First Bat Course on Ecology, Diversity, Conservation, And Ecosystem Services

Report

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INSTITUTO DE ECOLOGIA UNAM

DEPARTAMENTO DE ECOLOGÍA DE LA BIODIVERSIDAD

Mexico City, May 18th, 2020

Distinguished sponsors of the Global South Bats Initiative

Dear Sponsors,

It is with great pleasure that I write today on behalf of the team, staff and students who share the passion to create the Global South Bats Network (GSB). As originally planned, this initiative was to begin in Africa and include African and Latin American participants in a course to build capacity for the study and conservation of bats. In practice, as you know, the idea was to create this collaborative network across the Atlantic of smart, creative, active people who share goals, challenges, and opportunities. And the result was an overwhelming success.

The selection process took place over a couple of months, filtering from over 130 applicants from virtually all countries in Africa and Latin America, to keep the most creative and energetic 26 participants from 22 countries. Because of the dynamics established from the start, friendships and collaborations began flourishing from day one. Plans, ideas, Research projects, and more, sprouted every day. The course itself was a main axis of the creation of the network, but the fieldwork and extracurricular activities promoted the weaving of a very strong network that continues to grow. Next steps of course include future joint publications, parallel research projects, shared conservation strategies, additional meetings, and obviously incorporating Asia later this year or the next.

This great success would have been just one more idea dead on the road was it not for your firm commitment and true spirit of enterprise, always promoting the robust growth of networks, expanding exploration and investigation in the new generations, and helping secure the future of biological diversity through innovative, effective initiatives. I trust you will find this report enticing and fun, and I hope you will agree with us that this is an initiative worth supporting in the long term.

With my very best wishes for a safe quarantine and our heartfelt thanks for your support,

Dr. Rodrigo A. Medellin
Senior Professor, Institute of Ecology, UNAM
Project Leader, GSB, and Main Instructor

Thank you for your support!

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NATIONAL GEOGRAPHIC

Summary

This was the first bat course on ecology, diversity, conservation, and ecosystem services taught by and for Latin Americans and Africans. The objective was to create the global south bats network, a transcontinental group of scientists focused on working on research, conservation, and environmental education about bats, highlighting and promoting collaboration, cross-pollination, exchanges, professional interactions, mutual growth, respect and support. A historical development where people from two continents that share challenges, a common ground, threats, conditions, and opportunities, are joining forces to learn from each other, to help each other and to continue working together. The results were nothing short of revolutionary, with the birth of the global south bats network (GSB). The group identified the vision, the mission, the goals and objectives, and initial projects to join forces across the ocean. The structure was defined, and we will be an integral part of the development of this initiative. In addition, during the course, the group contributed to the knowledge of local bats on the coast of Diani, Kenya. We conducted acoustic monitoring of bats in the region for ten days and obtained information on extant species, recorded echolocation calls to build an acoustic library of African bats, conducted 6 team projects focused in ecomorphology, acoustics, and science communication (appendix VI). Our collective efforts resulted in identifying 23 of species (appendix II), sampling over 200 individual bats, and recording over 100,000 files of acoustic data. Furthermore, as part of our outreach activities, we created fact sheets for each of the captured bat species, curated release calls for our acoustic library and built the very first bat social community platform where all members can support each other, discuss relevant topics, and collaborate across continents. Our work is setting the basis to share knowledge, find solutions to common environmental challenges, and form a common agenda and collective actions to ensure bat conservation in the global south. The GSB has created a strong platform for partnerships and will continually encourage and support cross-continent collaboration to contribute to the conservation of unique species and ecosystems around the Global South.

What is the Global South Bats?

The term "*South-South*" or "*Global South*" refers to developing countries, which are located primarily in the Southern Hemisphere. It is a term coined by economists that we have adopted as it represents the places where biodiversity is the highest, but where economic and social challenges are also huge. Usually, people from the United States or Europe are the initiators, coordinators, leaders, and heads of the research and conservation that is conducted in Africa, Asia, or Latin America. In addition, the people from Africa, Asia, or Latin America, usually only talk to the people from the U.S. or from Europe. Rarely, if ever, someone from Africa talks to someone from Latin America, or vice versa. This is a terrible missed opportunity, and it is high time that the locals lead these efforts. This initiative provides the best opportunity for Latin Americans and Africans to compare notes, share experiences, lead projects, programs, and initiatives, and learn from each other. Our project links countries with similarities in their development contexts and conservation challenges. In this framework,

The Global South Bats (GSB) was born with the goal of creating a network where all its members could share knowledge, work together to find solutions to common environmental challenges, identify, train, and empower

The idea of creating the GSB came from numerous conversations and shared experiences by the founders of the network: Profs. Rodrigo Medellin and Paul Webala. They envisioned a network where its members could not only share their knowledge and experiences but where they could establish collaborations that have a real impact in bat conservation across the world. In their efforts to create the GSB, the First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services was held at Diani, on the south coast of Kenya in January 2020.

The proposal for the first bat course and the creation of the GSB created a lot of interest among bat researchers. An invitation to apply to the field course **attracted over 130 prospective** students with almost 50% of the applications coming from each side of the world. Interestingly, the gender distribution of all applicants was represented by 49% men and 51% women and noteworthy was the fact that applications from Africa corresponded to 65% male 35% female applicants, while applications from Latin America corresponded to 65% female and 35% male applicants.

The applicants underwent a thorough selection process conducted by the course organizers and were selected by reason of their demonstrated background as bat researchers, showing a keen interest in continuing their career as bat conservationists, their leadership experience and skills, and having a strong commitment and a proposal to the establishment and subsequent functioning of the GSB (see appendix V for examples of essays submitted by the applicants). International representation was also key to the establishment of the network; therefore, only the top candidates of each country were selected.

A total of 26 students from 20 different countries were invited to attend the field course. Additionally, the nationality of two professors increased the number of represented countries to 22 (Table 1, Figure 1).

Table 1 International representation at the First course on First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services. Diani Beach, Kenya 12-22 January 2020.

Country	No. students	No. of professors
Kenya	3	1
Mexico	2	2
Brazil	2	
Colombia	2	
Rwanda	1	1
Peru	2	
Malawi	1	1
Nigeria	1	
Democratic Republic of Congo	1	
Cameroon	1	
Uganda	1	
Ecuador	1	
Ghana	1	
Honduras	1	
Mauritius	1	
Namibia	1	
Costa Rica	0	1
Ivory Coast	1	
El Salvador	1	
Grenada	1	
Mozambique	1	
Spain	0	1
TOTAL	26	7

Figure 1 International representation at the First course on First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services at Diani, Kenya 12-22 January 2020.

Goals and objectives of the course

1. Conduct the First Bat Course on Ecology, Diversity, Conservation, And Ecosystem Services.
2. Weave the network and connect African and Latin American bat scientists
3. Establish the Global South Bats Network

Activities

The format of the course included an intense syllabus (appendix III) with topics on bat taxonomy, bat sampling and monitoring techniques, ecosystem services, threats to bats, disease ecology, behaviour, morphology, evolution, genetics, science communication, outreach, fundraising and grant writing. Additionally, the course emphasized on capacity building, collaboration and teamwork among countries.

The team of professors (appendix IV) who donated their time to achieve the goals of the GSB included local and international bat experts such as Prof. Rodrigo Medellin, Autonomous University of Mexico (UNAM); Prof. Paul Webala, Maasai Mara University, Kenya; Dr Angelica Menchaca, UNAM and the University of Bristol, UK; Prof. Julius Nziza, Gorilla Doctors, Rwanda; Prof. Bernal Rodriguez, University of Costa Rica; 6) Dr Rachael Cooper-Bohannon, Bats Without Borders, Malawi; and Dr Adria Lopez-Baucells, Natural Science Museum of Granollers, Catalunya, Spain. A brief resume of each professor is provided in Appendix IV.

The lectures were complemented with practical sessions that provided hands-on training on bat research and monitoring techniques. Additionally, students were asked to form teams comprised of both Africans and Latin Americans in each team and work in these groups in developing short-term research projects. Students were taught different methods of capturing bats using hand nets, mist nets, harp traps, and triple high nets. The students were also taught how to safely handle bats and to take measurements and samples for morphometric and genetic analyses that underpin systematic and ecological studies. Furthermore, students learned the basics of acoustic monitoring using Song Meter SM4 BAT-FS bat detectors (Wildlife Acoustics, Inc. Massachusetts, US) and the EchoMeter Touch 2 Pro (Wildlife Acoustics, Inc., Massachusetts, USA).

Team building

Throughout the course, we organised several team building activities to encourage participants to bond with each other and start building the GSB network. We wanted the students to interact as much as possible, learn how similar they are and start brainstorming ideas on how to build the GSB, continue their friendships and collaborate in future conservation projects. We wanted to make sure that they led the creation of the network as much as possible so that they created a sense of belonging and that they view the network as their own.

As we knew that some students might shy away in the presence of the professors and not get to interact with the students of the other continent and countries, we arranged that the students were accommodated at their own villa. Three students from different nationalities (two from Africa and one from Latin America, or vice versa) shared each cabin. Every day, they were picked up and transported to the course venue. This allowed students to spend their free time mingling, chatting, telling their stories and bonding.

