicological evidence must be considered. The potential of CAL to enrich mescals by increasing the antioxidant content was also demonstrated. CAL as an infusion, improved normal antioxidant status that was stable under storage conditions. The CAL-enriched mescal contributed amber tones and resinous nuances. Toxicological analyzes are needed to ensure the safety of the preparations. This evidence supports the potential of CAL as a source of compounds for biotechnological use and opens the field for additional research on innovative topics that revalue this pest as a natural resource that could be harnessed through technological advances and development of sustainable functional products.

Key Words: Locust, Chemical compounds, Food and biotechnological industry

SYMPOSIA 2

THE EFFECT OF HUMAN ACTIVITIES ON ORTHOPTERA

Organizer
David Hunter

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1. **Charly Oumarou Ngoute.** EFFECTS OF FOREST CLEARING ON GRASSHOPPER ASSEMBLAGES IN THE RAINFOREST AREAS OF SOUTHERN CAMEROON.
2. **Zoltán Kenyeres and Norbert Bauer**. DIRECT AND INDIRECT HUMAN EFFECTS ON CENTRAL EUROPEAN ORTHOPTERANS.
3. **Arianne Cease.** HOW NUTRIENTS MEDIATE THE IMPACTS OF GLOBAL CHANGE ON LOCUST OUTBREAKS.
4. **David H Branson**. IMPACTS OF CLIMATE CHANGE DRIVERS ON U.S. RANGELAND GRASSHOPPER OUTBREAKS.
5. **Allan Spessa and David Hunter.** HAS A SHIFT TO LONG DROUGHTS LED TO REDUCED OUTBREAKS OF THE AUSTRALIAN PLAGUE LOCUST EVEN WHEN RAIN FALLS?
6. **David Hunter and Hector Medina.** EFFECTS OF INCREASED TEMPERATURES AND LAND CLEARING ON OUTBREAKS OF THE SOUTH AMERICAN LOCUST *Schistocerca cancellata* (Serville, 1838).
7. **Michael R. Kearney.** PREDICTING ORTHOPTERAN BODY TEMPERATURE, SOIL TEMPERATURE AND SOIL MOISTURE WITH THE NICHEMAPR SHINY APPS.

EFFECTS OF FOREST CLEARING ON GRASSHOPPER ASSEMBLAGES IN THE RAINFOREST AREAS OF SOUTHERN CAMEROON

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The Congo Basin, located in central Africa, is the second largest rainforest in the world, having forests covering 240 million hectares. Substantial clearing of forests is occurring, and we show that in studies undertaken in the rainforest areas of southern Cameroon, such clearing has substantial effects on grasshopper biodiversity. The negative effects of forest clearing on grasshopper assemblages, have direct consequences for species conservation, land management, and pest control. In southern Cameroon, most grasshopper species found in forests either declined or were completely absent from fallow-land cleared of forest. The opening up of forests by human activities offers suitable environments for the proliferation of pest grasshopper species populations, such as *Zonocerus variegatus* (Linnaeus, 1758) and *Eyprepocnemis ibandana* (Charpentier, 1825). These species are adapted to Asteraceae plants of fallow-lands, close to the villager crop fields. The direct consequences of this are increased pest activities in crop fields and disruption of the balance of natural ecosystems. Furthermore, the other native forest species, such as *Mazaea granulosa* Stål, 1876, *Holopercna gerstaeckeri* (Bolívar, 1890), *Digentia fasciata* Ramme, 1929, *Parapetasia femorata* Bolívar, 1884 or *Gemeneta opilionoides* (Bolivar, 1905) decline dramatically due to deforestation. Such trends are likely to affect not only grasshoppers as indicator species, but many other organisms as well, which means that to retain native flora and fauna, conservation, and restoration measures need to be put in place.

Key Words: Forest clearing, species richness, diversity

DIRECT AND INDIRECT HUMAN EFFECTS ON CENTRAL EUROPEAN ORTHOPTERANS

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The presentation illustrates the effects of human activities on Central-European Orthoptera through some key case studies. The phenomena revealed by detailed examinations cover direct and indirect, negative and positive impacts.

The direct effects usually hurt the Orthoptera populations. Rotary mowing in hayfields causes significant (min. 40%) damage (mostly lethal) to imagoes (e.g., *Isophya costata*). Increasing spraying intensity and decreasing traditional land use (small parcels) in arable fields caused local restrictions or extinctions (e.g., *Tettigonia caudata*) (Fig. 1). Intense grazing in tall humid grasslands is usually followed by a decline of the habitat specialist species due to the removal of food base and egg laying place, trampling on eggs laid into the soil.

The most striking indirect effects sometimes also negatively impact the orthopterans. Wild boar and mouflon populations have increased tenfold regionally in the last few decades because of changing approaches and practices to game management (shortened hunting times require high numbers of games). Degradation and nutrient enrichment because of the trampling has a detrimental effect on the populations occurring on steppe patches (e.g., *Stenobothrus eurasius*). Positive indirect human effects are also detected recently. Although both intense grazing and the abandonment of grazing have a detrimental impact on sand habitat specialist orthopterans, moderate grazing is beneficial for them. In Central Europe, active heat sums above 10 °C in the summer months have increased. Some species (e.g., *Acrida ungarica*) seem to be supported by the global changes.

Figure 1. Cultivated habitat of *Tettigonia caudata* before and after harvest (no chemical-free edging left behind).

In conclusion, human effects in Central Europe have had the most influential impact on Orthoptera fauna and assemblages. There is a vast question: should we handle that as a phenomenon caused by socio-ecological factors and result in losers and winners of them, or do we have enough social support and financial opportunity in these globally critical years to soften the human impact on orthopterans?

Key Words: Mowing, Grazing, Cultivation

HOW NUTRIENTS MEDIATE THE IMPACTS OF GLOBAL CHANGE ON LOCUST OUTBREAKS

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Locusts are grasshoppers that can migrate *en masse* and devastate food security. Plant nutrients are a key variable influencing population dynamics, but the relationship is not straightforward. For an herbivore, plant quality depends not only on the balance of nutrients and anti-nutrients in plant tissues, which are influenced by land use and climate change, but also on the nutritional state and demands of the herbivore, as well as its capacity to extract nutrients from host plants.

This talk will give an overview of how locusts and grasshoppers balance macronutrients, what is known about how environmental factors affect protein and carbohydrate demand, and how anthropogenic factors may affect acridid populations through changes in insect physiology and nutritional landscapes. In contrast to the concept of a positive relationship between nitrogen or protein concentration and herbivore performance, a five-decade review of lab and field studies indicates that equating plant Nitrogen to plant quality is misleading because grasshoppers respond negatively or neutrally to increasing plant Nitrogen just as often as they respond positively. For locusts specifically, low Nitrogen environments are actually beneficial because they supply high energy rates that support migration. Therefore, intensive land use, such as continuous grazing or cropping, and elevated ambient CO2 levels that decrease the protein: carbohydrate ratios of plants are predicted to broadly promote locust outbreaks.

Key Words: Acrididae, plant-insect interactions, nitrogen, protein, carbohydrate, nutrition, Geometric Framework for Nutrition, Ecological Stoichiometry

IMPACTS OF CLIMATE CHANGE DRIVERS ON U.S. RANGELAND GRASSHOPPER OUTBREAKS

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GLOBAL change drivers such as elevated temperature, increased nitrogen deposition and altered precipitation regimes can have strong impacts on rangeland insect dynamics and grassland ecosystems. For over 20 years, our lab has examined how abiotic and biotic climate drivers influence grasshopper population dynamics in the central and western U.S. Mechanisms underlying grasshopper outbreaks remain poorly understood, but we conducted novel field experiments during a severe outbreak that demonstrated food limited competition can drive outbreak dynamics. Our work demonstrated that precipitation driven shifts in plant quality can cause severe outbreaks and that severe outbreaks can rapidly end due to food limitation.

This research conducted during an extreme outbreak enhanced understanding of what factors lead to the onset and end of outbreaks and can help predict when control efforts aren't warranted. Although drought has traditionally been assumed to positively impact grasshoppers in the northern Great Plains (U.S.), land managers' abilities to proactively manage grasshoppers are constrained by an inability to predict responses to weather variation. Changing climate conditions are predicted to result in more frequent extreme precipitation events, but no prior work had examined impacts of precipitation variability on grasshopper populations had not been examined.

We conducted novel drought manipulation research and demonstrated for the first time that precipitation events can directly drive outbreak dynamics.

Our results demonstrated that early summer drought strongly negatively influences grasshopper populations even with above average late summer precipitation, and that drought timing is critical, as moderate early summer drought enhanced grasshopper performance. The results confirm that drought timing affects outbreak dynamics and has strong control implications, as severe early summer drought would reduce the benefit of controlling an outbreak. More recent modelling work suggests that predicted climate conditions could intensify pest impacts in only some parts of Wyoming by 2040. In the first terrestrial model to incorporate climate indices as spatially varying coefficients, we found grasshopper densities in the western U.S. exhibited asynchrony and spatial non-stationarity. The results from the combined innovative manipulative experiments and modelling efforts have advanced the understanding of grasshopper population dynamics and can be used to assist managers in proactively responding to pest problems.

Key Words: grasshopper, climate change, outbreaks

HAS A SHIFT TO LONG DROUGHTS LED TO REDUCED OUTBREAKS OF THE AUSTRALIAN PLAGUE LOCUST EVEN WHEN RAIN FALLS?

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During most of the twentieth century, outbreaks and plagues of the Australian plague locust *Chortoicetes terminifera* were common across the agricultural areas of eastern Australia, west of the Great Dividing Range. *C. terminifera* is native to Australia, and the species has been studied and monitored extensively since the 1930s because it is arguably the most economically important pest of grain crops and pasture in eastern Australia. Detailed population records have been kept on the extent of locust infestations by the Australian Plague Locust Commission (APLC). The APLC became operational in mid-1977 through an agreement between the Commonwealth and four member states- New South Wales, Queensland, Victoria, and South Australia. The organization undertakes survey, forecasting and control activities, and these activities are bolstered by a steady stream of research projects.

Field data collected from various reliable sources and databased by the APLC reveal several interesting trends. One, locust bands and/or swarms were present somewhere in the agricultural zone in two out of three of years from 1930s to 2010. Two, there were 17 years when locust populations were classified at plague to major plague densities during this period. Three, control operations against bands and/or swarms have been conducted by the APLC in 25 of the 34 years from 1977 to 2010. Four, control operations have been conducted in only one of the 13 years since. This result is surprising, yet a convincing explanation remains elusive. This period has been characterised by extreme weather events associated with climate change where long droughts (2012-2015, 2017-19) were followed by a long-wet period (2020-23). However, during the long-wet period following the droughts, there were only some localised bands and swarms but no APLC control operations. That is, no outbreaks were recorded. Here we present the results of a quantitative analysis exploring the different ecological and climatic 'modes' potentially responsible for the sharp reduction in outbreaks frequency. We targeted two main modes as working hypotheses. One, high temperatures during droughts lead to an increase in locust mortality. Two, cooler temperatures and persistent wet cloudy conditions lead to development delays and increased numbers of natural enemies. The roles of ENSO and climate change are also discussed.

Key Words: locusts, droughts, natural enemies

EFFECTS OF INCREASED TEMPERATURES AND LAND CLEARING ON OUTBREAKS OF THE SOUTH AMERICAN LOCUST *Schistocerca cancellata* (Serville, 1838)

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For almost 60 years, there were occasional localized outbreaks of the South American locust (SAL), *Schistocerca cancellata* (Serville, 1838), but there was a sudden appearance of many swarms in Santiago del Estero province during July 2015, which was followed by a widespread upsurge that continued for several years. The precursors to these initial swarms were not found, and while recent studies (Trumper et al. 2022 Agronomy 12, 135) have indicated the possible importance of a decline in resources for survey, the effects human activities including climate change and land clearing are provided here.

SAL avoids development during the winter dry season, by adults entering diapause from late March onwards, with adults resuming egg maturation in spring, but only after rain has fallen. In many years, the first rains occur in mid to late spring so that egg maturation and oviposition do not occur until October or November. In this common situation, two generations per year are possible, but in some years winter/early spring rain allows maturation to begin in September, allowing three generations. Studies by Hunter & Cosenzo (1990: Bull. Entomol. Res. 80, 295-300) showed that in the 1970's and 1980's, the only regions warm enough for three generations were in the provinces of Catamarca and La Rioja and adjacent areas and for many years locust survey and control has concentrated in these areas with populations kept in check through a program of preventive locust management. But this period of low to moderate locust numbers ended with the sudden appearance of many swarms during winter 2015.

Detailed investigations have revealed that there has been an increase in maximum temperatures and rainfall in northwest Argentina in recent years related to climate change, which means that many more areas are warm enough for three generations in a season. In addition, there has been substantial clearing of the Chaco forests in northern Argentina, Bolivia and Paraguay, providing many new more open areas suitable for SAL breeding. During the recent SAL upsurge, a clear migratory circuit was evident where a spring/early summer generation in northwest Argentina was often followed by some or most of the locusts migrating north to Bolivia/Paraguay with a return migration to Argentina in winter. The increasing temperatures and rainfall combined with the clearing of forests for agriculture are likely to mean that many more areas have become very suitable for locust breeding, and the importance of the migratory circuit in reaching these many suitable areas is discussed.

Key Words: South American locust, upsurge, climate change, land clearing

PREDICTING ORTHOPTERAN BODY TEMPERATURE, SOIL TEMPERATURE AND SOIL MOISTURE WITH THE NICHEMAPR SHINY APPS

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Understanding and predicting how species respond to environmental change is a long-standing goal in pure and applied orthoptera research. In recent times there has been a focus on pattern-based approaches, where species responses (e.g., occurrences, abundances) are statistically linked to environmental data and then interpolated across time and space. Descriptive approaches are powerful but limited in their ability to predict to novel conditions and to suggest new measurements and experiments. In this talk I will introduce tools that take a mechanistic approach to understanding and predicting how species respond to environmental change, based on principles of energy and mass exchange between organisms and environment. This approach allows functional traits, such as thermal and hydric sensitivities and behavioural thresholds, to be connected to environmental conditions via microclimates to predict the temperatures, water loss rates and activity potential of organisms in nature. As an entry point to such approaches, I will introduce Shiny web applications of the NicheMapR package for 'mechanistic niche modelling' that can calculate environmental conditions (e.g., soil moisture, soil temperature, radiation environments, wind and air temperature near the ground) and translate these via functional traits (e.g., solar absorptivity, size, thermal thresholds on activity, lethal limits) into predicted response that can be measured directly and tested in the field. These apps can be used as stand-alone methods for research, but can be taken further with greater flexibility within the R programming environment via the NicheMapR package. They should help us make better predictions of how orthopteran eggs, nymphs and adults respond to their thermal and hydric environments and make better predictions for problems in pest management, conservation and pure research.

SYMPOSIA 3

ANTHROPOGENIC IMPACTS ON ACOUSTICALLY SIGNALLING ORTHOPTERANS

Organizer
Rohini Balakrishnan

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1. **Richa Singh and Manjari Jain.** THE CHIRP OF CHANGE: INVESTIGATING THE IMPACT OF ANTHROPOGENIC ENVIRONMENTAL FACTORS ON ACOUSTIC SIGNALLING IN THE NOCTURNAL ENISFERAN INSECT, *Acanthogryllus asiaticus.*
2. **Vanessa Couldridge and Rekha Sathyan.** THE EFFECT OF ANTHROPOGENIC NOISE ON MALE ACOUSTIC SIGNALLING IN THE BLADDER GRASSHOPPER *Bullacris unicolor*
3. **Marina H. L. Duarte, Ernesto P. Caliari, Marina D. A. Scarpelli, Gabriel O. Lobregat, Robert J. Young, Esther M. B. Bittencourt and Renata Sousa-Lima.** MINING NOISE AFFECTS CRICKET CALLING ACTIVITY IN A TROPICAL FOREST.
4. **Rohini Balakrishnan.** EVALUATING ANTHROPOGENIC IMPACTS ON ACOUSTICALLY COMMUNICATING ORTHOPTERANS THROUGH THE LENS OF SENSORY AND EVOLUTIONARY ECOLOGY.

THE CHIRP OF CHANGE: INVESTIGATING THE IMPACT OF ANTHROPOGENIC ENVIRONMENTAL FACTORS ON ACOUSTIC SIGNALLING IN THE NOCTURNAL ENISFERAN INSECT, *Acanthogryllus asiaticus*

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Insects are among the earliest terrestrial animals to employ acoustic signals for communication between conspecifics mainly for mate attraction and territorial behavior. These communication systems have evolved to be finely tuned to the specific conditions of their local habitats, as populations adapt to environmental pressures over time. However, recent anthropogenic modification has rapidly transformed many habitats, introducing new stimuli such as anthropogenic noise, and artificial lights at night. As the environment plays a critical role in shaping insect behavior and signals, it is essential to investigate the impact of these altered sensory environments on acoustic signals to gain a broader understanding of signal evolution.

This study examines how two key environmental factors: artificial lights at night (ALAN) and road traffic noise impact acoustic signalling of a nocturnal ensiferan insect, *Acanthogryllus asiaticus*. We investigated the effects of ALAN on these nocturnal insects by comparing their calling behavior in artificially lit and dark areas. Later, we examined the role of melatonin in regulating their calling patterns. To assess the impact of road traffic noise on A. asiaticus, we studied how long and short-term noise exposure affects their acoustic signal. We used field-based monitoring and laboratory-based experimental approaches to perform our study. The findings show that ALAN significantly affects signalling in this species, leading to disrupted calling rhythms that can be restored by melatonin. Increased ambient noise in traffic-prone areas has a significant impact on signalling whereas an immediate alteration in ambient noise levels does not have any effect on it. This study presents evidence of how sensory pollution can have ecological consequences and affect insect communication systems, highlighting the potential impact of novel anthropogenic stressors.

Key Words: Anthropogenic influence, Field cricket, bioacoustics

THE EFFECT OF ANTHROPOGENIC NOISE ON MALE ACOUSTIC SIGNALLING IN THE BLADDER GRASSHOPPER *Bullacris unicolor*

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Acoustic communication in animals relies upon specific contexts and environments for effective signal transmission. Increasing anthropogenic noise pollution as a result of urban development and transportation networks can disrupt acoustic communication systems. Despite their central role in food webs and fulfilling ecosystem services, and despite being the most numerous group of sound producing animals, surprisingly little research has been conducted on the effects of anthropogenic noise on insects. In this study, we investigated call parameter differences in the bladder grasshopper *Bullacris unicolor* inhabiting two adjacent reserves in Cape Town, South Africa, that differed in their noise levels. We aimed to examine the effects that increasing urbanisation may have on acoustic signalling in this species, which is heavily reliant on sound signals for mate attraction and location. Nocturnal calling activity was monitored continuously for three weeks during peak seasonality of the grasshoppers, using passive acoustic recorders. Weather conditions were also logged. We found that the interval between successive calls increased with higher noise levels at both sites, and the peak frequency became lower. The total number of calls detected also decreased with anthropogenic noise, but this relationship was only evident at the noisier site. In addition, grasshoppers shifted the timing of their calls to later in the night at the noisier site (CFNR), possibly to take advantage of relatively lower noise levels (Fig. 1). We also found that weather conditions, particularly temperature, had a significant influence on call parameters. Further studies are thus needed to disentangle the effects of anthropogenic noise and environmental variables on calling activity in this species.

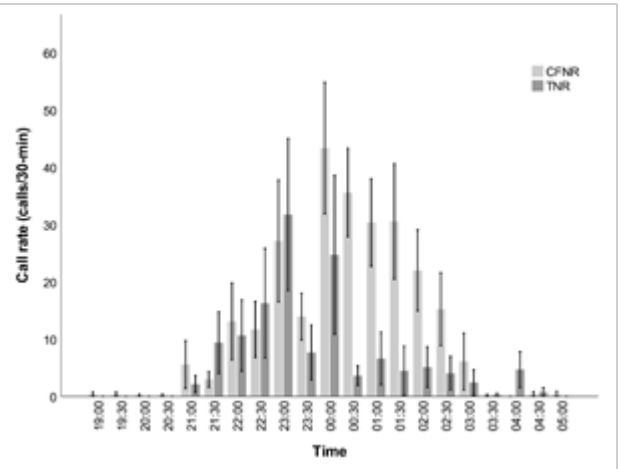

Figure 1. Calling rates of *B. unicolor* at the two study sites, the Cape Flats Nature Reserve (CFNR) and the Tygerberg Nature Reserve (TNR), measured as the number of calls (mean ± SD) per 30-minute interval.

Our results lend support to the growing concern regarding the effects of noise pollution on animal acoustic signalling systems, and also highlight the complexity of factors which affect sound signalling in natural environments.

Key Words: Anthropogenic noise, Passive acoustic monitoring, Pneumoridae

MINING NOISE AFFECTS CRICKET CALLING ACTIVITY IN A TROPICAL FOREST

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Anthropogenic noise is a global pollutant and several studies have showed its impact on wildlife. This research shows how the noise produced by mining affects crickets' acoustic communication. Two passive acoustic monitoring devices (Song Meter II – SM II) were installed in a forest fragment located at 500 m from an opencast mine in Brazil. Another two SM II were installed distant 2500 from the mine. The equipment recorded from 17:00 to 05:00 h during seven days in April 2013. We analyzed the spectral characteristics of acoustic activity of three species of crickets (*Anaxipha sp., Gryllus sp., and a* Podoscirtinae species) before, during, and after the passing of mine trucks.

For comparison we analyzed the acoustic characteristics for *Anaxipha sp*. and *Gryllus sp*. found in the distant site. Results showed a calling interruption for all the species during truck transit. *Gryllus sp*. emitted calls with higher maximum frequencies, average power, and larger bandwidth in the site close to the mine. Podoscirtinae species emitted calls with lower minimum frequencies, higher average power, and large bandwidth in the close site. We showed that insect acoustic behavior varies between areas with different levels of noise. The disruption of this behavior may have negative consequences for their reproductive success.

Key Words: ICO2023, Merida, Grasshopper

EVALUATING ANTHROPOGENIC IMPACTS ON ACOUSTICALLY COMMUNICATING ORTHOPTERANS THROUGH THE LENS OF SENSORY AND EVOLUTIONARY ECOLOGY

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We live in an era with an unprecedented rate of change of environments due to anthropogenic impacts, including climate change, urbanization, habitat modification and fragmentation, light and noise pollution. There are an increasing number of studies on the impacts of these changes on the behavior and ecology of both vertebrate and invertebrate species, in the context of mate-finding, sexual selection and foraging. Many orthopteran insects use sound for mate-finding and mate choice. There is evidence for impacts of traffic noise, light pollution and changing temperatures on calling behaviors and signals of orthopteran species. There is also some evidence of orthopteran species using human structures and human-modified landscapes to their advantage. Most studies have focused on field and tree crickets, and there is a dearth of studies on katydids, especially from the tropics. Most outdoor studies are correlative, whereas laboratory studies need to be extended to field conditions. Few studies take into account the physiology, ecology and evolutionary history of signalers and receivers.

In this talk, I will review studies on anthropogenic impacts, especially that of noise pollution, on acoustically communicating orthopteran species, and highlight the different approaches used. I will then present some data from our work on cricket and katydid signaling, masking interference, mate choice and mating success in relatively undisturbed habitats to make the case that observations on the impacts of anthropogenic noise need to be interpreted with caution.

On the one hand, we need to understand the spatiotemporal, spectral and amplitudinal aspects of the noise, as well as the sensitivity and frequency tuning of the sensory systems of our focal species, together with its spatial ecology. This will allow an understanding of how much masking interference may actually be experienced by individuals. We also need to understand their signaling and searching behavior, as well as fitness outcomes in natural environments to serve as a benchmark when interpreting or speculating upon the effects of anthropogenic noise. Finally, many species have evolved in naturally noisy environments and may be pre-adapted to deal with anthropogenic noise, with both behavioral and physiological coping strategies.

Key Words: Anthropogenic noise, sensory ecology, crickets, katydids

SYMPOSIA 4
CURRENT ORTHOPTERA RESEARCH IN LATIN AMERICA

Organizer
Celeste Scattolini, Ricardo Mariño & Salomón Sanabría

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1. **Mariottini Yanina,' María Laura de Wysiecki and Carlos E. Lange.** OUTBREAKS OF *Dichroplus maculpennis* AND *Bufonacris claraziana* IN ARGENTINA: WHAT DO WE KNOW?
2. **M. Celeste Scattolini, Cyril Piou, Héctor Medina, Rosario Iglesias and María M.** ECOLOGICAL STUDIES ON THE SOUTH AMERICAN LOCUST, *Schistocerca cancellata* (Serville, 1838)
3. **Elio Rodrigo Castillo, Sofía Chica Ruiz, Silvia Laphitz, María Marta Cigliano, Viviana Confalonieri and María Celeste Scattolini**. THE EVOLUTIONARY DYNAMICS OF SOUTH AMERICAN MELANOPLINAE CHROMOSOMES: AN INTEGRATIVE STUDY.
4. **Lucas Denadai de Campos*, Jorge Alves Audino, Laure Desutter-Grandcolas and Silvio Shigueo Nihei**. ¿ARE OECANTHID CRICKETS CEASING TO SING?
5. **Daniela Santos Martins Silva**. GRASSHOPPERS FROM BRAZIL PROJECT: DIVERSITY, NEW REPORTS, AND CURRENT CHALLENGES.
6. **Salomón Sanabría-Urbán, José David Gómez-Tapia, Fernanda Aguilar-Neri, Fabiola Soto-Trejo and David A. Prieto-Torres.** THE GRASSHOPPERS OF THE SUBFAMILY MELANOPLINEA (ORTHOPTERA; ACRIDIDAE) IN MEXICO: DIVERSITY, SYSTEMATICS, BIOGEOGRAPHY AND CURRENT CHALLENGES.
7. **Ricardo Mariño-Pérez.** PROCTOLABINAE AND OMMATOLAMPIDINAE IN MEXICO: RECENT FINDINGS IN THEIR NORTHERNMOST RANGE.

OUTBREAKS OF *Dichroplus maculpennis* AND *Bufonacris claraziana* IN ARGENTINA: WHAT DO WE KNOW?

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Since the beginning of agriculture and livestock farming in Argentina, some grasshopper species have been considered harmful to such activities. Over time and in different regions, significant outbreaks have been recorded. An increase in this problematic has been observed in recent decades, being the outbreaks of different species a recurrent phenomenon. The impact and magnitude of *Dichroplus maculipennis* in the South of the Pampas region (Between 2008 and 2021) and *Bufonacris claraziana* in diverse areas of Patagonia (Between 2016 and 2022) are worth mentioning. *Dichroplus maculipennis* is found in much of the country, and it is considered one of the most harmful grasshoppers, mainly in areas of the Pampas and Patagonia. *Bufonacris claraziana* is an endemic species of Argentinian Patagonia distributed from Neuquén to Santa Cruz provinces. With the aim of knowing the population dynamics of these species, we have carried out different studies about their ecology and biology.

Field sampling (from 2005 to the present), as well as laboratory studies, have revealed the abundance, phenology, age structure, and sex ratio of *D. maculipennis* populations in grasslands and crops of the southern Pampas, and characteristics of its life cycle such as longevity, survival, fecundity, food consumption and preferences, and ecological efficiency, among others.

Besides, studies on habitat preferences and the interaction between specific densities and climatic variables were performed. On the contrary, knowledge about population dynamics of *B. claraziana* is still very limited (Tab. 1). From 2017 to the present, field sampling has been carried out in various localities of the Santa Cruz and Chubut provinces.

In addition, some initial laboratory and field experiences have also been performed to evaluate the susceptibility of this species to the entomopathogenic *Beauveria bassiana*, a potential biocontrol agent.

Even today some relevant characteristics of the biology and ecology of most Argentinian grasshopper pests remain largely unknown. We consider that sustained ecological studies over time are necessary to understand the dynamic relationships between intrinsic characteristics and environmental factors since they will facilitate forecasting and management of the pest species.

Characteristics	*Dichroplus maculipennis*	*Bufonacris claraziana*
Embryonic development	-	-
Post-embryonic development	+++	+
Diapause	++	+
Eggs survival	-	-
Fecundity	++	-
Survival/longevity	+++	-
Food habits	+++	+
Food consumption	+++	+
Population density	+++	+
Outbreaks recorded	+++	++
Interaction whit climatic variables	++	-
Habitat preference	++	-
Entomopathogens as biological controllers	++	+

Table 1: Aspects of *D. maculipennis* and *B. claraziana* known to date. – Not studied, Partially studied, Studied, Well studied.

Key Words: *Dichroplus maculipennis*, Bufonacris claraziana, Population dynamic.

ECOLOGICAL STUDIES ON THE SOUTH AMERICAN LOCUST, *Schistocerca cancellata* (Serville, 1838)

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The South American locust, *Schistocerca cancellata* (Serville, 1838), is the only swarming locust in southern South America, with its maximum known invasion area covering nearly 4,000,000 km2 affecting central and northern Argentina, Uruguay, southern Brazil, Paraguay, southeast Bolivia, and central and northern Chile. During most of the first half of the 20th century, *S. cancellata* caused great economic losses in almost every cultivated area. Coinciding with the implementation of a preventive management program in 1954, there were no more large-scale upsurges. However, there was a resurgence of *S. cancellata* in 2015 when swarms hit northern Argentina extending into Paraguay and Bolivia.

During the last century, extensive research on the biology and ecology of some locust species and the subsequent development of preventive management strategies has led to a better control and to smaller invasions. However, given that the South American locust was in recession for six decades, there were very few studies performed on this species. Locust management generally involves GIS-based systems to locate when and where surveys should be conducted. To that end, it is indispensable to understand the critical factors that would lead to outbreaks. The recent upsurge has evidenced the need of more studies, including the application of new technologies such as remote sensing, to accurately identify suitable locust habitats.

The "Servicio Nacional de Sanidad y Calidad Agroalimentaria" (SENASA - National Service of Food Health and Quality) is in charge of conducting surveys and control actions of locusts through Argentina. SENASA survey teams periodically visit potential locust habitats and record presence or absence, and the phenological state of the South American locust. We used this data complemented with maps (DEM, soil's aridity, land cover and use) and remote sensing layers to further understand the ecology of *S. cancellata*. We performed comparisons of logistic regression models in a multi-model inference framework to test which combination of variables best explained different biological and ecological traits of the South American locust.

The distribution of the South American locust is extremely extensive and the areas are very difficult to access. To improve the preventive management of this plague it is imperative to achieve a better understanding of its biology and ecology. Mostly, considering the rapid climatic changes and land use modifications we are observing in the South American locust distributional area. In this presentation, we will discuss the recent studies performed to determine the critical factors that are associated with the spatial distribution of the potential breeding habitats of *S. cancellata*.

Key Words: GIS, logistic regression model, multimodel inference

THE EVOLUTIONARY DYNAMICS OF SOUTH AMERICAN MELANOPLINAE CHROMOSOMES: AN INTEGRATIVE STUDY

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Chromosomal rearrangements (CRs) generate variations in diploid number (2n); have profound effects on the rate of recombination; and are responsible for the formation of neo-sex chromosomes (neo-CS). South American Melanoplinae species from the tribe Dichroplini show a marked chromosomal variability, a unique pattern that differentiates from the stable ones observed at the superfamily level (Acridoidea). The described chromosomal variability is not randomly distributed among the clades, with genera where all species show rearranged karyotypes and neo-CS, and others where only some species show chromosome changes. Although there is knowledge about chromosomal evolution for some genera of Dichroplini, there are ecoregions where species have not been studied. Here, we performed the first cytogenetic study in Andean species of the genera *Orottetix* and *Chlorus*. We analyzed the structure and meiotic behavior of chromosomes in the species of both genera with classical and differential cytogenetic techniques. Males from *Orotettix* (*i.e. O. andeanus, O. carrascoi, O. astreptos*) showed 2n=21 and an X0 sex chromosome determination system. *Chlorusspatulus* exhibited males with 23 telocentric chromosomes (22+X0) and *Chlbolivianus* showed a 2n=18 plus the X chromosome.

We evidenced a conserved pattern related with the distribution of the constitutive heterochromatin (CH). The karyotype diversity within these genera could be associated only with the occurrence of CRs i.e. pericentric inversions.

Our preliminary study concerning the location and distribution of CH showed repetitive sequences in centromeric regions in all the cases. Although preliminary, these results show that CRs involved only autosomes and no cases of neo-sex chromosomes in Orotettix. Besides, an extreme reduction in the 2n of *Chl. bolivianus* suggest more than one CR involved in the chromosome structure. The present study is the first cytogenetic characterization in these Neotropical species, thus contributing to the knowledge of their karyotype structure. The analysis of our results, together with the previous information (*e.g. cytogenetic* data and phylogenetic hypothesis proposed), allows us to discuss the chromosome evolution in this Neotropical Melanoplinae group.

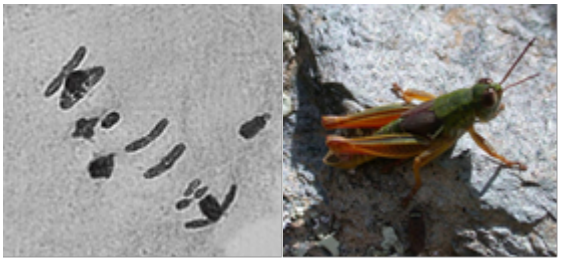

Figure 1. Male metaphase I of *Orotettix carrascoi.*

Key Words: Neotropical Melanoplinae, Chromosome rearrangements, pericentric inversions

ARE OECANTHID CRICKETS CEASING TO SING?

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True crickets are frequently used as models in many areas of science as acoustic communication, behavior, ecology, and neurobiology. However, only a few studies are focused on a phylogenetic context since the number of proposed phylogenies for this group is low. The acoustic communication of these insects is considered an essential element of their evolution. It is a subject constantly debated, but only a few works are in a phylogenetic frame. After all, is crickets' acoustic communication through forewings an evolutionary success or not? Recently, a fifth family of true crickets was proposed with a robust phylogenetic hypothesis, Oecanthidae. This clade is composed of cricket species living in vegetal stratification, from grasses to tall canopies. Moreover, they are morphologically diverse concerning sizes, forewings, genitalia, and ovipositors. The diversity of forewings within this group suggests a huge diversity of types of communication. To understand the evolutionary history of characters related to acoustic communication in the family of tree crickets, Oecanthidae, were used its dated phylogeny, based on molecular and morphological characters. The analyzed characters were forewings (development), their structures (venation composition), and tympana. In total, the history of six characters was analyzed. The results demonstrate that the independent losses of acoustic communication characters over time occurred for multiple oecanthid taxa. Moreover, the losses are correlated, mainly for the forewings characters. Consequently, several of these taxa in different clades of the Oecathidae family are not able to use forewings to stridulate. Thus, showing a tendency of losing acoustic communication through forewings over time in the second most diverse family of true crickets. This is the first time that these evolutionary tendencies are proposed for crickets. Our results also suggest that new investigations on Grylloidea could elucidate whether the sing of true crickets is a successful adaptation (or not) in these famous orthopterans.