During the first day of the course, we asked students to pair up with someone from the opposite continent and introduce each other so that the African student would introduce the Latin American and vice versa. Every day, the professors and students had lunch together and rotated with the professors during bat capture sessions. Some team building activities included a friendly football match on the beach, safari trip, group projects, fundraisers, and student competitions, which are described as follows:

Encourage creativity

We organised a student competition aimed at promoting student's individual creativity and imagination. We asked them to design a logo that would represent the course. We subsequently let them vote for the winning image. The winning logo was designed by Ugo Diniz from Brazil and portraits the faces of a "species" from Latin America and a "species" from Africa in a ying-yang circle (Figure 2)

Figure 2 Logo of the First course on First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services by Ugo Diniz

After the course, Ugo Diniz, volunteer to design the logo that represents the GSB. The design has five overlapping bats of different colours (red, green, blue, yellow and red). Each colour or a combination of them can be found in every flag in the world, thus representing unity (Figure 3)

Figure 3 Logo of the Global South Bats network by Ugo Diniz

The power of social media

A second competition aimed at showing students the power of social media and its importance to promote their work; we asked them to share a photo, video, or message using the hashtags associated with the course. The winner tweet by Cecilia Montauban from Peru was selected based on the number of shares and likes, with 37 shares and 119 likes (Figure 4). Link: https://twitter.com/CmMontauban/status/1218954802085990400?s=20

Figure 4 Tweet by Cecilia Montauban during the First course on First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services

Field trip to caves

Visits were organised to two unprotected caves on community lands with thousands of several bat species: Mdenyenye cave in Fikirini village and Shimoni Slave cave, Kenya (Figure 5 and 6). This was necessary in part to sample some of the rich bat fauna at Kenya's south coast that could not be captured in mist nets but also to demonstrate to students the importance of natural caves as bat roosts in an agricultural matrix. These caves also contain high species richness of other cave organisms and indicate high priority sites for biodiversity conservation in areas threatened by human activities such as agriculture and resource extraction.

Figure 5 Prof. Medellin teaching students how to identify bat species based on morphological features in Mdenyenye cave, Fikirini village, south coast of Kenya, which harbours thousands of 7 different colonially-roosting bat species. Photo credit: Angelica Menchaca

Figure 6 Visit to Shimoni Salve cave, Kenya. Photo credit: Quincy Augustine

Safari trip

We organised a safari trip to Shimba Hills Forest National Reserve in order to let students enjoy a bit of the beautiful natural habitats of Kenya and, for most of them, experience the African fauna for the first time. The safari trip was announced as a surprise during the course, but we wanted students to value the costs of organising such an “impromptu” trip. So, instead of just inviting them and let them assume that the trip was covered by the organisers, we asked them to donate anonymously as much as they could or what they thought was enough so that everybody could go to the safari (Figure 6).

Figure 7 Visit to Shimba Hills National Reserve. From left to right: Luisa Gomez, Islamiat Raji, Julius Nziza, Paul Webala, Angelica Menchaca, Ana Ribadeneira, Adria Lopez-Baucells, Karla Saldana, Bernal Rodriguez.
Photo credit: Bego ña Iñarritu

Fundraising

At the time of the course, the fires in Australia were devastating its forests. So, the money collected to “pay” for the safari trip was instead donated to an organization to help relief the outcomes of the fires. In this way, we connected the students with an event that was happening across the world and showed them that their collective efforts actually made a significant difference in conservation. Furthermore, the final ($ 382) amount was doubled by

Prof. Medellin´s own funds and sent to <WIRES, New South Wales Wildlife Information and Rescue> Australia.

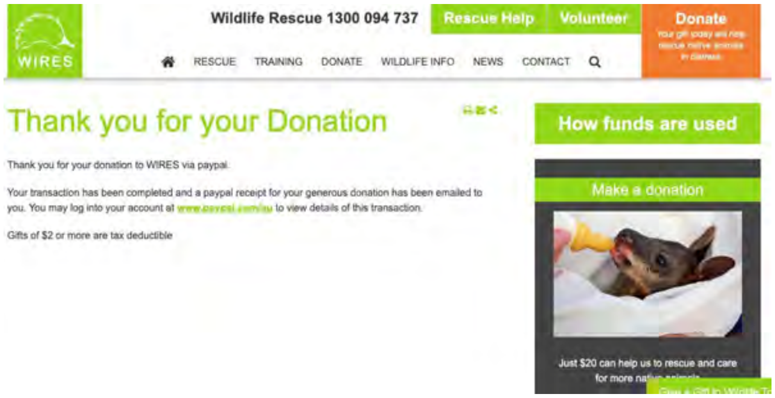


Figure 8 Donation to Wires, New South Wales Wildlife Rescue, Australia.

Cross cultural gift exchange

During the last night of the course, we organised a gift exchange. In advance of the course, each student was asked to bring a small gift from their home country that they could exchange with other participants. We were amazed by the excitement and pride everyone showed to share the story behind their gift and why it was special for them. Even when we asked them to bring something small and inexpensive, some students brought a little something for everyone, and some brought gifts that took pretty good space in their luggage! (Figure 8).

Figure 9 Cross cultural gift exchange. Left: Marilia Abero sa de Barros and Grace Waiguchu. Right: Carol Sierra and Madalitso Mwaungulu. Photo credit: Angelica Menchaca

Mission, vision and objectives of the GSB

To define the mission, vision, and objectives of the GSB we had brainstorming sessions and defined these as follows:

"Our mission is to promote and advance self-sufficient initiatives and applied research that ensures the conservation of bats across the Global South."

Vision:

- To empower a new generation of bat conservationists across the GSB network
- Create a network led by the next generation of bat conservationists
- To be a reference of work and effort to other groups
- To promote the importance of bats as ecosystem service providers in each of our countries and ensure their effective conservation
- Centralize conservation efforts and create the guidelines to achieve common conservation goals

Objectives:

- Focus research efforts that promote bat conservation
- Promote capacity building and education of on-the-ground practitioners
- Establish monitoring guidelines and periodic surveys of bats across the Global South
- Engage private and public stakeholders (collaboration and partnership)
- Share knowledge with other bat conservationists and the general public
- Create a platform for sharing information, communicate with each other and collaborate across borders
- Promote, connect and collaborate with other bat researchers in the Global South
- Share information relevant to bat conservation in social media to encourage the appreciation of bats by the general public.

Finally, the last day of the course, we asked the students to vote for two representatives, one from each continent. The representative's job until the next Global South Bats session, will be to maintain communication amongst students, coordinate activities and oversee the implementation of the GSB. Additionally, each student joined one or more of the following immediate projects: 1) collate information regarding each bat species captured during the course to make the species infographics; 2) build the GSB social platform and promote the network via social media; 3) write a blog post for the website; and 4) collaborate in a publication looking at the main threats to bats.

Future activities and implementation of the GSB

The January 2020 First Field Course was historical in the sense that it is connecting people from developing countries from two continents. People learned to work in an international, transcontinental setting, and there are short, medium, and long-term goals and objectives. Some of the most promising initiatives include a publication identifying and ranking the top 20 threats to bat conservation in Latin America and Africa as well as review and evaluate future prospects of each threat in the Latin American and African context.

In addition, we are working to bring a small contingent of African participants to the upcoming Third Latin American Congress in Merida, Mexico, in October 2020, to continue strengthening the growth of the network and the cross-continental collaboration. The GSB will continue to support research in Latin America and Africa by providing guidance to its members on the best practices to study and conserve bats. Additionally, it will encourage new members to take part in one of the chapters of the initiative. Furthermore, we intend to register the GSB as an NGO by January 2021.

Future plans include a second phase network meeting with a subset of the original group and additional new participants. We will continue supporting all of the initiatives and the first publications, and other results will see the light in 2021. We are exploring ways to help and support some of the most proficient students to apply for grants including the National Geographic Society and the Rufford Foundation. We are also helping them write proposals and explore ways to continue with graduate studies abroad

The website’s content will be continuously updated to provide resources generated by GSB members. Here, the general public will be able to read a monthly blog post about work being done by the GSB. The website will also provide species information sheets containing the most current information available for a species, a high-quality photograph, echolocation calls, and will highlight its importance in the ecosystem. The website will also provide direct access to the YouTube channel “Murcielagos desde Mexico”, where Prof. Medellin presents the natural history of bat species around the world. Furthermore, GSB members will be able to sign up to our own social network, where they will be able to discuss bat-related topics, network, post and answer questions and collaborate in future projects.

Figure 10 Members of the GSB. From left to right: Sospeter Kibiwot, Cecilia Montauban, Rodrigo Medellin, Luisa Gomez, Islamiat Raji. Photo credit: Bianca Otero

Conclusion

Compelling evidence point to a historic loss of biological diversity and abundance around the world. This   dramatic biodiversity loss make it clear that addressing the scope of the challenges facing conservation efforts around the world today will require concerted action on a much larger scale than has happened to date because conservation challenges are increasingly complex and dynamic, comprising of multi-faceted social, institutional, and ecological factors that span local to global levels.

The Kenya January 2020 First Field Course marked the historic beginning of a new way of doing conservation. We believe there has never been an event like this, bridging and empowering local students from 22 countries from two developing regions of the world of this magnitude that generated so much interest and with the clear vision of changing how conservation is being done. The course was a success in the way that it presented the initiative to the first members of the network, and already we see it come to fruition. We have no doubt that the GSB will attract many more members and that we will soon see on-the-ground conservation actions guided by its members. The GSB has the potential to grow exponentially and is determined to build the strongest task force of bat conservationists.

The creation of the GSB, which is explicitly designed to support collective action, opens doors to the much-needed international collaboration and local empowerment of South-South countries. This is a critical step in building a critical mass of the next generation of bat biologists and conservation practitioners to address conservation challenges locally and in the global south, regions that are arguably the richest in biodiversity in the world but with limited capacity for research, especially in Africa. Ultimately, working together in partnership across the global south towards shared objectives will raise the profile of bats, the second most diverse group of mammals that provide key ecosystem services but are greatly imperilled by inefficient conservation policies and human impacts, including persecution, rampant deforestation, agricultural expansion and urban spread.

APPENDICES

I. Letter to participants

Dear Global South Bats members,

Thanks to your commitment, motivation, and insatiable curiosity we had an incredible First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services! As we embark into an exciting project forming the Global South Bats Network, we wanted to take the time to reflect on our first field course and share some of our highlights.

Together, we established the first-ever network of bat researchers from the Global South. Traveling from 22 different countries and working alongside for 10 days we formed a new bat conservation task force that will undoubtedly make significant contributions to our living planet. From setting up nets in the forest to recording bat echolocation calls, we managed to register 23 species of bats. Our collaborative efforts showed us the importance of synergizing research techniques to better study and conserve bats. We learned together that Africa and Latin America are more similar than previously thought and that political boundaries will not restrict our efforts.

We explored the beautiful coast of Diani and were amazed to see the spectacle of hundreds of roosting Egyptian fruit bats (*Rousettus aegyptiacus*), and we saw the incredible giant roundleaf bat (*Macronycteris gigas*). Collectively, we sampled over 200 individual bats and recorded over 50 hours of echolocation calls. As part of our outreach activities, we created species fact sheets, curated release calls for our library, and built the very first bat social community platform where all members can support each other, discuss relevant topics, and collaborate across continents.

Most importantly, we became one team between students, professors, and park staff. We have no words to express our gratitude to your commitment, energy and attitude towards our goal. As we all shared our passion for experiencing nature and conserving the astounding life it hosts, we thank you for having become part of the Global South Bats family and encourage you to keep connected and collaborate with each other in the future.

Asante sana,
Angelica Menchaca, Rodrigo Medellin & Paul Webala

II. General bat survey outcomes

Bat sampling activities were conducted in four locations alongside Diani coast as follows: 1) within the premises of Jacaranda Indian Ocean Beach Resort; 2) within the premises of Diani Bay Resort; 3) in Shimoni Slave Caves; and 4) in Three Sisters Cave (Figure 11).

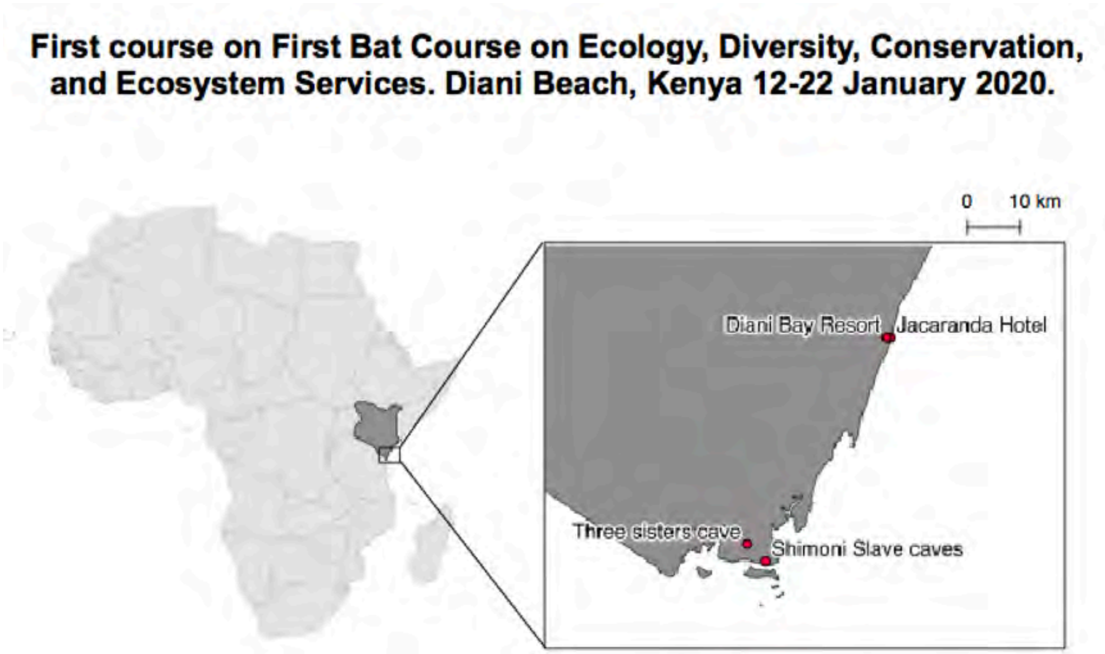


Figure 11 Bat sampling localities along Diani Coast, Kenya.

An approximate 200 bats were caught in 8 nights, which represent 23 bat species corresponding to 10 families (table 2). The family with the highest number of species was Vespertilionidae with 8 species, followed by Pteropodidae with 4 species and families Rhinolophidae, Hipposideridae, Megadermatidae, Emballonouridae, Nycteridae, Miniopteridae, Rhinonnycterinae and Mollosidae with 1-2 species each. Acoustic monitoring confirmed the presence of some species identified via active capturing techniques and allowed us to identify additional species and families.

Table 2 List of species recorded during the First course on First Bat Course on Ecology, Diversity, Conservation, and Ecosystem Services. Diani Beach, Kenya 12-22 January 2020.

Family	Genus	Species
Vespertilionidae		
	Neoromicia	*nana*
	Neoromicia	*capensis*
	Neoromicia	*rendalli*
	Scotophilus	*trujilloi*
	Scotophilus	*andrewewborii*
	Scotoecus	*hirundo*
	Scotoecus	*albigula/hindei*
	Pipistrellus	*rueppellii*
Pteropodidae		
	Epomophorus	*wahlbergi*
	Epomophorus	*minimus*
	Rousettus	*aegyptiacus*
	Eidolon	*helvum*
Rhinolophidae		
	Rhinolophus	*landeri*
	Rhinolophus	*eloquens*
Hipposideridae		
	Macronycteris	*gigas*
	Macronycteris	*vittata*
Megadermatidae		
	Cardioderma	*cor*
Emballonuridae		
	Taphozous	*hildegardeae*
	Coleura	*afra*
Nycteridae		
	Nycteris	*thebaica*
Miniopteridae		
	Miniopterus	*minor*
Rhinonycterinae		
	Triaenops	*afer*
Molossidae		
	Chaerephon	*pumilus*

III. Course Syllabus

Day 1.

Arrival of professors and students at Diani Beach Hotel, Kenya

Welcome from the organisers

Day 2.

Lectures:

Introduction to African and Latin Bats

- Origin and Evolution
- Bat diversity and Taxonomy
- African and Latin American bats: a comparative approach

Day 3.

Key questions in bat research

- Ecology and Natural History of African Bats
- What can morphology tell us about ecology?
- Acoustic Monitoring, I

Day 4.

How to study bats

- Monitoring and Inventorying
- Landscape ecology of bats
- Roosting Ecology

Day 5.

How to study bats

- Knowledge of bats in Africa
- Emerging Infectious Diseases and zoonosis
- Immunity and the evolution of flight in bats

Day 6.

Student Projects

- How to find funding
- Niche modelling for bat conservation

Day 7.

New Techniques in Bat Ecology

- Molecular techniques in bat research
- How to succeed at bat conservation
- Dietary studies of bats

- Major threats to bat conservation

Day 8.

Establishing the GSB

- How to conduct environmental and outreach programs
- Establish GSB’s mission, vision and objectives
- GSB brainstorming on how to create a student-led network
- GSB what do we want to achieve and will make us different to other NGOs?

Day 9.

Establishing the GSB

- Strategies and examples
- Organizations, alliances, and the future of bat conservation
- Draft future activities and implementation plans for the GSB
- GSB logo competition
- Selection of GSB student leaders and board of directors

Day 10.

Student presentations and group reports

IV. Short biographies of professors and organisers

Prof. Rodrigo Medellin. - Rodrigo A. Medellín is Senior Professor of Ecology at the Institute of Ecology, University of Mexico. He has worked on ecology and conservation in Mexico and elsewhere for over 40 years and has authored over 190 publications. Medellin was the President of the Society for Conservation Biology, is the founder of the Program for the Conservation of Bats of Mexico and is the founding Director of the Latin American Network for Bat Conservation. He was recently featured in a BBC documentary, The Bat Man of Mexico, narrated by Sir David Attenborough.

Prof. Paul Webala. - Paul is a National Geographic Explorer, published author (with over 30 publications), and a senior lecturer of wildlife biology at Maasai Mara University, Kenya. He is a regional expert on small mammals, especially bats, with extensive fieldwork experience. He is primarily a community ecologist, although his research addresses a variety of important questions for improving bat conservation in Africa. His research also spans several subfields of biology, as my work examines behavioural, ecological and systematic/taxonomic questions.

Prof. Bernal Rodriguez.- His interest is the ecology and conservation of mammals. He is working as professor and researcher of Biology School, University of Costa Rica; he is curator of the collection of mammals at the Museum of Zoology. His publications (more than 80) are about various topics, but mainly about roost ecology, dispersion issues, bio-acoustics and animal behaviour especially in the group of bats. Actively participates in conservation processes not only nationally but also Central and Latin American.

Prof. Julius Nziza.- Research Project Coordinator for PREDICT Rwanda. Dr. Julius was born in Uganda and obtained his Doctor of Veterinary Medicine degree from Makerere University in Kampala, Uganda. He is currently completing a Master of Science degree in International Infectious Disease Management from Uganda's Makerere University. Before working at Gorilla Doctors, Dr. Julius worked for the Department of Tourism and Conservation of the Rwanda Development Board for 3 years, serving as the veterinary warden at Nyungwe National Park in the southwestern corner of Rwanda.