Key Words: Tree crickets, Grylloidea, character evolution, forewings

GRASSHOPPERS FROM BRAZIL PROJECT: DIVERSITY, NEW REPORTS, AND CURRENT CHALLENGES

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The Grasshoppers from Brazil project proposes to raise as the first group to specifically study the grasshoppers (Orthoptera: Caelifera) in Brazil, South America's largest and only Portuguese-speaking country of Latin America. This country comprises widespread heterogeneity in climate and environment patterns, which turn into a huge diversity of terrestrial biomes. Hosting one of the highest biodiversity in the world, the Caelifera suborder includes 890 species known. Since the very first species founded and described for Brazilian fauna for our time, historically most of the grasshoppers specialists were researchers that originated from North America and Europe.

The comprehensive research on Orthoptera diversity was developed by Brazilians only from the 1930-40's, with studies of Cândido Firmino de Mello Leitão, Ângelo Moreira da Costa Lima and, mainly Salvador de Toledo Piza Júnior. Recently, many new researchers were formed, and the taxonomy of these insects has been becoming more refined. Although grasshoppers constitute a highly diversified group of insects, the knowledge regarding their geographic distribution (i.e., the so-called Wallacean shortfall) and diversity patterns is poorly known. In addition to these issues, old species descriptions are generally outdated and sometimes oversimplified, and inexistence information about biology, ecology, or natural history. Also, there is a large deficit of sampling in the country, with little representation in scientific collections for a rare specimen, and specimens not properly preserved. Based on these gaps, the objectives of this project are (i) sampling material in the underrepresented areas, focusing on Cerrado (Brazilian Savanna), Caatinga and Amazonia; (ii) collecting of taxa poorly represented in collections such as Tetrigidae, Tridactyloidea and Proscopiidae; (iii) study of materials deposited in museums; (iv) description of new species; (v) description of new occurrences and reports; (vi) including biology and ecology description of the studied species; (vii) gathering material for genetic studies, and (viii) investigate the naturalist and social medias information about grasshoppers. As our firsts results, (i) the description of a new genus of Tetrigidae for the Brazil northern region and (ii) a new species for the state of Minas Gerais; (iii) a new occurrence of a rare species, Legua rosea Amédégnato & Poulain, 1986; (iv) new report of *Ripipterygidae* for the state of Minas Gerais; (v) new report of *Pycnosarcus atavus* (Saussure, 1859); (vi) new report of *Prionacris* specimens in two spots in Minas Gerais. For these *Prionacris* specimens, finding them was unexpected since we weren't supposed to collect them in disturbed Cerrado area. This genus presents dendrophilic habits, since usually rests down on trees high branches, and we notice its presence because they loud singing. Thus, all these specimens are still being processed, and written into manuscripts. Although all these sufficiently good initial results, I should also highlight that in the context of the disastrous reductions in the budget provided by the Brazilian federal government to the universities, museums, and research institutions in the last 4 years, the results of the project were impacted by all these inconveniences. However, the new government is reoccupying investments in STEM, and we can proceed with the project.

Key Words: Brazil, Caelifera, Cerrado

THE GRASSHOPPERS OF THE SUBFAMILY MELANOPLINEA (ORTHOPTERA; ACRIDIDAE) IN MEXICO: DIVERSITY, SYSTEMATICS, BIOGEOGRAPHY AND CURRENT CHALLENGES

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The grasshoppers of the subfamily Melanoplinae represent the most diverse group Acrididae in Mexico, where these insects also have a considerable ecological and economical importance. Yet, so far, our understanding about their diversity, evolutionary relationships and biogeography in Mexico is far to be complete. Aiming to fulfill these gaps, we synthetized the current knowledge of geographic distribution of species in order to identify geographic patterns of diversity of melanoplines in Mexico. In addition, we conducted molecular phylogenetic and biogeographic analyses that involved a wide taxon sampling of genera and species groups of Melanoplinae. Our results, indicate that major mountain ranges of Central and Northeast Mexico harbor the highest species' richness of melanoplines, suggesting that diversification of melanoplines in these regions could be promoted by topographical complexity and the low dispersal capabilities of the studied grasshoppers. However, differences in species richness of Melanoplinae across Mexico can also be explained by a deficit of taxonomic studies on several areas of the country. Moreover, we also detected moderate to high species turnover between mountain ranges and other biogeographic provinces of Mexico, suggesting considerable historical isolation among these areas. On the other hand, our phylogenetic reconstruction indicates that at least five major clades of Melanoplinae are present in Mexico and some of them are geographically restricted to different portions of the country. Moreover, divergence among these major clades and genera occurred mainly between 30 and 10 million years before the present, and some of these cladogenetic events correlate temporally with major biogeographic events in Mexico. In general, our results indicate that biogeographic and evolutionary history of the members of Melanoplinae distributed in Mexico is more complex than previously considered. In addition, several taxonomic changes are proposed, and we encourage further taxonomic and phylogenomic research in this grasshopper of great biological, ecological and economical importance in Mexico and North America.

Key Words: Melanoplinae, Molecular systematics, Biogeography

PROCTOLABINAE AND OMMATOLAMPIDINAE IN MEXICO: RECENT FINDINGS IN THEIR NORTHERNMOST RANGE

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The subfamily Ommatolampidinae (Orthoptera: Acrididae) is distributed throughout the Neotropics from Mexico and the Great Antilles to South America and consists of 115 genera with 294 valid species. The highest diversity of Ommatolapidinae is found in South America, whereas only seven genera with 13 species have been recorded from Mexico: (1) *Abracris* Walker, 1870 with one species: A. flavolineata (De Geer, 1773); (2) *Microtylopteryx* Rehn, 1905 with one species: *M. fusiformis chiapensis* Rehn, 1955; (3) *Omalotettix* Bruner, 1906 with one species: *O. chapadensis* Bruner, 1908; (4) *Reyesacris* Fontana, Buzzetti & Mariño-Pérez, 2011 with one species: *R. amedegnatoae* Fontana, Buzzetti & Mariño-Pérez, 2011; (5) *Rhachicreagra* Rehn, 1905 with four species: *R. chiapensis* Amédégnato, 2000, *R. mexicana* Hebard, 1932, *R. ocotei* Amédégnato, 2000, *R. olmeca* Jago & Rowell, 1981; (6) *Teinophaus* Bruner, 1908 with three species: *T. hodgei* Shane, 1948, *T. matilei* Amédégnato & Poulain, 2000, *T. saussurei* Bruner, 1908; and (7) *Vilerna* Stål, 1873 with one species: *V. pygmaea* (Saussure, 1861). The genus *Reyesacris* was recently established by Fontana, Buzzetti and Mariño-Pérez in 2011 to accommodate a single species, *R. amedegnatoae*. This species was discovered in the cloud forests of the southern portion of the Sierra Madre del Sur, in the State of Oaxaca, a highly diverse region with Neotropic and Nearctic elements. Recently, after a careful examination of 138 specimens from 28 localities from museums and expeditions, four additional species were described. Additionally, the genus *Reyesacris* was placed in the tribe Ommatolampidini and furthermore, assigned to subtribe *Vilernina* based on several external and internal genitalia characteristics.

The subfamily Proctolabinae (Orthoptera: Acrididae) is distributed throughout the Neotropics from Mexico and some islands in the Caribbean (St. Barthelemy Island and Trinidad Island) to South America and consists of 29 genera with 215 valid species. The highest diversity of Proctolabinae is found in Central and South America with 201 species. For Mexico, only four genera with 15 species have been recorded: (1) *Adelotettix* Bruner, 1910 with one species: *A. collaris* (Bruner, 1908); (2) *Leioscapheus* Bruner, 1908 with two species: *L. mexicanus* Descamps, 1976, *L. variegatus* Bruner, 1908; (3) Tela Hebard, 1932 with four species: *T. annulicornis* (Bruner, 1908), *T. bolivari* Descamps, 1976, *T. chlorosoma* Hebard, 1932, *T. viridula* (Bruner, 1908); and (4) *Proctolabus* Saussure, 1859 with eight species: *P. brachypterus* Bruner, 1908, *P. cerciatus* Hebard, 1925, *P. chiapensis* Descamps, 1976, *P. diferens* Márquez-Mayaudón, 1963, *P. edentatus* Descamps, 1976, *P. gracilis* Bruner, 1908, P. mexicanus (Saussure, 1859), *P. oaxacae* Descamps, 1976. Recently, after a diligent examination of hundreds of specimens from UMMZ, ANSP and CAS, at least eight new species of *Proctolabus* are being described. The cerci form and internal genitalia are the main characteristics to separate species in this genus. Even though Mexico is the northernmost range for these two subfamilies and the species and genera richness is not as diverse as in Central and South America, these recent findings have increased in 30 and 50% the diversity of Ommatolampidinae and Proctolabinae respectively.

Key Words: *Proctolabus*, *Reyesacris*, northernmost range

SYMPOSIA 5

NEW VISION ON LOCUST AND GRASSHOPPER MANAGEMENT

Organizer
Long Zhang, David Hunter & Mario Poot-Pech

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1. **Alexandre V. Latchininsky**. LOCUST AND GRASSHOPPER MANAGEMENT IN THE 21ST CENTURY: CHALLENGES AND WAY FORWARD.
2. **Galindo Mendoza María Guadalupe.** FIELD RADIOMETRY FOR LOCUST SURVEILLANCE AND PROTECTION.
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7. **Mario Poot-Pech, Esaú Ruiz-Sánchez, Maria de Jesús García-Ramírez.** KAIROMONES AND THEIR POTENTIAL USE FOR THE CENTRAL AMERICAN LOCUST MANAGEMENT.
8. **Mohamed Abdallahi Ould Babah Ebbe, Mohamed El Hacen Jaavar, Marie Françoise COUREL, François Querci and Koutaro Ould Maeno.** THE USE OF LOCUST AND GRASSHOPPER FOR FOOD AND FODDER AS AN OPTION OF LOCUST MANAGEMENT CONTROL STRATEGY.

LOCUST AND GRASSHOPPER MANAGEMENT IN THE 21ST CENTURY: CHALLENGES AND WAY FORWARD

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During past 25 years, the world experienced the increased frequency and severity of locust and grasshopper outbreaks, which jeopardize food security of entire regions. Some examples are: Italian Locust (*Calliptamus italicus*) in Kazakhstan in 2000 (8.1 M ha treated), grasshoppers in Wyoming, USA in 2010 (2.4 M ha protected), Moroccan Locust (*Dociostaurus maroccanus*) in Southern Russia in 2011 (the first invasion in 80 years) and in 2020 in Sardinia, Italy (the first invasion in 70 years), South American Locust (*Schistocerca cancellata*) in 2016 in Argentina (the first invasion in about 60 years), Desert Locust (*Schistocerca gregaria*) in Kenya in 2019-2021 (the first invasion in 70 years) and others. Locust management faces numerous challenges in the 21st century, such as, but not limited to: (1) insufficient scientific knowledge of factors governing population dynamics of certain locust species, particularly in the changing climate context; (2) inefficient survey and forecasting methodology; (3) outdated control "toolbox" with high risks to human health and the environment; and (4) inadequate cooperation between neighboring states sharing same locust problem.

Some of these challenges, for example, (2), can be addressed using technological advances introduced in locust and grasshopper management worldwide. Above all, geospatial technologies, satellite imagery and Geographic Information Systems revolutionized acridid monitoring, information management and forecasting while drones became increasingly available primarily for survey operations. Increased role and functionality of regional organizations such as Desert Locust regional commissions (CLCPRO, CRC and SWAC) acting under the aegis of FAO or Central American OIRSA focusing on Central American Locust are instrumental in addressing challenge (4). However, even if we know when and where we need to control locusts or grasshoppers, probably the biggest challenge (number 3) is how we do it. The contemporary arsenal of acridicides consists of broad-spectrum insecticides such as organophosphates, pyrethroids, phenyl-pyrazoles and neo-nicotinoids. Most of these products are old-chemistry ones, found harmful for human health and the environment, particularly for non-target arthropods such as honeybees, other pollinators and pest natural enemies. It is evident that many of the insecticides currently used to control locusts and grasshoppers are under the increasing pressure from human health and environment protection agencies, and this tendency will intensify in the future.

The only way to address this challenge is to change the paradigm of locust and grasshopper control from reaction to prevention. Under the preventive strategy, it is imperative to introduce and widely use biopesticides, as the least harmful for human health and the environment means of locust and grasshopper management. Biopesticides, for example, those based on entomopathogenic fungi, should become key tools in sustainable locust and grasshopper management. Their introduction into practice will require tremendous educational efforts at all levels, from locust and grasshopper control agencies to national and international decision makers and donors.

Key Words: Locust and Grasshopper management, survey, preventive strategy, biopesticides.

FIELD RADIOMETRY FOR LOCUST SURVEILLANCE AND PROTECTION

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Preventative locust management requires early warning and rapid response capacities in locust-afflicted regions. This involves the monitoring of environmental conditions and the level of locust populations, as well as the implementation of control against the first gregarious populations. A successful preventative strategy relies upon knowing where and when locust populations occur. However, predicting the potential areas of locust outbreaks have been challenging due to the vast areas that locusts occupy. Therefore, a more accurate characterization of locust biotopes is required, and, in this study, we have shown that the combination of field spectroradiometry with satellite imagery can be an effective tool for delimiting outbreak risk areas for the Central American locust. The use of NDVI alone is not very effective for characterizing locust risk areas because of its low spatial resolution of 1 km. The use of EVI with a spatial resolution of 250m is a bit more effective due to its finer resolution. However, the process of generating risk maps requires more precision, which will allow concentrated efforts on specific areas for locust prospecting, thereby reducing the physical area to survey considerably as well as the costs for survey. The complementary use of field spectroradiometry considerably reduces the degree of error in the analyses, since this method allows to seek specific spectral similarities, which is analogous to the concept of fingerprinting. According to NOAA, since April 2020 the world, and particularly Mexico, has been affected by the "LA NIÑA" phenomenon, which provides ideal conditions for the formation of Central American lobster sleeves. This situation forced us to issue the alert and the radiometric risk map on December 17, 2020 of epidemiological regions 6 and 9 that include Hasteca Potosina and Tamaulipeca and up to Nuevo León. For February 1, 2022, the outbreak of the Central American locust was reported in the La Cáscara community, in the municipality of Montemorelos, Nuevo León. There was an accuracy of 89% coinciding with me-thane emissions from both forest and agricultural burned areas (figure 1).

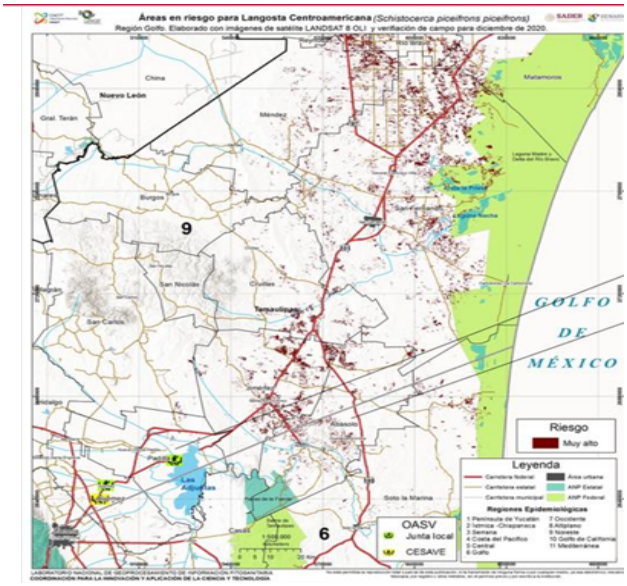

Figure 1. Figure 1. Radiometric map in epidemiological regions 6 and 9, 2020

The need to delimit smaller areas where surveillance activities can be concentrated, the field radiometry can solve this problem since it can be used to distinguish specific areas with spectral signatures similar to the known locust outbreak areas.

Key Words: espectroradiometry, locust, surveillance, remote sensing ICO2023, Merida, Grasshopper

SPATIOTEMPORAL RISK FORECASTING FOR LOCUST MANAGEMENT USING MACHINE LEARNING

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The desert locust is the most dreadful pest in the Indo-Sahelian region, with the ability to change its behavior, morphology, and development based on population density. At the gregarious phase, this pest can form swarms that cover hundreds of square kilometers, causing significant damage to crops and posing a threat to food security across multiple countries. To manage this pest, preventive measures are taken to assess the risk of an upsurge in population abundance and take early action. In this talk, I will present the existing approaches currently implemented to forecast these risks, including our new approach using multi-model ensemble forecasts in 10 countries in West and North Africa. We trained models using 10 years of satellite data and ground survey observations that were aggregated every ten days on a spatial grid of 1km resolution. The best-performing machine learning algorithms were found to be random forests that included effects of spatial autocorrelation in locust observations and effects of environmental variables such as vegetation index NDVI and soil moisture measured at various time lags. These findings corroborate previous research indicating that the presence of locusts is linked to arid habitats that can quickly vegetate after precipitation, in sandy sites suitable for egg laying and with sufficient soil moisture. By using new satellite data on climatic and habitat conditions with machine learning, we can regularly provide and update occurrence maps and predict the aggregation of individuals in the gregarious phase. This iterative process may significantly improve the desert locust early warning system, help orientating the teams in the field, especially when multiple models are evaluated. However, these models are long to train, sometimes overfitted and difficult to interpret. To enhance decision-support systems in locust control, we recommend that future research integrate more mechanistic models to the current forecasting approach, focusing on the ecology and population dynamics of the desert locust.

Model	AUC	Sensitivity	rmse
Pres/Abs	0.77	0.69	0.17
Sol/Greg	0.75	0.72	0.12

Table 1. Evaluation of the best models to forecast presence/absence and solitarious/gregarious given presence trained on 8 years data in 10 countries (FAO locust hub)

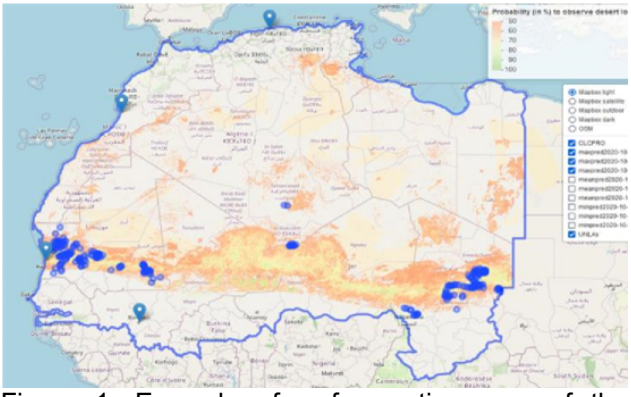

Figure 1. Example of a forecasting map of the maximum probability of desert locust occurrence in October 2020. The color gradient from orange to green stands for a 50% to 100 % chance of observing the species. Blue points represent the observed location at this date.

Key Words: *Schistocerca gregaria*, preventive management, machine learning, remote sensing

IMPROVED FORECASTING FOR RAPID RESPONSE PREVENTIVE LOCUST MANAGEMENT

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Preventive management is being increasingly recognized as the most effective and environmentally sound strategy for locust control. Such a strategy relies on beginning treatments early in outbreaks and continuing treatments every generation thereafter. The gregariousness of locusts means they are often found in a small proportion of the area and intervention early in outbreaks and upsurges strongly relies on forecasting where and when outbreaks are likely to be. Forecasts rely on having a reasonably good understanding of the factors that lead to outbreaks and recent work using detailed multifactor and spatiotemporal analyses and machine learning have been used in recent years to estimate risk factors for locust population increase. Weather factors are often a key driver of locust outbreaks, some species are favored by wetter than normal conditions while others are favored by drier and forecasting is becoming increasingly reliant on estimates of vegetation condition using short- and medium-term rainfall/temperature forecasts, satellite imagery and soil moisture data. Such estimates of current and near future vegetation condition along with locust survey data are incorporated into a Geographic Information System, where models provide forecasts can be made of increased likelihood of locust outbreaks, increased gregarization, and where and when dense infestations needing control are likely to be found so that survey and control efforts can be concentrated effectively as part of a rapid response.

For locusts that require regular treatment programs, forecasts of the likely size and locations of infestations can give notice of whether greater or fewer resources are likely to be needed in certain areas so that resources can be concentrated where they are needed most.
For locusts that have outbreaks from time to time, the forecast of increased risk of outbreaks or upsurges allows those responsible for locust survey and local control during recessions to prepare for a likely treatment program, including organizing for the increased resources required, whether from local national or international organizations

As pointed out by Piou & Marescot (2023: Current Opinion in Insect Science 56:10102), the forecast of risk implies a degree of uncertainty, so that while forecasts can estimate the likely level of threat, funding and control entities organizing increased resources need to understand that the threat might occur at levels lower than forecast so that some or all of funds provided might not be used. Mechanisms that allow unused part of funds to be kept as a reserve have proven valuable where they have been implemented: studies have shown that the return on locust treatment programs range from 10-20 times that of the costs of the program an excellent return on investing in a rapid response risk management strategy for locust control.

Key Words: locusts, rapid response, preventive management. Forecasting

A NEW MICROBIAL CONTROL AGENT FOR ADULTS OF GRASSHOPPERS AND LOCUSTS

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MICROBIAL control is currently used for effective suppression of early (nymphal) stages of the locusts, but frequently less effective against the adults. It is necessary to develop high effective biocontrol agent for adult locusts.

We had isolated a new locust pathogen from a dead locust collected from Xinjiang Uyghur autonomous region, China and then identified it as a fungus *Aspergillus oryzae* (*a.k.a. locust Aspergillus*, Laory). Bioassay in the lab showed that it had high virulence against both nymphs and adults of *Locusta migratoria* (about 90%). We want to know if it also had good efficacy under field exposure conditions. Field-cage experiment showed that the mortalities of adult *L. migratoria* were 98.10%±1.91% and 97.18%±1.44%, respectively at day 20 after inoculation with 3×105 and 3×103 spores/m2 of Laory. A large-scale experiment (≈ 800 ha) was conducted to test the efficacy of Laory against locusts in Kenli County, Shandong Province, China during 20th of June to 23th of July, 2022. The mixed populations of locusts were mainly adults of *L. migratoria* and *Epacromius* spp. in the test field. Laory spores were prepared as the water suspension at the concentration of 2×108 spores/ml and were sprayed in 15L/ha by a DRONE. Locust densities were significantly reduced by 85.35%±7.94%-94.87%±5.13% (Figure 1). In addition, the infection rates of survival locusts collected from the plots of Laory treatment were 79.55% and 78.26% on the 17th and 31st days after treatment respectively.
These results indicate that Laory has a high virulence against adult locusts and has the potential for locust adults control.

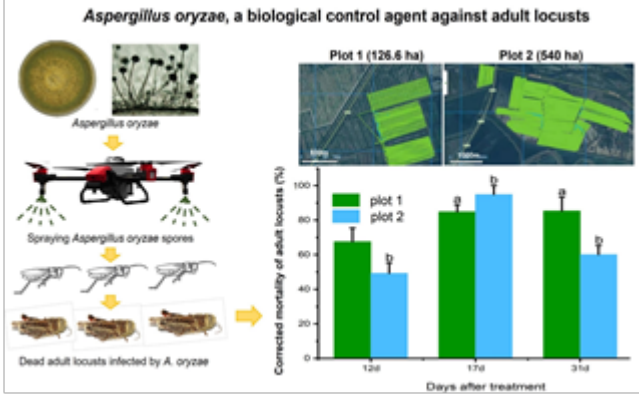

Figure 1. The results of application of A. oryzae spores against locust adults in large scale.

Key Words: Biological control, adult locust, *Aspergillus oryae*, mortality, field trials, reduction of density

CYCLOPEPTIDES PRODUCE BY FUNGI AS BIORATIONAL AGENTS FOR LOCUST MANAGEMENT: DESCRIPTION OF THEIR MODE OF ACTION AND INSECTICIDE POTENTIAL

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Fungi produce a wide range of biologically active secondary metabolites, including a variety of cyclopeptides that have enormous potential for the development of next generation insecticides. Cyclopeptides are produced by various entomopathogenic fungi as part of the pathogenesis process. Studies on the biochemical and physiological effects on cyclopeptides have been carried out with the cyclopeptides destruxins, which actions include suppression of the immune response, disruption of the epithelial cell membrane, induction of oxidative stress, inhibition of the hydrolytic activity of V-type ATPase of the excretory system and induction of membrane depolarization in skeletal muscle.

Destruxins (destruxin A–E) are cyclic hexadepsipeptides that have insecticidal effects on various insect species from the Lepidoptera and Hemiptera groups, mainly, but the orthoptera group has been also found to be susceptible to these compounds.

Destruxins were first found to be involved in the pathogenesis by the entomopathogenic fungi *Metarhizium anisopliae*. These studies were carried out in the 80´s and were led by A. K. Charnley and S. E. Reynolds from the University of Bath. In the following three decades after those studies, destruxins were evaluated and found to be lethal to various insect models. Insect bioassays pointed out that destruxins could suppress the immune responses in insects and thereby assisting entomopathogenic fungi lethal effects.

In 2010 other studies led by I. Orchard and A. Lange from the University of Toronto and E. Ruiz-Sanchez for Tecnologico Nacional de Mexico found evidence that destruxins target key insect physiological processes. In insect epithelial tissues, such as renal excretory tubules, destruxin A changed the properties of the transepithelial potential suggesting that one of the target sites might be associated with inhibition of the apical V-type H(+) ATPase of tubule cells. Particularly, in locust, the effects of destruxin A were evaluated on oviducts and hindgut of *Locusta migratoria*. Findings pointed out that Destruxin A induced tonic contraction in oviducts and increased the frequency of spontaneous contractions in hindgut and oviducts. The effect of destruxin A was dependent on extracellular, but not on mobilizing intracellular calcium, suggesting that destruxin A may be acting by moving extracellular calcium into the cells via voltage-gated calcium channels.

As for the insecticide effects on insects, destruxins are highly lethal, but some considerations may be taken into account to develop these compounds as source or leading molecules for new generation insecticides. For example, more toxicological studies and evaluation of field efficacy are also important to asses. Biotechnological work is also required, particularly on aspects related to how to enhance the cyclopeptide yield in fungal culture, improving the formulations and effective methods of application.

Key Words: cyclopeptides, fungal metabolites, biorational insecticide

KAIROMONES AND THEIR POTENTIAL USE FOR THE CENTRAL AMERICAN LOCUST MANAGEMENT

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The Central American locust (CAL) *Schistocerca piceifrons piceifrons* is one of the most harmful plant pests in the Yucatan Peninsula, where an important gregarious zone is located.
The main control agent of CAL has been through the use of chemical insecticides, therefore is necessary to find ecological alternatives.
The olfactory response of the CAL to odor of various plant species was evaluated using an olfactometer test system. In addition, the host plant acceptance was assessed by the consumption of leaf area.
Results showed that the CAL was highly attracted to odor of *Pisonia aculeata*. Evaluation of host plant acceptance showed that the CAL fed on *Leucaena glauca* and *Waltheria americana*, but not on *P. aculeata* or *Guazuma ulmifolia.* Analysis of leaf thickness, and leaf content of nitrogen (N) and carbon (C) showed that the CAL was attracted to plant species with low leaf C content (Poot-Pech et al. 2016. Olfactory response and host plant feeding of the central American locust *Schistocerca piceifrons* Walker to common plants in a gregarious zone. Netropical Entomology. 45: 382-8)
The response of the CAL might have been initially guided by leaf volatiles, where safe sources of food with no toxic compounds could be found. At first glance, plants that attracted the CAL were expected to be highly accepted as source of food. However, feeding test did not fully support this inference, as *Pisonia aculeata* that highly attracted the CAL was not significantly consumed. In addition, only two sources of odor (*L. glauca* and *W. americana*) out of three that somewhat attracted the CAL were significantly consumed. These results suggest that the interaction between the CAL and potential host plants is affected by two distinct elements, one related to olfactory response and another related to food acceptance. In the first case, plant volatiles may play an important role, whereas in the second case, leaf traits, like physical characteristics and the presence of antinutritional compounds, may be determinant.
Because the locusts were fed with small maize plants this plant was not considered in the results, however it also produced a significant attraction.
These results suggest the possible use in the field as a preventive measure to attract CAL to sites for monitoring or subsequent control purposes. In other words, the possible use of plants patches in the field that had a high attraction, especially in periods of recession.
In the field we have observed similar results as those of the olfactometer: high attraction to the *P. aculeta* bush with minimal defoliation, high attraction and consumption of *Zea mays* and L. *glauca* low attraction and high consumption.
Additionally, in the field the field locust officers in Yucatan the surveys are directed to areas where these plants with great attraction of locusts are found.

Key Words: Prevention, ecological management, feeding, attraction.

THE USE OF LOCUST AND GRASSHOPPER FOR FOOD AND FODDER AS AN OPTION OF LOCUST MANAGEMENT CONTROL STRATEGY

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Desert locusts have cause serious problems for agriculture and livelihoods of human in many countries when they outbreak since more than 3000 years. Chemical control by using pesticides is one of the most practical methods, but controlled locusts have not been used industrially for resource as human food and fodder despite its very high nutritional value (protein (48.2g/100g), fat (38g/100g), carbohydrates (1.1g/100g) and an energy value of 559 kcal/100g) (Insect Food, 2014) and its edibility allowed in the 3 Holy book (Thora, Bible, Coran) in addition to the fact that EU has legislated its use for food. Locusts also have been consumed in 65 countries for millennia but only traditionally. To use locusts as a natural resource, effective locust collection techniques have been required. Understanding of their spatio-temporal distribution patterns, i.e., when and where they aggregate can help to collect locusts in large numbers. We have conducted a long-time field survey in the natural habitats and found that gregarized locusts of nymphs and adults tend to spatio-temporally aggregate at a certain time and location. Both nymphs and adults roost on relatively large plants in a dense group before sunset and stay there next morning. Sexually matured adults form either male- or female-biased groups. Gravid females visit male-biased group and mating occur. Pairs started to lay eggs after sunset in a dense group. From the perspective of pest control and locust collection, it is more efficient to wait for the timing of egg-laying at night, instead of immediately controlling the male locust population when it is found during the day. The application of the desert locust ecology is expected to lead to natural and environment-friendly pest control that does not require the use of pesticides more than necessary. Therefore, depending on the developmental stage and topography, it is more efficient to harvest locusts at night.

However, adapted healthy locust collecting and processing materials still needs to be developed in order to use it safely for combatting food security for human and animals in affected countries.

Figure 1. Group oviposition of desert locusts

Key Words: desert locust, control, edible insects

SYMPOSIA 6

RECENT ADVANCES IN LOCUST PHASE POLYPHENISM RESEARCH

Organizer
Hojun Song & Bert Foquet

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1. **Bert Foquet, Drew Little, Jorge Medina Durán, Adrian Castellanos, Alyssa Canova, Hojun Song.** A COMPARATIVE APPROACH OF PHENOTYPIC PLASTICITY IN A LOCUST AND CLOSELY RELATED NON-SWARMING SPECIES.
2. **Darron A. Cullen, Gregory A. Sword, Stephen J. Simpson, Jozef Vanden Broeck.** ANTI-HARASSMENT SIGNALING IN LOCUSTS.
3. **Marescot L., Toure M., Cease A., Diouf E.1, Piou C.** COMBINING POPULATION DYNAMICS AND NUTRITIONAL ECOLOGY IN AN AGENT-BASED MODEL TO EXAMINE THE EMERGENCE OF *Oedaleus senegalensis* GREGARIOUS BEHAVIOR IN DIFFERENT LANDSCAPES.
4. **Spencer T. Behmer, Christopher Brennan, Hojun Song, Greg A. Sword, and Heiko Vogel.** DIET MIXING IN LOCUSTS: PHYSIOLOGICAL AND MOLECULAR INSIGHTS.
5. **Gregory A. Sword, Sercan Sayin, Inga Petelski, Einat Couzin-Fuchs, Iain D. Couzin.** LOCUST DENSITY-DEPENDENT COLOR CHANGE AS AN INTRASPECIFIC VISUAL SIGNAL REVISITED.
6. **Jozef Vanden Broeck.** MOLECULAR PHYSIOLOGICAL ASPECTS OF PHASE POLYPHENISM IN THE DESERT LOCUST, *Schistocerca gregaria.*

A COMPARATIVE APPROACH OF PHENOTYPIC PLASTICITY IN A LOCUST AND CLOSELY RELATED NON-SWARMING SPECIES.

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Locusts are grasshoppers (Acrididae) that form large migratory swarms or marching bands, and show an extreme form of density- dependent phenotypic plasticity. They can be found in one of two alternative phenotypes, named the solitarious and the gregarious phase and which can be found under low and high population densities, respectively. These two phases differ strongly in their behavior, morphology, nymphal coloration, physiology, reproduction, and a variety of other traits. The genus *Schistocerca* contains three swarming locust species and more than 40 non-swarming sedentary species, and its phylogeny is now well understood. The three locusts in the genus do not form a monophyletic clade, but are instead more closely related to non-swarming grasshoppers. In this study, we aimed to better understand the evolution of phenotypic plasticity in this genus. We first characterized the extent of density-dependent phase polyphenism in the Central-American locust, *S. piceifrons*, and three closely related non-swarming grasshoppers: S. americana, *S. serialis cubense*, and *S. nitens*. Subsequently, we performed a backcrossing experiment between S. piceifrons and S. serialis cubense and characterized the extent of density-dependent phase polyphenism in back-crossed hybrids. We expected that (1) these four species form a spectrum in the degree of density-dependent phenotypic plasticity, and (2) that the various traits influenced by population density are not genetically linked to one another, and thus show distinct patterns in backcrossed hybrids. We reared all four species and backcrossed hybrids under isolated and crowded conditions. Subsequently, we quantified behavior, nymphal coloration, size, and gene expression for all four species, while only the first three traits were quantified for backcrossed hybrids. Behavior was quantified for at least 50 isolated-reared and 50 crowd-reared individuals in an assay system designed by Roessingh et al. (1993), and data were analysed in Ethovision. After each assay, pictures were taken of the head, thorax and hind leg. The extent of black patterning was analysed with the R-package Patternize, and head width, pronotum length, and hind femur length were measured in ImageJ. RNA was extracted from head and thorax of five isolated-reared and five crowd-reared females for each species. RNA were sequenced on an Illumina HiSeq 4000, after which transcriptomes were assembled using Trinity and annotated using BLAST2GO. Differential gene expression was analysed with edgeR, DEseq2, and WGCNA. Our data shows that there is indeed a spectrum of density-dependent phase polyphenism in this clade for all four tested traits: behavior, nymphal coloration, size, and gene expression. *S. piceifrons* is the most plastic species, while *S. americana*, *S. serialis cubense*, and *S. nitens* are gradually less plastic. Additionally, the behavior, nymphal coloration and size show distinct patterns in backcrossed hybrids, without phenotypic correlations between these traits. This suggests that they evolved independently.