Angelica Menchaca, PhD.- Angelica is a Mexican researcher and a recent graduate of the University of Bristol, UK. She has dedicated her career to the conservation of mammals and has used genetic tools to answer ecological questions. Her research has focused on learning about the genetics of bats and their relationship to the environment. During her PhD project, she studied the Tequila bat (*Leptonycteris yerbabuenae*) where she tried to understand why these nectar feeding bats take part in a long-distance migration and how adaptations in the shape of their wings allow them to achieve one of the most remarkable migrations in the bat world.

Adria Lopez-Baucells, PhD.- Adria is a bat researcher and conservationist focused on habitat management and connectivity to improve bat conservation. He has worked on assessing forest fragmentation's impact in the Amazon, habitat use in Catalunya, ecosystem services in Colombia, and behavioural ecology in Australia as well as bat-related expeditions in the UK, North-Africa, Kenya, Madagascar and Borneo.

Rachael Cooper-Bohannon, PhD.- Rachael was born in Zambia and grew up in Zambia and South Africa. She has lived in the UK for a number of years - studying her BSc at the University of Bristol, UK and completed her PhD titled: 'Assessing the distribution of bats in southern Africa to highlight conservation priorities' at the University of Stirling, Scotland. Her fieldwork has taken her to remote and beautiful areas of South Africa, Namibia and Botswana. She currently lives in Malawi and she hopes to make a lasting impact on bat conservation in southern Africa, which was the main driver for founding Bats without Borders.

Luis R. Viquez, Mr.- Luis is a Costa Rican bat biologist. He has been working with bats for more than 12 years. His work expands from roosting ecology to microbiome research and immunology of bats. During the past 10 years has been involved in the design and implementation of acoustic monitoring programs in Mexico, USA, Costa Rica, Nicaragua, Peru, Kenia and Germany. He is currently finishing his PhD in the University of Ulm working with immunology of migratory bats.

V. Examples of the best student essays

Name: Ms Begoña Iñarritu
Country: Mexico

I believe I am a great candidate for this course because, for the last five years, I have demonstrated a commitment to bat conservation. I have formed strong links with international researchers that, like me, want to advance our knowledge of bats and their ecosystems in Mexico and the world. I am a recent bachelor's graduate from the National Autonomous University of Mexico, the number one university in Latin America, and a proud National Geographic Explorer grantee. I was interested in bats from a very early stage, and I had the opportunity to join Rodrigo Medellin's lab, where I conducted my first independent research. This allowed me to develop a project focused on bat behaviour of Leptonycteris yerbabuenae. During the three years that I was part of this research team, I learned to overcome many professional and personal challenges. For example, I had to work under harsh conditions in the Pinacate cave in the Sonoran Desert and caves in Juxtlahuaca, Guerrero. Two places that are affected by social and political struggles and that encounter narcotrafficking-related problems, habitat fragmentation, and lack of environmental awareness. However, I successfully conducted my research in these places and was able to interact with local communities and tried to transmit my knowledge on bats. Although for many years, I considered myself an introvert, I became aware of this as a limitation for becoming a successful scientist and also to communicate the importance of bats in areas where people dislike them. I quickly realized that by being myself and showing a keen interest in listening to people's concerns and believes, I was able to establish trusting relationships and to build strong professional collaborations. I think that without passion for research and passion for connecting with people, conservation will not have the same impact.

My main research line has been bat behaviour, particularly mother-pup dynamics. There are plenty of unanswered questions in this area, which I am very keen to address. For example, I would like to test whether acoustic and scent cues are the main features that allow mother-pup recognition in different species of bats. In particular, I would like to test if fruit bats depend more on scent to recognize their young, given that their echolocation system is less developed than in new world bats. I believe that expanding our knowledge on natural history is key to understanding ecological processes and how changes in the ecosystem may affect bats (e.g. would bats recognize their pups in a polluted environment?). I am eager to learn from other researchers and also to bring on skills for the study of bat behaviour in the wild with the South-South workgroup. In this course, I would like to lead a group of south-south bat scientist interested in ethology. And I would like to create a standardized protocol for studying life-history traits. Furthermore, I'm passionate about science communication. I have had the chance of giving talks to the public, teaching high-schoolers, given interviews, and appearing on television. I want to share my experiences with other bat scientists like me so that together we come up with fresh new ideas that promote bat appreciation.

I consider that tracking the productivity of the network is of enormous importance. Coming up with tools that allow us to measure its success will help us learn if the network is helping to fulfil knowledge gaps about bats around the world. For instance, I would like to track how several on-going online platforms such as Wikipedia, OneZoom, PanTheria, ToL (Tree of Life) and gBif increase the information about underrepresented bats species after the bat course in Kenya. I propose to first build-up the role that each contributor will have, then gather the necessary information needed and detect knowledge gaps for ten underrepresented species. Then, after I return to Mexico, I will continue building upon this exercise, pinpoint what worked and what didn't, and then continue increasing the information for more bat species. Another proposal that I want to implement is to make a 'Story Map' about the course and the South-South network. This is an ArcGIS platform that can show data dynamically in a website and is an excellent tool for public awareness, engagement and fundraising.

Additionally, I'd really want for bats to take advantage of the concept of 'Cinderella species'. A cinderella species is one potentially appealing but currently overlooked species (Smith et al. 2012). Large-sized animals are overrepresented on conservation efforts and public awareness. So, people are highly biased on species conservation issues, and many stakeholders may be basing their opinions and decisions on such biased information. So, the discovery and selection of the cinderella bats can be used to prioritize future conservation education and campaigns aiming to raise the profile of listed species currently attracting less attention. Many bats of Rhinopodidae, Pteropodidae and (possibly) Rhinopomatidae have a huge potential for this goal since they have many traits similar to other considered friendly mammals. This concept has a huge potential for the S-S bat network.

This course will undoubtedly impact my development as a bat conservationist. I have realized how important it is for me to continue growing as a bat scientist to be part of the change that this world needs. For the last two years, I have worked in conservation and teaching. My role in the Mexican National Commission for Natural Protected Areas (CONANP) was an excellent experience to learn that bureaucracy and science have to blend, no matter how different fields they are, to implement nation-wide conservation projects. Teaching high-schoolers was a great way to learn that to motivate younger generations; we have to be super creative and keep up with technology. These two experiences were fantastic to experience the world from a very different perspective, and they allowed me to realize that my true passion is field-based research and science communication. I cannot wait to go back to the scientific world but apply my skills of the 'outer' world, and I am eager to interact with people in different disciplines to meet far-reaching goals for bat conservation.

I am lucky enough to have built links with other bat researchers that I am eager to strengthen. I continue to collaborate with Medellin's lab (Ecology Institute) and with Robyn Hudson’s lab (Biomedical Research Institute). And I have also been in close collaboration with Dr Menchaca, who has motivated me to stay in academia and bat conservation. I cannot wait to continue my career as a bat scientist and to implement conservation projects in Mexico and Africa. This course will be a platform that I will use to pursue a higher degree during 2020, focusing on bat behaviour, ecology and conservation. With it, I will also be able to contribute to the establishment of the South-South Network.

Name: Claude Mande

Country: Democratic Republic of Congo

I have been a devoted researcher in bat studies since 2014 in the Congo Basin. My experience in this area has made me realize that there is a great need for capacity building in order to better protect the bats that inhabit one of the most biodiverse places in Africa. This course is a rare and exciting opportunity to learn new practices with scientists of specific backgrounds. It is also a great opportunity for me to network with that are struggling with similar conservation issues. Furthermore, the opportunity to create a link with other bat researchers around the world will open the doors to collaborations and with ground-breaking scientific community worldwide, which in low-income countries is still poorly supported and in great need of action.

After being a volunteer field researcher, I have been gained skills in relevant studies in various components of mammals' ethical monitoring, infectious diseases surveillance, and molecular laboratory techniques. To date, I am conducting bat research in a cohesive institutional collaborative framework. I am co-supervising bat studies at the six field stations scattered in five provinces in the Democratic Republic of Congo (DRC): Lomami National park (two sites), Yangambi Man and Biosphere reserve, Rubi-Tele Hunting reserve, Okapi Faunal reserve, and Albertine Rift highland forest. Three of these stations are my doctoral research sites where I am using bats' functional variability as forest disturbance indicator. As bat species exhibit distinct activity patterns in ecosystem functioning due to their difference in traits, I evaluate microchiropteran species foraging activity and sonotype association with habitat characteristics. I also analyse phylogenetic and phylogeographic relationships for samples collected in either long-disturbed or never disturbed forests. Besides my doctoral research project, I have performed a systematic serological survey of Orthopoxvirus, including bats, in a transdisciplinary approach “One health”. In this context, I stressed the need to integrate human, animal and ecosystem health considerations in order to explain the links between biodiversity and infectious diseases. In the Albertine Rift, we aimed to have a bats' checklist of this highland forest, which is significant importance for conservation and evolutionary ecology studies similar to island biogeography.

After completion of the course, (i) I will schedule a talk in Ecology and Wildlife Management department (University of Kisangani) to convey the results of my findings and the goals of the South-South Bat Research Network. (ii) to plan various hands-on-training in data acquisition and management, in particular I am interested in learning about acoustic monitoring in forests similar to Congo, morphological analyses, and genetics as this will link my line of work to that of other researchers across borders, and (iii) to develop an information exchange framework with freely available data as I will be volunteer to curate acoustic data from the Congo Basin.