Key Words: Central American locust, phenotypic plasticity, evolution, behavior

ANTI-HARASSMENT SIGNALING IN LOCUSTS.

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Gregarious locusts, like many group-living animals, are often said to "take safety in numbers", but what are the costs associated with such a high-density lifestyle? I recently discovered an important function for yellow colouration in the Desert Locust, *Schistocerca gregaria*, which is much brighter in gregarious males than in females. I used RNA interference (RNAi) 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 (Cullen et al., 2022). Yellow colouration therefore appears to act as a male-male anti-harassment signal, preventing mistaken sexual identity at high densities. 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.

The evolution of an anti-harassment signal highlights the persistent threat of mistaken - and potentially costly sexual attention within a swarm. What other mechanisms have evolved to a similar end? And what else might the yellow colour be signalling? I will outline some of my recent work, and plans for my new lab at the University of Hull.

COMBINING POPULATION DYNAMICS AND NUTRITIONAL ECOLOGY IN AN AGENT-BASED MODEL TO EXAMINE THE EMERGENCE OF OEDALEUS SENEGALENSIS GREGARIOUS BEHAVIOR IN DIFFERENT LANDSCAPES

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The Senegalese grasshopper, *Oedaleus senegalensis*, is a prominent pest in the Indo-Sahelian area, posing a threat to agricultural regions. It can swarm and migrate long distances, causing serious crop damage and food security problems throughout the Sahel region. Contrary to the protein-limitation paradigm which stipulates that low N concentration in plants impairs herbivores fitness, recent experimental studies have shown that the Senegalese grasshopper can maximize its performance by selecting foods with high carbohydrate content relative to protein. However, the extent to which the nutritional ecology of individuals may influence the emergence of gregarious behaviors and shape population dynamics at a landscape scale remains unknown. To address this knowledge gap, we developed an agent-based model that describes the life-cycle and the nutritional ecology of this migratory pest in two fictive landscapes: one with a stratified structure and the other presented as a heterogeneous mosaic. In a ten-year simulation study, we examined population composition (solitarious vs. gregarious), feeding behaviors ("gluttony" vs. "picky"), and foraging movement patterns across stratified and mosaic landscapes. We observed a significantly higher abundance of gregarious individuals in the stratified landscape. Gregarious individuals displayed a preference for gluttony behavior and had more frequent transitions towards high carbohydrate-rich food compared to solitarious individuals. This led to their convergence towards a higher carbohydrate-to-protein intake target, surpassing the average composition observed in the overall population within the stratified landscape. Our findings demonstrate that in landscapes featuring extensive areas of high carbohydrate content food sources, such as cereal monocultures, there is a favorable environment for increased local population density, the transition to gregarious behavior, and a shift in feeding behavior towards excessive consumption. This behavior, when magnified at larger scales, can lead to a significant escalation in crop damage. We believe that such model can further provide evidence-based management strategies to support farmers in making informed decisions regarding soil amendment and crop rotation. These strategies can help maintaining the pest population below a density threshold that minimizes crop damage.

DIET MIXING IN LOCUSTS: PHYSIOLOGICAL AND MOLECULAR INSIGHTS

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Generalist insect herbivores face complex challenges when feeding. Aside from encountering variation in nutrient content, both within and between plants, herbivorous insects regularly encounter nonnutritive plant compounds. Furthermore, different plants can contain different types of plant allelochemicals.

The challenge, therefore, is to balance the need to match nutritional requirements against limiting the intake of potentially harmful toxins. Work by Bernays and her colleagues in the early 90s demonstrated that generalist herbivores often benefited from eating a mixed diet, although mechanistic reasons for this enhanced growth could only be speculated. In this study, we reared early instar nymphs of the desert locust (*Schistocerca gregaria*) on two native host plants – *Schouwia purpurea* (*Brassicaceae*, containing high levels of glucosinolates) and *Hyoscyamus muticus* (*Solanaceae*, containing high levels of tropane alkaloids). Performance, measured in terms of survival and days to molting, was best for nymphs on the mixed plant treatment, relative to the single plant treatments. We then used a sequencing approach to reveal novel insights into the benefits and costs, at the molecular level, of diet mixing. The transcriptional responses of *S. gregaria* on the different treatments show markedly unique gene expression patterns. We highlight some of the key differences and discuss the power of using molecular approaches to better understand the functional benefits of diet mixing in generalist insect herbivores.

Key Words: locust, nutrition, physiology

LOCUST DENSITY-DEPENDENT COLOR CHANGE AS AN INTRASPECIFIC VISUAL SIGNAL REVISITED

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Locusts express a remarkable form of density dependent phenotypic plasticity known as phase polyphenism. Although locust species can express density-dependent changes in many traits, behavior and color are some of the most dramatic and widely studied, particularly in the infamous desert locust, *Schistocerca gregaria*. In desert locust juveniles, density-dependent color change has been shown to function as part of an anti-predator strategy with the high-density gregarious phase phenotype acting as an interspecific aposematic visual signal to predators indicating toxicity. In adult males, color change has also been shown to result in aposematism, but in this case as an intraspecific warning signal to avoid sexual conflict with other males. An alternative intraspecific hypothesis for juvenile density-dependent color change is that the resulting phenotypes may function as visual signals that affect either the initial gregarization process, or subsequent interactions among gregarious phase individuals involved in collective movement.

We reevaluated the role of density-dependent color change in juveniles as a visual signal involved in collective movement using field data collected in Kenya in conjunction with a novel locust virtual reality (VR) system in the lab. The VR system enabled quantification of movement behavior of focal individuals in response to simulated marching locusts with systematically varied phenotypes and densities. We found that visual stimuli in the absence of tactile and olfactory cues can produce the hallmarks of marching behavior. Focal locusts exhibited stronger alignment in the presence of high-ordered marching bands, with alignment being robustly correlated with visual coherence even at low group densities. In the absence characteristic gregarious phase color patterns, focal locusts demonstrated comparable alignment to virtual conspecifics generated with uniform colors. However, focal gregarious phase locusts strikingly failed to align and march within virtual marching bands comprised only of solitarious phase locusts. Conspecific movement information, in the absence of the appropriate color signal, was insufficient to induce collective behavior. Thus, an interspecific anti-predatory signal for juvenile locusts is also being utilized for intraspecific information flow, fostering collective marching. These findings elucidate the multi-faceted roles of density-dependent color changes and provide a comprehensive insight into the complex interactions underpinning locust swarm formation and movement behavior.

Key Words: locust, behavior, evolution

MOLECULAR PHYSIOLOGICAL ASPECTS OF PHASE POLYPHENISM IN THE DESERT LOCUST, *Schistocerca gregaria*

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Locusts are swarm-forming orthopteran species belonging to the family of Acrididae ('short-horned grasshoppers'), in which different locust species are distributed over distinct subfamilies. They exhibit an extreme type of phenotypic plasticity, generally known as locust phase polyphenism. Depending on their population density, locusts can develop into two very distinct phenotypes or 'phases', the solitary and the gregarious phase, which show prominent differences in their behavior, coloration, morphology, physiology, and reproduction (Uvarov, 1921; Pener & Yerushalmi, 1998; Verlinden et al., 2009; Tawfik, 2012; Cullen et al., 2017). Although the ability of one locust phase to undergo a transition to the other phase is already known for more than one century (Uvarov, 1921), the exact physiological mechanisms by which this is achieved remain poorly understood. Nevertheless, fragmentary knowledge, as pieces of a very complex puzzle, has been accumulating over many decades of research, which mainly focused on a limited number of species, i.e., the migratory locust, *Locusta migratoria* (subfamily *Oedipodinae*), the Australian plague *locust, Chortoicetes terminifera* (subfamily *Oedipodinae*), and the desert locust, *Schistocerca gregaria* (subfamily *Cyrtacanthacridinae*). Considering the many aspects, which are associated with locust phase polyphenism and situated at different levels of biological organization, the integration of ecological, (epi) genetic, neurobiological, endocrinological, developmental (including the Eco-Evo-Devo links), physiological, and biochemical information may become a gigantic task.

In this presentation I will primarily focus on the desert locust, *S. gregaria*, a classic hemimetabolan/orthopteran research organism, which is feared for its highly mobile, devastating swarms and therefore considered being the most dangerous migratory pest worldwide (http://www.fao.org/locusts). The availability of a sequenced *S. gregaria* genome (Verlinden et al., 2020) ensures that data resulting from 'omics' approaches can now be interpreted with more precision and, since the desert locust possesses a highly robust RNAi response upon injected dsRNA (Santos et al., 2014), these can be combined with functional analyses. I will present a brief overview of current knowledge and zoom in on recent studies from my lab, including the elucidation of a century-old enigma (Cullen et al., 2022).

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Key Words: behavior, enzyme, genome, hormone, omics, receptor, RNA interference

SYMPOSIA 7

Management and implementation of regional and national programs for locust management

Organizer
David Hunter, Hector Medina and Mario Poot-Pech

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1. **Carlos Urías, Xavier Euceda, Mario Poot-Pech.** LOCUST-GRASSHOPPER MANAGEMENT IN CENTRAL AMERICA.
2. **Hector E. Medina.** MANAGEMENT OF LOCUSTS AND GRASSHOPPERS IN SOUTH AMERICA.
3. **Kathleen King.** MANAGEMENT OF LOCUSTS AND GRASSHOPPERS IN NORTH AMERICA WITH EMPHASIS ON THE UNITED STATES.
4. **Hamouny Mohamed Lemine; Khaled Moumene and Shoki AlDobai.** DESERT LOCUST MANAGEMENT IN THE WESTERN REGION.
5. **Khaled Moumene, Mohamed Lemine Hamouny, Hichem Dridi.** MANAGEMENT OF LOCUST CRISIS IN THE WESTERN REGION- 2020 THREAT CASE.
6. **Mamoon AlSarai Alalawi.** DESERT LOCUST CONTROL IN THE CENTRAL REGION – LESSONS AND EXPERIENCES.
7. **David Hunter.** LOCUST MANAGEMENT IN AUSTRALIA.
8. **Shoki Al-Dobai.** LESSONS LEARNED FROM THE MANAGEMENT OF THE DESERT LOCUST EMERGENCY RESPONSE TO THE 2019-2021.
9. **David Hunter**. INTERNATIONAL BEST PRACTICE IN LOCUST MANAGEMENT.\
10. **Shoki Al-Dobai**. FUNCTIONING AND ACTIONS OF THE FAO LOCUST GLOBAL PROGRAMME.
11. **Hector E. Medina.** OBJECTIVES OF THE INTER-AMERICAN GROUP ON ORTHOPTERAN PESTS
12. **Arianne Cease, Rick Overson, Mira Ries.** IMPORTANCE OF COOPERATION BETWEEN DIFFERENT REGIONS OF THE WORLD FOR LOCUST RESEARCH AND MANAGEMENT

LOCUST-GRASSHOPPER MANAGEMENT IN CENTRAL AMERICA

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OIRSA was created in 1953, this year celebrates the 70th anniversary of its foundation. Its origin was due to locust migration and damage on crops in Central America and Mexico.

Nowadays the Central American locust *Schistocerca piceifrons piceifrons* is monitored by the Ministries and Secretaries of Agriculture before a possible population increase.

OIRSA provides technical strengthening, consultancy, financial support and the development of an early warning and reaction system for a locust outbreak. In recent years there have also been outbreaks of the Giant Grasshopper *Tropidacris cristata dux*, which has produced damage on crops as palms, forest trees, mangoes among others.

The capacity strengthening is very important, OIRSA constantly develop workshops on Locust Management in a member country. In times of covid, an online course was held: Locust Management, towards a preventive approach; which 19 Latin American countries participated. This course was important in the decision making of the great outbreak of 2020-2021.

In order to have a consultation or reference document, the Locust Management Action Plan was prepared in 2020, this has the harmonized criteria for the region.

For the monitoring of the large extension susceptible to locust attack, remote surveillance has been developed, climatic variables such as temperature and precipitation are considered mainly, agricultural burning and field information (state, color, density, etc.) to have the reference of the situation in the field and a short-term forecast.

OIRSA considers biological control as a fundamental tool in the management of this acrid, which it has encouraged its development and use; the advantage of remaining in the environment, self-regulating populations and not harming other animals or contaminating the environment, provides a great viable alternative.

The regional coordination is important because the locust is a migratory pest and the risk of damage to crops is high.

The challenge is the ecological management of the Giant Grasshopper, because the breeding zone are forest areas, sometimes ecological reserves, it is a plan the use fungi *Metarhizium acridium* in the future.

Conclusions. The national and regional coordination is very important in the grasshopper-locust management, they are transboundary pests and it is necessary the interchange of information to improve the warning and reaction early. The biological control as a preventive agent of self-regulation is a key in the locust reduction in log term.

Key Words: Regional Management, Early Warming, Early Reaction

MANAGEMENT OF LOCUSTS AND GRASSHOPPERS IN SOUTH AMERICA

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The South American region is home to various species of locusts and grasshoppers that hold significant economic and social importance. Among the locust species identified in the region are *Schistocerca interrita*, *Schistocerca piceifrons peruviana*, and the most prominent one, *Schistocerca cancellata* (Figure 1).

In recent years, the South American locust (*S. cancellata*) has experienced a resurgence, impacting several countries with migratory swarms covering vast areas up to 25 km2. Additionally, various species of grasshoppers are considered pests due to their economic, social, and political implications. Consequently, national and regional plant protection organizations concentrate their efforts on a limited number of grasshopper species to mitigate their impact.

Species belonging to the *Tropidacris* genus are closely monitored and controlled due to their large adult size and social impact. Notably, *Rhammatocerus schistocercoides* has been a significant species in Brazil in the past and has recently caused outbreaks in Colombia. Argentina and Uruguay grapple with species of the genus *Dichroplus*, while *Bufonacris claraziana* is a concern in Patagonia, Argentina, and *Elasmoderus wagenknechti* in Chile. Several countries, such as Argentina, Paraguay, and Bolivia, have established specific sanitary programs to manage locust populations. Other nations incorporate locust and grasshopper management actions within the scope of their national organizations. Additionally, regional organizations like COSAVE and CAN play a pivotal role in coordinating cooperation between countries. Notably, COSAVE has a Technical Group dedicated to managing locusts and grasshoppers. This group facilitates the exchange of critical information to address phytosanitary emergencies, especially during outbreaks of the South American locust. Moreover, COSAVE has developed and implemented a monitoring, management, and alert system that enables timely warnings to be disseminated across the region whenever locust swarms are detected.

It's crucial to highlight that both COSAVE and CAN are part of the Technical Group on Orthoptera Pests within the Inter-American Plant Health Coordination Group (GICSV). These regional plant protection organizations represent the South American region and spearhead essential actions in this part of the continent.

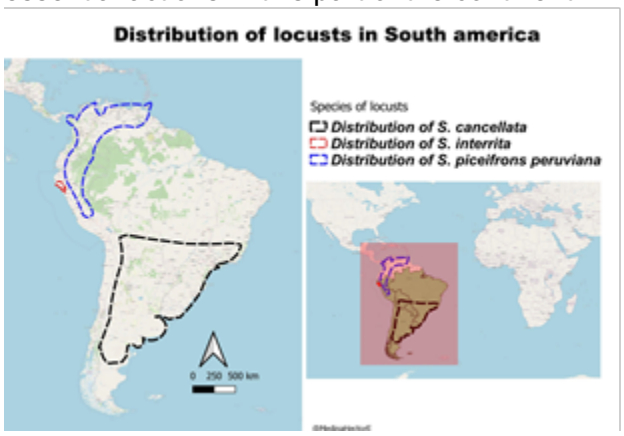

Figure 1. Distribution of locust species in South America

Key Words: Locust, Management, South America

MANAGEMENT OF LOCUSTS AND GRASSHOPPERS IN NORTH AMERICA WITH EMPHASIS ON THE UNITED STATES

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The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) Rangeland Grasshopper and Mormon Cricket Program survey and protect rangeland in the western United States. There are over 400 species of grasshoppers known to inhabit the 17 western United States. Of these, approximately 70 species are common enough to be encountered regularly and only about a dozen species are considered pest species of crops or rangelands. All species are native to North America and are important for nutrient cycling, ecosystem food webs, and stimulating plant growth. Monitoring species populations is important for managing these populations. Outbreak situations may benefit from suppression activities in certain cases, however not all species are managed the same. A few species exhibit characteristics similar to locusts (*i.e. Melanoplus sanguinipes*, (Fabricius, 1798); *Camnula pellucida*, (Scudder, 1863)) but true locusts such as *Shistocerca gregaria*, (Forsskal, 1775) are not typically present in outbreak populations. A few species of true locust occur in the United States such as *Schistocera americana* (Drury, 1770), *Schistocera lineata*, (Scudder, 1899).

Mormon crickets (*Anabrus simplex* (Haldeman, 1852) are also capable of experiencing outbreak populations and may benefit from suppression activities. Mormon crickets have been known to band together and march, damaging rangeland forage or crops. Not all management practices are effective or efficient across all areas in all states of the US. Land ownership plays a big role in species management in western US states. Federal lands may be managed by Forest Service, Bureau of Land Management, Department of Recreation, National Park Service or Bureau of Indian Affairs. State lands are managed by each state independently. Private lands are managed by each private landowner's discretion. Small, localized outbreaks are managed differently from very large widespread outbreaks and resources vary by situation (i.e. financial availabilities and commitments, available personnel, requests from landowners and land managers).

Key Words: Grasshopper, APHIS, United States

DESERT LOCUST MANAGEMENT IN THE WESTERN REGION

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The Desert Locust can threaten the livelihoods of one-tenth of the world's population in up to 60 countries (Brader et al., 2006). A regional approach is essential to coordinate prevention and control actions. The FAO Commission for controlling the Desert Locust in the Western Region (CLCPRO) with 10 countries (Algeria, Burkina Faso, Chad, Libya, Mali, Mauritania, Morocco, Niger, Senegal and Tunisia), is responsible for promoting national, regional and inter-regional actions for the prevention and control of Desert Locust invasions. It has successfully implemented two phases (2006-2010 and 2014-2017) of an FAO prevention program called EMPRES, designed to assist countries threatened by Desert Locust in their prevention and control efforts. This program was implemented in the Western region with significant donor support. Much of the activities focused on Chad, Mauritania, Mali and Niger—the "frontline countries"—where most of the Desert Locust breeding areas are located. The main results of the EMPRESRO program are significant capacity building in countries with the establishment of national locust control units (with administrative and financial autonomy), national early warning systems, environmental specifications and locust risk management plans. In 2009 CLCPRO organized a meeting of the ministers in charge of locust control in the 10 member countries resulting in a tripling of their annual contributions expected to be made to their Commission's trust fund, from 227,000 USD to 639,000 USD starting in 2011. This significant increase was based on the Gross Domestic Product (GDP) and thus indirectly institutionalized the support of the North-West African countries to the Sahel countries (south-south cooperation). In addition, CLCPRO continues its efforts and has developed a proactive mechanism —financial and operational— to address the locust emergency, emphasizing South-South cooperation and strengthening the role of CLCPRO. The financial mechanisms —approved in 2017— consist of two regional funds: (1) the Commission's Trust Fund for locust low-outbreak situations, funded by contributions from CLCPRO member states; and (2) the Regional Locust Risk Management Fund, a new financial instrument for major/ early resurgence situations. So far, 6 of the 10 CLCPRO member countries have made their voluntary contribution to this new fund. The operational mechanism (called the “Western Region Response Force”) is designed to rapidly strengthen the capacity of countries to respond to a locust emergency. It is established in two countries (Chad, Mauritania), which have been equipped with survey and treatment vehicles and surveillance drones. Recently Cabo Verde, Cameroon and Gambia applied for membership in CLCPRO. Western region is now facing major challenges such as increasing insecurity that may compromise the positive results achieved (8 outbreaks controlled since 2012). New approaches are being identified, relying more on local populations, satellite imagery and drones, also taking into account the impact of climate change.

Key Words: FAO, CLCPRO, Desert Locust, Management, Western Region.

MANAGEMENT OF LOCUST CRISIS IN THE WESTERN REGION - 2020 THREAT CASE -

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At the end of 2019, Desert Locusts increased rapidly in the central and eastern regions and spread to the Horn of Africa causing an un-precedented upsurge in early 2020. Considering warnings from the FAO Desert Locust Information Service (DLIS) of a possible arrival of swarms in West Africa in July 2020, the Executive Secretariat of the Commission for controlling the Desert locust in the Western region (CLCPRO), developed an action plan in April 2020 to deal with a possible invasion of locusts, for the treatment of an area estimated at 300,000 ha (scenario II: June to August). To this end, the Locust Risk Management Plan (FRGRA), was activated with financial needs estimated at 9.6 million USD.

The FRGRA is made of four (04) components: a component for monitoring the locust situation and forecasting its evolution according to scenarios; a logistics component to assess material requirements, acquire them and ensure their operationality; a communication plan; and a health and environmental component to ensure that control operations have no impact on the health of pesticide handlers and the environment.

As an urgent measure, CLCPRO mobilized an amount of 365,454.96 USD from its regional locust risk management fund to finance the national surveillance systems of frontline countries (Mali, Mauritania, Niger and Chad), made up of 53 survey/control teams, for the summer period, and to support national training sessions of the personnel to be deployed, which allowed the training of 266 technicians in locust survey and spraying techniques, as well as in health and environmental monitoring. In terms of coordination, CLCPRO Secretariat coordinated the implementation of the PGRA with the FAO's Regional Resilience, Emergency and Rehabilitation Office for West Africa/Sahel (REOWA) and FAO Representations. Together with REOWA and the Locusts and Other Transboundary Plant Pests and Diseases (NSPDM) group at FAO Headquarters, CLCPRO also pre-pared FAO's Global Response Plan to locust invasion threat in the Western Region, including aspects of locust control and population resilience (scenario 1: 300,000 ha/50 million USD; scenario 2: 500,000 ha/75 million USD). In addition, the CLCPRO Secretariat participated in the meeting of Ministers from ECOWAS member countries and North African countries, with an oral presentation on locust situation and the components of the PGRA.

The international response to the FAO appeal resulted in financial support of over 6 million USD. This financial support was directed to-wards anticipatory actions, through the reinforcement of the capacities of the Western Region Intervention Force (FIRO) by 17 vehicles and 16 drones bringing the total number of vehicles to 34, the triangulation of a quantity of

60,000 liters of pesticides to Chad and Niger and the acquisition of various survey and control equipment.

Despite all the anticipatory measures taken by the commission at regional level, the locust invasion from the Horn of Africa did not occur. However, in order to capitalize on all the efforts made to this end, the CLCPRO Executive Secretariat organized a workshop in Senegal, in 2022, to update the national plans and the regional locust emergency plan. Discussions highlighted the positive and negative points that characterized the implementation of the PGRA and recommendations were made for future improvements.

Key words: FAO, CLCPRO, Desert Locust threat, Western Region.

DESERT LOCUST CONTROL IN THE CENTRAL REGION – LESSONS AND EXPERIENCES

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CRC, the Commission of Desert Locust Control in the Central Region was established in 1967 and is the largest of the three FAO regional bodies, with currently 16-member states includes those which are located within red sea area, and horn of Africa, the most sensitive locust breeding areas at all. The commission promotes synergies and cooperation between its member countries and engages national and regional organizations that contribute to crop protection and agricultural research that reduce and manage locust risk. This is embodied in CRC desert locust preventive control strategy, the strategy that provides means of preparation, monitoring, warnings and alerts and early intervention against desert locust infestations. This is in addition to the technical and financial support provided by the Commission's secretariat to member states, such as building national human capacities, and introducing of modern approaches in survey and control operations.

The 2019-2021 Desert Locust upsurge is a perfect example of how important is, the role of CRC regarding the desert locust management. In July 2019, before the outbreak, the Commission's secretariat called for an emergency meeting to present the desert locust situations. Then, during the upsurge the commission has provided technical and material support, the support which helped a lot in limiting the damage caused by the infestation.

An online questionnaire has been developed, to identify strengths and weaknesses that formed during the upsurge, and the data analysis showed that there were some strength points includes: Reliance on surveys and national resources to get locust information; the availability of operations vehicles, pesticides, vehicle-mounted sprayers, ULV pesticides and biopesticides (figure 1); and the availability of national and emergency funds, Desert Locust action and contingency planning, reporting of DL situation, coordination of operations, campaign evaluation and the role of media.

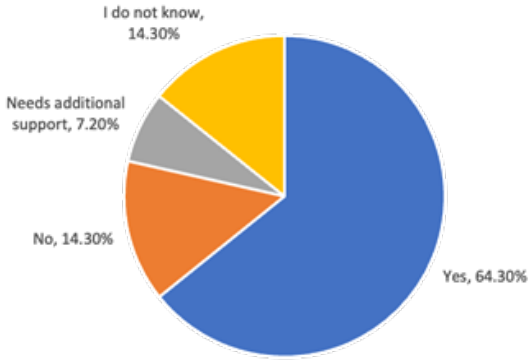

Figure 1. Pesticide availability during the upsurge

The results however showed that there were many weaknesses includes: less reliance on DL monthly bulletins, and communication with CRC Secretariat and neighboring countries, eL3m and eL3w; Lack of manpower (figure 2), training, sprayers (Backpack, aerial), funds (from CRC and other national sources) and external aids; Heavy use of EC pesticides; and Absence of strategy for dealing with environmentally sensitive areas and recording crop losses.

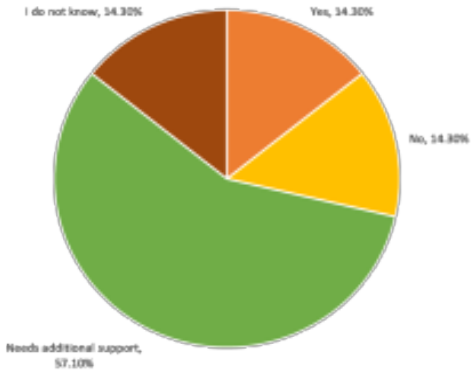

Figure 2. Manpower availability during the upsurge

Acknowledgment: We thank the member states for their continued efforts to control desert locust. We also thank regional and international donors for their support to contain the 2019-2021 outbreak

Key Words: CRC, Desert locust upsurge

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LOCUST MANAGEMENT IN AUSTRALIA

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The Australian plague locust forms dense bands and swarms that can cause substantial damage to pastures and crops. For many years, the Departments of Agriculture in each of the Australian states conducted control programs to protect crops in the agricultural areas but as it became increasingly evident that locusts were capable of long-distance migration between states, the Australian Plague Locust Commission (APLC) was set up in 1974, to manage the locust problem in eastern Australia. The Australian plague locust has a migratory circuit between the subtropical interior that has a summer rainfall maximum and the temperate agricultural zone where rain is more common in winter. The APLC conducts a preventive management strategy that aims to minimize economic loss by conducting early intervention treatments as soon as outbreaks develop and continuing treatments whenever and wherever bands or swarms of locusts are found, whether in the subtropical interior or in the agricultural areas.

Critical in the process of early intervention is monitoring of locust populations by regular surveys and treatment of any semi-gregarious or gregarious infestations detected. Early intervention has the greatest chance of success if they are combined with a reasonably good understanding of the factors that lead to outbreaks and of where locusts are more likely to be. To rapidly locate and control localized locust infestations over the several million km2 of eastern Australia, a Decision Support System for locust management was set up to help operations staff determine where and when to concentrate survey and control efforts.

Rainfall is a key driver of locust outbreaks but in the inland of Australia, rainfall reporting stations are limited, satellite imagery is used either to detect rainfall directly or through vegetation response. Rainfall distribution and temperature data along with data from locust surveys in the field are downloaded directly into the Decision Support System where models provide forecasts of likely population levels in various regions in eastern Australia.

When an increased risk of outbreaks or upsurges are forecast, the APLC prepares for possible treatment programs. But before locusts can be treated, they must be rapidly detected, and for many years, Australia has used aircraft to rapidly locate the densest infestations for treatment. And once infestations are detected, it is important to be able to treat locusts wherever they are found including in environmentally sensitive areas and organic properties. To ensure such treatments, Australia includes the biological control agent Green Guard, that contains the naturally occurring fungus *Metarhizium acridum* in treatment programs. Also important in the APLC locust management strategy is the existence of a Reserve Fund that provides for the substantial additional resources often needed during control programs.

The combined efforts of the Federal (APLC) state and local governments along with landholders protecting their crops have led to an effective locust management program in Australia.

Key Words: locusts, upsurge, preventive management

LESSONS LEARNED FROM THE MANAGEMENT OF THE DESERT LOCUST EMERGENCY RESPONSE TO THE 2019-2021

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THE 2019-2021 desert locust upsurge was the worst of such crisis to strike the Greater Horn of Africa and Yemen in decades. The upsurge presented an unprecedented threat to food security and livelihoods, with the potential to cause widespread suffering, displacement and conflict in the region, hence urgent need for management.

Generally, the locust campaign is conducted by the plant protection directorates/services under the responsibility of the Ministry of Agriculture and with the support of other ministerial departments that can contribute to the various field operations. In 2020-2022 campaign, the major impediment for field operations was the lack of preparedness coupled with the Covid-19 pandemic, insecurity in some countries, the lack of organizational, logistical and technical experience, and the lack of qualified human resources. Despite these impediments, the unprecedented locust threat was halted from developing into a plague, thanks to the timely and generous support of FAO's resource partners.

FAO mobilised about USD 243 million from 31 resource partners, the resources that enabled FAO to: (i) provide technical and operational assistance for surveillance and control operations, (ii) provide livelihood support for affected farmers and herders, and (iii) build and sustain the capacity of national and regional actors to cope with similar outbreaks in future. Cumulatively, a total of 3.2 million ha was treated and 313 200 households supported. This effort averted 4.5 million tonnes of crop losses, saved 900 million litres of milk production, and secured food for 41.5 million people. The commercial value of the cereal and milk losses averted through this response was estimated at USD 1.77 billion.

The successfully campaign against the upsurge provided important lessons that when addressed would inform future Desert locust management. Some of the lessons include:

- Countries to increase the transparency about response to desert locust invasion
- Countries' level of preparedness acquired through FAO response during the upsurge needs to be maintained.
- Countries' institutional set up and preventive control capacities should be strengthened to avert future outbreaks and invasions
- Clearly communicate locust situation briefs, forecasts and warnings.
- No-regrets approach to donor assistance should be maintained.
- Build in-country capacity and upscale real-time field data collection and submission
- Increase the use of biopesticides and insect growth regulators
- Mentor and train the new generation of locust experts
- Develop and use innovative technologies such as EarthRanger to better manage aerial operations

Details of the lessons learnt during the upsurge will be discussed during the oral presentation.

Key Words: Desert Locust, Upsurge, Food Security, Biopesticides

INTERNATIONAL BEST PRACTICE IN LOCUST MANAGEMENT

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Effective control of locusts is beyond the capabilities of landholders trying to protect their crops. Consequently, locusts are usually managed by locust control organizations and world's best practice is to use a strategy of preventive management that aims to minimize economic loss by conducting early intervention treatments as soon as outbreaks develop and continuing treatments whenever and wherever bands or swarms of locusts are found.

Critical in the process of early intervention is monitoring of locust populations by regular surveys and treatment of any semi-gregarious or gregarious infestations detected. Such early intervention programs have the greatest chance of success if they are combined with a reasonably good understanding of the factors that lead to outbreaks and of where locusts are more likely to be. Weather factors are often a key driver of locust outbreaks either directly by providing suitable conditions for population increase or indirectly through effects on natural enemies. In world's best practice systems, data from locust surveys are downloaded into a Geographic Information System where models based on medium term weather forecasts and critical locust population factors provide forecasts of likely population levels.

When an increased risk of outbreaks or upsurges are forecast, locust management organizations prepare for possible treatment programs, including organizing for the increased resources required. With locusts that have intermittent outbreaks, a small locust unit and minimal resources are sufficient for the regular monitoring and the initial treatment of outbreaks. But if outbreaks continue and populations upsurge, it is essential that substantial resources are made available either from a Reserve Fund set aside for the purpose or from special government or international grants. Obtaining the latter is best facilitated by accurate forecasts of upsurges.

Once upsurges are underway, it is important to treat populations whenever and wherever they are. Most effective programs involve national and local government organizations conducting as much treatment as possible in areas far from crops. And in cropping regions, most treatments by both government organizations and landholders are of nymphal bands before they reach the very damaging adult stage.

The gregariousness of locusts means that populations are often found in only a small part of an area and location of populations by ground methods is slow and very time consuming. Rapid location of areas dense enough for treatment is essential to limit migration to crops, so techniques need to be developed to detect both bands and swarms from the air as has been done effectively in Australia for many years and recently for the desert locust in East Africa.

And to ensure locusts are treated whenever and wherever they are found, both biological and chemical pesticides need to be used, applied using a wide range of techniques. The ways in which all of the world's best practice methods mentioned here can combine for effective locust management will be discussed.

Key Words: locusts, upsurge, preventive management

FUNCTIONING AND ACTIONS OF THE FAO LOCUST GLOBAL PROGRAMME

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Locusts are very voracious and dynamic migratory pests with a vast distribution area and wide host plant range, more than 500 plant species. The Desert Locust (*Schistocerca gregaria*) is considered the most dangerous of all migratory pest species in the world, in addition to other several important locust species, such as Asian and African Migratory Locusts, Red Locust, Italian Locust, Moroccan Locust, Central and South American Locusts and others. The biology and behavior of the locusts make them challenging to monitor and control. Their effective monitoring and control require unique technical approaches with adequate national institutional and cross-border monitoring and coordination mechanisms at regional and global level.