Since most areas in Africa don't have sufficient call libraries, particularly Afrotropical region, this course will be particularly important to me to fill some gaps in this area. Hence, gained knowledge will be used to achieve my goals to enhance bat monitoring through echolocation surveys. Thus, collected data will be made available for the network to expand the libraries of Afrotropical region. I will use the training to enhance bat acoustic monitoring in Yangambi (fieldwork is ongoing), Lomami (work will start in February 2020) and Albertine Rift (September 2020) in the DRC, all of which I plan to record and create a file for the library.

Although there has been an increasing international attention to tropical bat surveys, bat research initiatives in global southern countries are never well-supported due to seemingly diverging research priorities. Despite some exported data towards Northern countries, most field researches are generally site-specific and scattered in unpublished reports, with poorly analysed or even descriptive data. Accordingly, governments and other stakeholders do not have more objective information at wide range to support their management policies. Establishing a successful South-South Bat Research Networks suggests the creation of regional laboratories network to enhance both bat conservation and zoonotic disease mitigation. This initiative will require hands-on "One Health" research approach, hypothesis-driven research projects that integrate applied bat ecology with disease surveillance. My proposal complies with this One Health concept which is a worldwide strategy for expanding interdisciplinary collaborations in various aspects of the nexus between health care for human, animal, and ecosystems. This collaboration should be used to facilitate laboratory training and data analyses focusing on bats' phylogenetic and phylogeographic relationships with molecular and experimental virology. However, it is still early to have advanced university laboratories, accessible and established in the Southern countries. Hence, a coordinated partnership with Northern countries' laboratories specializing in genetics should be used as an alternative. The network's thematic groups should ensure the exchange of data for more publications, international and regional political and scientific forums attendance to call for action. I therefore propose to create a liaison between my university and a university or institute in Latin America that is interested in similar goals as my own and that can provide the infrastructure to help me move forward for relevant field practice and/or laboratory work in some case, and vice versa.

Research sites that mentioned above (point "2") constitute a research-hub for South-South network building. We are working in a sustainable partnership with the University of Kisangani (my affiliated institution), Biodiversity Monitoring Centre (laboratory facilities at University of Kisangani), Institut Congolais pour la Conservation de la Nature (National Authority for Protected Areas in the DRC), Frankfurt Zoological Society (Lomami National Park's partner). We have recently concluded a financial partnership with National Geographic for biodiversity monitoring in the Albertine Rift. I have also been in close communication with Dr. Menchaca Rodriguez since the beginning of my doctoral studies and I am eager to continue strengthening our collaboration in the near future.

Name: Marilia Abero Sa de Barros
Country: Brazil

My name is Marília Barros, I am a Brazilian biologist and I should be considered for a place in the course for three reasons: 1) I have several years of experience in bat research; 2) I am a communicative person with teamwork skills; and 3) I have a good network with bat researchers and stakeholders in bat conservation in Brazil. I have been studying bats for 17 years; since 2002, when I was an undergraduate student, I constantly participate in fieldwork and research focused on bats. Throughout my academic formation, I have worked on different subjects and Brazilian biomes: diet of nectar-feeding bats in Atlantic rainforest during my undergraduate years, activity of insectivorous bats in southern grasslands (Pampa) in my Master's degree, and interactions between bats and wind farms in dry forests (Caatinga) in my PhD. Because I am intrinsically motivated by research, I have attended all Brazilian conferences about mammalogy and bats since 2001. Throughout these meetings, I had the opportunity to meet, talk and establish partnerships with researchers from several institutions and regions of Brazil.

I will bring to the implementation of the South-South network my skills related to environmental impact assessment. Wind power is currently one of the major global threats to bats. I studied the impact of wind turbines on bats for eight years – four years as an environmental consultant (2006-2009) and four years as a PhD student (2015-2019). As one of my PhD products, I developed guidelines for impact studies of wind farm on bats in Brazil, which are available online (https://www.sbeq.net/licensing) and have been used in the last two years by environmental agencies, consultants and companies to consider bats in licensing of wind energy in the country. Therefore, my experience in this area will help in the elaboration of conservation strategies associated with environmental licensing, and with other natural resource exploration activities in Latin American and African countries. I am also a natural organizer and I will be helpful for South-South network by organizing and updating data, plans and schedules.

The knowledge learned during the course will be essential for the implementation of South-South network. Course content, location and lecturers will teach me large amount of new information about African bats, their ecological requirements and threats. From this, I intend to find similarities with Latin America and outline research and conservation plans to be built and implemented together with African institutions and colleagues. The classes and examples on environmental education and conservation strategies during the course will be very useful for bringing ideas and models that will support these collaborative programs.

This course is very important to my personal development as a bat conservationist for two reasons: I will have a unique opportunity to meet and interact with excellent professionals from Latin America and Africa, and also to broaden knowledge and learn new tools for the study and conservation of bats. I deeply believe in the power of collaboration to achieve goals and maximize results, so making alliances with bat researchers and conservationists from such different countries and realities will be one of the richest experiences of my career – especially from Latin and African countries where complex political and social problems often make it difficult to preserve nature and wildlife. In addition, the knowledge learned in classes and activities on bat conservation strategies, environmental education programs and molecular techniques will be critical to improve my skills as a bat conservationist and researcher.

I intend to apply the gained knowledge in developing bat conservation strategies, environmental education actions and scientific research, both in collaboration with the South-South network and in my personal career. For each individual project, I will set goals and then measure the success of them by assessing the proportion (%) of achieved results. Possible overall performance indicators would be, for instance, expected vs. observed number of: 1) meetings and actions with public agencies, local communities and decision-makers that affect bat conservation; 2) people, localities and/or schools participating in educational activities; and 3) fieldwork days/months, collected data or research experiments. I will also identify what factors were responsible for both occasional failures and positive results, in a constant exercise of finding solutions and improving performance of future activities.

To establish the South-South network, I propose that the group formed during the course discuss (via e-mail, videoconferencing meetings etc.) to identify and rank the top 10–20 threats to bat conservation in Latin America and Africa (by February 2020). For each threat, the group will then define at least three priority actions (by March 2020), to be implemented by South-South network members in their respective countries over the coming months/years. This set of threats and conservation strategies should be organized in a publication as a first product of the South-South network. I undertake to write the first version of this publication by the end of May 2020, so that the team members could make their contributions to the text until the end of June 2020. The final article could be submitted or published in the second half of 2020 (as a research paper, technical report or other media). I believe it would be an important first step for organizing our challenges and opportunities, guiding future activities and helping publicize the South-South network.

I recently (September 2019) assumed the position of 1st Secretary in the Brazilian Bat Research Society (Sociedade Brasileira para o Estudo de Quirópteros-SBEQ); this new management will last two years. Since promoting bat conservation is one of the new team's top priorities, I propose a partnership between the South-South network and SBEQ. As a partner institution, SBEQ could propose a cooperation agreement with the South-South network to set common goals and projects. In addition, I could open and lead a new committee in SBEQ dedicated to the alliance with the South-South network. Finally, I plan to propose workshops, symposiums and/or panel discussions about the South-South network to be presented at upcoming congresses of the Brazilian Society of Mastozoology (Sociedade Brasileira de Mastozoologia-SBMz), which take place every two years.

Name: Bismark Opoku

Country: Ghana

I aspire to build a career in conservation science with focus on bats. My studies thus far has been directed towards the largely ‘neglected’ insectivorous bat taxa in Ghana. I am very confident that participating in this course will equip me with practical training in current applied concepts in global bat research which will be invaluable to my future doctoral studies and subsequent career on bats. It will help me build a beneficial research and conservation network as the course will provide the platform to discuss my career goals and plans with other fellows and seasoned researchers. This will be useful for exploring future research collaboration needed for bat research in Africa. Also, it will provide a unique learning experience to draw lessons from bat experts/students and be inspired by their research and conservation success and most importantly learn how they overcame some conservation challenges to be able to do the same in the future when I face similar challenges.

It is my expectation that I will have an improved working knowledge on current bat research methods, a beneficial research and conservation network and will gain more experience on bat research after this course. I am an excellent candidate for this course because, in addition to my academic and research experiences, I am hardworking, determined, self-motivated and a good team player who is very adept at applying himself.

Both my bachelors and master’s thesis focused on the ecology of Ghanaian bats and by that, I have gained valuable experiences in capturing and handling of bats. I have acquired useful field skills in setting mist nets for bat capture, handling and collection of biological samples including tissue and blood samples as well as recording morphometric data on bats. I have acquired relevant skills in tracking bats in the field using radio telemetry and extraction and analysis of DNA samples from bat tissue in the laboratory. In addition, I have gained good project design and management skills through my education and Tropical Biology Association field course in Kirindy, Madagascar. I have developed good human relations through interactions with different people from different backgrounds and I am aware of cultural sensitives associated with working with different groups. Lastly, my academic training in natural resource management and zoology puts emphasis on planning and management, critical thinking and problem-solving, community resource management as well as good oral and written skills. I am confident that these skills will be valuable to the South-South bat network.

The knowledge gained from the course will be used to support bat research and conservation in my home country Ghana. The acquired knowledge will directly support the training of a master student I work with in the field and other undergraduate students through a training workshop I will organize. This is to build the capacity of other students and create a local network of bat scientist. It will further guide my future doctoral studies as it will serve as guiding principles during field work. The knowledge gained will be beneficial to local primary/junior high in Kwamang (the community where my field work is based) where I plan to give a talk on bats.