The Food and Agriculture Organization (FAO) of the United Nations (UN) is the global organization coordinating the Desert Locust monitoring, early warning, forecasting and control. FAO's current role in Desert Locust monitoring and control dates back to nearly 70 years, since the establishment of FAO's Desert Locust Control Committee in 1955.

FAO operates a centralized Global Desert Locust Information Service (DLIS) at FAO HQs that monitors the Desert Locust situation in about 60 countries throughout the world and maintains historical locust archives that date back to the 1930s.

All Desert Locust affected countries are members of FAO and their national Desert Locust Centers are linked electronically to DLIS and transmit locust data to FAO who in turn analyze this information on the locust situation in each country and provide warnings and advice on control actions.
At the field level, FAO operates three Desert Locust Regional Commissions (Commission for Controlling the Desert Locust in the Western Region (CLCPRO), Commission for Controlling the Desert Locust in the Central Region (CRC), and Commission for Controlling the Desert Locust in South-West Asia (SWAC)).

The Commissions support the implementation of the locust preventive control strategy by promoting the establishment of autonomous national Desert Locust units and strengthening national capacities of their member countries in survey and early warning, reporting, preventive control, training, contingency planning and human health, environmental and safety standards. In addition to the Desert Locust Global Programme, FAO implements an Inert-regional Programme to manage three key locust species (Asian Migratory Locust, Italian Locust, Moroccan Locust) in the Caucasus and Central Asia (CCA) countries. The Programme aims to reduce the occurrence and intensity of locust outbreaks, and to improve the national and regional locust management capacity.

Global and regional collaboration are key for successful monitoring and management of migratory pests such as locusts to ensure that they are well monitored and controlled. Thus, it is crucial to bring more global actors to work hand in hand with FAO to support the efforts of FAO to shift from traditional locust emergency responses to locust preventive and sustainable management approach.

Key Words: Locusts, Desert Locust, locust management, global coordination

OBJECTIVES OF THE INTER-AMERICAN GROUP ON ORTHOPTERAN PESTS

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THE Inter-American Plant Health coordination Group (GICSV) is a collaborative initiative comprising the Regional Plant Protection Organizations (RPPOs) of the Americas, namely NAPPO, OIRSA, CAHFSA, CAN, and COSAVE, with support from the Inter-American Institute for Cooperation on Agriculture (IICA) acting as the Group's Technical Secretariat. The primary objective of GICSV is to foster effective and unified actions to prevent the introduction and dissemination of pests in plants and plant products, while promoting suitable measures for their control.

The main functions of the GICSV encompass: a) Establishing a continental coordination forum for the development of phytosanitary standards and guidelines. b) Identifying and analyzing crucial phytosanitary challenges and proposing strategies to enhance phytosanitary protection across the Americas. c) Facilitating trade by promoting the principles and objectives of the SPS/WTO Agreement and the IPPC (International Plant Protection Convention). d) Advocating for the adoption of phytosanitary standards and guidelines throughout the continent. e) Serving as a consultation mechanism and information exchange channel for critical phytosanitary matters in the Americas. To address the diverse phytosanitary challenges specific to the continent, the GICSV has established various technical groups. These groups, including those focusing on Fruit flies, Electronic Certification (e-Phyto), FocTR4, and pest orthoptera, work collaboratively to tackle pertinent issues. One such group, tasked with addressing locusts and grasshoppers, initiated its work in 2019, prompted by significant outbreaks of the South American locust and Central American locust. This technical group aims to serve as the continental reference point for enhancing the technical capabilities of different regions (RPPOs) throughout the American continent that encounter locust and grasshopper problems. The group diligently monitors the locust and grasshopper situation, generating periodic reports, and actively fosters cooperation among the American continent's regions, as well as with international organizations and specialists in this field. The primary goal is to enhance preventive management systems and emergency response strategies. Through its efforts, the group has compiled reports on relevant species in the region and assessed the availability and usage of insecticides. Additionally, webinars have been conducted to share experiences from the region on utilizing remote sensing, biological control, and weather forecasting for managing locust and grasshopper populations.

For more information, please visit: https://bit.ly/3Df7NmE

Key Words: Locust, Management, Americas, GICSV, Cooperation

IMPORTANCE OF COOPERATION BETWEEN DIFFERENT REGIONS OF THE WORLD FOR LOCUST RESEARCH AND MANAGEMENT

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Locust swarms have the potential to devastate crops, disrupt food security, and undermine livelihoods on a significant scale. Their unpredictable boom-bust cycles pose challenges for consistent management. During recessions, monitoring and response systems weaken, leading to a loss of institutional knowledge. This perpetuates a vicious cycle of reactive rebuilding of networks, training, and information resources when outbreaks inevitably resurface.

Cooperation at both national and international levels is essential for effective locust management. Locusts do not adhere to borders or geopolitical boundaries and easily connect seemingly distinct people and places. Although there are some systems in place for collaboration between international organizations, national governments and regional commissions, much could be gained by opening cooperation efforts more broadly. Lessons learned in one region could save time, resources, and struggle in another. However, to move to a more global perspective of locust management, true cooperation must address issues of trust, transparency, value differences, political tension, communication styles and the unfortunate lack of consistent streams of funding. We must acknowledge locusts as a part of a social-ecological-technical-system and draw on all of these factors for success to move toward a more sustainable way of living with locusts.

This talk will build on previous talks in this session in highlighting needs and opportunities for cooperation at a global scale. At the Global Locust Initiative (GLI), we engage key actors in locust research and management to develop partnerships and solutions for transboundary pest management in agroecosystems around the world. We will share two primary resources for the GLI Network. HopperLink is a network of 200+ members from 40 countries including farmer's groups, students, researchers, and government officials. HopperWiki is a centralized location where the global community can access and contribute to valuable information on locusts and grasshoppers in a digestible format. It is readily accessible in any language that google translates.

Key Words: locust, grasshopper, global, collaboration, network, community resource, transboundary migratory pest, management, social-ecological-technological system

SYMPOSIA 8
MYCOPESTICIDES FOR LOCUST CONTROL

Organizer
Mohamed Lemine, David Hunter & Mario Poot-Pech

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1. **Meriem Laidani and Mohamed Lemine Hamouny.** POLICY OF PROMOTING BIOPESTICIDES FOR DESERT LOCUST MANAGEMENT IN THE WESTERN REGION.
2. **Elie Samson and Lionel Legros.** USE AND BENEFITS OF *Metarhizium Acridium* IN LOCUSTCONTROL OPERATIONS, AND MAIN INDUSTRIAL CHALLENGES FOR A SUSTAINABLE PRODUCTION.
3. **Mohamed Etheimine; Mohamed Abdallahi Babbah Ebbe and Mohamed El Hacen Jaavar.** STUDY OF FACTORS INFLUENCING THE STABILITY, EFFICACY AND PERSISTENCE OF *Metarhizium acridum* IN BIOLOGICAL CONTROL AGAINST THE DESERT LOCUST, *Schistocerca Gregaria* (ORTHOPTERA: ACRIDIDAE) UNDER OPERATIONAL CONDITIONS.
4. **Mario Poot Pech, Carlos Urías, Xavier Euceda.** ORIGIN AND USE OF *Metarhizium acridium* IN MEXICO AND CENTRAL AMERICA.

POLICY OF PROMOTING BIOPESTICIDES FOR DESERT LOCUST MANAGEMENT IN THE WESTERN REGION

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The Desert Locust *Schistocerca gregaria* (Förskal), is considered to be one of the most harmful pests threatening crop production, putting livelihoods and food security at severe risk over or into parts of 55 countries. The FAO Commission for Controlling the Desert Locust in the Western Region (CLCPRO) has been working to control the Desert locust since its creation in 2002s. The Commission fosters sustainable management of this pest by implementing its regional approach based on preventive system with harmonized tools and processes for locust monitoring and control in its member states. Despite the efficient application of conventional pesticides in locust control, it is underscored by many negative externalities including environmental degradation, direct impacts on the ecosystem, but also the possibility of human intoxication. In response to concerns over pesticide use, an internationally funded Programme called LUBILOSA was set-up to develop a safe and effective biological product "the Green Muscle" against locusts and grasshoppers based on the fungus *Metarhizium anisopliae var. acridum*. After the 2003-2005 locust invasion in the western region when nearly 13 million Liters of mainly organophosphate pesticides were sprayed, the actors in charge of locust control became aware that health and environmental protection is critical while carrying out locust control operations. In this context, FAO held an international workshop at Saly, Senegal in 2007, to develop an action plan for incorporating biological control strategies for locust. In 2009, a second international workshop was organized in Rome (Italy) on the future of biopesticides in Desert Locust management. CLCPRO has been fully involved in the promotion of *Metarhizium* based mycopesticide by planning related operational research activities in all planning schemes of the EMPRES operational plan in the Western region, financing national research projects on the biopesticide optimization in locust control, by involving member countries in regional training workshops on *M. acridum* use, in addition to the development in 2008 of the Environmental Requirements (CCE) that locust campaigns should comply with, and obviously through the acquisition of the Green muscle and Novacrid bio-products for the benefit of member countries to be used when field conditions allow it. Moreover, as part of the AFD project set up in 2018: Consolidate the bases of the preventive control strategy and develop operational research on the Desert Locust in the Western region, CLCPRO has designated a specific component on the protection of the environment through the use of biopesticides. As concrete actions to promote use of biopesticides against

Desert locust two workshops have been jointly organized with FAO in 2019 and 2022 in Morocco, at Rabat and Agadir respectively, on the use of *M. acridum* in biocontrol of Desert locust, and to take stock of the use of this entomopathogenic fungus in control operations and discuss the constraints of its use in the field. As for acquisitions, CLCPRO procured significant quantities of the biopesticide (Novacrid) of 1590 kg for eight (08) member countries that have registered the product. To date, The Mauritanian locust control center (CNLA) has used the biopesticide during locust resurgence recorded in October 2022, to treat an area of 392 ha out of a total treated area of 4775 ha i.e. 8%, setting an example for integrated locust management in the region. Preventive and proactive approaches to controlling Desert locust using least disruptive and eco-friendly alternatives should be the ultimate goal.

Key Words: CLCPRO, *Schistocerca gregaria*, Biocontrol, *M. acridum*, biopesticide, Environment.

USE AND BENEFITS OF *Metarhizium Acridium* IN LOCUST CONTROL OPERATIONS, AND MAIN INDUSTRIAL CHALLENGES FOR A SUSTAINABLE PRODUCTION

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Locusts swarms represent a major concern toward worldwide food availability and threatens crops in many developing countries. Cli- mate change and global warming are increasing the risk by making more likely outbreaks and crisis as observed during the last big outbreak of desert locust from 2019 to 2021 in the Horn of Africa, and the *Schistocerca cancellata* outbreak in 2022 in Argentina. Historically, locust control methods were performed using conventional chemical insecticides, and most of the time in non-agricultural are as sprayed using ultra-low volume (ULV) technology. However, the use of these chemical substances at large scale brings other side concerns: soil and water pollution, damages on fauna (especially bees, birds or other beneficial insects or pollinators), human health issues, and even risk of quick locust reinfestation due to the low persistence of such substances. In this context, several research programs have been carried out on biological substances as a safer alternative to chemical pesticides.

During the LUBILOSA program *Metarhizium acridum* spores proved to be the best candidate for a long-term sustainable locust control. In addition to its high efficacy level, it is also selective to locust and grasshoppers and naturally found in soils. The fungus was found to be safe to environment, fauna, flora and human beings, and is suitable for curative and preventive control in many environments worldwide.

For large scale production of *Metarhizium acridum,* the company Elephant Vert invested in a dedicated production site in Meknès (Morocco), able to produce 12 T of commercial product per year (strain EVCH077 under brand name Novacrid® or strain IMI 330189 under brand name Green Muscle® as exclusive worldwide producer). The production process includes a liquid state fermentation of spores, followed by a solid-state fermentation step, performed in sterile conditions to prevent it from contamination.

Many trials have been carried out, under laboratory or field conditions, on a wide range of locusts and grasshoppers species, always showing high efficacy comparable to conventional insecticides. However, producing a selective insecticide dedicated to be used only in locust or grasshopper outbreak conditions remains a strong economical and industrial challenge, in parallel with the need to register such products as they belong to Plant Protection Registration. Having a production facility inactive during years of low locust activity and able to produce several tons of active substance during crisis is impossible, and a steady production of 2 T/year at least is mandatory to ensure the long-term sustainability of the facility and possibility to ramp up with high quantities to apply during crisis.

Figure 1. Area treated in Africa for locust control (thousands of hectares/year).

Therefore, the sustainability of such activity relies on commitment of various countries to adopt a preventive protection approach against locusts more than curative, and defend a worldwide partnership to commit on the use of such innovative products.

Key Words: ICO2023, Merida, Grasshopper, Bio- insecticide

STUDY OF FACTORS INFLUENCING THE STABILITY, EFFICACY AND PERSISTENCE OF *Metarhizium acridum* IN BIOLOGICAL CONTROL AGAINST THE DESERT LOCUST, *Schistocerca Gregaria* (ORTHOPTERA: ACRIDIDAE) UNDER OPERATIONAL CONDITIONS

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Within the framework of Desert locust preventive control strategy, the use of *Metarhizium acridum* based biopesticide, is an environmentally-friendly option. However, the biopesticide storability in ambient conditions, its efficacy in field conditions and its high cost are the main shortcomings associated with its large-scale use. The storability of five different formulations of the biopesticide was investigated under ambient store conditions through conidial germination tests (Fig. 1). The powder formulations maintained a good conidial viability of 60%±0.96 after 10 months of storage.

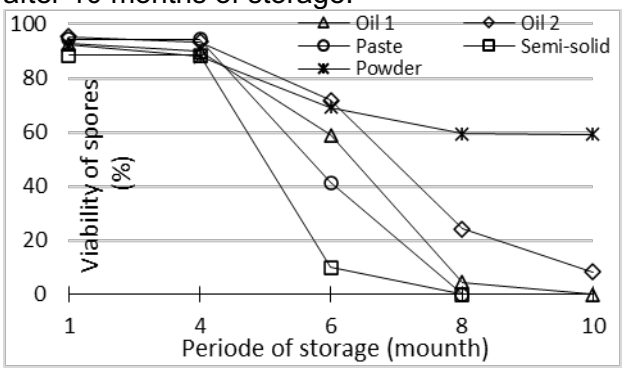

Fig 1. Spore viability of different formulations (500 g each) stored at ambient conditions (23-39 °C).

The effect of vegetation cover on biopesticide efficacy was evaluated in short and tall vegetation. The bioinsecticide was effective when sprayed on both low and tall vegetation covers. However, its efficacy was greater on tall vegetation (greater biomass) (Fig. 2). The effect of time spent by the insect in contact with treated vegetation, using the barrier spraying technique, was evaluated by exposing untreated insects to treated vegetation at different time intervals (Fig.3). This investigation shows the feasibility of barrier spraying technique with the biopesticide.

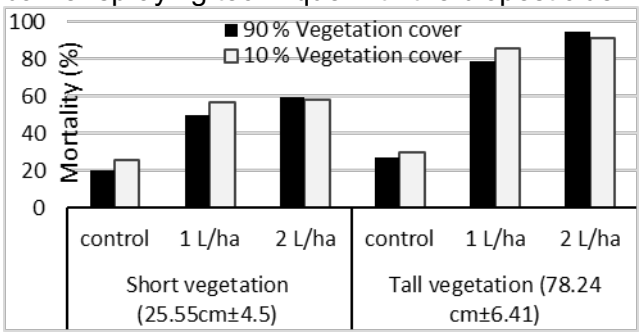

Fig 2. Mortality rate of a mixed population of 3rd and 4th instars treated with a dose of 2.5 x 1012 spores/ha under different vegetation covers (Millet) in semi-field conditions (cages of 2 x 2 x 1 m with 100 insects/cage).

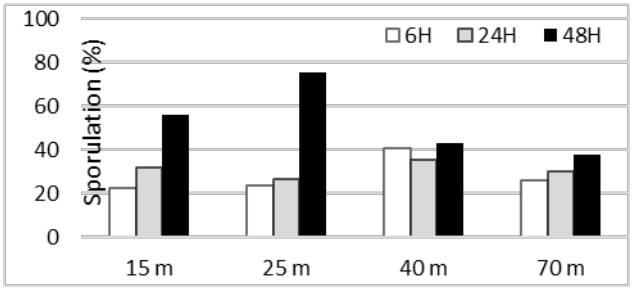

Fig 3. Sporulation of *M. acridum* on untreated insect cadavers exposed to treated vegetation (barrier) at different time intervals and at different distances from the pass.

The results of this study encourage systematic integration of the biopesticide in Desert locust management. Future areas of research should focus on improving its effectiveness with respect to its slow action, thereby increasing the evidence base for promoting its use in large-scale field.

Key Words: *Metarhizium acridum*, Desert locust, storability, conidial persistence.

ORIGIN AND USE OF *Metarhizium acridium* IN MEXICO AND CENTRAL AMERICA

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Mexico and Central America have historically been invaded by locust *Schistocerca piceifrons piceifrons* (walker 1870), currently it is still a food security problem for the region in which different activities are carried out.

One of the control methods that has become relevant has been the use of biological control through the fungus *Metarhizium acridum* (Driver & Milner) which the MaPL32 y MaPL40 strains have been the most virulent and effective in controlling locust outbreaks, it has even been compared to the Australian strain FI985 with similar results of high effectiveness.

The search for entomopathogenic fungi began in December 1995 to February 1996 on Socorro Island, Colima, on those dates swarms were presented on that island, therefore in 1999, the Government of Mexico start the promotion the use of this control agent, which there are States that it has been used more widely, such as in Yucatan where the aerial application is of 2, 000 to 800 ha per outbreak year.

In 2020, the *M. acridum* strain was donated to Centro America through the efforts of OIRSA, where it was reproduced in local laboratories for its development and subsequent application.

After 3 years, the applied area in the region has been low in countries as Guatemala y El Salvador, in which the main factors have been the coincidence of locust outbreaks and the availability of the fungus. The results in small treated areas have been very acceptable since the population has been reduced to levels that do not cause harm.

It is important to encourage the reproduction of this agent in Government laboratories and facilitate its shipment between countries for use. This agent offers a great opportunity to be applied in the nymphal stage of the locust in a preventive manner, reducing environmental contamination and its possible establishment in the area for self-regulation.

Reference

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Key Words: Prevention, Autoregulation, Bioinsecticide.

SYMPOSIA 9
SYSTEMATICS & PHYLOGENETICS

Organizer:
Martina Pocco, Maria Marta Cigliano, Martin Husseman, Lara-Sophie Dey

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1. **Claudia Hemp, Klaus-Gerhard Heller, Elzbieta Warchalowska Sliwa, Beata Grzywacz**. SPECIATION MECHANISMS OF AFRICAN ORTHOPTERA WITH A FOCUS ON EAST AFRICA.
2. **Viviana Confalonieri, Luciano Gandini, Elio Castillo, Maria Marta Cigliano and Noelia Guzmán.** GENOMIC EXPLORATION APPROACHES REVEAL HYBRID ZONES AND HIDDEN BIOLOGICAL UNITS IN AN ANDEAN GRASSHOPPER SPECIES GROUP WITH CHROMOSOMAL INVERSIONS.
3. **Lara-Sophie Dey, Axel Hochkirch, Hojun Song, Marianna Simoes, Karen Meusemann, Oliver Hawlitschek & Martin Husemann**. SAME SAME BUT DIFFERENT – GENOMIC DATA, MORPHOMETRICS AND ECOLOGICAL NICHE MODELLING CONFIRM LARGE SCALE CONVERGENCE OF WING MORPHOLOGY IN OEDIPODINAE.
4. **L. Lacey Knowles, JR Wood, Ricardo Mariño Pérez, JoVonn G. Hill, Salomón Sanabria-Urbán.** PHYLOGENETIC TESTS OF DIVERSIFICATION MODELS: REPEATED COLONIZATION, NOT IN SITU DIVERGENCE, BUILT-UP AN ENDEMIC MEXICAN FAUNA OF MELANOPLINES.
5. **Tony Robillard.** THE ROLE OF TAXONOMY AND NATURAL HISTORY EXPLORATION TO ADDRESS EVOLUTIONARY QUESTIONS: THE CASE-STUDY OF ENEOPTERINAE CRICKETS.
6. **Martina E. Pocco, Noelia V. Guzmán, Viviana A. Confalonieri, Hojun Song and María Marta Cigliano.** SYSTEMATIC STUDIES IN ROMALEINAE (ACRIDOIDEA: ROMALEIDAE) WITH THE HELP OF TAXONWORKS.
7. **Battal Ciplak**. CONTRASTING SPECIATION IN NORTH AND SOUTH OF A REFUGIUM: GLACIAL ORTHOPTERAN EVOLUTION IN ANATOLIAN REFUGIUM.

SPECIATION MECHANISMS OF AFRICAN ORTHOPTERA WITH A FOCUS ON EAST AFRICA

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The East African region is known for its rich biodiversity, particularly in the mountainous areas of the Eastern Arcs that stretch through Tanzania and southern Kenya. Recent surveys of the Orthoptera fauna in these mountains have shown that they also harbor a diverse array of orthopteran insects with a high degree of endemism.

The geologically young volcanoes adjacent to the northern branch of the Eastern Arc chain, such as Mount Kilimanjaro and Mount Meru, were thrown up during the uplift of the rift valley system about 1–2 million years ago. The patterns of geographical species distribution found on these mountains can be explained by the expansion and retraction of forests during humid and dry periods, respectively. The vegetation corridors along rivers facilitated the dispersal of coastal taxa into the hinterland along the east African coast. During dry and warm periods, taxa that became trapped in montane habitats adapted to the montane climate or went extinct. The unique arrangement of mountain chains in the region likely facilitated speciation, and climate fluctuations and orogenesis, rather than a long-lasting and stable climate, are the most likely reasons for the high diversity found on the Eastern Arc Mountains and inland volcanoes.
On a larger scale diversification of East African taxa was triggered by large-scale climatic changes of the forest cover in Africa. African Tettigoniidae are thought to have been forest dwellers since humid Africa was more or less continuously covered by forests (Eocene pan-African rain forest). During the Oligocene a period of drastic global cooling occurred resulting in a drier climate at equatorial levels fragmenting the Eocene pan-African rain forest probably leading to a diversification in west and east African taxa. A trend from fully alate species to species with reduced wings is seen in e.g Hexacentrinae.

The insights gained from studying Orthoptera can shed light on the factors that promote speciation and contribute to the rich biodiversity of African forests. Overall, understanding the mechanisms of speciation is crucial for conserving unique and irreplaceable ecosystems in Africa.

Key words: Orthoptera, East Africa, speciation

GENOMIC EXPLORATION APPROACHES REVEAL HYBRID ZONES AND HIDDEN BIOLOGICAL UNITS IN AN ANDEAN GRASSHOPPER SPECIES GROUP WITH CHROMOSOMAL INVERSIONS

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South America harbors five of the world's biodiversity hotspots and its biodiversity is likely to have been modeled by geological events, marine introgressions and climatic oscillations. Among the former, the uplift of the Andes (23 to 5 My) has been associated with the most rapid and diverse radiations on Earth. *Trimerotropis* Stål is a grasshopper genus distributed across the Americas from Canada to Chile and Argentina with more than 40 species inhabiting dry and temperate regions. In South America it inhabits high-altitude environments along the Andes Mountain range. The reported number of species in this subcontinent has varied over the last 160 years with only three species being finally recognized. However, as some of them were found to comprise several genetic lineages, the South American representatives of the genus are now considered as a complex (i.e. "*T. pallidipennis* complex"). The *Trimerotropis sp*. lineage is distributed in Argentina and segregates for four to seven chromosomal inversions that display clinal variation. Using genome wide single nucleotide polymorphisms (SNPs) and network analytical approaches to find loci in linkage disequilibrium (LD), three clusters of correlated loci were found to be associated with inversion karyotypes; furthermore, non-neutral loci associated with environmental variables mapped to two of these LD-clusters. This result, together with the finding that inversion frequencies remained stable for more than 20 generations, led to postulate that: i) inversions play a role in the adaptation of *Trimerotropis sp* populations to new environments; and ii) the clines could be the consequence of a coupling between extrinsic postzygotic barriers and spatially varying selection along environmental gradients, resulting in a hybrid zone between *Trimerotropis sp* and a different genetic lineage. To further investigate this subject, we expanded the geographic scope in relation to previous analyses, including new samples from Chile, Bolivia, Perú, as well as samples from a new altitudinal cline in Argentina.

We analyzed the genetic structure, lineage diversification and environmental requirements within the entire *Trimerotropis* complex and its association with geography and Pleistocene glaciations, using SNPs and ecological niche modeling. The analyses revealed the existence of at least five lineages, two of them with a restricted and the other three with a very wide geographic distribution. Glacial cycles most probably isolated widely distributed lineages on the eastern and western sides of the southern Andes, potentially driving the emergence of the *Trimerotropis sp*. lineage, which can tolerate more temperate habitats. One of the aforementioned restricted genetic lineages have been most probably isolated in a valley refuge at 32°S latitude in the southern Andes during the last Patagonian glaciations, thereby differentiating from *Trimerotropis sp*. and giving rise after secondary contacts to an hybrid zone. Our results provide evidence for the effects of Quaternary climatic changes, refugial areas and chromosomal inversions on the diversification history of a South American grasshopper species complex.

Key Words: Inversion Clines, SNPs, Genetic Lineages, Pleistocene glaciations

SAME SAME BUT DIFFERENT – GENOMIC DATA, MORPHOMETRICS AND ECOLOGICAL NICHE MODELLING CONFIRM LARGE SCALE CONVERGENCE OF WING MORPHOLOGY IN OEDIPODINAE

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Convergently evolving traits are a frequently observed evolutionary mechanism: similar traits are evolving without common ancestry. This mechanism was investigated in a large number of species that show similar ecological or morphological traits despite geographical separation. Species of the grasshopper subfamily Oedipodinae show similar morphological traits at different continents, yet their relationships is not fully understood. In this study we used a hybridization capture approach to build a stable phylogeny of the group. We used eleven pairs of morphologically similar species from different continents and analyzed these using geometrical morphometrics of 12 landmarks. We tested the similarity of the climatic niche via niche overlap analyses and reconstructed potentially suitable habitats on the counterpart continent. Finally, based on hundreds of single-copy protein coding molecular markers we reconstructed the relationships of the target taxa. Phylogenomic tree reconstruction showed a separation of American and Eurasian and African Oedipodinae rather than a clustering by taxonomical traits. The morphometric analyses clustered the species into four groups, which all contain individuals from both geographic regions, without any separation by geography. We found niche overlap in eight species pairs. Ancestral niche reconstruction showed less evolutionary steps in the morphometric, than in the molecular based phylogeny. Our analyses suggest that the morphologically similar taxa have undergone convergent evolution most likely due to similar ecological conditions despite geographical separation.

Figure 1. The left box (brown) represents the American species, while the right box (blue) shows the Eurasian-African morphologically similar counterparts.

Key Words: Oedipodinae, convergence, geometric morphometrics, ecological niche modelling, genomics

PHYLOGENETIC TESTS OF DIVERSIFICATION MODELS: REPEATED COLONIZATION, NOT IN SITU DIVERGENCE, BUILT-UP AN ENDEMIC MEXICAN FAUNA OF MELANOPLINES

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Testing the evolutionary processes underlying regional endemicity is essential to understanding the biogeographic context of diversification. Moreover, when this endemic species diversity occurs in the tropics, questions about diversification often focus on the timing of diversification to test whether taxonomic diversity accumulated over a relatively short period of time versus a prolonged period. Such tests in relatively understudied taxa and regions are needed to evaluate the generality of processes. The fauna of Mexico has drawn the attention of researchers as a region of both high endemicity and species diversity, especially in relation to the biodiversity hotspot of central Mexico, which is characterized by high topographic complexity characterized and by pronounced environmental clines, as well as isolated pockets of habitat for taxa that inhabit the sky islands of Mexico's mountain tops. However, to date, phylogenetic tests have focused primarily upon vertebrates, leaving many invertebrate taxa underrepresented. The grasshoppers of Mexico are one such group. Mexico hosts many endemic grasshopper taxa, including 14 endemic genera with 34 endemic species of grasshoppers in the family Melanoplinae, the most diverse sub-family of Acridid grasshoppers. The diversity of these Melanopline grasshoppers also peak in the mountains of Mexico, a recognized biodiversity hotspot in other taxa.

As with other patterns of tropical diversity, the circumscribed endemic Melanpline grasshopper fauna may have radiated *in situ* in Mexico. Given the diversity of endemic Melanoplinae genera, perhaps diversification took place over a prolonged history such that there was sufficient time for the accumulation of phenotypic differences that typify the splitting of species across different genera. However, rapid evolutionary change across Mexico could have also contributed to pronounced morphological differences sufficient to warrant divisions of species into different genera, especially if the divergence process was accompanied by shifts across the different biomes of Mexico (e.g., in desert versus forested mountains or montane meadows).

Alternatively, instead of *in situ* diversification generating the species diversity of the Mexican Melanopline fauna, species diversity may have accumulated through repeated colonization from North America, where most of Melanopline diversity is distributed. This raises intriguing questions about the accumulation of Melanopline diversity in Mexico. Specifically, a model of repeated colonization of Mexico from North America could produce the observed diversity patterns, and the morphological divergence accompanying colonization events might be sufficient to divide the Melanopline taxa into the 14 endemic genera of Mexico.

Here we use a phylogenetic framework to estimate the evolutionary relationships of the endemic Mexico taxa, in addition to taxa that are distributed in Mexico and North America, to test alternative hypotheses about their diversification history. Specifically, If the taxa from Mexico originated through *in situ* diversification, we expect the taxa to form a monophyletic clade. Alternatively, if the taxa from Mexico are more closely related to North American taxa that also occur in Mexico, the data would support a model of repeated colonization of Mexico. Our results show strong support for the repeated colonization of Mexico to build-up its endemic Melanopline fauna, and this diversification took place over a prolonged period during the Pleistocene that includes some very recently derived taxa.

Key Words: diversification, endemic, Melanoplinae

THE ROLE OF TAXONOMY AND NATURAL HISTORY EXPLORATION TO ADDRESS EVOLUTIONAlnY QUESTIONS: THE CASE-STUDY OF ENEOPTERINAE CRICKETS

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In this contribution, I will discuss various aspects of how taxonomy, natural history information and descriptive approaches are central to the study of evolution.

There are almost as many ways of addressing evolutionary studies and biodiversity as there are disciplines with this ambition. This can be done at the scale of a few model organisms whose genomes are finely compared, or at the scale of whole phyla to study evolution using phylogenies. From the molecule to the ecosystem, from the individual to the phylum, it all revolves around the scale at which one wishes to focus. There is no right or wrong positioning in this field, but rather questions that can be more or less well addressed at a given scale. These multiple points of view are often complementary, and it is often necessary to adopt one in order to better understand another.

However, all of this work depends on a single initial scale of study: that of descriptive approaches of biodiversity, which includes disciplines such as taxonomy and nomenclature, and the description of all the traits of the species, such as their behavior and life histories. It is all of these components – known as “natural history” – that form the foundation of natural history museums, and make up their wealth of collections and knowledge.

After a brief reminder that taxonomy is part of the comparative approaches, I will discuss the common issues and pitfalls faced by researchers willing to clarify the taxonomic context for their focal group before addressing evolutionary questions.
I will use the example of the cricket subfamily Eneopterinae Saussure as a study model, reviewing the recent contributions related to taxonomic work in terms of knowledge on phylogenetic relationships and biogeographic patterns. Through this case study, I will address the question regarding the usefulness of taxonomic exploration to study the evolution of communication in crickets.

Key Words: Taxonomy, Systematics, Museomics, Biogeography, Acoustic communication

SYSTEMATIC STUDIES IN ROMALEINAE (*ACRIDOIDEA: ROMALEIDAE*) WITH THE HELP OF TAXONWORKS

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One of the most diversified groups of Neotropical grasshoppers is the subfamily Romaleinae (Romaleidae). The Romaleinae include the largest and most colorful representatives within the Neotropical Acridoidea, and they are found in a wide range of habitats, from semi-arid conditions to tropical rain forests, exhibiting a high heterogeneity in terms of their morphology and ecology. This group, which is comprised by 266 species and 44 subspecies included in 69 genera, currently grouped in 10 tribes, covers the entire range of distribution of the family, from southern South America to Mexico, with only a few members reaching the south of the Nearctic region. Several morphology-based classification schemes have been proposed for the subfamily, although none of them was based on phylogenetic studies. Due to the great diversity of forms across Romaleinae, the current taxonomic classification could probably be affected by convergent characters. In this study, we analyzed the usefulness of morphological characters defining the groupings within Romaleinae, and we evaluated the phylogenetic relationships. We employed an integrated web-based workbench for taxonomists and biodiversity scientists, Taxon-Works (TW), to organize the available data, an-notate characters and states with images, and build a matrix for phylogenetic analysis. This matrix was also used to create an interactive key. Our morphological dataset included members from 56 genera of the subfamily Romaleinae, representing about 80% of the total genera of this subfamily (69 valid genera), and 16 Bactrophorinae as outgroups, and 131 morphological characters. The molecular set (66 specimens from 34 genera) included fragments of COI, COII and H3 genes. The results obtained from the different analyses reflect conflicts in the current classification of Romaleinae, showing a high amount of homoplasy. Most of the groupings were not recovered as natural. Some others are redefined and new groups are delimited. We also discuss the usefulness of cybertaxonomic tools available at TW, which facilitate the proper taxonomic workflow, being particularly helpful in highly diverse groups.

Key Words: Grasshoppers, phylogeny, cybertaxonomy, Neotropics

CONTRASTING SPECIATION IN NORTH AND SOUTH OF A REFUGIUM: GLACIAL ORTHOPTERAN EVOLUTION IN ANATOLIAN REFUGIUM

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Phylogeographic studies considering the Pleistocene period have significant partake in popularity of the field due to several reasons. First climatic cycles in the last 2.5 million years are the main determinants forming present communities, (ii) pioneer studies of the field primarily proceeded from glacial phylogeography, the tenets and terminology of the field founded mainly by glacial phylogeography, and (iv) glacial phylogeography provided pro-found insights for conservation approach and activities for a warming globe. However, there are still many unknown aspects of glacial phylogeography and possibility of the different past evolutionary processes in south and north sides of a refugium is such an aspect waiting for attention.