Personally, researching and conserving non-charismatic species such as bats has been my life-long goal which I hope to fulfill to its fullest. Undoubtedly, this first bat course will serve as a platform for training future bat researchers and conservationist and I therefore want to make myself available for this once in a life time opportunity to receive such training. This course represents a great platform to learn up-to-date skills in bat research and form life-long collaborations that will benefit bat research in Africa, particularly, my home country Ghana. I strongly identify with this course and I am optimistic it will eventually contribute to the development of my doctoral studies which will focus on bats. I am very hopeful that I would be able to conceptualize and synthesize from the training ideas needed to initiate important ecological and conservation projects to protect bats in Ghana.

The success of the knowledge I gain will be monitored through the exchange of knowledge with other students and school children, my ability to incorporate the knowledge into my on-going and future research and in the long-term my ability to influence policy on wildlife (bats) with my research.

Land-use changes remain a global phenomenon for which Africa and Latin America bear the greatest brunt. Yet studies on the responses of tropical bats to habitat changes have largely concentrated on Neotropical bats and are rare for African species. For e.g. in Ghana, many insectivorous bats roost in caves in an increasing changing agricultural landscape yet there is little or no information on how these bats use the landscape. My project will therefore seek to understand how bats outside protected areas in Africa use the ever-changing landscape. This will involve sampling of bats in areas outside of protected areas, recording of echolocation calls and implementing automatic acoustic monitoring across the landscape. These data will allow us to compare differences in bat activities among species and between habitat types.

I hope to discuss my plans for developing echolocation call libraries for African bats particularly West African bats and how best to support bat research and conservation in West Africa. I will want to discuss plans of building linkages between local NGO's such as Batlife Ghana with NGO's in Latin America to develop capacity, build stronger networks that promote bat conservation and research. Lastly, I hope to discuss my plan of improving bat museum collections at the Zoological museum of the Department of Animal Biology and Conservation Science, University of Ghana. There is need the for developing capacity for preparation of museum specimen and management. I therefore want to discuss possible strategies for linking the Department's museum and South-South bat network.

VI. Student project reports

Habitat use by bats in a coastal environment in east Africa: a preliminary assessment

By Karla Zaldaña, Marília A. S. Barros, Cárol Sierra-Durán,
Lina M. Mushabati, Bismark Appiah Opoku

Abstract

Insectivorous bats are one of the most diverse and widespread group of mammals. However, there is little information about the ecology and habitat usage of several aerial insectivorous species due to the difficulty of capture them using the traditional methods. Therefore, the activity patterns of insectivorous bats of Diani beach were assessed using Song Meter 4 recorders (Wildlife Acoustics) for a day. Specifically, we compared the bat activity among three different habitats namely open space, forest and built area. A total of 620 bat passes were recorded across all habitats. We identify higher overall activity in buildings and less in open areas. *Coleura afra* and *Scotophillus trujilloi*/ *rendalli* were recorded more frequently in the forest, and Molossidae bats were recorded more frequently near the buildings and in the open area. This information is a preliminary assessment to understand how the insectivorous bats use the habitat in the coastal environment of east Africa.

Keywords: acoustic monitoring, activity patterns, bat activity, echolocation, Kenya, timing activity.

Introduction

Insectivorous bats comprise a diverse and widespread group of mammals that account for more than 70% of all bat species in the world (Simmons 2005). These bats have several adaptations for detecting and feeding on insect prey, especially in their echolocation calls, which are closely associated to foraging habitat (Schnitzler & Kalko 2001). Thus, insectivorous bat species have preferences for different types of habitat, as open areas, forests, vegetation edges and water bodies like rivers and lagoons (e.g. Celuch & Kropil 2008; Morris et al. 2010; Russ & Montgomery 2002). Bats have also shown a species specific response to habitat, specifically to vegetation and in time of their activity (Fern et al. 2018).

Our study examined how bat use the different habitat types at Diani Beach, Mombasa, in a coastal environment in Kenya, east Africa. We tested the hypothesis that bat activity (both overall activity and for individual species) varies among three different habitat types.

Materials and methods

Study site

We studied the diversity and activity of insectivorous bats at the Jacaranda beach resort in the coastal environment in Kenya The area around the resort was categorized into micro-habitats namely open space, forest and built area (Figure 1).

Acoustic Survey

To investigate the crepuscular activity of the insectivorous, 4 Song Meter Passive Bat Detectors (SM 4_Wildlife Acoustics) were positioned in three different habitats. Detectors were mounted ~1.5 m above ground on a tree to prevent false recordings from wind and rain. The microphone was placed at a 45° downward angle pointing at expected fly ways. Recorders were programmed to sample at a rate of 500 kHz for period of 12 hours. Release calls of mist-netted bats were recorded using Echo Meter Touch 2 pro to provide reference call library.

Analyses

Recordings were analyzed using Kaleidoscope 5.1.8. A filter was applied to delete noise files and create files of five seconds. Bats were identified based on an echolocation identification key for the insectivorous bat species of Diana beach (Acoustic group). An activity was defined as a file of 5-sec duration with at least 2 echolocation pulses (Miller 2011). Recording from the first two hours after sunset were considered during the analysis due to time constraints.

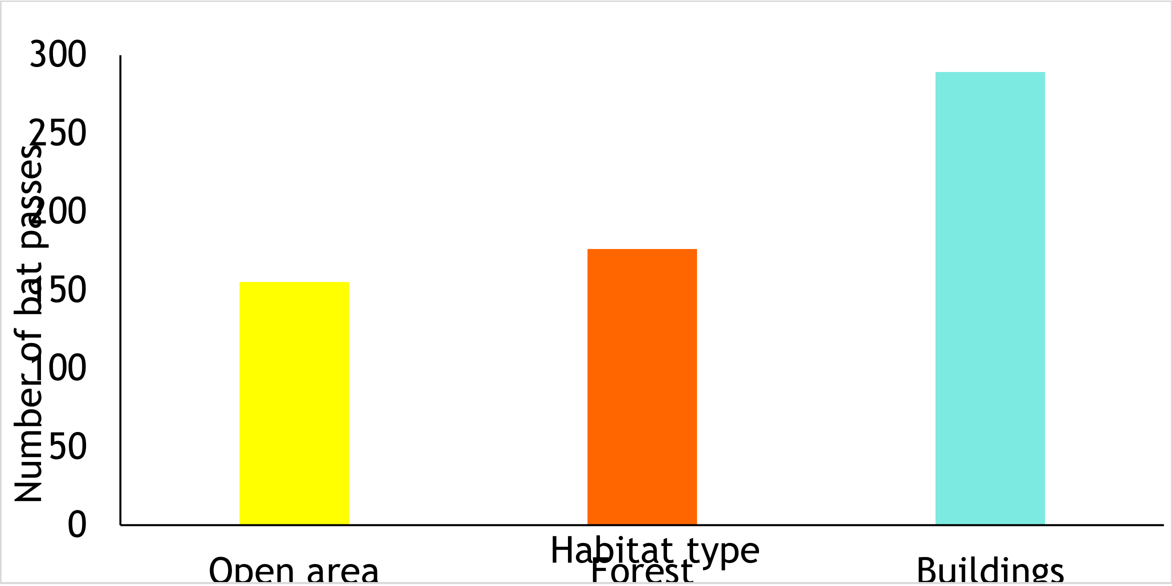
The data set was elaborated with the information of passes, species, and hour of activity, data was arranged by habitat in order to make the subsequent analysis. We analyzed the activity of species from sunset until 8:00 PM, the graphic was elaborated using the passes and time of activity which we divided in fragments of 15 minutes in order to identify the activity peaks. We also did an overall activity analysis were we compared the activity between the habitats of open space, forest and buildings. Then we compared the time activity peaks of two species.

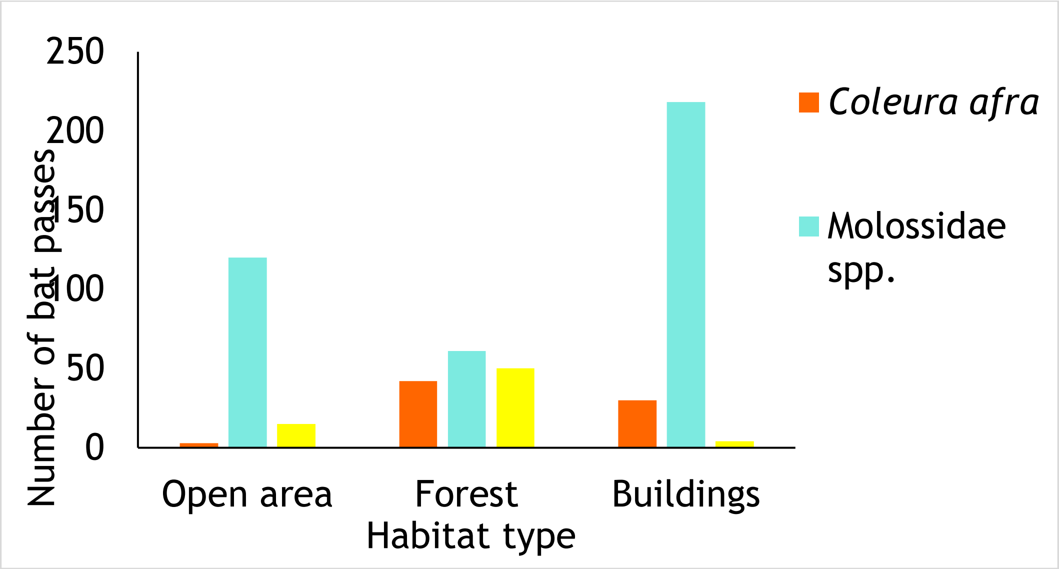
Results

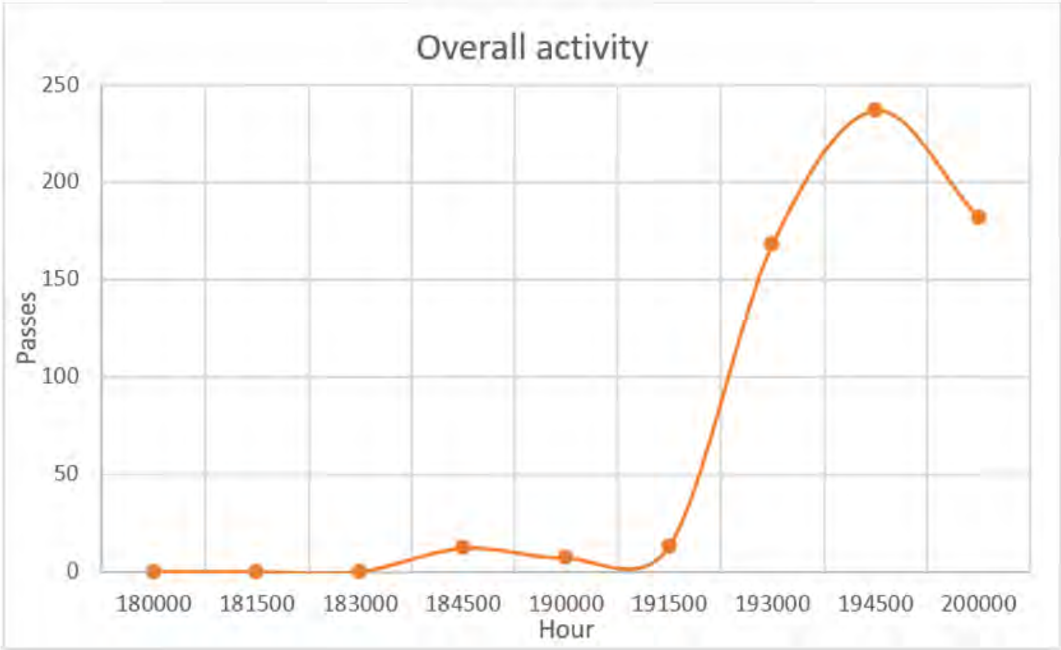
In total, we recorded 24.267 files; after filtering noise and manually checking the remain files, we obtained 620 bat passes. The site that shown the higher number of bats passes was near the buildings, where 289 bat passes were recorded (47% of total number of bat passes) (Figure 2). The number of bat passes was similar between the forest (176 bat passes; 28%) and the open area (155 bat passes; 25%).

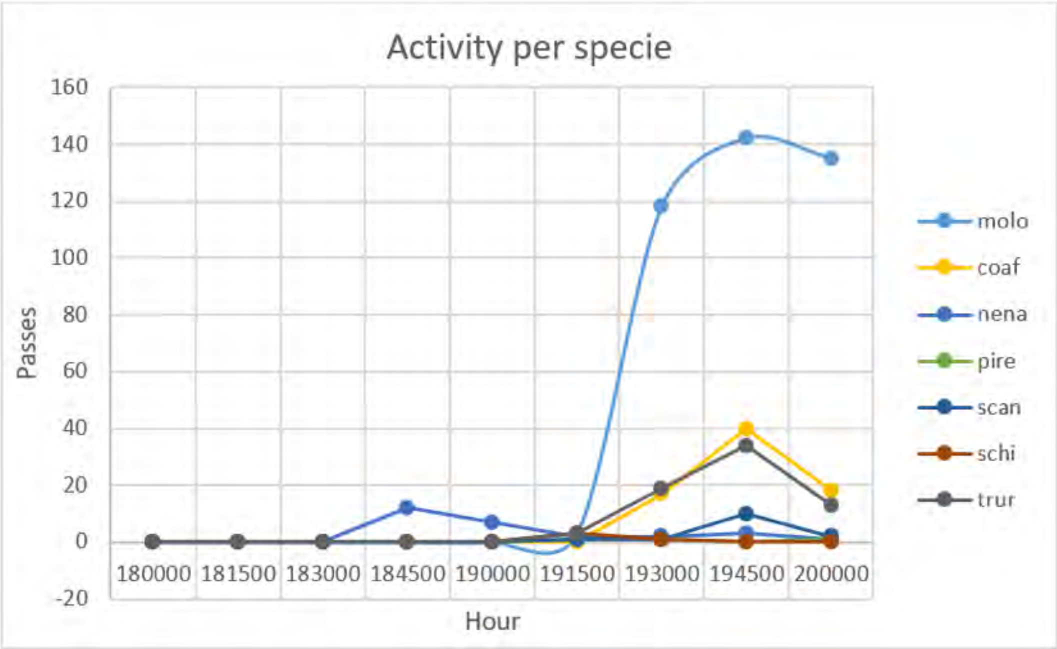
We recorded 15 different species/sonotypes, 10 vespertilionid bats, one complex including all molossid species and four unidentified Chiroptera (Table 1). *Coleura afra*, *Scotophillus trujilloi*/ *rendalli* (Vespertilionidae) and Molossidae spp. complex were the only species/sonotypes with sample size > 50 bat passes, and then we analyzed habitat use for each of these species/complexes separately. *Coleura afra* and *Scotophillus trujilloi*/ *rendalli* were recorded more frequently in the forest, and Molossidae bats were recorded more frequently near the buildings and in the open area (Figure 3).

In general, bat species showed a light peak of activity at 18:45 and a very sharp one at 19:45 (Figure 4). The activity starts to decrease again at 20:00. When species are analyzed separately, we can see that the first peak of activity is only present for *N. nana*, that starts to foraging earlier than any other bat in the area (Figure 5). After this peak, it remains inactive for the time. Then, the high peak is mainly associated with molosids, that show a much higher activity than the other species. Then, *C. afra* and *S. trujilloi/S. rendalli* had a peak at the same time but with less than a half of the amount of activity of molosid. *Scotophillus andrewreborii* has a much lower peak at that time and finally *S. hirundus* remains flat.




250
200
150
100
50
0
Number of bat passes
Open area
Forest
Buildings
Habitat type
Coleura afra
Molossidae spp.


Overall activity
250
200
150
100
50
0
Passes
180000
181500
183000
184500
190000
191500
193000
194500
200000
Hour



Discussion

The higher activity around the buildings are probably associated with the use of this area as roost and/or windbreak during foraging activity (Russ et al. 2003). In addition, insectivorous bats can forage on insects attracted by the lights (Frank et al. 2018).

The high number of bat passes of *Coleura afra* and *Scotophillus trujilloi*/ *rendalli* are expected, since these species usually forage near the vegetation in forested habitats (Monadjem et al. 2001). The high activity of molossid bats near the buildings is also expected, since molossids frequently use human constructions as day roosts (Fabián & Marques 1996) and are aerial insectivorous highly adapted to hunt in open spaces above the ground or the canopy (Denzinger & Schnitzler 2013).

References

Celuch, M. & Kropil, R. 2008. Bats in a Carpathian beech-oak forest (Central Europe): habitat use, foraging assemblages and activity patterns. Folia Zoologica, 57: 358-372.

Denzinger, A. & Schnitzler, H.U. 2013. Bat guilds, a concept to classify the highly diverse foraging and echolocation behaviors of microchiropteran bats. Frontiers in Fisiology, 164: 1-15.

Fabián. M.E. & Marques, R.V. 1996. Aspectos do comportamento de *Tadarida brasiliensis* (Chiroptera, Molossidae) em ambiente urbano. Biociências, 4: 65-86.

Fern, R., Campbell, T & Davis, D. 2018. Summer activity patterns of four resident south Texas bat species. Global Ecology and Conservation, 6: e00500.

Frank, T., Gabbert, W., Chaves-Campos, J. & LaVal, R. 2019. Impact of artificial lights on foraging of insectivorous bats in Costa Rican cloud forest. Journal of Tropical Ecology, 35: 8-17.

Miller, B. 2001 A method for determining relative activity of free flying bats using a new activity index for acoustic monitoring. Acta Chiropterologica, 3(1): 105-105.

Monadjem, A., Taylor, P. J., Cotterill, W. & Schoeman, M.C. 2001. Bats of southern and central Africa: a biogeographic and taxonomic synthesis. Johannesburg, Wits University Press.

Morris, A.D., Miller, D.A. & Kalcounis-Rueppell, M.C. 2010. Use of forest edges by bats in a managed pine forest landscape. Journal of Wildlife Management, 74: 26-34.

Russ, J.M. & Montgomery, W.I. 2002. Habitat associations of bats in Northern Ireland: implications for conservation. Biological Conservation, 108: 49-58.

Russ, J.M., M. Briffa & W.I. Montgomery. 2003. Seasonal patterns in activity and habitat use by bats (*Pipistrellus* spp. and *Nyctalus leisleri*) in Northern Ireland, determined using a driven transect. Journal of Zoology 259 (3): 289-299.

Simmons, N.B. 2005. Order Chiroptera, p. 312-529. In: D.E. Wilson & D.M. Reeder (Eds). Mammal species of the world: a taxonomic and geographic reference. Baltimore, The Johns Hopkins University Press, vol. 1.

Schnitzler, H.-U. & E.K.V. Kalko. 2001. Echolocation by Insect-Eating Bats. BioScience, 51: 557-569.

Public Knowledge on Bats In Open Access Platforms

By Ashmi Bunsy, Aicha Djame, Begoña Iñarritu & Grace Waiguchu.