Anatolia was considered a complex glacial refugium in West Palearctic and present Anatolian biodiversity mainly formed by repeated shuffling processes forced by climatic cycles of Quaternary. Orthoptera was considered as a marker group to detect imprints of these past events and recent studies on several lineages belonging to Tettigoniidae allow new generalizations for Anatolia and other refugia of West Palearctic. Inferences from these studies indicate that evolutionary consequences of climatic cycles are different in south and northern parts of the Anatolian refugium. This difference is possibly due to following reasons. First, altitudinal heterogeneity has special partake in north/south difference and presence of numerous discontinuous altitudinal chains played a special role especially by leading altitudinal range shifts. In turn, altitudinal range shifts lead formation of numerous long-term isolated rear edge populations. The southern edge populations were more stable and rapidly diverged, and produced a local endemic diversity. This case is especially prominent for cold demanding species/population. In contrary altitudinal heterogeneity is less prominent in the northern side, the area located in glacial/permafrost borders during glacial period. Such conditions prevented long-term isolated populations. Opposite to south of refugia, the northern edge population were trailing, periodically isolated and frequently hybridized. In consequence speciation process were much rapid in south of refugia compared to the north.

Key Words: Glacial phylogeography, Anatolian refugium, rapid speciation, Tettigoniidae

SYMPOSIA 10
ORTHOPTERA CONSERVATION

Organizer
Axel Hochkirch

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1. **Soňa Nuhlíčková, Ján Svetlík, Benjamín Jarčuška, Peter Kaňuch and Anton Krištín.** INSIGHTS INTO THE EVOLUTION AND ECOLOGY OF *Isophya beybien-koi*: LESSONS FOR THE CONSERVATION OF AN ENDEMIC BUSH-CRICKET.
2. **Axel Hochkirch.** THE IUCN SSC GRASSHOPPER SPECIALIST GROUP, THE SPECIES CON-SERVATION CYCLE AND FUNDING OPPORTUNITIES.
3. **Michael Sergeev, Sergey Storozhenko, Vladimir Molodtsov, Natalya Sokolova, Marya Kim-Kashmenskaya, Kristina Popova and Oxana Yefremova.** RARE ORTHOPTERA OF SOUTH SIBERIA AND ADJACENT AREAS: DISTRIBUTION PATTERNS AND ECOLOGO-GEOGRAPHIC MODELLING.

INSIGHTS INTO THE EVOLUTION AND ECOLOGY OF Isophya beybien-koi: LESSONS FOR THE CONSERVATION OF AN ENDEMIC BUSH-CRICKET

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The Bei-Bienko's Plump Bush-cricket (*Isophya beybienkoi* Mařan, 1958) is an en demic species in the Slovak Karst (Slovakia, Central Europe). The bush-cricket is listed as Critically Endangered in the IUCN Red List, as it occurs only in small and isolated populations and has a negative demographic trend. This flightless species inhabits a very specific habitat characterized by steep rocky grasslands or scrublands at the edge of karst plains (400–800 m a.s.l.). The main threat to this endemic bush-cricket seems to be the intensive change in vegetation cover in recent decades, especially due to the abandonment of traditional grazing combined with forest overgrowth. To understand how to mitigate specie's decline and prevent its extinction, we have analyzed the genetic structure of the species in relation to its demography, habitat suitability and individual dispersal ability. This novel information increases our knowledge of evolutionary mechanisms involved in the survival of fragmented populations. Our findings are therefore crucial for the development of a conservation strategy and long-term habitat management for this endemic species.

Key Words: Central Europe, conservation, critically endangered species, endemism, Orthoptera, Slovakia.

Acknowledgements: The authors would like to thank the staff of the Slovak Karst National Park for their cooperation and help in the field. We also thank Stanislava Pekárová for her assistance with data collection. Finally, we thank the Mohamed bin Zayed Species Conservation Fund, which kindly supported this study.

THE IUCN SSC GRASSHOPPER SPECIALIST GROUP, THE SPECIES CONSERVATION CYCLE AND FUNDING OPPORTUNITIES

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The IUCN SSC Grasshopper Specialist Group was founded in 2010 with the aim to facilitate the conservation of Orthoptera and related insects throughout the planet. The group has currently 135 members from 47 countries. The activity of the group follows the "species conservation cycle", which contains the elements Assess, Plan, Act, Network and Communicate. (1) Assess: Red List assessments have been a major goal of the group as only 74 Orthoptera species had been assessed for the IUCN Red List prior to 2010. Meanwhile, a total of 1,495 Orthoptera species, 104 Phasmida and 38 Mantodea have been assigned a Red List status, with more than one third being listed as threatened (i.e. either Critically Endangered, Endangered or Vulnerable). Orthoptera data have also contributed to new IUCN standards, such as the Key Biodiversity Standard and the Green Status of species assessments. (2) Plan: Conservation Planning is an important part of the work of the GSG. Conservation action plans have been crated for Prionotropis rhodanica, Zeuneriana marmorata and Peripodisma ceraunii, facilitating fund raising for conservation projects for these species, including 1.9 million Euro fun-ding by the EU LIFE Programme for P. rhodani-ca. (3) Act: Conservation Action is the priority of the SSC. The implementation of conservation action plans has led to improvements of habitat management and ultimately the population of threatened Orthoptera. Many conservation projects of GSG members have been supported by the Mohamed bin Zayed Species Conservation Fund. (4) Network: The IUCN SSC Grasshopper Specialist Group colla-borates with many other IUCN groups, including the Conservation Planning Specialist Group, the Species Monitoring Specialist Group, the KBA Standards and Appeals Committee, as well as the IUCN secretariat. The group has increased substantially since its foundation, covering now also underrepresented regions, such as Asia and Africa. The regional vice chairs are Charly Oumarou Ngoute (Africa), Dhaneesh Bhaskar (India), Soňa Nuhlíčková (Europe), Tara Murray (Astra-lia / Oceania), Celeste Scattolini (South Ame-rica), Ricardo Mariño-Pérez (North and Meso-America), Edward Baker (Phasmida) and Roberto Battiston (Mantodea). (5) Communicate: The GSG publishes a newsletter called "Newshopper". We are also organizing workshops and symposia (such as this symposium on Orthoptera conservation). Our members regularly publish scientific papers on Orthoptera conservation. We are still keen to accept new members who want to engage in Orthoptera conservation. The IUCN SSC particularly aims to increase diversity, and there is still a strong male bias in the Grasshopper SG as well as a bias towards members from Euro-pe. We also want to encourage young Orthopterists to join us.

Key Words: insect conservation, IUCN, Red List

RARE ORTHOPTERA OF SOUTH SIBERIA AND ADJACENT AREAS: DISTRIBUTION PATTERNS AND ECOLOGO-GEOGRAPHIC MODELLING

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The orthopteran fauna of South Siberia and adjacent territories includes several genera and many species with limited ranges and/or with low abundance. The area of this region is comparable with the area of Europe, but a few orthopterists worked and continue to work here. This is why we don't commonly have real data concerning many populations and statuses of many of them are not known. This results either in some dubious suggestions concerning some species or, on the contrary, in missing some species prospective for global and regional conservation programmes.

The local endemics and subendemics are from the families Prophalangopsidae and Pamphagidae, the subfamilies Zichynae, Odonturinae, Conophymatinae, Melanoplinae, Gomphocerinae etc. and the tribes Drymadusini, Bergiolini, Platycleidini, Hypernephiini etc. The enigmatic *Cophoprumna surda* (Melanoplinae) is known only from the type locality.
The comparative analysis of species ranges shows that the distribution of several rare taxa (*Eremippus simplex, Mesasippus arenosus, Aeropedellus baliolus, A*. reuteri et al.) did not change significantly during last decades, but *Asiotmethis jubatus, Stenobothrus carbonarius, Sphingonotus coerulipes* and some others became extremely rare. In the steppes of West Siberian Plain, the Siberian grasshopper *Gomphocerus sibiricus* was one of the main pest species in the first half of 20th century and became very rare in the beginning of the 21st century.

The Maxent algorithm (Phillips et al., 2006, 2011) and several sets of environmental variables from different sources were used to model the species distribution over the region.

Our results show that, in many cases, the set of the so-called standard bioclimatic variables is not enough for good spatial forecasts due to small numbers of localities and their performance remains relatively low (the area under the receiver operating characteristic curve values are lower than 0.9), but after adding some variables (solar radiation, elevations, soil types and/or vegetation characteristics), reliability of models can increase significantly. This is true for both plain and mountain endemics.
These studies were financially supported by the grant of the Russian Science Foundation 22-66-00031 (https://rscf.ru/en/project/22- 66-00031).

Key Words: Endemic, Biodiversity, Species Range

ORAL SESSIONS

ORAL SESSION A

SYSTEMATICS & PHYLOGENETICS

Chairman: Jorge H. Medina

1. **Hojun Song, Seunggwan Shin, Austin J. Baker, Jacob Enk, and Duane D. McKenna.** ADVANCES IN PHYLOGENOMICS OF ORTHOPTERA.
2. **Olivier Béthoux, Dong Ren and Jun-Jie Gu.** FROM PROTORTHOPTERA TO STEM-ORTHOPTERA.
3. **Jeanne Agrippine Yetchom Fondjo and Martin Husemann**. INTEGRATIVE TAXONOMY OF DIFFERENT GRASSHOPPER GENERA FROM THE HUMID FOREST ZONES OF CAMEROON.
4. **Daniela Matenaar.** NEW FINDINGS REGARDING EXTERNAL MORPHOLOGICAL CHARACTERISTICS OF *Betiscoides Sjöstedt*, 1923: A USE CASE FOR APPLYING EXTENDED DEPTH OF FIELD 3D IMAGERY TO TACKLE THE CHALLENGES OF CRYPTIC DIVERSITY IN SPECIES DELIMITATION AND TAXONOMY.
5. **Carla de Loera, David B. Weissman, David A. Gray and Hojun Song.** PHYLOGENETIC COMPARATIVE ANALYSIS OF STRIDULATORY APPARATUS AND CALLING SONGS OF FIELD CRICKET GENUS *Gryllus* (ORTHOPTERA: *GRYLLIDAE: GRYLLINAE*)
6. **Brandon Woo, Julianne Allred , Jackson Linde, Jorge Medina Duran , Hojun Song**. THE PHYLOGENY OF PYGMY MOLE CRICKETS (*ORTHOPTERA: TRI-DACTYLIDAE*) AND THEIR RELATIVES USING PHYLOGENOMIC DATA
7. **Jorge H. Medina-Duran & Hojun Song.** THE REVISION OF EUGREGARINES (APICOMPLEXA) IN THE ORTHOPTERA (INSECTA).
8. **Riffat Sultana.** ONE NEW SPECIES OF THE GENUS *Hieroglyphus Krauss*, 1877 (ORTHOPTERA: ACRIDIDAE: HEMIACRIDINAE) FROM KASHMOR SINDH, PAKISTAN

ADVANCES IN PHYLOGENOMICS OF ORTHOPTERA

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With advances in high-throughput sequencing and bioinformatics techniques, we are currently witnessing revolution in the field of insect phylogenetics. Novel phylogenetic hypotheses for major insect orders have been proposed based on phylogenomic data, both confirming and challenging previous hypotheses based on small number of genes and/or morphology. One of the most promising methods for phylogenomic data generation is a technique known as target enrichment which uses hybrid capture probes (or baits) to collect specific genes of interest prior to sequencing. This approach generally targets single copy orthologs with an appropriate amount of variation for phylogenetic analysis. The targeted genes are enriched after hybridization, which greatly increase the coverage of genes of interest for final sequencing. Furthermore, due to the enrichment process, this method does not require live specimens or freshly collected samples, and it can even be applied to dried museum samples, thus applicable to a much greater taxon sampling. Using available and newly produced genomic resources, we have developed an Orthoptera-specific target enrichment (OR-TE) probe set as a new phylogenomic toolkit for the orthopterist community. Specifically, we first compiled transcriptome data from 80 orthopteran species across the phylogeny, 30 of which were newly generated, as a new genomic resource to identify phylogenetically informative orthologs. From this initial set of orthologs, we identified both slow-evolving and fast-evolving loci that could resolve relationships at different scales to narrow down the number of target loci to 1,828, which were used to develop target enrichment probes. We designed and manufactured a custom-designed probe set with 39,809 baits, and validated the effectiveness of this probe set by generating target captured loci from 36 orthopteran species across the phylogeny, which were used for inferring the phylogeny of Orthoptera. We explicitly documented the process of probe design and bioinformatics procedures, so that this newly developed tool can be widely adopted and used by the orthopteran systematist community and beyond. We also extensively tested this new tool for resolving relationships across broad taxonomic scales from higher-level to species-level and both Caelifera and Ensifera. We demonstrate the utility of this tool and the potential for broader use.

Key Words: Target enrichment, molecular phylogeny, genomics

FROM PROTORTHOPTERA TO STEM-ORTHOPTERA

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At the end XXth century a large proportion of Late Carboniferous insects were classified as 'Protorthoptera', best understood when considering 'Proto-' as the equivalent of our modern 'stem-', and '-orthoptera' in its wide sense, in other words more or less equivalent to our modern 'Polyneoptera'. Indeed, the Protorthoptera proved to be a mixture of stem-groups of various polyneopteran lineages and, possibly, including genuine stem-Polyneoptera (besides groups of yet unknown affinities). In the last 20 years revisions of known material and descriptions of new specimens from various localities, in particular from the Carboniferous, led to tentative identifications of genuine stem-Orthoptera among the protorthopteran ragbag, essentially based on characters of wing venation. The idea of a prevalence of relatives of Orthoptera in early insect faunas emerged, although the actual affinities of the corresponding fossil taxa, and notably the 'lobeattids', remained debated. Discoveries made at the Xiaheyan locality (Ningxia, China) provided decisive inputs, in two res-pects. Firstly, the abundant, exhaustive sample made it possible to provide, for the first time, reliable quantitative data on the abundance of the various insect species occurring in a Late Carboniferous locality. Secondly, it has been possible to observe, in superbly preserved female specimens of a lobeattid species, *Ctenoptilus frequens*, the occurrence of an ovipositor provided with two valve-interlocking mechanisms, a unique apomorphy of Orthoptera. It follows that lobeattids are stem-Orthoptera. The new data depict early relatives of Orthoptera as both abundant and highly diversified as early as 315 million years ago.

Key Words: fossil, Carboniferous, wing venation, ovipositor

INTEGRATIVE TAXONOMY OF DIFFERENT GRASSHOPPER GENERA FROM THE HUMID FOREST ZONES OF CAMEROON

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The Cameroon humid forest zone has long been considered as the most species-rich zone in Central Africa due to its high diversity of flora and fauna. However, this forest biodiversity is still understudied, and is undergoing heavy deforestation. Despite the high level of deforestation, little taxonomic work has been done on grasshoppers in Cameroon. Currently, the taxonomic and systematic position of several cameroonian Orthoptera groups are controversial, the species boundaries within grasshopper groups being unclear and requiring further studies.

In the present work we explored the taxonomic positions of several groups of cameroonian grasshoppers of the subfamilies Catantopinae, Coptacrinae, Oxyinae and Pyrgomorphinae, using an integrative approach that combines morphological studies, particularly of the phallic complex, with standard DNA barcoding.

The results showed that all known species are clearly distinct and are identifiable by DNA barcoding. In addition, we discovered cryptic diversity in several groups. High interspecific distances were found between species of several genera. The combination of morphological features and genetic sequence data enabled us to distinguish species that were previously over-looked and misidentified in several genera.

Our data show that the diversity of Cameroon grasshoppers has been underestimated and new species can be readily discovered using an integrative approach. A future use of additional molecular markers may be especially useful for taxa in which barcodes alone did not result in distinct patterns.

Key Words: ICO2023, Systematic, DNA barcoding, Afrotropical areas

NEW FINDINGS REGARDING EXTERNAL MORPHOLOGICAL CHARACTERISTICS OF *Betiscoides Sjöstedt*, 1923: A USE CASE FOR APPLYING EXTENDED DEPTH OF FIELD 3D IMAGERY TO TACKLE THE CHALLENGES OF CRYPTIC DIVERSITY IN SPECIES DELIMITATION AND TAXONOMY

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Discovering and handling cryptic diversity among species challenges taxonomists around the world. Up to date, the drivers of cryptic diversity are not fully understood and consequently the global distribution of cryptic diversity remains unclear. For instance, it is not proven, that cryptic diversity is higher in tropical than in temperate regions. However, there is a tendency towards a correlation of diverse habitat structure and high rates of diversification with increased occurrence of cryptic diversity. South Africa houses one of the earths' six floral kingdoms and is known for its tremendous biodiversity, including high numbers of endemic species and a high level of cryptic diversity. Genetic analyses of the lentulid ge-nus *Betiscoides* Sjöstedt, 1923 revealed a high number of divergent evolutionary lineages and - at first sight -, high cryptic diversity within this genus. Detailed and extended depth of field imagery enabled a novel assessment of the external morphological characteristics used for defining and describing the genus *Betiscoides* Sjösdtedt, 1923, leading to a new definition of the genus' characteristics as well as a revision of some character traits of B. parva Key, 1937. An integrative taxonomic approach revealed, inter alia, plastic morphological characters within potential new species. Some of the external characters were only identified by using 3D imagery metadata, exposing differences in the levels of specific structures from a lateral point of view. In this study, *Betiscoides* served as a use case for applying extended depth of field 3D imagery to unravel external morphological characters in "cryptic" species. Firstly, these findings shall contribute to promote efforts being made to establish image based taxonomic identification for researchers worldwide. Secondly, they shall enable stakeholders (field rangers etc.) to identify specimens or species groups in the field without applying time consuming and technical demanding ex situ equipment and analyses on the long term; despite the difficulties in detecting fine scale morphological differences in living individuals that still prevail at the moment. Considering the facts, that identification apps and the underlying AI are ubiquitously accessible and will gain increased importance in the future, while simultaneously imaging techniques are rapidly improving whilst getting affordable, it will become much easier in the future to apply those tools in the field and gain successful identification. This study was partly funded by Deutsche Forschungsgemeinschaft (DFG project nr. 495869174).

Key Words: cryptic diversity, image based taxonomic identification, *Betiscoides*

PHYLOGENETIC COMPARATIVE ANALYSIS OF STRIDULATORY APPARATUS AND CALLING SONGS OF FIELD CRICKET GENUS *Gryllus* (ORTHOPTERA: GRYLLIDAE: GRYLLINAE)

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The genus *Gryllus* in North America includes familiar field crickets that fill the soundscape of summer nights. There are about 35 recognized species in the U.S. which are externally very similar and can only be identified to species based on male calling songs. Crickets produce songs by rubbing their forewings against each other, and it is known that the differences in the shape of stridulatory apparatus could lead to differences in calling songs. Calling songs differ among species in terms of the number of chirps per second and pulses per chirp. However, it has not been fully investigated whether there is any correlation between the morphology of stridulatory apparatus and the parameters of male calling songs. In this presentation, we examine the evolution of the stridulatory apparatus and male calling song of the North American *Gryllus* in a phylogenetic framework.

Key Words: Cricket, character evolution, communication, song

THE PHYLOGENY OF PYGMY MOLE CRICKETS (ORTHOPTERA: TRIDACTYLIDAE) AND THEIR RELATIVES USING PHYLOGENOMIC DATA

Brandon Woo[1], Julianne Allred[2], Jackson Linde[2], Jorge Medina Duran[2], Hojun Song[2]
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Pygmy mole crickets (Orthoptera: Tridactylidae) are a fascinating and ancient group of insects that have received little scientific attention. Their phylogenetic position as an early-branching lineage of Caelifera is wellsupported, but internal relationships remain unknown, and a phylogeny of the family has never been published. Current classification of subfamilies and genera is based entirely upon morphology and has never been rigorously tested. Here we present the first preliminary molecular phylogeny of the group, utilizing phylogenomic data for about 50 taxa, focusing mainly on the North American fauna. The monophyly of Tridactyloidea is supported, as well as the relationships between its constituent families Tridactylidae, Ripipterygidae, and Cylindtrachetidae. Relationships within Tridactylidae are discussed, particularly in lineages where current hypotheses are discordant with those of prior morphological studies. Future work will incorporate additional taxa and explore the biogeography of the North American fauna.

Key Words: ICO2023, Merida, Pygmy mole cricket

THE REVISION OF EUGREGARINES (APICOMPLEXA) IN THE ORTHOPTERA (INSECTA)

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The Eugregarinorida (Fig. 1) is a highly diverse group of apicomplexan parasites that is closely related to parasites of medical concern such as malaria. Eugregarines are characterized by infecting a wide range of invertebrate phyla and possessing large extracellular life stages. These features have enabled the description of multiple species, resulting in abundant literature on their morphologies and their associations with their hosts. Despite the wealth of morphological data, no comprehensive quantitative morphological analysis of these parasites has been conducted to date. Thus, we have undertaken a thorough revision and meta-analysis of the eugregarines described for orthopteran insects, which harbor the second-highest number of gregarine species with more than 120 gregarine species in approximately 370 host species.

By compiling qualitative traits, host associations, and linear and shape morphometric data of gregarine infect stages from existing taxonomic descriptions that span two hundred years, we aim to assess the validity of current taxonomical classifications, clarify morphospecies boundaries, evaluate the diagnostic value of morphological traits, and identify patterns of host specificity. Based on this framework, we propose recommendations for standardizing gregarine taxonomic descriptions.

Integrating the wealth of morphological data with the emerging phylogenetic and genomic perspectives of their diversity is crucial for understanding gregarine biology, host specificity, distribution, and the drivers of their diversity. Our study serves as a model for future research on the morphological diversity of gregarines in other insects and invertebrate hosts, and to ultimately advance gregarine research towards the field of evolutionary ecology.

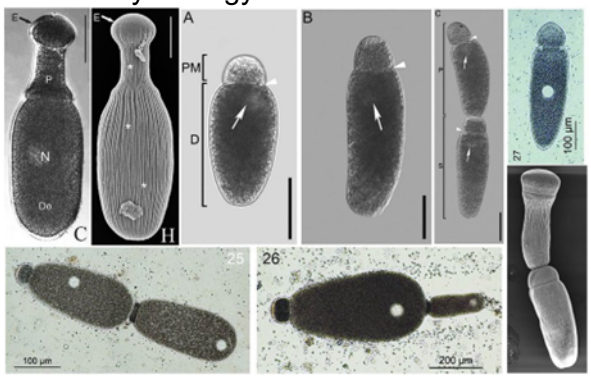

Figure 1. Overview of diversity of trophozoites, gamonts and associations of eugregarines

Key Words: Meta-analysis, gregarines, Orthoptera

ONE NEW SPECIES OF THE GENUS Hieroglyphus Krauss, 1877 (ORTHOPTERA: ACRIDIDAE: HEMIACRIDINAE) FROM KASHMOR SINDH, PAKISTAN

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THE genus *Hieroglyphus* Krauss 1877 is represented by six species from Pakistan, including one new species reported herein, and 14 known species worldwide. *Hieroglyphus Kashmorensis* sp. nov. was collected from district Kashmore (28.432997o N 69.583710o E) and described based on its morphology and genitalic components. The sulcion the pronotum are moderate, with the anterior sulcus being bow-shaped and the posterior sulcus curved at the center. The prosternal process is conical, and unlike in H. *kolhaporinesis*, the second sulcus line in this new species is depressed rather than continuous towards the lateral line with a large black deep line. An identification key for all known Pakistani *Hieroglyphus* species is provided, along with data on taxonomic descriptions, host plants, occurrence, and distribution, and observations on the ecology of each species. Proper identification and understanding of the host plants and habitats of these species is crucial for devel-oping effective management strategies against pests of cultivated crops.

Key Words: *Hieroglyphus Kashmorensis* sp. nov, Pakistan, Kashmore, morphology, effective management

ORAL SESSION B

DEVELOPMENT & PHYSIOLOGY

Chairman: Esaú Ruíz

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1. **Sydney Millerwise, Stav Talal, Phoenix Pulver, Emma Goethe, Geoffry Osgood, Emily Cossey, Rick Overson, Jon Harrison, and Arianne Cease**. FOOD, AGING, AND BABIES; HOW MACRONUTRIENT BALANCE AFFECTS *Locusta migratoria* (Linnaeus, 1758) LIFESPANS AND LIFETIME REPRODUCTION.
2. **Mehreen Tahir, Tamir Lichaa, Jon Harrison, Rick Overson, Stefan Jaronski, and Arianne Cease.** THE EFFECT OF MACRONUTRIENT CONSUMPTION ON SUSCEPTI-BILITY TO PATHOGENIC INFECTION IN DESERT LOCUST, *Schistocerca gregaria*.
3. **Christopher Brennan and Spencer Behmer.** THREE'S A CROWD: HOW DENSITY AND TEMPERATURE GUIDE NUTRIENT REGULATION IN A PHENOTYPICALLY PLASTIC HERBIVORE.
4. **Vivian Peralta Santana and Hojun Song.** MOTHER KNOWS BEST: UNRAVELING THE TRANSCRIPTOME OF FEMALE DESERT LOCUST ACCESSORY GLAND AFTER MATING.

FOOD, AGING, AND BABIES; HOW MACRONUTRIENT BALANCE AFFECTS *Locusta migratoria* (Linnaeus, 1758) LIFESPANS AND LIFETIME REPRODUCTION

Sydney Millerwise[1], Stav Talal[1], Phoenix Pulver[1], Emma Goethe[2], Geoffry Osgood[1], Emily Cossey[1], Rick Overson[1], Jon Harrison[1], and Arianne Cease[1,2]

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Macronutrient consumption influences several important life history characteristics including survival and reproduction across animal taxa. Diets with a high protein to carbohydrate ratios tend to increase reproductive rates and ultimately result in lower lifespans, potentially due to a high cost of reproduction. Many orthopterans show a pattern of female lifespans being more susceptible to differences in macronutrient content compared to males, potentially due to the costs of different reproductive strategies. To test how macronutrients affect reproduction and ultimately lifespans, we reared the migratory locusts (*Locusta migratoria*) from 5th instar through adulthood on one of three artificial isocaloric diets varying in protein (p): carbohydrate (c) ratios (14p:28c; 21p:21c; 35p:7c). We then put pairs of locusts in cages to measure male and female survival, the number of eggs and egg pods laid, and total lifetime hatchlings per reproductive pair. We found that macronutrient consumption had limited effect on total eggs laid and total hatchlings over the lifetime. Although there were significant differences in numbers of egg pods laid by locusts on each treatment, locusts consuming high p:c diets had the most eggs per pod, and eggs from the first few pods were significantly lighter than eggs laid by locusts on lower p:c diets. Female locusts on the highest p:c diet laid the fewest egg pods over their lifetimes, largely because these locusts had the shortest lifespans. However, male locusts across diet treatments had similar survival rates (Fig. 1). These results suggest that consumption of high p:c diets accelerates aging in reproductively active females, but not males, and that the lifespan-shortening effect of high p:c diets is not due to side-effects of reproduction. Other taxa showed similar effects of macronutrients on males and female lifespans, while orthoptera seem to show a common pattern of female lifespans being more sensitive than males. Macronutrient consumption has important implications for population dynamics of locusts by impacting numbers of eggs per egg pod, total egg pods laid over lifespans, and ultimately female mortality. This work was supported by NSF # 1942054.

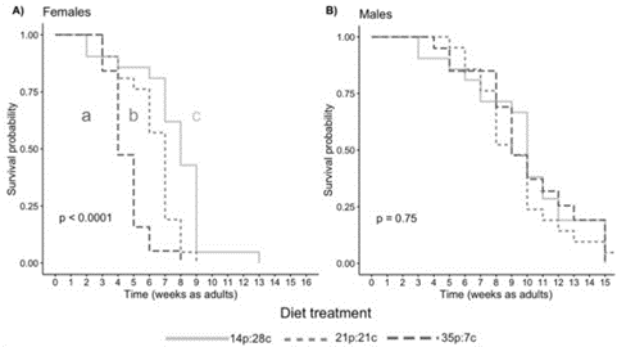

Figure 1. Kaplan–Meier analysis and log-rank tests show that *L. migratoria* (A) female survivorship was shortest on a high p:c diet, and longest on a low p:c diet and (B) male survivorship was not different across diet treatments.

Key Words: Macronutrients, reproduction, lifespan.

THE EFFECT OF MACRONUTRIENT CONSUMPTION ON SUSCEPTI-BILITY TO PATHOGENIC INFECTION IN DESERT LOCUST, *Schistocerca gregaria*

S. Mehreen Tahir[1], Tamir Lichaa[1], Jon Harrison[1], Rick Overson[1], Stefan Jaronski[2], and Arianne Cease[1]

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Locusts are grasshoppers that exhibit density-dependent phase polyphenism and can migrate long distances in massive groups causing devastating impacts on agriculture. Fungal *Metarhizium spp*. biopesticides may be a viable alternative to synthetic chemical pesticides, however, challenges in their efficacy re-main. Australian plague locusts (*Chortoicetes terminifera*) that select higher protein (p) to carbohydrate (c) diets mount a higher constitutive immune response than locusts selecting low p:c diets yet have lower survival rates. Migratory grasshoppers (*Melanoplus sanguinipes*) eating either low or high p:c diets survive longer than those eating a balanced 1p:1c diet, furthermore, fungal sporulation post-mortem only occurs on grasshoppers fed 1p:1c diets. These two studies suggest that different mechanisms may affect locust survival when eating high p vs high c diets, however these responses are poorly understood. We tested the effect of macronutrient balance on the ability of the desert locust (*Schistocerca gregaria*) to stave off the pathogen. Infected final instar locusts were restricted to a carb- or protein biased, or a balanced diet. *Metarhizium* inoculation suppressed phenoloxidase (PO) activity at day 3 but not prophenoloxidase (Pro-PO), possibly because the infection utilizes and removes PO or because production of Pro-PO is inhibited. Preliminary results showed that higher protein diets were associated with higher Pro-PO levels, but this was not associated with higher survival. Inoculated desert locusts eating protein-biased diets tended to die sooner than locusts eating higher carb diets, similar to the pattern found for Australian plague locusts. Thus, for locusts eating high carbohydrate diets, *Metarhizium* may be suppressed not through locust immune response, but through other pathways, potentially because the fungus is starved of protein. These results suggest that in the field, *Metarhizium* treatments may act more quickly on locusts eating high protein plants.

Key Words: *Metarhizium*, Biopesticide, Phenoloxidase, Locusts, & Immune response

THREE'S A CROWD: HOW DENSITY AND TEMPERATURE, GUIDE NUTRIENT REGULATION IN A PHENOTYPICALLY PLASTIC HERBIVORE

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Nutrition and temperature are two complex factors that affect the lifespan, fecundity, mortality, and growth of organisms. These two factors also vary largely over time and location and thus successful organisms must adapt to the changing environment. One-way organisms adapt to environmental variation is through plastic traits. A prominent example of which is the density-dependent phenotypic plasticity of the desert locust, *Schistocerca gregaria.* While nutritional regulation has been heavily studied in this organism, past research has primarily contained only one density treatment, that being arenas with a singular locust. However, gregarious locusts exist in groups which can drastically change their behavior, physiology, and nutritional availability. Therefore, the role of density needs to be investigated to fully understand nutritional regulation in locusts. This study aims to investigate if macronutrient regulation varies across densities, to identify differences in feeding behavior across temperatures, and to examine the impact of temperature and nutrient availability on performance. To address these aims, final instar *S. gregaria* were randomly placed into one of three density treatments: (i) solo (by themselves), (ii) divided (with two conspecifics each separated by mesh), or (iii) free-roaming (with two conspecifics and no physical restrictions). Locusts in the first two treatments are each provided with their own food source. In the latter two treatments individuals can smell, see, and touch each other with risk of competition and cannibalism only being present in the free-roaming treatment. Solitary individuals were only exposed to the solo density treatment. Individuals were given a choice between two diets that vary in their protein-carbohydrate composition or restricted to a single diet, in ambient temperatures of 30°C or 34°C. We found that the ratio of protein-carbohydrates consumed when allowed to freely feed was robust to environmental variation with all treatments regulating to an intake target of 1P:1C. However, the regulation strategy employed when nutrients were restricted varied. At 30°C nutrient regulation was dependent on the phenotype of the locust whereas at 34°C the strategy was consistent across densities. At warmer temperatures all nymphs molted faster and had similar total consumption. However, unlike gregarious individuals, solitary nymphs had the same weight gain and total consumption across temperatures. These results suggest that solitary nymphs are more robust to environmental change and that, in high temperatures, phenotypic differences in nutritional regulation are not present.

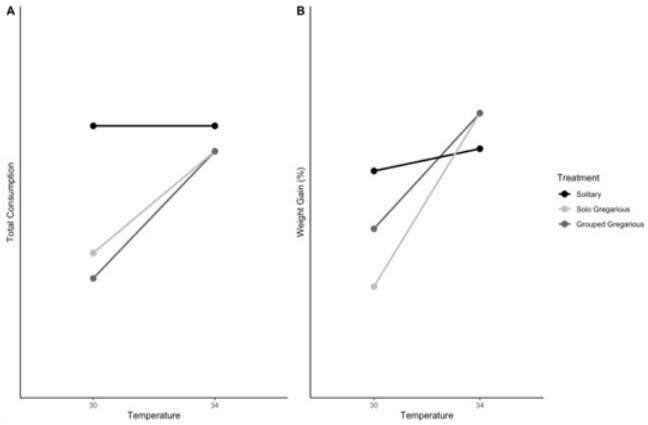

Figure 1. Reaction norms of performance measures (A) total consumption and (B) weight gain across temperatures.

Key Words: Nutritional regulation, Temperature, Phenotypic plasticity, *Schistocerca gregaria*

MOTHER KNOWS BEST: UNRAVELING THE TRANSCRIPTOME OF FEMALE DESERT LOCUST ACCESSORY GLAND AFTER MATING

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The desert locust, *Schistocerca gregaria*, displays one of the most prominent examples of phenotypic plasticity among insects. An increase in local population density causes shy, sedentary, and cryptic individuals (solitarious phase) to transform into highly active, gregarious, and conspicuous locusts (gregarious phase) that can migrate en masse. These traits fluctuate based on local population density but are also passed down via a maternal effect. The mother's experience of density at the time of oviposition affects the developmental trajectory of her offspring, leading them into a different phase state. An active compound deposited with the foam bathes their eggs during oviposition and is responsible for the phase status of the hatchling. Previous studies suggest that the foam is produced by the accessory gland of the female locust and that its identity may be an L-dopa analogue. We performed a study to explore and understand genes related to the accessory glands and accessory tract before oviposition, by analyzing the transcriptome profile of these tissues in females *S.gregaria* after mating and ex-posed to different treatments.

Figure 1: Gregarious (top) and Solitarious (bottom) phase of *S. gregaria*

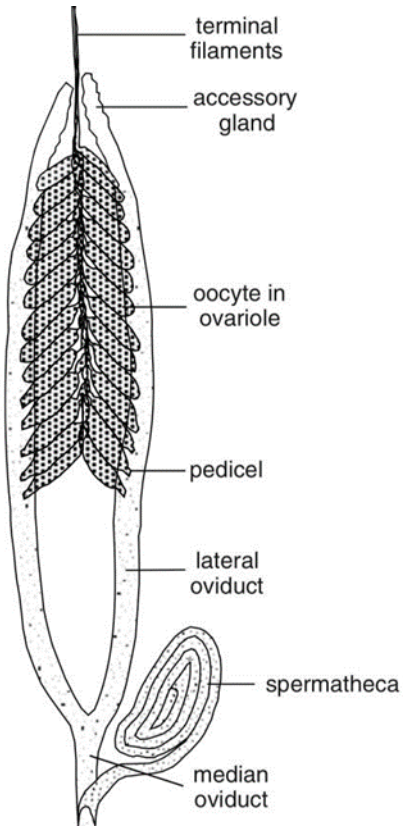

Figure 2: Diagram showing the reproductive tract of fe-male Schistocerca. Accessory glands are above ovarioles.

Key Words: Accessory Gland, *Schistocerca*, Phenotypic Plasticity, Maternal Effect

ORAL SESSION C

POPULATION BIOLOGY & MANAGEMENT

Chairman: Ludivina Barrientos

1. **Robert Srygley.** FOOD, LIGHT, WATER, OR HEAT: WHICH FACTORS AFFECT MORMON CRICKET EGG DIAPAUSE? - *Anabrus simplex* (Haldeman, 1852).
2. **Alain Simeu-Noutchom, Sévilor Kekeunou, Alain Christel Wandji, Marcelle Mbadjoun nzike Alfiery and Laurel Djomnang Nkwala.** IMPACT OF THE TYPE OF VEGETATION AND SOIL PHYSICOCHEMICAL PROPERTIES ON THE OCCURRENCE OF MOLE CRICKET (ORTHOPTERA: *GRYLLO-TALPIDAE*) IN CAMEROON.
3. **Jeram Das and Riffat Sultana**. UNCOVERING THE NATURAL PREDATORS OF LOCUST AND GRASSHOPPER IN THE THAR DESERT OF PAKISTAN.
4. **Mamour Toure, Arianne Cease, Marion Le Gall, Amadou Fall, Alana Burnham and Alioune Beye**. COMMUNITY-BASED PEST MANAGEMENT IN THE GROUNDNUT BASIN IN SENEGAL: MILLETFERTILIZATION DECREASES SENEGALESE GRASSHOPPER (*Oedaleus senegalensis*) (Krauss,1877) DAMAGE AND INCREASES YIELD.
5. **Jackson B. Linde and Hojun Song**. INVESTIGATING POPULATION STRUCTURE AND GENE FLOW IN MORMON CRICKETS, *Anabrus simplex* (Haldeman, 1852) USING POPULATION GENOMICS.
6. **Alyssa Canova, Maeva Techer and Hojun Song.** POPULATION STRUCTURE AND SPATIAL PATTERNS OF GENETIC DIVERSITY IN THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons* (ORTHOPTE-RA: ACRIDIDAE).
7. **Wim C. Mullié, Adam Prakash, Alexander Müller and Elena Lazutkaite**. INSECTICIDE USE AGAINST DESERT LOCUST IN THE HORN OF AFRICA 2019–2021 REVEALS A PRESSING NEED FOR CHANGE.
8. **Santosh Kumar and Riffat Sultana.** RARE SIGHTING OF *Poekilocerus pictus* IN THE ARID CHOLISTAN DESERT OF PUNJAB, PAKISTAN.
9. **Michael Sergeev, Vladimir Molodtsov, Irina Van'kova, Muratbek Childebaev, Natalya Sokolova, Marya Kim Kashmenskaya, Kristina Popova and Oxana Yefremova.** THE ITALIAN LOCUST *Calliptamus italicus* (L.) IN THE NORTH-EASTERN PARTS OF ITS RANGE: WHAT WILL THE FUTURE BRING?

FOOD, LIGHT, WATER, OR HEAT: WHICH FACTORS AFFECT MORMON CRICKET EGG DIAPAUSE? – *Anabrus simplex* (Haldeman, 1852)

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Improving our ability to forecast outbreaks of Mormon crickets would greatly assist land managers in preparations for control efforts. Conventionally, Mormon crickets are thought to have an annual life cycle and require a single winter in diapause to hatch, but a population high in the Bighorn Mountains of Wyoming was described as biennial with a delay in embryonic development until the second growing season and hatching every other year. Recently, I buried eggs from the Bighorn Mountain population (2800 m) across an elevational gradient from 1200-2800 m. Monitoring development and hatching, I observed a median hatching time of two years to at least seven years, depending on the elevation and microhabitat. Hence, Mormon crickets are best described as a plurennial species. The eggs were derived from identical genetic stock with the same proportions of siblings buried at each location. Hence, differences in development rate were mainly due to environmental differences across elevation, such as cooler soil temperatures and greater moisture at high elevations relative to lower ones. In a laboratory study, Mormon cricket eggs from the Bighorn Mountain population postponed development during drought. However, restoration of moisture did not lead to a sudden increase in the number of eggs developing and hatching. The parental environment also influenced the duration that eggs were in diapause. Parental photoperiod, body temperature, and nutrition all had some effect on embryo development and the amount of time that eggs remained in diapause. The thermal performance curve for embryonic development in the Bighorn Mountain population was best described by a Gaussian curve with a peak at 27°C, and critical thermal minimum and maximum equal to 20°C and 34°C. Due to aestivation in later stages of development, the optimum temperature declined to 24°C and the performance breadth narrowed to 10°C. These thermal constraints on development have major impacts on the embryos buried across the elevational gradient. At high elevation sites, the season for embryonic development is short and embryonic growth can only occur when the soil heats up during the day. Hence, slow embryonic development is a natural consequence of temperatures at high elevation. In an environmental chamber with a cycling temperature set to optimize egg development, the median time for eggs from the Bighorn Mountain population to complete development was 104 weeks, on average. In other words, multiple growing seasons were required for half of the embryos to develop. Similarly, a population from the North Rim of the Grand Canyon (2800 m) had a median time to complete development of 125 weeks. In conclusion, prolonged egg diapause and cool temperatures enhance the persistence of Mormon crickets in high elevation egg beds.

Key Words: Maternal effects, Life-cycle, Hatch

IMPACT OF THE TYPE OF VEGETATION AND SOIL PHYSICOCHEMICAL PROPERTIES ON THE OCCURRENCE OF MOLE CRICKET (ORTHOPTERA: *GRYLLOTALPIDAE*) IN CAMEROON

Alain Simeu-Noutchom[1], Sévilor Kekeunou[1], Alain Christel Wandji[1], Marcelle Mbadjounnzike[1] Alfiery and Laurel Djomnang Nkwala[2]

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Mole crickets are burrowing insects known to be serious crop pests because of their feeding on the root system. Successful mole cricket management requires knowledge of their ecology. The literature on the ecology of mole crickets is still very little known, despite their proliferation in many types of vegetation in Cameroon. With a view to setting up control mechanisms for these pests, we carried out this work, whose main objective is to assess the impact of habitat characteristics on the occurrence of mole crickets.

Data collection was done in three agroecological zones in Cameroon. In each area, four types of vegetation, namely forest, agroforestry, fallow land, and a crop field, were surveyed. In each type of vegetation, mole crickets were collected through pitfalls, and soil characteristics such as pH, humidity, and sand content were evaluated. The results show the occurrence of mole crickets was affected by the type of vegetation and soil properties. Mole crickets were more frequent in crop fields and grassy fallows than in agroforestry and forests. The occurrence of mole crickets was higher in soils with a pH range of]5-6] and was very low in soils with a pH range of]3-4] "Fig. 1". The occurrence of mole crickets was higher in soils with a moisture content between 5% and 20%, while it was very low between 20% and 35%. The occurrence of mole crickets was higher in soils whose sand content was between 40% and 55% and very low between 25% and 40%.

These results are an asset that will aid in implementing sustainable management control of mole cricket in Cameroon.

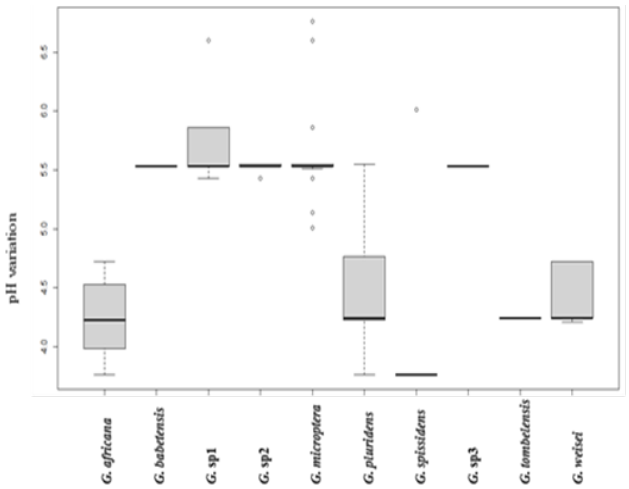

Figure 1. *Gryllotalpa* species occurrence according to soil pH variation.

Key Words: *Gryllotalpa*, pest, ecology, soil

UNCOVERING THE NATURAL PREDATORS OF LOCUST AND GRASSHOPPER IN THE THAR DESERT OF PAKISTAN

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The Thar Desert in Sindh, Pakistan is known for its diverse array of locust and grasshopper species, many of which can cause significant damage to crops and other vegetation. In order to develop effective strategies for managing these pests, it is important to understand the natural predators that exist in the ecosystem. This study aimed to identify and document the natural predators of locust and grasshopper in the Thar Desert.

We conducted several field surveys in various habitats across the desert during 2022-2023, collecting specimens of both the pests and their predators. These specimens were then identified using morphological and molecular techniques. During the field survey, it was observed that the parasitic wasp of the genus Scelio targets the eggs of many grasshoppers. *Stomorhina lunata*, a fly that looks like the housefly, often travels along with swarms of locusts and is an egg predator of locusts. The larvae of *Systoechus*, a beefly, nourish themselves on grasshopper eggs by piercing them and sucking the sub-stance. The larvae of Trox procerus, a beetle, feed on the eggs of the desert locust. Places crowded with ants (Formicidae) occasionally feed on newly emerged hoppers. The species of Sphex, a digger wasp, attack and paralyze grasshoppers. Then they pull away, lay an egg on each grasshopper, and bury them along with their eggs in the soil." The natural predators found in the Thar Desert are helpful for the biocontrol of locust and grasshopper pests to prevent the damage of seasonal crops in the area. The results of this study have important implications for the development of integrated pest management strategies in the Thar Desert. By identifying the natural predators of locust and grasshopper species, it may be possible to develop more sustainable and environmentally friendly approaches to pest control, such as promoting the presence of these predators in agricultural landscapes.

Key Words: Thar Desert, Locusts, Grasshoppers, Predators, Scelio, *Stomorhina, Systoechus* Praying Mantis, Biocontrol, IPM.

COMMUNITY-BASED PEST MANAGEMENT IN THE GROUNDNUT BASIN IN SENEGAL: MILLETFERTILIZATION DECREASES SENEGALESE GRASSHOPPER (*Oedaleus senegalensis*) (Krauss,1877) DAMAGE AND INCREASES YIELD

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Oedaleus senegalensis (Krauss, 1877) is a widespread pest in the Sahel and causes significant losses of food crops. This insect prefers nitrogen-poor plants, with low protein and high carbohydrate contents, in natural and laboratory environments. The main objective of this study was to scale up results from prior studies to implement a soil amendment intervention at the community level. We worked with 100 farmer participants from two villages in the Kaffrine and Fatick regions of Senegal. Each farmer delineated one hectare of their millet for control and amended another hectare with the ISRA recommended application of fertilizer for millet in the region. We found that, in fertilized fields as compared to control fields, (a) millet leaf protein: carbohydrate ratio increased; (b) *O. senegalensis* densities and grasshopper damage were decreased by an average of 34.42% and 51.92%, respectively; (c) and millet yield was increased by 45.74%. Further, millet leaf protein: carbohydrate ratio was negatively correlated with *O. senegalensis* densities and positively correlated with millet yield. These results suggest that community-based management that increases soil fertility for cereal crops has the dual benefit of enhancing crop growth and creating an unfavorable nutritional environment for a major Sahelian pest, ultimately increasing yield and improving food security.

Table 1: Protein/Carbohydrate ratios at Gossas

Field types	Mission 1	Mission 2	Mission 1 et 2
Unfertilized field	0.913	1.268	1.008
Fertilized Field	1.088	1.504	1.223

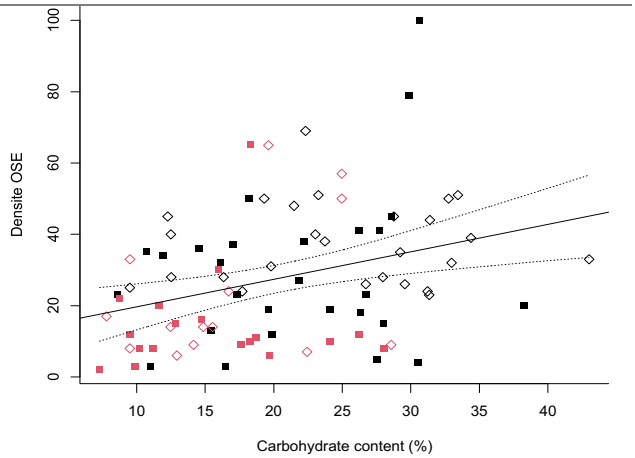

Figure 2: Effect of millet leaf carbohydrate content on OSE density in fertilized (filled squared) and control fields (empty diamonds) in Gossas for the first (black) and second (red) mission. Lines correspond to an adjusted linear model and its confidence interval at 95% for all points together.

Key Words: *Oedaleus senegalensis*, density, nitrogen, production, millet

INVESTIGATING POPULATION STRUCTURE AND GENE FLOW IN MORMON CRICKETS, *Anabrus simplex* (Haldeman, 1852) USING POPULATION GENOMICS

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Mormon crickets, *Anabrus simplex* (Haldman, 1852), are a species of katydid or bush cricket found east and west of the Rocky Mountains in North America. Some populations are considered gregarious "phase", while others are considered solitary. Gregarious phase populations band together and march long distances while solitary phase populations do not. Previous work based on mitochondrial DNA suggested a pattern of solitary populations existing broadly east of the Rocky Mountains and gregarious populations being more restricted to the west. While this work has allowed for the characterization of gene flow and population structure in these katydids to an extent, next generation sequencing which provides vital population-level resolution, has yet to be applied to this system. To test the veracity of the hypothesis that gene flow is limited by the geographic barrier imposed by the Rocky Mountains, we have sequenced 90 genomes (3-5X) consisting of several individuals from 16 populations throughout the United States (see figure 1). This project has 3 major foci to illuminate population genomic patterns in Mormon crickets.

(1) Sequence the whole genomes of 90 individual Mormon crickets from 16 different populations of gregarious and solitary individuals. (2) Reconstruct a robust, population-level phylogeny of these sequenced Mormon cricket.

(3) Analyze the gene flow and population structure of these Mormon crickets.

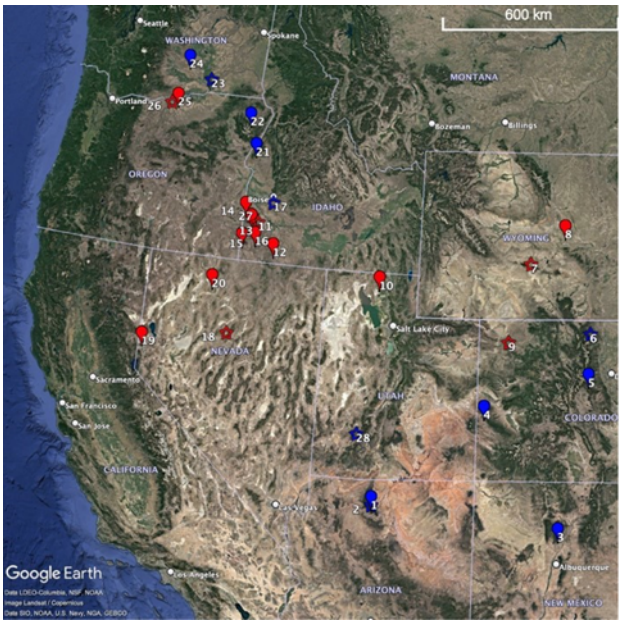

Figure 1. Overview of Mormon cricket populations collected for this study.

Gregarious phase populations are indicated in red, while solitary phase is blue. Populations sequenced in the study are indicated by the star shape.

Key Words: Tettigoniidae, Mormon crickets, speciation, population genomics, phylogeny

POPULATION STRUCTURE AND SPATIAL PATTERNS OF GENETIC DIVERSITY IN THE CENTRAL AMERICAN LOCUST, *Schistocerca piceifrons* (ORTHOPTERA: ACRIDIDAE)

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The Central American Locust, *Schistocerca piceifrons*, is a destructive locust species prevalent throughout Mexico and other parts of Central America. Understanding the population structure of this species can inform targeted control strategies that consider regional genetic variation and prevent the spread of pesticide resistance. This research is also critical for future monitoring programs, as *S. piceifrons* resides less than 200 miles from the Texas-Mexico border in the state of Tamaulipas, Mexico and may become a threat to the United States in the future.

Here, I uncover the population structure of this species and examine genomic differentiation between populations (Fst). I predict geographic barriers to dispersal, such as the Sierra Madre Mountain, will not affect *S. piceifrons* since it is a migratory species capable of long-distance flight. Therefore, I expect to see one panmictic deme with high gene flow rather than multiple demes with low gene flow. Field samples were collected from Socorro Island in 2006 and 14 additional populations across Mexico and Central America in 2018. The sampling covered five regions: Campeche, Chiapas, Guerrero, Huastecas, and Northern Yucatan (Fig.1). The number of individuals collected from each site ranged from 3 to 20, with an average of 8. After the DNA was extracted, ddRAD-seq was performed to reduce the complexity of the genome. Our 1X sequencing coverage produced Single Nucleotide Polymorphisms that were used alongside the high-quality *S. piceifrons* reference genome for down-stream bioinformatic analyses.

Our results suggest there to be multiple demes rather than one panmictic deme. It seems that wind current patterns in the Gulf of Mexico may be significant in limiting gene flow between the Northern Yucatan and Huastecas regions in some instances but not others. Improving the quality of our data by increasing coverage and expanding our sample area may provide more clear answers. I plan to do this by partnering with Mario Poot-Pech, the Local Control Coordinator for the Yu-catan State Plant Protection Committee. To reduce costs, we will perform Whole Genome Resequencing on one sample per population then develop hybrid target capture probes for SNPs to generate data from the entire taxon sampling.

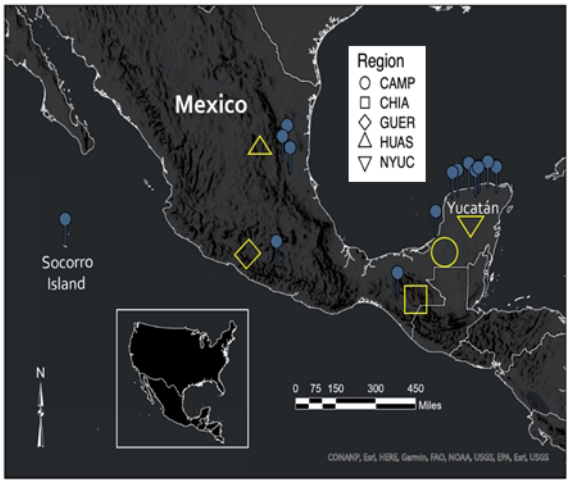

Figure 1. Collection sites throughout Mexico. Outbreak and recession zones are monitored by the Locust Control Program in the Yucatán Peninsula.

Key Words: ICO2023, Merida, Grasshopper, Population Genomics, *Piceifrons*

INSECTICIDE USE AGAINST DESERT LOCUST IN THE HORN OF AFRICA 2019–2021 REVEALS A PRESSING NEED FOR CHANGE

Wim C. Mullié[1], Adam Prakash[2], Alexander Müller[2] & **Elena Lazutkaite**[2]
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The desert locust upsurge in the Horn of Africa over 2019–2021 led to a total of 1.6 million ha being treated with broad-spectrum organophosphate and pyrethroid insecticides in Ethiopia and Kenya, while insect growth regulators and the entomopathogenic fungus *Metarhizium acridum* were applied in Somalia. Environmental monitoring was largely absent, with limited surveys conducted in Kenya and Ethiopia. Overdosing of fenitrothion of a 960 g/L formulation in Kenya led to non-target mortality, including birds and honeybees. In Ethiopia, chlorpyrifos and malathion applications coincided with a honey production decline of 78% in 2020 compared to pre-upsurge levels. The use of *M. acridum* on nearly 253,000 ha was a breakaway from previous campaigns, in which its successful application in Somalia against both hopper bands and swarms shows that the persistent and pervasive use of organophosphate insecticides can no longer be justified. Furthermore, future procurement of organophosphate insecticides and possibly insect growth regulators could become increasingly problematic due to measures enacted by the European Union. It is recommended that the complementary impact of *M. acridum* and bird predation on locusts should be considered in an integrated management approach for both swarm and hopper control.
Source: Mullié, W.C.; Prakash, A.; Müller, A.; Lazutkaite, E. Insecticide Use against Desert Locust in the Horn of Africa 2019–2021 Reveals a Pressing Need for Change. Agronomy 2023, 13, 819.
https://doi.org/10.3390/agronomy13030819

Table 1. Total surface area (ha) treated from 1 August 2019 to 31 December 2021.

Insecticide	Ethiopia	Kenya	Somalia	Total	%
chlorpyrifos	440,610			359,287	27.48
malathion	679,380	2050	15,732	359,287	43.49
fenitrothion	35	32,136		32,171	2.01
deltamethrin		72,048		72,048	4.49
M. acridum	102	*	252,689	252,791	15.77
teflubenzuron			68,761	68,761	4.29
triflumuron			400	400	0.02
other	14,285	3187	21,705	39,177	2.44
Total	1,134,412	109,421	359,287	1,603,120	100

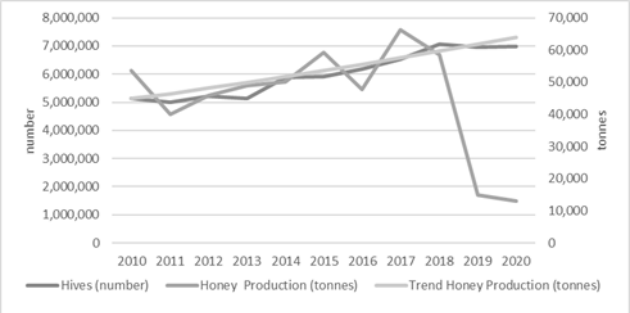

Figure 1. Beehives and honey production in Ethiopia, 2010-2020. Source:

Key Words: ICO2023, *Schistocerca gregaria*; East Africa; chlorpyrifos; fenitrothion; malathion; deltamethrin; teflubenzuron; *Metarhizium acridum;* environmental monitoring; honeybees; bird predation

RARE SIGHTING OF *Poekilocerus pictus* IN THE ARID CHOLISTAN DESERT OF PUNJAB, PAKISTAN

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[2]Department of Zoology, University of Sindh, Jamshoro, Pakistan, riffat.sultana@usindh.edu.pk

The *Poekilocerus pictus*, commonly known as the painted grasshopper, is a colorful and visually striking insect often found in grasslands and open areas. However, this species is also found in desert areas, which is surprising given the harsh enviromental conditions of these regions. The aim of this study is to provide an overview of the occurrence of *P. pictus* in the Cholistan desert area at 28.5062° N, 71.5724° E. The Cholistan University campus area reported a significant outbreak of both nymphs and adult P. pictus during July 2022, which has had a significant impact on varieties of *Calotropis gigantea* (akk plants). However, previous research indicates that damage has also been observed in castor, papaya, and watermelon crops in the Lasbella area of Balochistan, as well as in cotton seedlings, melon, chili, and vegetables in the Punjab region of Pakistan. Similarly, bamboo, citrus plants, papaya, lady's finger, brinjal, tomato, castor, and various flowers have also been affected in various parts of India. These sightings suggest that the species has adapted to survive in arid conditions and may have unique physiological and behavioral characteristics that enable them to thrive in these regions. The reasons for the occurrence of *P. pictus* in desert areas are not well understood, but it might be a response to changes in climate and vegetation, while others speculate that the desert environment may offer protection from predators. Overall, the occurrence of *P. pictus* in desert areas is a fascinating example of the adaptability and resilience of insects. Thus, effective management of *P. pictus* outbreaks requires a comprehensive understanding of the local environmental and ecological factors that contribute to the outbreak, as well as the social and economic impacts of the outbreak on local communities.

Key Words: *Poekilocerus pictus*, Cholistan desert, climate, vegetation, predators, adaptability impacts

THE ITALIAN LOCUST *Calliptamus italicus* (L.) IN THE NORTH-EASTERN PARTS OF ITS RANGE: WHAT WILL THE FUTURE BRING?

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The Italian locust is one of the most important pest in extra-tropical Eurasia. It is distributed from the western parts of Europe to the southern parts of West Siberia, East Kazakhstan, and North-West China. In 2000 only, it's extremely abundant populations occupied more than 16 x 106 ha in Kazakhstan and Russia. The patterns of dynamics of the Italian locust local populations are quite different. As a result, opportunities to produce applicable long-term and spatial forecasts are very limited.

We tried to use the Maxent algorithm (Phillips et al., 2006, 2011), the sets of the so-called standard bioclimatic variables for 1970–2000 and for two future periods (2021–2040, 2041–2060) plus several Shared Socioeconomic Pathways (1-2.6, 2-4.5, 3-7.0) to model the species distribution over the north-eastern parts of the range (mainly across the steppe and semi-deserts between the Volga and Ob Rivers) now and in the future. The comparative analysis of the Italian locust distribution across the region shows very similar patterns for three periods: before 1961, in 1961–1997, and 1998–2022 (after the beginning of the last huge outbreak). There are no significant differences between them and no evident range shifts.

The model generated for the contemporary climatic conditions supports our knowledge concerning species distribution: all steppes and semi-deserts between the Ural Mts. on the west and the Altai-Sayan Mts. on the east look like the optimal areas for the Italian locust. Besides, very suitable conditions for this species are in the northern deserts of Kazakhstan and some parts of Xinjiang and Kyrgyzstan (especially in the Tien Shan Mts.). High levels of habitat suitability show opportunities of the species upsurges.

The forecasted shifts become more significant if the level of expected greenhouse emissions increases. They also increase from now until 2041–2060. Almost all possible shifts are predicted for West and Central Siberia. The local parts of the species range will able to move northwards and north-eastwards to the modern forest-steppes and south taiga, but the optimal territories will remain almost the same. Hence, the Italian locust outbreaks will able to develop over the same areas as in the end of 20th and in the beginning of the 21st centuries.

These studies were financially supported by the grant of the Russian Science Foundation 22-66-00031 (https://rscf.ru/en/project/ 22-66-00031).

Key Words: Acrididae, Population, Management

ORAL SESSION D

BIODIVERSITY BIOGEOGRAPHY & ECOLOGY

Chairman: Ricardo Mariño-Pérez

1. **James Miskelly**. INVENTORY OF THE ORTHOPTERA OF BRITISH CO LUMBIA AND YUKON, CANADA.
2. **Waheed Ali Panhwar**. INVESTIGATING THE BIODIVERSITY OF ORTHOPTERA FROM NARA DESERT SINDH PAKISTAN.
3. **Simeon Borissov, Nefeli Kotitsa and Dragan Chobanov**. PAST AND FUTURE OF THE BALKAN STEPPES AND THEIR INHABI-TANTS FROM THE PERSPECTIVE OF MODEL ORTHOPTERANS.
4. **Nefeli Kotitsa, Simeon Borissov and Dragan Chobanov.** PATTERNS OF SKY ISLAND DISPERSAL AND SPECIATION: A CASE STUDY FROM THE BALKANS (THE ENDEMIC GENUS *Parnassiana* Zeuner, 1941).
5. **Holger Braun**. RIVER-BORNE DISPERSAL OF ORTHOPTERA IN NORTHEASTERN ARGENTINA.
6. **Raùl Cueva del Castillo; Salomón Sanabria Urbán, Ricardo Mariño Pérez and 3Hojun Song**. SEASONALITY, BODY SIZE, AND SEXUAL SIZE DIMORPHISM IN THE EVOLUTION OF PYRGOMORPHIDAE.
7. **Barkat Ali Bighio and Riffat Sultana.** EXPLORING THE DIVERSITY AND DISTRIBUTION PATTERNS OF BAND-WINGED GRASSHOPPERS (OEDIPODINAE: ACRIDIDAE: ACRIDOIDEA: ORTHOPTERA) IN PAKISTAN.

INVENTORY OF THE ORTHOPTERA OF BRITISH COLUMBIA AND YUKON, CANADA

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British Columbia (BC) and Yukon represent the two most western jurisdictions in Canada. Together, they form a mountainous region with tremendous ecological diversity, ranging from temperate rainforests and arid steppe to arctic tundra. Despite strong interest in biodiversity in the region, many insect groups remain understudied, including the Orthoptera. With a few exceptions, historical collecting of Orthoptera in the region was opportunistic, unfocussed, and limited in geographic scope.

For the past 15 years, a project has been underway to inventory the Orthoptera of BC and Yukon and raise the level of knowledge of the order. The basic questions this research seeks to answer are which species live in the region, where do they live, what are their habitat as-sociations, and are any of them rare or at risk. Over the course of this project, 19 species have been documented in BC that were not previously recorded and three species have been added for Yukon. Most of these represent species that are assumed to have always been present but were not previously detected. Two species appear to have increased in range in modern times, possibly as a result of climate change. Five species are non-native and have been introduced from either Europe or eastern North America. Over the course of this study, several pervasive errors in identification of museum specimens have been corrected. Other complex taxonomic problems have been discovered that have yet to be resolved.

There are now 124 species known from BC and 20 from Yukon. Only two species that occur in Yukon do not occur in BC, bringing the total for both regions to 126 species. Diversity is concentrated in the warmest and driest parts of the southern portion of the region. The north-ern 2/3 of the region has relatively low diversity, though pockets of higher diversity occur wherever there are dry grasslands. Much of the diversity in these pockets is made up of species with highly disjunct distributions, possibly representing relictual populations that originated under periods of warmer climate. One species has been listed as endangered in Canada and another is in the assessment process.
Other researchers have recently completed similar work in Alaska. British Columbia, Yukon, and Alaska together represent an area of more than 3,000,000 km2, an area larger than Mexico and equivalent to 30% of the area of Europe. A field guide or manual of the Orthoptera of this region is in development and could be a significant resource for those interested in the Orthoptera of northwestern North America and adjacent regions.

Key Words: ICO2023, Merida, Grasshopper, Canada, British Columbia, Yukon

INVESTIGATING THE BIODIVERSITY OF ORTHOPTERA FROM NARA DESERT SINDH PAKISTAN

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One of the largest orders of grassland insects is called orthoptera. The orthopterans are found throughout the world's physiographic zones, although the vegetation found in grasslands, woodlands, and agricultural fields plays a significant role in how widely they are distributed. Due to their role as essential main herbivores (particularly grasshoppers) and their contribution to the food of several other creatures (birds, spiders, and reptiles), orthoptera play a significant role in the economy of grass-land ecosystems. They are a key component of food webs since they are primarily herbivorous and provide a plentiful source of food for other species including lizards, raptors, and birds. The natural ecosystems of Sindh include deserts, marshes, grasslands, and agricultural areas. Orthoptera are well known for contributing significantly to both the biodiversity of agricultural lands and grasslands. For four reasons, orthopterans are particularly fascinating to examine in connection to semi-natural grasslands. Sampling of the orthopteran fauna was conducted in Nara (desert) from march 2020 to march 2022 and field sites included Sikandarabad, Choondiko, Khehwari, Nara proper and Kotjabo having sandy, loamy, and few patches of medium fertile soil with cultivated field area. During the present study, a total 23 species namely : *Acrida exaltata* (Walker, 1859), *Acrida gigantea* (Herbst, 1786), *Truxalis eximia eximia* Eichwald, 1830, *Duroniella laticornis* (Krauss, 1909), *Heteracris littoralis* (Rambur, 1838), *Anacridium aegyptium* (Linnaeus, 1764), *Spathosternum prasiniferum* (Walker, 1871), *Acrotylus hum-bertianus* Saussure, 1884, *Acrotylus longipes longipes* (Charpentier, 1845), *Aiolopus thalassinus thalassinus* (Fabricius, 1781), *Oxya velox* (Fabricius, 1787), *Cyrtacanthacris tatarica tatarica* (Linnaeus, 1758), *Anacridium rubrispinum* Bey-Bienko, 1948, *Schistocerca gregaria* (Forskål, 1775), *Gryllodes sigillatus* (Walker, 1869), *Gryllodes supplicans* (walker, 1859), *Gryllus bimaculatus* de Geer, 1773, *Acheta domesticus* Linnaeus, 1758, *Turanogryllus histrio* Saussure, 1877, *Turanogryllus lateralis* (Fieber, 1853) *Conocephalus* (Anisoptera) *Maculatus* (Leguillou, 1841), *Bolivaritettix nilgiricus* (Hebard, 1930), and *Eucriotettix montanus* (Hancock, 1912) have been documented. Beside this detail study on genitalia, description of species and key to species is provided.

Key Words: Orthoptera, Desert, Pakistan

PAST AND FUTURE OF THE BALKAN STEPPES AND THEIR INHABITANTS FROM THE PERSPECTIVE OF MODEL ORTHOPTERANS

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The Eurasian steppes are one of the largest biomes on Earth, stretching through most of the Palearctic, from the Black Sea coast to China. These continuous open grasslands are generally defined by macroclimate. In contrast, the European steppes are represented by small, disconnected patches in Central Europe and the Mediterranean Peninsulas. These 'extrazonal' steppes are suffering from extensive anthropogenic impact causing rapid decrease in their area, habitat quality and genetic diversity. Despite being fragmented and significantly threatened by human activities, the European steppes share similar features with the zonal steppes and show significant diversity, being inhabited by species of diverse origin. Hence, their protection is of particular importance, especially concerning habitat specialists that are most sensitive to habitat deterioration.

Three main types of natural dry grasslands can be delineated on the Balkan Peninsula – (1) the Ponto-Sarmatic steppes at the western edge of the zonal steppes, found at the northeastern tip of the Balkans, 2) the extrazonal Pannonic loess steppes distributed as patches along the Danube River, and 3) the sub-Mediterranean dry grasslands found scattered across the Peninsula.

In the present study we explore the historical dispersal patterns and the response to habitat reduction and fragmentation of four model orthopteran taxa with different levels of steppe habitat specialization. Those are *Onconotus servillei* Fischer von Waldheim (a specialized inhabitant of the Pannonic steppes along the Danube), *Montana medvedevi* (Miram) (a relict steppe inhabitant of the Pannonic steppes), *Stenobothrus eurasius macedonicus* F. Willemse (with fragmented distribution within Ponto-Sarmatic steppes and sub-Mediterranean dry grasslands), and *Arcyptera microptera* (Fischer von Waldheim) (tolerating broader range of natural dry grassland habitats).

We measure the genetic diversity of populations in order to detect any recent bottlenecks and population expansions. We apply ecological niche modelling to compare the ecological requirements and estimate the niche overlap between model species. Additionally, we analyze historical land-cover data to estimate the extent of habitat loss of steppe species due to human activities during the 20th century.

Our results suggest that the small disjunct patches of extrazonal steppes provide diverse ecological conditions that define their complex faunal composition and high conservation importance. Our study also endorses the bio-indicator potential of the tested model taxa for habitat type, physiognomy, and quality. The strong preference to habitat type and quality defines the vulnerability and need of protection of such habitat specialists in times of currently raising pressures on the European steppe remnants.

This study is funded by grant KP-06-N31/13 of the National Science Fund (the Ministry of Education and Science) of Bulgaria to Dragan Chobanov.

Key Words: steppes, Orthoptera, genetic diversity, habitat loss

PATTERNS OF SKY ISLAND DISPERSAL AND SPECIATION: A CASE STUDY FROM THE BALKANS (THE ENDEMIC GENUS *Parnassiana Zeuner*, 1941)

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The Balkan Peninsula is a well-known Palearctic biodiversity hotspot. It has a complex geological history and geomorphology that boosted speciation processes, resulting in a large number of endemic taxa. Many long mountain ranges and isolated mountains alternate over the Balkans, whose summits, often higher than 2000 m asl., can be characterized as sky islands due to their high degree of isolation. One typical group restricted to the high altitudes (above 1600 m) of the mountain summits of the South-Western Balkan Peninsula is *Parnassiana*. This flightless bush-cricket genus consists of 13 known species scattered in small, isolated populations, some of which have unclear taxonomic status and may represent taxa new to science.

We aim to reconstruct and date the phylogenetic tree of *Parnassiana*, and discuss hypotheses about the origin of the genus and its dispersal patterns along the sky islands of the Balkan Peninsula.

To achieve our aim, we performed collecting trips throughout the mountains of Peloponnese, Central Greece, Evvoia, the Pindos range and the mountains of southern Albania. The collected specimens were initially referred to morpho-species. Total DNA was isolated from individuals from each sampled locality. Mitochondrial (NADH2, COI) and nuclear (ITS) molecular markers were sequenced via the Sanger method. Received sequences were complemented with sequences of presumably closely related genera in order to reconstruct their phylogenetic relationships. Phylogenetic trees were created using BI and ML analyses. Dating was performed with BEAST using two approaches: biogeographic calibration and the mutation rate suggested for related genera. Our results suggest that the Peloponnese species form a well-supported monophyletic clade, with each mountain hosting a single species. The specimens from central Greece and the Pindos range show a more complex pattern: some populations that occur in mountains geographically close to each other appear distant in the phylogenetic tree, while some populations from distant areas appear to be more closely related. Moreover, some mountains possess two species that co-exist in the same spots, at least one of which possibly represents a taxon new to science.

We discuss the origin and historical dispersals of *Parnassiana* and infer that the Pleistocene glacial cycles have played an important role in the evolutionary history and current distribution patterns of the genus, as is the case for numerous other groups and species in the area.

We conclude that *Parnassiana* is a group of high biogeographic interest and conservation importance. In addition, this study will set a background for taxonomic revisions, for discussions on species response to climate change, and for defining adequate conservation measures for the genus.

This study was partly funded by the Theodor J. Cohn Research Fund of the Orthopterists' Society, grant to Nefeli Kotitsa, and grant KP-06-N31/13 by the National Science Fund of Bulgaria to Dragan Chobanov.

Key Words: *Parnassiana*, molecular phylogeny, sky islands, Balkans, glacial cycles

RIVER-BORNE DISPERSAL OF ORTHOPTERA IN NORTHEASTERN ARGENTINA

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Two katydid species distributed in the south of Brazil show curious and fairly recent records in Argentina. On a closer look, these isolated records follow major rivers and most of them are located near the shore of the Río de la Plata, a large estuary formed by the confluence of Río Paraná and Río Uruguay. A tiny population of *Xenicola dohrni* right at the flood line of the Río de la Plata could be confirmed for only one subsequent summer, whereas *Conocephalus ochrotelus* apparently has itself established permanently in coastal nature reserves in the city of Buenos Aires. The cricket *Neometrypus aculeatus argentinus*, a subspecies described in 2017, shows a similar distribution. Interestingly, its type locality is among several downstream records in the province of Buenos Aires, whereas a single record is located 900 km air-line distance further north. So, the entire "original" distribution is still unknown. All three species have reduced wings and are unable to fly, so they most likely travelled southward on floating vegetation, probably as eggs. Presumably floating aggregations of water hyacinths are involved, but so far there is no direct evidence, and long-range waterway transportation of insects in South America requires further investigation. With global warming it will possibly enable many more species to establish surviving populations south of their subtropical homeland.

Key Words: distribution, iNaturalist, Neometrypini, Tettigoniidae

SEASONALITY, BODY SIZE, AND SEXUAL SIZE DIMORPHISM IN THE EVOLUTION OF PYRGOMORPHIDAE

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In many animal species, a large body increases male mating success and female fecundity. However, because there is a strong relationship between maturation time and body size in in-sects, there is a trade-off between body size and sexual maturation. In high seasonality environments, natural selection can favor faster maturation, which reduces the risk of pre-reproductive death, but it comes at a cost, namely a smaller body size. Maturation time can be influenced by environmental temperature, season length, and food availability associated with the rains. The geographic variation in these parameters opens the opportunity to test their impact on the adaptive evolution of body size in the grasshoppers of the family Pyrgomorphidae. In this study, using a phylogenetic framework, we analyzed the evolutionary trends in the evolution of body size, and we evaluated if the body size divergence in males and females of these grasshoppers can be attributed to sexual selection or fecundity selection testing the Rench's Rule, and the impact of weather condition in the evolution of males and females body size.

We found that an intermedium body size was the ancestral condition in Pyrgomorphidae (Fig 1). These grasshoppers follow the Rench's Rule (Fig 2), meaning that the evolution of sexual size dimorphism (SSD) can be explained by sexual selection on males' body size. Moreover, species with smaller Femur III males are adapted to places with low annual temperatures and species in which SSD in the thorax width is bias to the males in places with lower annual temperatures.

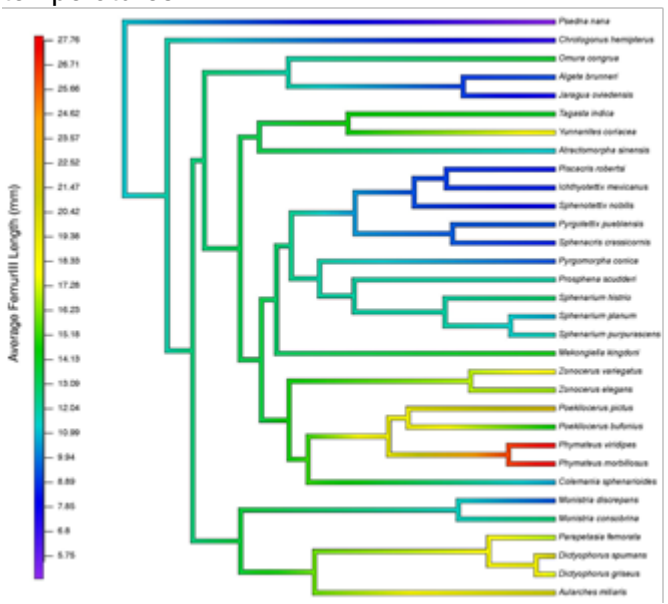

Figure 1. Ancestral reconstruction of body size (Length of Femur III) of Pyrgomorphidae grasshoppers.

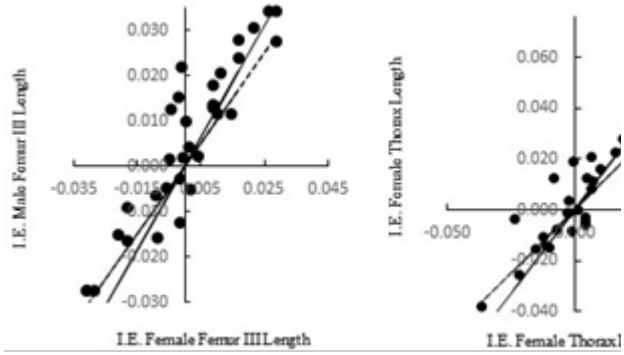

Figure 2. Mayor Axis regressions of the independent contrasts of femur III and Thorax length of males on the independent contrasts of Femur III and thorax length of females of grasshoppers of the family Pyrgomorphidae. Both regressions are significant and consistent with Rench's Rule.

Key Words: Body size, Rench's Rule, Seasonality, Local Adaptation

EXPLORING THE DIVERSITY AND DISTRIBUTION PATTERNS OF BAND-WINGED GRASSHOPPERS (OEDIPODINAE: ACRIDIDAE: ACRIDOIDEA: ORTHOPTERA) IN PAKISTAN

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BAND-WINGED grasshoppers (Oedipodinae) are a diverse group of insects that play a significant role in ecosystems and agricultural landscapes. This study focuses on investigating the taxonomy, diversity, and distribution patterns of band-winged grasshoppers in Pakistan. Field surveys were conducted across various regions of Pakistan to collect grasshopper specimens from different habitats, including agricultural fields, hilly areas, semi-deserted regions, and grass-lands. Morphological characteristics, including wing morphology, coloration, and other distinguishing features, were carefully examined for species identification. A comprehensive examination of the collected specimens resulted in the description of 33 species and subspecies of Oedipodinae grasshoppers in Pakistan. Among these, two new species (*Hilethera balucha* and *Sphingonotus sindhensis*) and one subspecies (*Sphingonotus nebulosis tokhai*ˆ) were discovered, contributing to the scientific knowledge of this insect group. Detailed descriptions, synonymy, and taxonomic keys based on external morphology and genitalia were provided to facilitate accurate identification and differentiation of tribes, genera, and species within the Oedipodinae subfamily. This research significantly enhances our understanding of Oedipodinae grasshoppers in Pakistan, including their taxonomy, distribution, and ecological significance in different habitats. The findings are crucial for proper identification and enable accurate diagnosis of species. The provided taxonomic keys and descriptions offer valuable tools for researchers and entomologists working in this field. Overall, this study contributes to the broader knowledge of grasshopper diversity and taxonomy, shedding light on the importance of band-winged grasshoppers in the ecosystems of Pakistan and their role in agricultural landscapes.

Key Words: Band-winged grasshoppers, Taxonomy, Diversity, Distribution patterns, Pakistan.

ORAL SESSION E

Behaviour & communication

Chairman: Gregory Sword

1. **Varvara Vedenina**. COMPLEX COURTSHIP REDUCES BEHAVIOURAL HYBRIDIZATION BARRI-ERS BETWEEN CLOSELY RELATED GRASSHOPPER SPECIES.
2. **Audélia Mechti, Kendall Walton and Gregory Sword.** TO MARCH OR NOT TO MARCH: QUANTIFYING PATTERNS OF COLLECTIVE MOVEMENT ACROSS SWARMING AND NON-SWARMING *Schistocerca* SPECIES.
3. **Víctor Hugo Ramírez-Delgado and Raúl Cueva del Castillo**. TESTING BACKGROUND MATCHING AND DISRUPTIVE COLOURATION IN A SEXUALLY DICHROMATIC GRASSHOPPER: A COMPUTER DETECTION EXPERIMENT.
4. **David Gray**. WHAT *Gryllus* CRICKETS ARE SAYING WHEN THEY TALK TO EACH OTHER.
5. **Nikita Sevastianov and Varvara Vedenina.** COURTSHIP SONG EVOLUTION WITHIN SUBFAMILY GOMPHOCERINAE (ORTHOPTERA: ACRIDIDAE).
6. **Diego A. Gomez-Morales, David A. Gray and Jeffrey Cole**. APPROACHING INSECT BIOACOUSTICS TO BEGINNERS: A GUIDE TO AUDIO RECORDING AND COLLECTION OF ACOUSTIC INSECTS, INCLUDING AN OPEN-ACCESS APP FOR EASY PLOTTING.
7. **Sarah Maria Gaugel and Ricardo J. Pereira**. BREAKING BARRIERS: THE ROLE OF WING SHAPE IN BEHAVIORAL ISOLA-TION IN THE *Chorthippus biguttulus* GROUP.

COMPLEX COURTSHIP REDUCES BEHAVIOURAL HYBRIDIZATION BARRIERS BETWEEN CLOSELY RELATED GRASSHOPPER SPECIES

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WHEN differentiated populations meet and produce hybrids, the latter ones may suffer reduced fitness. In particular, mating signals of hybrid males are intermediate between the parental signals and unattractive not only to parental but also to hybrid females. Such hybrid unfitness is called 'behavioural hybrid dysfunction' (BHD).

The studies of the song or mating preferences were conducted in three pairs of hybridizing grasshopper species, which demonstrate complex courtship behaviour. Cryptic species *Chorthippus albomarginatus* and Ch *oschei* hybridize in a wide contact zone in Ukraine and Moldova. The species are similar in calling songs but quite different in courtship songs. In mate choice experiments, females could choose between parental and hybrid males, and the experimenter estimated the percentage of copulations. Closely related species *Stenobothrus clavatus* and *S. rubicundus* hybridize in a narrow contact zone on Mount Tomaros in northern Greece. The species are remarkably different in several morphological characters, as well as in both calling and courtship songs. Cryptic species *S. eurasius* and *S. hyalosuperficies* hybridize in a wide contact zone in south-east of European Russia.

They also different in both calling and courtship songs (Fig. 1). Moreover, *S. rubicundus* and *S. hyalosuperficies* generate sound not only by common femoral-tegminal stridulation, but also by wing clapping. In playback experiments, females were presented with parental and hybrid songs, and the experimenter estimated the acoustic responses of females.

In all experiments, parental females showed significantly higher preferences for parental songs or parental males than for hybrid songs / males. Thus, hybrid males can possess a reduced fitness in the parental-like biotope. Hybrid females, however, showed similar preferences for different song types / males. Thus, hybrid females can even have an advantage over parental females in mixed populations.

The number of courtship elements in all three pairs of hybridizing grasshopper species varies in the range of 3 – 5. Some of these elements seem to be homologous between hybridizing species, whereas others are non-homological. This can explain why hybrid songs possess superposition of parental elements or intermediate elements (Fig. 1). Based on revealed nonhomology of the parental elements,

two pattern-generating neuronal networks are suggested to be formed in the central nervous system of the hybrids. Similarly, an absence of BHD in hybrid females can be explained by an expression of both parental neuronal filters for song recognition. Activation of one neuronal filter could be sufficient for positive response in hybrid females.

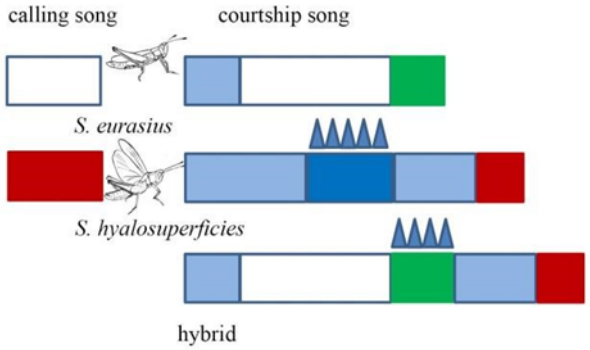

Figure 1. Schemes of songs in parental species and hybrid. Different colors indicate different song elements. Red color element is generated by wing clap-ping. Triangles indicate visual display.

Key Words: Grasshopper, stridulation, court-ship song, hybrid zone, playback

TO MARCH OR NOT TO MARCH: QUANTIFYING PATTERNS OF COLLECTIVE MOVEMENT ACROSS SWARMING AND NON-SWARMING *Schistocerca* SPECIES

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Phenotypic plasticity, when a single gene can result in multiple phenotypes, separates locusts into different phases. Termed 'phase polyphenism,' this phenomenon results in either a solitarious phase that is characterized, among others, by a sedentary lifestyle and repulsion towards conspecifics, or a gregarious phase, where individuals show a greater level of activity and a high relative congeners at-traction. In response to a changing environment, solitarious locusts switch to the gregarious phase, forming gigantic swarms of thou-sands marching juveniles and flying adults, decimating any food in their path.

This study aims to analyze the patterns of collective movement across swarming locusts, Schistocerca gregaria, and non-swarming locusts, Schistocerca americana, by tracking collective movement in an enclosed circular arena. Seven different densities were recorded for 6 hours and analyzed with an automated tracking software.

S. gregaria, a known swarming species, is hypothesized to have a lower threshold density for marching behavior as compared to *S. americana*, a species that was thought to lack swarming characteristics and not commonly known to swarm.

Key Words: Locusts, Phenotypic Plasticity, Marching, Swarming Behavior

TESTING BACKGROUND MATCHING AND DISRUPTIVE COLOURATION IN A SEXUALLY DICHROMATIC GRASSHOPPER: A COMPUTER DETECTION EXPERIMENT

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Cryptic colouration is an adaptative mechanism against predators. Colour patterns can become cryptic through background matching and disruptive colouration, which breaks up the outlines of an animal because the pattern does not coincide with the shape and outline of the animal's body. Background matching could be advantageous in chromatically homogeneous microhabitats, whereas disruptive colouration can be favoured in visually heterogeneous microhabitats. Grasshoppers of the genus *Sphenarium* (Orthoptera: *Pyrogomorphidae*) inhabit very heterogeneous environments and exhibit both strategies. Adults show substantial continuous variation in colouration and longitudinal and transverse bands on the thorax and abdomen. However, males often exhibit considerably more variation in the number of longitudinal and transverse bands than females, which tend to have more uniform colouring (flatter patterns). In this study, we analysed the cryptic properties of the colour patterns of males and females of *Sphenarium zapotecum* Sanabria-Urbán, H. Song & Cueva del Castillo and tested the effectiveness of background matching and disruptive colouration using humans as 'preda-tors' in a computer detection experiment. We found that the females and males are dichromatic and seem to follow different cryptic strategies in their colouration: males are more disruptive to the background than females, whereas females have a higher level of background matching. In addition, in visually heterogeneous areas, predators spent most time searching for striped male morphs with lower back-ground matching and higher disruptive proper-ties, as well as for female morphs with high background matching, potentially increasing prey survival. As background matching is associated with females and disruptive colouration with males, our results could help explain the evolution of sexual dichromatism in this and other species of grasshoppers of the genus *Sphenarium.*

Key Words: background matching, crypsis, disruptive colouration, predation, *Pyrogomorphidae*, sexual dichromatism, *Sphenarium zapotecum*, strategies, survival

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WHAT *Gryllus* CRICKETS ARE SAYING WHEN THEY TALK TO EACH OTHER

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Sexual signals convey multiple kinds of information. Signal traits which are species-specific 'recognition' signals need to be stereotyped with low variation among individuals, whereas signals of individual 'quality' are expected to be dynamic and variable among individuals. In addition, 'recognition' signals should be subject to stabilizing mating preferences and should change at speciation, resulting in low phylogenetic signal. 'Quality' signals, on the other hand, should be subject to directional mating preferences and need not change during speciation, likely resulting in higher phylogenetic signal. Here I analyze the songs of all 39 acoustic species/lineages of *Gryllus* crickets found in the United States and Canada.

I show that the properties of signals processed first by the sensory-neural system are consistent with them being 'recognition' signals, and that 'quality' information is only processed contingent upon 'recognition.' Specifically, frequency, pulse rate and pulse duty cycle, which are processed first, have low among-individual coefficients of variation, are subject to closed female preference functions, and tend to have low phylogenetic signal, whereas pulses per chirp, chirp rate and chirp duty cycle, processed only if frequency and pulse traits are recognized, show higher among-individual coefficients of variation, are subject to open female preference functions, and tend to have higher phylogenetic signal.

In collaboration with Drs Steve Dudgeon (CSUN) and David Weissman (Cal Academy of Sciences), I then also show that the macro-evolutionary patterns of pairwise divergence of signals among species depends upon whether the signals convey 'recognition' or 'quality' information, and on whether the pairwise comparisons are of allopatric or sympatric taxa. Using Bayesian models, we show that regressions of 'recognition' signal divergence on genetic divergence have elevated intercepts and lower slopes than regressions of 'quality' signal divergence on genetic divergence. Furthermore, we show that 'recognition' signals have diverged faster in sympatry than in allopatry. This suggests that 'recognition' signals evolve in a punctuational manner, whereas 'quality' signals evolve gradually. Together these results show that *Gryllus* calling song conveys two distinct messages: 'who' and 'how sexy.' These differences select for different attributes and affect the patterns of song diversification and speciation.

Key Words: *Gryllus*, speciation, sexual selection

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COURTSHIP SONG EVOLUTION WITHIN SUBFAMILY GOMPHOCERINAE (ORTHOPTERA: ACRIDIDAE)

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Gomphocerinae grasshoppers evolved complex mating behaviour and can produce several types of song. Courtship song can be very complex and accompanied by variable visual elements. Here we analyse phylogenetic distribution of selected courtship characters and reconstruct their evolution.

First, we used four markers (COI, cytB, ITS1 and ITS2) for phylogenetic reconstruction. Our dataset included 89 species of Palearctic Gomphocerinae. Second, we chose six universal characters of courtship: 1) difference between courtship and calling songs, 2) degree of divergence of the calling song element within courtship song, 3) the number of sound elements, 4) the number of different leg movement patterns, 5) the number of visual elements and 6) mechanisms of sound emission. We estimated phylogenetic signal and performed ancestral state reconstruction using R software.

We found a relatively high phylogenetic signal (0,5 > Pagel's lambda > 0,7) for difference between courtship and calling songs, the number of sound elements and the number of different leg movement patterns. These characters suggested to be relatively stable and so they could reflect evolutionary trends within the considered taxon. Other characters were found to evolve rapidly and chaotically.

Our reconstructions suggest that common ancestor of the tribe *Stenobothrini* and *Chorthippus pullus* already evolved complex courtship song consisting of two sound elements (Fig. 1). The song structure became to be more complicated independently within the genera *Omocestus, Myrmeleotettix* and *Stenobothrus*. The generation of visual elements was found to be an ancestral character state for *Stenobothrus genus*. The presence of two sound elements in the calling or courtship songs was found as an ancestral state for *Gomphocerini*. Complex courtship was reconstructed as an ancestral state only for *Chorthippus albomarginatus* group, although complex courtship evolved several times within *Glyptobothrus* cluster. A controversial result being the song simplification in *Chorthippus biguttulus* group should be discussed and reviewed.

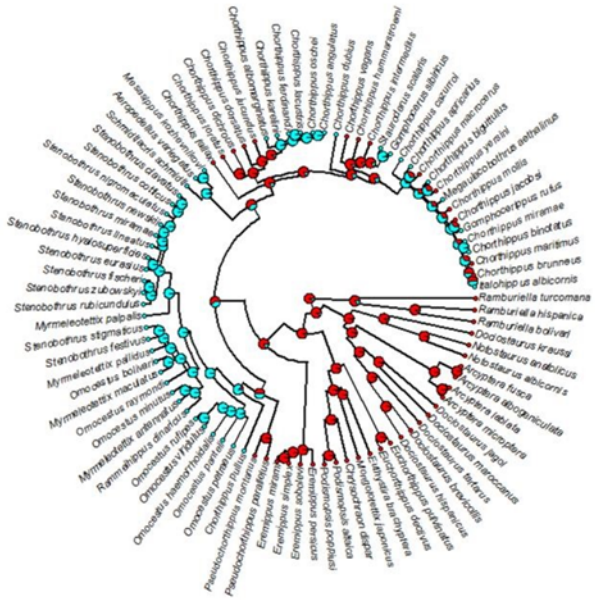

Figure 1. Ancestral state reconstruction of difference between courtship and calling songs. Red – courtship song is identical to calling song; Blue – courtship song differs from calling song in temporal structure.

Key Words: Gomphocerinae, courtship, mating behaviour, evolution reconstruction

APPROACHING INSECT BIOACOUSTICS TO BEGINNERS: A GUIDE TO AU-DIO RECORDING AND COLLECTION OF ACOUSTIC INSECTS, INCLUDING AN OPEN-ACCESS APP FOR EASY PLOTTING

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Insect bioacoustics use for scientific and environmental studies is still limited compared to more charismatic groups like birds or amphibians. One of the main reasons is the lack of methodologies, information and tools for beginners interested. We provide some recommendations and best practices for recording terrestrial insects in the field and in captivity, some guidance for collecting specimen vouchers, and present a tool for easy bioacoustics plotting. This is meant as a very introductory guide to some common considerations and principles of working with common acoustic insects (crickets, katydids, cicadas). We discuss (i) audio recording equipment and strategies, (ii) collection techniques, (iii) curation of specimens and recordings, iv) basic plotting and measurements using a novel webapp based on R seewave (Fig. 1). We do not cover either manual or automated digital sound analysis techniques as these will depend to a large extent on the purpose of the study. Many of the basic principles could be applied to other acoustically communicating organisms, whether done professionally, as community science, or as a personal hobby in natural history. As singing insects are present almost everywhere, familiarity with their sounds can be highly rewarding for the public, and can inform studies of taxonomy, behavior, and conservation.

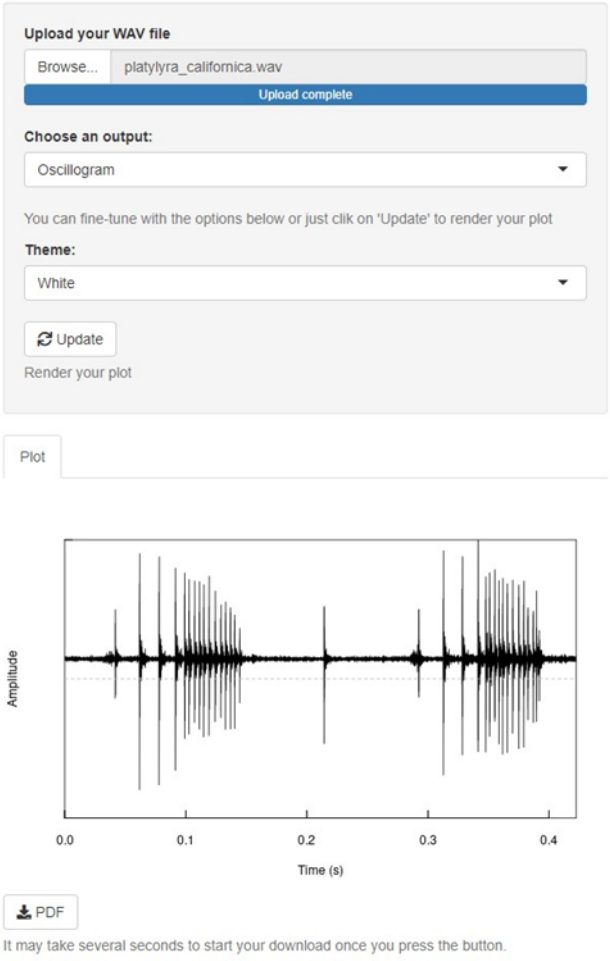

Figure 1. Sample of the use of the webapp based on R seewave, for easy plotting of animal sounds.

Key Words: beginners, insects, recording, bioacoustics, app

BREAKING BARRIERS: THE ROLE OF WING SHAPE IN BEHAVIORAL ISOLATION IN THE *Chorthippus biguttulus* GROUP

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With approximately 30,000 species described, Orthoptera is among the most diverse insect orders. In this order, the evolution of behavioral isolation due to association of male song and female preference resulted in multiple species radiation. Although divergence in male song is an efficient reproductive barrier, the morphological traits underlying such song are less known, making it difficult to distinguish species. This is particularly challenging in the presence of hybridization, which is common in young radiations of orthopterans. To understand the traits underlying behavioral isolation, we focus on a young radiation of the *Chorthippus biguttulus* group, which is hypothesized to hybridize, producing new species with intermediate male song. We use traditional and geometric morphometric analyses to test if male forewing shape can serve as a proxy for male song. We analyze wing shape variation between the parental species (C. *biguttulus*, C*. brunneus* and C. *mollis*) and a putative hybrid species characterized by intermediate song (*Ticino brunneus*) in the Alps. Our preliminary results suggest partial overlap in wing shape with the width of the wing showing most variation between species, particularly between the sister taxa C. *brunneus* and C. *biguttulus*. The putative hybrid species indeed has intermediate wings, but overlaps with the more divergent taxon (C. *mollis*). Moreover, we use genomic data to test whether genomic ancestry could predict wing morphology, i.e., whether there is a correlation between shape variation and genomic admixture. We expect to find no correlation with wing morphology implying a relatively small number of loci underlying behavioral isolation which is typical in early stages of divergence. Together, our results show that wing shape can be a proxy for behavioral isolation in grasshopper species, providing a tool to diagnose cryptic species in a highly specious group. However, variation in wing shape does not follow phylogenetic divergence, consistent with this trait being under sexual selection.
This study will inform future research on quantitative genomic analysis of behavioral isolation and provides insights into speciation based on radiation via sexual selection on behavioral traits.

Key Words: *Chorthippus*, radiation, behavioral isolation

A MOLECULAR DISSECTION OF SEXUAL EVOLUTION IN THE DECORATED CRICKET *Gryllodes sigillatus.*

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Sexual conflict, which arises when mating males and females have differing optimal fitness strategies, is very common among insects. This often leads to the evolution of sexually antagonistic traits, by which males attempt to manipulate female behavior and physiology to increase their share of paternity. Nuptial food gifts provided at copulation to females by some male insects, including many Orthopterans, may also serve this function. In the decorated cricket *Gryllodes sigillatus*, females mate multiple times and use a mix of sperm from different males to fertilize their eggs. During mating, males transfer a nuptial food gift named the *spermatophylax*, a gelatinous mass that forms part of the spermatophore. *Spermatophylax* feeding deters females from prematurely removing the sperm containing portion of the *spermatophore* (ampulla). As such, it increases sperm transfer and thus a male's paternity share, and it is to the male's benefit that the female feeds on this gift as long as possible. In addition, the male *spermatophylax* may influence female behavior and physiology in ways unrelated to maximizing sperm transfer. In the face of such manipulation, females are expected to evolve resistance to male manipulation through counter mechanisms. The evolution of these opposing male and female traits is predicted to depend upon the intensity of sexual conflict. We used experimental evolution lines varying in the intensity of sexual conflict in which crickets were maintained under a male- or female-biased adult sex ratio for 20 generations. We subsequently assessed gene expression pro-file changes in male accessory glands, female ovaries, and female heads. For each tissue, five samples were collected from each of three lines per regime (male-biased or female-biased). For the 30 male accessory glands and the 30 female head tissues included in this study, dissections were performed two hours after mating. For the ovaries, we collected tissues from both mated females and virgins, bringing the total number of samples for this tissue to 60. RNA from all 120 samples was extracted using a Trizol-based phase separation, followed by a DNAse treatment. Samples were sequenced on an Illumina HiSeq. The sequencing reads were trimmed based on their quality and they were filtered for bacterial and viral contamination. We assembled and an-notated de novo transcriptomes for each tissue. Discovery of differentially expressed genes was performed with both edgeR and glmmSeq. We found that there were only small numbers of differentially expressed genes in the male accessory glands and none of the known *spermatophylax* proteins were differentially expressed. Similarly, there was only a very small number of differentially expressed genes in female head tissue. However, in the female ovaries we found a very large effect of both the selection regime (male-biased vs female-biased) and mating status (virgin vs mated) on gene expression, with sever-al hundreds of differentially expressed genes for each comparison. This indicates that differential selection based on variation in adult sex ratios, and hence the intensity of sexual conflict, can lead to rapid changes in molecular signatures in females.

Key Words: Sexual conflict, nuptial gift, evolution

POSTER SESSIONS

A NEW GENUS OF TETRIGIDS (CAELIFERA: TETRIGIDAE) FROM SOUTH AMERICA

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The family Tetrigidae are distinguished from other caeliferans by the pronotum partially or completely covering the abdomen, with varying shape and ornate in certain groups; a forehead arranged as a collar surrounding the mouth-pieces (*sternomentum*); tegmina, when present, reduced and placed laterally to the body; wing, when present, with expanded anal region; absent tympanic organ; tarsal formula 2-2-3; missing arolium; male genitalia composed of two layers, and wine-bottle shaped, cylindrical eggs with a tapered end. In this taxon, there are interesting examples of morphological convergence in geographically distant taxa, such fore or middle femur are flatted in *Amorphopini–Xerophyllini*; costa frontal expanded in a scutellum in different groups mainly Cladonotinae, and head protuberances in *Miriatrini–Cleostratini*. In this context, the head shape also presents a variety of formats that occur in different evolutionary groups. Most of these differences are associated with the presence of a projection on the top of the head that is usually exemplified by a 'horn'. This protuberance is defined as a long and pointed chitinous process of the head, and it originates from different head structures. There are several caeliferans that present a diversity of horn-like morphology, and among the Neotropical groups, highlight out the Central American–Amazonian *Bactrophora* Westwood, 1842 that is easily recognized by the unusually long horn, derived from a long fastigium; the stick grasshoppers of *Proscopiidae* species, with a fastigium formed by the extension of the vertex, and some members of tetrigids. In this context, in some *Metrodorinae* in South America there are head projections of different formats, ornaments and dimensions. Thus, in this study, we described a new genus and species from Brazilian Amazonia that shows a pattern morphologically similar to Rostella Hancock, 1913, an Asian genus. Both genera are recognized by conspicuous horn-like projection on the head. This new taxa can be distinguished from the other genera by the following combination of characters: (i) long upwards rising horn-like projection with the lateral margins strongly notched, and the rounded at tip; (ii) well-marked fascial carenae, with a “V” inverted shape; (iii) fore femur with arc-shape upper and lower margin, almost shield-like, with lappets in the ventral margin; (iv) middle femur upper face carenated and lower margin with two lappets and (v) hind femur slender and elongated at male and robust at female. Tetrigids systematics has been severely neglected for over half a century and only recently, new studies of this group have been made in the Neotropical region. This new report is the first tetrigid record of a new genus in over sixty years for Brazil. The report of new species in environments that are highly threatened and that are, simultaneously, centers of biodiversity, such as Brazilian Amazonia, reiterates the importance of such areas as hotspots of diversity and emphasizes the need for its conservation.

Key Words: Brazil, horn-like, pygmy grasshoppers

CRICKET COMMUNITY RESPONSE TO THE IRON ORE TAILINGS SPILL DISTURBANCE IN MARIANA, BRAZIL

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Disasters caused by mining, such as the rupture of the Fundão dam in Mariana in 2015, can generate major environmental disturbances, influencing the diversity and ecosystem functions of arthropod communities in the region. Among the possible groups of indicator arthropods, the Orthoptera stand out, since they are sensitive to environmental changes and play an important role in the functioning of ecosystems. Our aims were to evaluate the effects of disturbance on species richness, abundance, and evenness (Pielou index) of litter crickets (Orthoptera: Grylloidea), as well as to identify indicator species. We settled 16 sampling sites within riparian forest, spaced 1 km apart from each other, seven in reference and five in affected areas. At each sampling site, we installed two plots of 10x4 meters, spaced 50 meters apart, and measured the distance to the riverbank. In each plot, we installed two sets of three pitfall traps containing 500ml of ethanol and left in the field for 48 hours. We adjusted generalized linear mixed effects models (GLMMs) to assess the influence of the disturbance, incorporating the identity of the sampling sites as random effect, avoiding unwanted effects of pseudo-replication. Each set of traps was considered a sampling unit (n=64); distance to the river was adjusted as covariate. To detect the indicator species of the areas, we calculated the indicator value of each species with the IndVal function. We collected 1247 individuals, 761 in affected and 486 in reference areas: Trigonidiidae (874), Phalangopsidae (177), Gryllidae (32), Anostostomatidae (9), Mogoplistidae (2), Oecanthidae (2). Species richness ($\chi2$= 0.06, p= 0.80) and abundance ($\chi2$= 0.22, p= 0.63) were not influenced by the disturbance. However, the disturbance influenced marginally the evenness ($\chi2$= 3.79, p= 0.051), and influenced the litter height ($\chi2$= 5.50, p= 0.01) being higher in the affected areas. We detected one single indicator species, for reference areas (*Amanayara* sp1, IndVal= 0.5812, p= 0.04). Our results suggest that the cricket community may be resilient in the medium term (seven years after the disaster), mainly due to the extensive vegetation cover in the region, allowing its reestablishment after the disturbance. However, our results evidence the importance of environmental conditions for sensitive crickets, such as *Amanayara* sp1. Our results might result from the high forest cover in the studied region, contrasting to most of the Doce River basin. Therefore, our results demonstrate the importance of assessing the impact of environmental disasters and providing useful information to guide management and conservation measures for fauna in areas affected by disturbances.

Key Words: Community, disaster, mining

GRASSHOPPER COUNTY RECORDS IN WYOMING SHOW SPECIES MOVEMENT

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Grasshopper survey has been conducted in Wyoming, USA since the 1930s. Original survey work was comprised of general coverage sampling of the state, returning to areas where grasshoppers or Mormon crickets (Tettigoniidae*: Anabrus* simplex) were a known problem. In 1988, the United States Department of Agriculture (USDA), Animal and Plant Inspection Service (APHIS), Plant Protection and Quarantine (PPQ) and the University of Wyoming (Wyoming, U.S.A.) collaborated on developing a systematic, comprehensive species-based survey of grasshoppers and Mormon crickets in the state. The resulting database serves as the foundation for information and maps which provide a valuable tool for grasshopper and Mormon cricket management and biological research.

Collecting specimens is an important component. Samples are collected at random throughout the state, at high density locations found during survey, and during special focused collecting efforts each field season (May through September). Not all survey locations have a corresponding specimen sample. Orthoptera specimens collected are identified to genus and species. These identifications are added to the USDA's database and entered in the National Agricultural Pest Information System (NAPIS) housed by Purdue University in Indiana, USA each year.

Species are tracked by presence in each county of Wyoming and when a species is newly recorded in a county, it is marked as a county record. County records have occurred in general surveys at random locations and at established permanent sites in Wyoming. These permanent sites were established in 1988 and are visited at least once during each season.

Identification data from 15,357 bulk specimen collections taken during 1987 – 2022 have been catalogued which resulted in the identification of 449,979 grasshoppers. Approximately 107 state records and 1,349 county records were established. ArcGIS Pro was used to map these county records, annual survey efforts, and distributions maps by species. Comparing distribution maps to maps of county records shows grasshopper species maybe expanding their ranges or grasshopper community complexes may be changing.

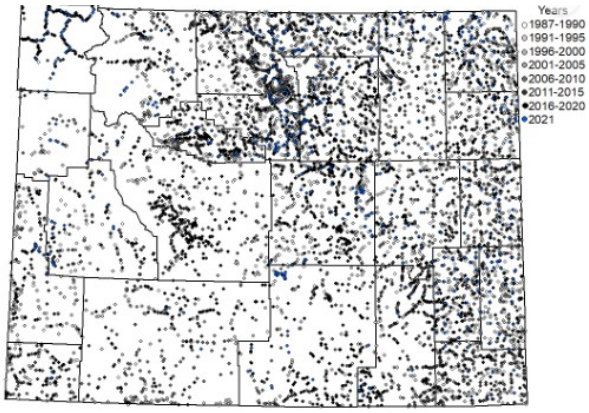

Figure 1. Grasshopper collection sites in Wyoming.

Key Words: Wyoming, Grasshopper, elevation, APHIS, survey

IMPACT OF THE IRON ORE TAILINGS SPILL ON BLATTODEA COMMUNITY OF THE DOCE RIVER BASIN, BRAZIL

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In 2015, occurred the largest environmental disaster in Brazil, with the collapse of an iron ore tailings dam in Mariana-MG, discharging tens of tons of tailings into the environment, mainly along river channels, but also spilling over the river margins, flooding the riparian vegetation. Here we evaluated if cockroach communities inhabiting riparian vegetation presented medium-term (seven years after the disaster) changes in response to the disaster. We also evaluated alternative drivers of Blattodea communities: (i) the disturbance, (ii) hydrophily (distance to river), (iii), resource availability (litter weight) and (iv) environ-mental heterogeneity (litter components s.d.). We hypothesized that either diversity (genera), abundance (individuals), or community structure (Pielou's evenness index) of Blattodea were changed. We sampled five regions along the Doce River basin, so as to ac-count for spatial heterogeneity. In each region we sampled one affected and one reference area, with 20

Replicates within each area, in a total effort of 200 sets of three pitfall traps, let 48h in the field. We collected 292 Blattodea individuals, from four genera: *Epilampra* (Burmeister, 1838), *Cariblatta* (Hebard, 1916), *Poeciloderrhis* (Stål, 1874) and *Pycnoscelus* (Scudder, 1862). Blattodea abundance decreased with distance to river in reference (χ2=5.14, p=0.023), but not in affected (p>0.9) areas. Blattodea genus richness increased with litter humus in reference areas (χ2=4.81, p=0.0282), but not in affected areas (p=0.9). Blattodea communities' evenness presented a more complex response. Evenness decreased with distance to the disaster's origin and increased with distance to river in reference (χ2=4.16, p=0.041), but not in affected (p=0.3) areas. Our results evidenced the medium-term effects of the mining disaster unto terrestrial cockroaches. For all three evaluated response variables, affected differed from reference areas: local environmental correlations present in reference areas disappeared in affected sites. The effects were not straightforward but mostly indirect. This study contributes to a better understanding of the response of Blattodea communities to environmental impacts and may help identify conservation and management measures for ecosystems affected by mining activities.

Key Words: *blattaria*, iron tailings, abundance

INVESTIGATING SOUTH AFRICAN ORTHOPTERAN SPECIES DIVERSITY USING PASSIVE BIO-ACOUSTIC MONITORING

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Phytophagous insects make up a large amount of the globe's animal species. Insect diversity data is only available for a small portion of insects in South Africa. It is estimated that more than half of all insect species in South Africa remain unknown to science. Orthopteran species (grasshoppers, crickets and katydids) have species specific signals which enable researchers to find species using bio-acoustic methods. These recordings can be used to detect new species, endemics and mapping of ranges, abundances and species richness. Due to these unique sounds (mating calls), orthopteran species are perfectly suited for research using bio-acoustic monitoring to contribute towards greatly needed datasets.

The aim of this project was to initiate biodiversity monitoring of acoustically signaling orthopteran species across different habitat types and seasons. Sampling sites were selected that represent different vegetation types across South Africa. Acoustic monitoring was done for one-week periods. Weather-proof, battery-powered recorders were mounted two meters above the ground. Both audible (up to 20 kHz) and ultrasonic (up to 128 kHz) sounds were recorded. Kaleidoscope Pro software (Wildlife Acoustics) was used for sound analysis. The number of species within each suborder was determined. Additionally, overall orthopteran species richness will be measured by counting the number of "sonotypes". Sonotypes were identified from spectrographic characteristics (frequency and temporal structure). Sonotype data was used to calculate an Acoustic Diversity Index (ADI), Normalized Difference Soundscape Index (NDSI) and a Bio-acoustic Index (BI) for each site. Preliminary data is presented.

Key Words: Passive acoustic monitoring, bio-acoustic index, biodiversity monitoring

THE PROCESSES IN THE HYBRID ZONE BETWEEN SIBLING GRASSHOPPER SPECIES OF THE *Stenobothrus eurasius* GROUP (ACRIDIDAE, GOMPHOCERINAE)

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Two sibling grasshopper species, *Stenobothrus eurasius* and S. *hyalosuperficies* have completely different acoustic behaviour (Tarasova et al., 2021). *S. eurasius* males produce their songs by common femorotegminal stridulation. A calling song consists of the prolonged echemes of compound syllables, genera-ted by the complex leg-movement pattern. A courtship song of *S. eurasius* includes three elements (A, B and C) followed in a strict order. Element B has the same structure as the calling song. In contrast to *S. eurasius*, both sexes of *S. hyalosuperficies* produce sound not only by common stridulation, but also by wing clap-ping. The calling song consists of the short wing beats. In the courtship song, the wing clapping (element D) alternates with two elements generated by stridulation (A' and C'). Despite strong difference in the acoustic behaviour, the species hybridize in a contact zone in south-eastern part of European Russia.

In the contact zone, we found eight populations, which we considered to be hybrid. In observed populations hybrid males show a wide range of songs, which might be divided between *eurasius*-like and *hyalosuperficies*-like songs. In five populations the *eurasius*-like songs were dominant. They contained element B, being specific for S. eurasius, and element D typical for S. *hyalosuperficies*. In most cases hybrid songs appeared to be the same as in S. *eurasius*, but with addition of short element D. However, there were songs with novel features (fig 1). In element B leg movement pattern changed, which affected on sound structure. Structure and duration of element C also changed in those hybrids. In three populations pre-vailed *hyalosuperficies*-like songs. In such songs changes in element C' were mainly found. In general, intermediate song variants were extremely rare in the contact zone.

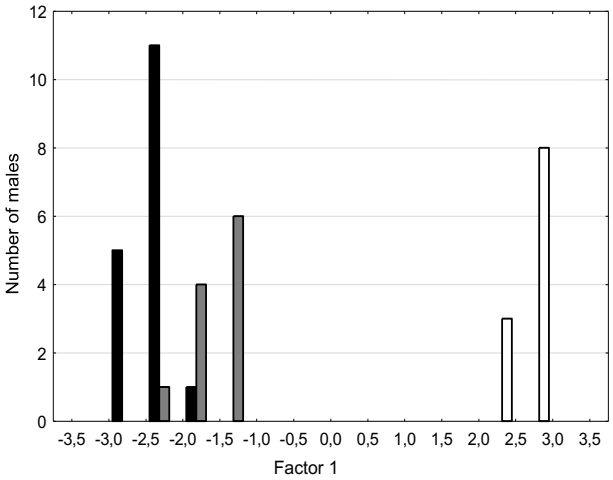

Figure 1. Distribution of the principal component (PC) 1 scores at allopatric S. *eurasius* populations (black bars), allopatric S. *hyalosuperficies* populations (white bars) and hybrids from *eurasius*-like population with novel signs (grey bars).

Key Words: grasshopper, mating behaviour, female response, hybridization.

NEW RECORD OF THE RARE GRASSHOPPER *Gemeneta opilionoides* (Bolívar, 1905): DISTRIBUTION, HABITAT, THREAT AND CONSERVATION ACTION

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Gemeneta opilionoides (Bolívar, 1915) is a rare and endemic grasshopper from Cameroon and Equatorial Guinea. The aim of this work is to present a new population of the species, habitat, threats and conservation actions in Cameroon. We used both field observations and surveys with questionnaires. We observed the species in its living environment, identified the plant species composition of this habitat, and noted the threats to it. Villagers were interviewed individually using a rapid rural assessment method in the form of a semi-structured survey. A total of 140 people were interviewed.

The study increased the number of known *G. opilionoides* localities to four: Biafra in Equatorial Guinea; Makak, Ngutadjap and Ngoyla in Cameroon. The species habitat was swampy are-as of lowland rainforest with abundance of Maran-thaceae and Acanthaceae. In this habitat the species was rare (From 2017 to 2023, just 9 specimens were observed both at Ngutadjap and at Ngoyla). In general, 29.3% of the interviewed people said they knew *G. opilionoides*. Among them, 27.1% reported that the species habitat is swamp part of forest while 7.1% reported dry part of forest. People (26.4%) recognized *G. opilionoides* as being rare.

The threats observed in the species habitat were multiple, among them local people citing mainly wood cutting (82.1%), market gardening (70.7%), bush fire (57.1%), bamboo exploitation (43.5%), sand mining (16.4%) and fish pond installation (4.2%).

According to them, the most important threats that could lead to 50 to 75% of habitat loss would be wood cutting (27.1%), market gardening (17.1%), bush fire (9.2%) and sand mining (7.1%).

Our sensitization actions against the destruction of the *Gemeneta*'s habitat were the only ones directly oriented to the conservation of the target species. Other actions, for the conservation of swamp forests in general, were awareness sessions by the local Investment Community Groups (ICG), the Cameroon Minister of Forest and Wildlife (MINEFOF), and the World Wildlife Fund (WWF) mainly made for mammal species. The villagers said MINEFOF and WWF awareness could have 50–100 % of efficiency in management of swamp forests. The above data which highlight the importance of preserving *G. opilionoides* habitat are useful in the assessment of the IUCN extinction risk of the species.

Fig. 1. Gemeneta opilionoides

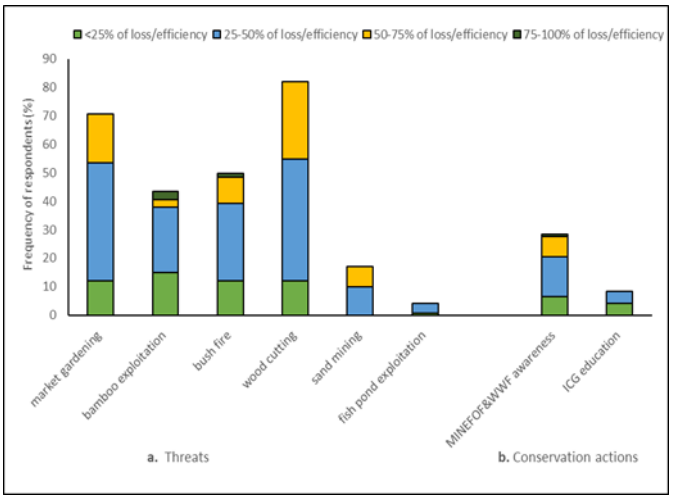

Fig. 2. Impact of threats in the loss of *Gemeneta opilionoides* habitat (a) and efficiency of conservation action cited by the local people (b).

Key Words: *Gemeneta opilionoides*, swamp forest, deforestation, sensitization

THE PROSPECTS OF USING RETROTRANSPOZON iPBS TO CHARACTERIZE THE GENETIC DIVERSITY OF WETLAND GRASSHOPPER SPECIES *Stethophyma grossum* (Linnaeus, 1758) & *Chrysochraon dispar* (Germar, 1834)

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Wetlands are globally protected by the Ramsar convention and are important habitats to a unique species complex. Multiple wetland Orthoptera species have experienced rapid declines in Europe, main drivers being draughts, deterioration of habitats and land use intensification [3]. When planning habitat management for conservation goals it is important to know how habitat configuration in the landscape translates to the longevity of habitat specialist populations, which in turn depends on their genetic diversity. Molecular markers provide the opportunity to quantify genetic similarity between populations giving an insight of the functional connectivity of habitat patches. Grasshoppers have one of the largest insect genomes, especially *S. grossum* and *C. dispar* [2]. One of the reasons for the large genome is believed to lay in the large amounts of replicates, among which retrotransposons dominate [5], and their activation can be used as environmental stress induced genetic diversity indicator [1]. We hypothesize that a retrotransposon-based marker could use this genomic particularity as a basis for characterizing genetic diversity. In this study we assess the use of retrotransposon based molecular marker – iPBS (inter-primer binding sequence), for the first time to characterize the genetic diversity of two wetland specialist species with varying dispersal abilities – *S. grossum* and *C. dispar*. We carried out a thorough iPBS primer screening (71 out of 83 primers were tested) for each species. Using PCR efficiency scale [4] we evaluated the results depending on the number of produced bands on agarose gel electrophoresis. The results show that multiple iPBS primers have high PCR efficiency and DNA fragment polymorphism. We conclude that iPBS can be used to study the genetic diversity and population genetic differences of acridid species.

Key Words: Acrididae, genetic diversity, transposable elements, iPBS

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USING DNA METABARCODING TO EXPLORE DIET OF THE CRITICALLY ENDANGERED BUSH-CRICKET *Isophya beybienkoi*

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The Bei-Bienko's Plump Bush-cricket (*Isophya beybienkoi* Mařan, 1958) is an endemic species of the Slovak Karst (Slovakia, Central Europe), which is listed as Critically Endangered (CR) on the IUCN Red List, with a negative demographic trend. To mitigate this decline and prevent the bush-cricket from extinction, better knowledge on the ecology of this species is urgently needed. Especially, there is a lack of information on diet composition and feeding preferences of *I. beybienkoi*.

This study used DNA metabarcoding of faecal samples to determine the herbivore diet of this species for the first time and, thus, identify habitat requirements. The entire procedure included non-invasive collection of faeces, ensuring the full survival of the animal, hence representing the ideal tool usable for conservation purposes. The metabarcoding results allowed the evaluation of differences in dietary compositions between individuals, males and females collected from different study plots. Data from in-situ sampling of the vegetation composition of study sites allowed placing the metabarcoding results in an ecological context. Therefore, this novel information will be crucial for the development of a conservation strategy and long-term habitat management for this endemic species.

Key Words: Central Europe, critically endangered species, diet, endemism, metabarcoding, Orthoptera, Slovakia.

Acknowledgements: The authors would like to thank the staff of the Slovak Karst National Park for their cooperation and help in the field. Katharina Gebauer helped in analyzing the metabarcoding data. Finally, we thank the Stiftung Artenschutz, which kindly supported this study.

BIOLOGICAL CONTROL TRIALS OF SOUTH AMERICAN LOCUST WITH *Beauveria bassiana*

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Locusts are highly feared pests due to their ability to form voracious swarms that cause considerable damage to crops. The South American locust (*Schistocerca cancellata*) has historically represented the biggest problem for agricultural activity in Argentina, causing serious economic losses. Since 2015 and after 60 years of recession, there has been a resurgence of *S. cancellata* that affects Argentina, Bolivia and Paraguay. In addition to responding to emergency situations, locust pests are managed globally within the framework of preventive management, consisting of permanent surveillance and early control. In Argentina, phytosanitary products of chemical synthesis continue to be the only means available for the control of locusts. However, there are antecedents in other countries that consider biological control as a fundamental insecticidal strategy. In this sense, the objective of this study was to validate the use of entomopathogenic fungi to effectively reduce the population of *S. cancellata*, providing a new alternative with low environmental im-pact for the management of the pest. A pro-spection was carried out in search of entomopathogenic fungi that naturally affect *S. cancellata*, resulting in the detection, isolation and identification of three isolates of *Beauveria bassiana*: LPSc 1225, 1226 and 1227 (Figure 1). The morphological identification was corroborated by using molecular techniques. Through laboratory tests, the efficacy of the three strains was analyzed and the relationship between their levels of chitinases, proteases and lipases at different temperatures and the insecticidal activities of these fungi was determined. Due to the results obtained, the LPSc 1227 strain was selected for a preliminary evaluation under field conditions (Figure 2), obtaining an average mortality of 62,4% in the treated insects. In this work, it was possible to isolate for the first-time native strains of *B. bassiana*, naturally affecting *S. cancellata*. This study has provided valuable information on the potential of entomopathogenic fungi as biological control agents for locusts and further research on the feasibility of their application in pest management should be continued.

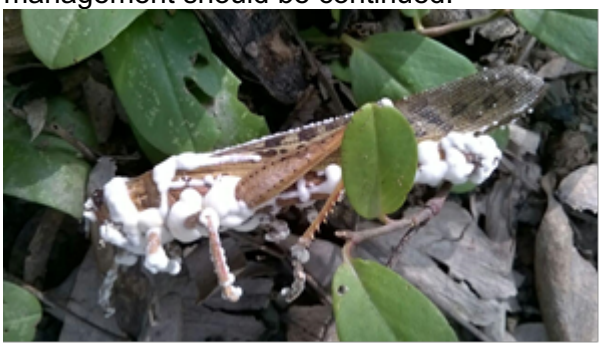

Figure 1. Locust infected with *B. bassiana*

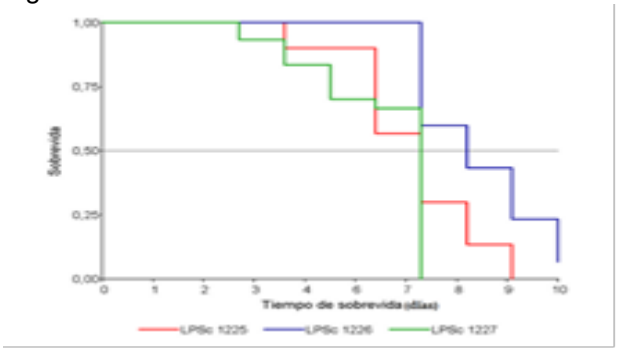

Figure 2. Survival curves on third instar nymphs of S. cancellata when a con-centration of 1x108 conidia/ml of each of the B. bassiana strains LPSc 1225; LPSc 1226 and LPSc 1227 was applied to the nymphs.

Key Words: Locust, Biocontrol, *Beauveria bassiana*

SURVEILLANCE, MANAGEMENT AND ALERT SYSTEM FOR LOCUSTS IN THE REGION COSAVE

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The Plant Health Committee (COSAVE) serves as the Regional Plant Protection Organization (RPPO) for the Southern Cone of South America. Its primary function is to act as an intergovernmental forum, promoting coordination and joint efforts to address phytosanitary issues of common interest among its Member Countries, thereby bolstering regional phytosanitary integration. The genesis of COSAVE can be traced back to the battle against locusts in the region. Between 1947 and 1964, collaborative and coordinated actions for locust control demonstrated to the countries of the Americas, and subsequently to the COSAVE members, that successful pest control in agriculture relies on a coordinated approach to phytosanitary measures. Among COSAVE's activities are the endeavors of various technical groups, including the Technical Group on locusts. While the region hosts three locust species, the primary concern arises from the resurgence of the South Ameri-can locust (*Schistocerca cancellata*), which has posed a threat to agricultural production in member countries since 2015. In response to this challenge and to improve response times to migratory swarms moving between Bolivia, Paraguay, and Argentina, near the border of Brazil and Uruguay, Senasa Argentina, in collaboration with COSAVE and IICA, has developed the "Regional Locust Monitoring, Management, and Alert System" (Figure 1). The locust alert system enhances the capacity for anticipation and response by systematizing monitoring information through a mobile application that directly captures field data in the various countries, making it quickly available. The system's regional nature enables simultaneous operations in the region, reporting pest progress in real time in all countries, without waiting for decisions and human actions to communicate, which can be time-consuming. Automatic alerts or notifications are sent upon pest detection, improving communication between RPPOs and allowing the private sector to be promptly informed about the pest situation in real-time. Additionally, RPPO specialists have access to a unified platform for information management through the Locust GIS (Figure 2), facilitating decision-making and the implementation of control measures. For further information, please visit: https://bit.ly/3Ps4lwv

Figure 1. COSAVE Locust Alert System website

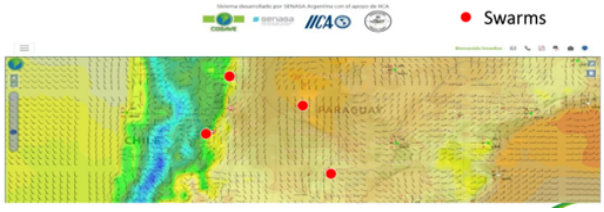

Figure 2. GIS Locust image

Key Words: Locust, COSAVE, Alert, System, Response, Emergencies

PREVENTIVE LOCUST MANAGEMENT OF THE CENTRAL AMERICAN LOCUST IN YUCATAN, MEXICO.

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In Mexico, Yucatan State has an important breeding zone of the Central American Locust (CAL) *Schistocerca piceifrons piceifrons*, every year different population level of locust appears. Different strategies for reducing the CAL are implemented in coordination among Federal, State and Municipal Government and farmers and livestock associations. In Yucatan, as in all of Mexico, there is a permanent campaign against CAL that has allowed to give continuity to the preventive strategies. We account the number of acridians formations (swarms, bands, patches and solitary forms) for nine years (2014-2022) and found a reduction of those formations to the current time; in analysis we obtained in upsurge year (2014, 2018 and 2020) and the last one year (2022) a R2:0.92 and P value: 0.04

To achieve this reduction, different strategies have been developed and are executed permanently every year (figure 1):

a) Survey.
b) Biological Control.
c) Chemical Control.
d) Training to field locust officers.
e) Diffusion with farmers and ranchers.
f) Geospatial Analysis of CAL population.

Geospatial analysis has made it possible to define the area with the highest risk of CAL development in a specific year. The traditional development area of CAL had been 767,328 ha, with the Kernel point density technique it was reduced to 126,718 ha, this is a decrease of 16.5% with high probability of early detection, its zone was called "Kukulkan" (figure 2).

Figure 1. Flow chart of strategies for CAL prevention.

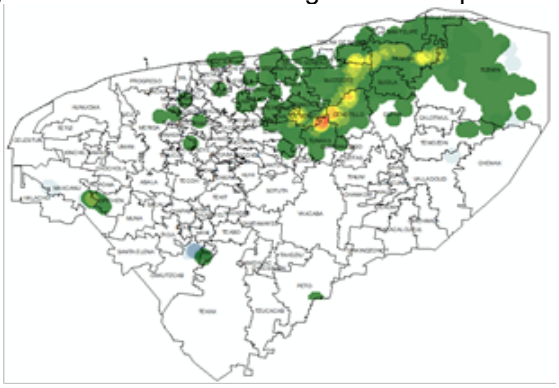

Figure 2. Point density of CAL survey.

In conclusion, the prevention strategies and territorial analysis of CAL through GIS helps to reduce the locust search areas, saving human and economic resources and greater preservation of the environment by carrying out a focused preventive control.

Key Words: Strategies, Breeding zone, Acridian formations

CENTRAL AMERICAN LOCUST *Schistocerca piceifrons piceifrons* (WALKER) (ORTHOPTERA: ACRIDIDAE) THREAT AND MANAGEMENT STRATEGIES

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The livelihoods of thousands of producers in the region are threatened by pests such as the Central American locust, which can generate significant losses and affect food security in our countries.
Locusts are considered one of the most harmful pests in the world.

Corn, beans, sugarcane, bananas, coffee, citrus fruits, pepper, pastures, and many other crops, as well as wild vegetation can be the target of locusts, whose swarms ("mangas") are favored by the change in the rain pattern and the cli-mate variability.

Management strategies

1. Prevention through monitoring that allows the Early Warning System to be activated.
2. Use of entomopathogenic fungi, such as strains of *Metarhizum anisopliae* based on surveillance and location of points.
3. Coordination among National and Regional Organization, farmers and researchers.
4. Capacity building, on site and on line, to locust field officers.

If you suspect the presence of locust, report it to the nearest plant protection authority.

14th INTERNATIONAL CONGRESS OF ORTHOPTEROLOGY
Mérida, Yucatán, México

A MOLECULAR DISSECTION OF SEXUAL EVOLUTION IN THE DECORATED CRICKET *Gryllodes sigillatus*

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Sexual conflict, which arises when mating males and females have differing optimal fitness strategies, is very common among insects. This often leads to the evolution of sexually antagonistic traits, by which males attempt to manipulate female behavior and physiology to increase their share of paternity. Nuptial food gifts provided at copulation to females by some male insects, including many Orthopterans, may also serve this function. In the decorated cricket *Gryllodes sigillatus*, females mate multiple times and use a mix of sperm from different males to fertilize their eggs. During mating, males transfer a nuptial food gift named the spermatophylax, a gelatinous mass that forms part of the spermatophore. Spermatophylax feeding deters females from prematurely removing the sperm-containing portion of the spermatophore (ampulla). As such, it increases sperm transfer and thus a male's paternity share, and it is to the male's benefit that the female feeds on this gift as long as possible. In addition, the male spermatophy-lax may influence female behavior and physiology in ways unrelated to maximizing sperm trans-fer. In the face of such manipulation, females are expected to evolve resistance to male manipulation through counter mechanisms. The evolution of these opposing male and female traits is predicted to depend upon the intensity of sexual conflict. We used experimental evolution lines varying in the intensity of sexual conflict in which crickets were maintained under a male or female-biased adult sex ratio for 20 generations. We subsequently assessed gene expression profile changes in male accessory glands, female ovaries, and female heads. For each tissue, five samples were collected from each of three lines per regime (male-biased or female-biased). For the 30 male accessory glands and the 30 female head tissues included in this study, dissections were performed two hours after mating. For the ovaries, we collected tissues from both mated females and virgins, bringing the total number of samples for this tissue to 60. RNA from all 120 samples was extracted using a Trizol-based phase separation, followed by a DNAse treatment. Samples were sequenced on an Illumina HiSeq. The sequencing reads were trimmed based on their quality and they were filtered for bacterial and viral contamination. We assembled and annotated de novo transcriptomes for each tissue. Discovery of differentially expressed genes was performed with both edgeR and glmmSeq. We found that there were only small numbers of differentially expressed genes in the male accessory glands and none of the known spermatophylax proteins were differentially expressed. Similarly, there was only a very small number of differentially expressed genes in female head tissue. However, in the female ovaries we found a very large effect of both the selection regime (male-biased vs female-biased) and mating status (virgin vs mated) on gene expression, with sever-al hundreds of differentially expressed genes for each comparison. This indicates that differential selection based on variation in adult sex ratios, and hence the intensity of sexual conflict, can lead to rapid changes in molecular signatures in females.

Key Words: Sexual conflict, nuptial gift, evolution

PHYLOGENETIC RELATIONSHIPS AMONG THE MEXICAN MELANOPLINES (ORTHOPTERA: ACRIDIDAE: MELANOPLINAE)

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The subfamily Melanoplinae is one of the most diverse groups of grasshoppers in the world, which is distributed in the Americas and Eurasia. Particularly, a great proportion of the diversity of genera and tribes of this subfamily in the Americas take place across Mexico. Although the knowledge about the evolutionary relationships of these grasshoppers has increased recently, it remains limited in part by the underrepresentation that the Mexican taxa have had in previous phylogenetic studies. Thus, the objective of this work was to reconstruct the phylogeny of Melanoplinae including most of the Mexican supraspecific taxa to contribute to the understanding of the evolution- nary relationships of the subfamily. To achieve this goal, the genetic variation of 5 widely used genomic regions (nuclear and mitochondrial) of 237 species of Melanoplinae was used, among which 80% of the Mexican genera and all the recognized tribes of the subfamily were represented. In the obtained phylogeny (Fig. 1), 7 main lineages of Melanoplinae were recognized, of which 5 of them are present in Mexico.

Although the support of the identified lineages and their phylogenetic relationships was mostly moderate or low, these results were largely consistent with morphological similarities and the geographic distribution of the members of those lineages, as well as with the biogeographic history proposed for the subfamily by previous studies. The results of this work indicate that the evolutionary history of Melanoplinae grasshoppers in Mexico is complex and suggest multiple and important taxonomic changes in various genera, tribes, and even between the currently recognized members of the Melanoplinae.

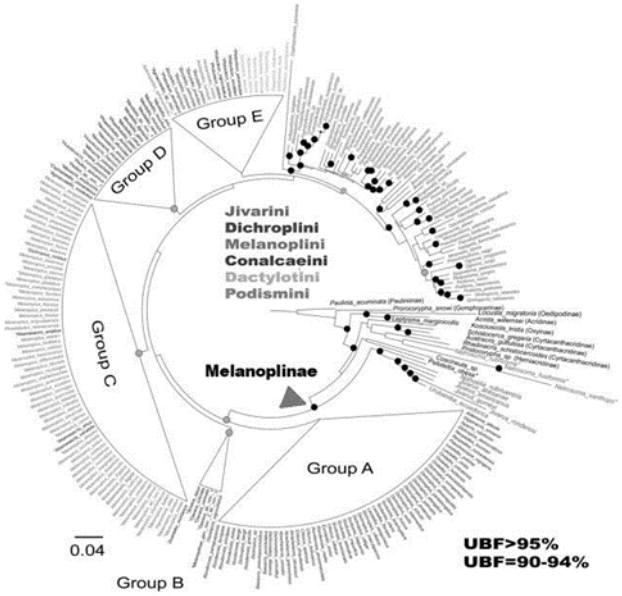

Figure 1. Maximum likelihood phylogenetic re-construction of the subfamily Melanoplinae based on the total genetic information obtained from 5 genes.

Key Words: Grasshopper, Melanoplinae, Phylogenetics

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