Abstract:

For different reasons, the availability of biodiversity-related information varies considerably over space, time, taxa, and types of data, thereby causing gaps in knowledge. In the case of bats, due to its misconception and their natural ability of flight, are the most unknown group of vertebrates. We made a review to have a clearer idea of what kind of information and quality of it can be found on feasible open-access platforms in order to focus the approach of general bat biology captured during the 10 days course in Diani, Kenya.

Keywords: bats, biodiversity data, conservation science, gap knowledge, gaps, open-access platforms

Introduction:

Bats belong to the order of Chiroptera, with approximately 1,406 bat species described worldwide and among the approximately 5,000 mammal species known to date (Bannet-Garcia, 2003). They are remarkable mammals with nocturnal activity. The stigma and gullibility of human beings are the origin of their dark past. It's unfair that they have been given negative connotations and such prejudices contribute greatly to their manifested persecutions in a world scale (Bakwo Fils, 2009), which makes them the most unknown group of vertebrates to date (Zerguini and Zizi, 2013). Due to many constraints, the simplest general information like their distribution is lacking, which leads to gaps in the knowledge of Chiroptera (Tatsuya et al., 2016). Despite growing awareness of this issue among scientists, it is still poorly known how—and whether— scientific efforts have contributed to overcoming these information gaps (Tatsuya et al., 2016). Moreover, most of the Afro-tropical species are unknown to the general public and there is limited information on the Internet on them. In fact, this gap stresses the urgent need to update the information and improve online public knowledge on bats. More specifically, this report will have a look at the different online access platforms and review how much a bat species is represented on each platform we selected.

Methods:

We designed this report in a workshop setting from 13th to 19th January 2020. During the course, we captured, processed and released about 20 bat species, which occurred within Jacaranda Hotel, Diani Bay Resort, Shimoni Caves, and the Fikirini Three Sisters Caves in Kwale Couny, Kenya. We also chose 9 most commonly used open-access online platforms where general public could access to have information about bats (Wikipedia, International Union for Conservation of Nature [IUCN], Encyclopedia of Life [EoL], Map of Life [MoL], iNaturalist, OneZoom, GBIF, Tree of Life [ToL], the Integrated Taxonomic Information System [ITIS], Bat Names and the Kenya Wildlife Service [KWS].) We then checked the kind of information that is available of the 20 bat species we captured and processed during the course to serve as the foundation for a heat map of the information gap of bat biology of these species online.

The 10 online platforms and 20 species formed a grid map of 200 cells in which each cell represented an intersection between one online platform and one bat species. For each cell, we searched each species in each of the online platform and gave it a color code depending on how much information is available online. We selected 9 attributes to select the color code: characteristics (taxonomy), diet, distribution, conservation status, reproduction, ecology, threats, image and references. If the platform included 1 to 2 attributes, we chose red color, if included from 3-6 attributes we chose yellow color and if it included more than seven, we chose green, if there is absolutely no information about the species, we chose white.

Then, we selected the species that had the less online information but reports and papers published in order to update its page on Wikipedia. Finally, we constructed an infographic with the information on these platforms plus the one found on scientific literature.

Results:

In Fig. 1 the heatmap showed that only about 35% of information on the species is available on Wikipedia of the 20 species we analyzed. IUCN and EoL has the most information on bats; the Kenya Wildlife Service website has no information on bats. It is surprising that *Bat Names,* which is very specific to bats, is lacking a lot of information on species. OneZoom, iNaturalist and MoL websites link their information resource to Wikipedia.

80% of the species we sampled are listed as least concern on IUCN. Two of the species *Nycteris thebaica* and *Miniopterus minor* are data deficient, *Macronycteris vittatus* is listed as Near Threatened and *Taphozorus hildegardea* is listed as Vulnerable. *Scotophilus hirundo* has no information on IUCN.

Family	Species	C.S	Wikipedia	IUCN	EoL	MoL	iNaturalist	OneZoom	GBIF	ITIS	Bat names	KWS
Vespertilionidae	*Neoromicia nana*	*LC*									N/A	N/A
	Neoromicia rendalli	*LC*									N/A	N/A
	Neoromicia capensis	*LC*									N/A	N/A
	Pipistrellus rueppellii	*LC*					N/A				N/A	N/A
	Scotophilus trujilloi	*LC*				N/A	N/A	N/A			N/A	N/A
	S. andrewewborii	*LC*						N/A				N/A
	Scotophilus hirundo	*N/A*										N/A
Nycteridae	*Nycteris thebaica*	*DD*									N/A	N/A
Hipposideridae	*Macronycteris gigas*	*LC*									N/A	N/A
	Macronycteris vittatus	*NT*		N/A	N/A	N/A		N/A	N/A	N/A		N/A
	Triaenops afer	*LC*						N/A	N/A			N/A
Megadermatidae	*Cardioderma cor*	*LC*										N/A
Pteropodidae	*Epomophorus wahlbergi*	*LC*										N/A
	Epomophorus minimus	*LC*							N/A		N/A	N/A
	Roussettus aegyptiacus	*LC*				N/A					N/A	N/A
Rhinolophidae	*Rhinolophus landeri*	*LC*									N/A	N/A
	Rhinolophus eloquens	*LC*									N/A	N/A
Emballonuridae	*Coleura afra*	*LC*				N/A	N/A			N/A	N/A	N/A
	Taphozorus hildegardea	*VU*									N/A	N/A
Miniopteridae	*Miniopterus minor*	*DD*										N/A

Figure 12. A heat map where each cell represents the intersection between one online platform and one bat species and the color is based on the number of attributes the platform has. From 1-2 attributes is red, from 3-6 is yellow and more than 7 is green. Empty box for no information.

THE GIANT ROUNDLEAF BAT

MACRONYCTERIS GIGAS

IUCN STATUS: Least Concern

Some things about me..!

Taxonomy and distribution- I am a bat species in the family Hipposideridae[1]. I was formerly considered as *M. commersoni*, but the latter is now restricted to Madagascar[2] and I am found throughout much of western Africa.

Characteristics- I am a very large leaf-nosed bat, with forearm length reaching 124 mm and average mass of 148 g. My larger size distinguishes me from *M. vittata*. The colour and thickness of my fur differs between sexes and individuals, with longest fur in females. My wings in both sexes are pale brown and my ears are small and round with pointed tips[3]. A well developed frontal gland further distinguishes mature males from females[4].

Acoustics- I produce HD-CF calls with an intermediate peak frequency of 56 kHz[5].

Foraging ecology– this is not well studies, but it is likely to be similar to *M. vittata*, which forages in a 'flycatcher style', which often intercepts large flying insects from a foraging perch.

Reproduction- My reproductive cycle includes seasonal events of copulation and parturition that are confined with large caves, on which I am entirely dependent to raise my single young!

Captured *M. gigas*. © A. Menchaca

References:

[1]Wilson, D.E., Reeder, D.M., 2005. Mammal species of the world: a taxonomic and geographic reference. JHU Press.

[2]Foley, N.M., Goodman, S.M., Whelan, C.V., Puechmaille, S.J., Teeling, E., 2017. Towards navigating the Minotaur's labyrinth: cryptic diversity and taxonomic revision within the speciose genus

[3]Monadjem, A., Taylor, P.J., Cotterill, W., Schoeman, M.C., 2010. Bats of southern and central Africa: a Hipposideros (Hipposideridae). Acta Chiropterologica 19, 1–18.

[4]Brosset, A., Saint Girons, H., 1980. Cycles de reproduction des microchiroptères troglophiles du nord-est du Gabon. Mammalia 44, 225–232.

[5]Vaughan, T.A., 1977. Foraging behaviour of the giant leaf nosed bat (Hipposideros commersoni). Afr. J. Ecol. 15, 237–249.

Bat Facts!

- Formely divided into megabats and microbats, Order Chiroptera (bats) is now classified into Yinpterochiroptera and Yangochroptera.
- Family Hipposideridae is a family of bats commonly known as Old World leaf-nosed bats.
- *Macronycteris gigas* is a large sized bat and is second in size and mass to *Saccolaimus peli*.
- *M. gigas* and *M. vittata*, can be distinguished from each other by the difference in frequency of CF-component by the relatively short calls (10-20 ms) with only a terminal FM-component .

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Discussion:

For the majority of species analyzed, none of them were lacking information in the IUCN platform and three other platforms (OneZoom, iNaturalist and MoL) are linked to Wikipedia so we can consider the latter as a rather complete and reliable source for biodiversity data. GBIF is linked to ITIS (Integrated Taxonomic Information System). This doesn't mean that is not scientific info not uploaded but that the info doesn´t exist and the niche is open. Conclusively, our results showed that Wikipedia and EoL are highly re-linked and as such the main objective was to update and edit the Wikipedia page of a selected species, name *Macronycteris gigas.* The unequal distribution of biodiversity data across the globe, particularly the lack of information in highly biodiversity- regions has been repeated since the 1980s (Tatsuya et al., 2016) and we invite our colleagues to make an effort to avoid this circumstance.

Conclusion:

To invite the new network of the Global South Bats to collectively and independently update an existing wiki page of a bat of its region in order to improve online public knowledge on bats representative of the Tropics.

References:

1. **Bannet-Garcia N., 2003**. *La Protection Des Chauves-Souris:* Ses Enjeux Ecologiques Et Sanitaires. Mémoire Pour L'obtention Du Diplôme De Médecine Agricole. Institut National De Médecine Agricole. 76p
2. **Bakwo Fils E. M., 2009.** Inventaire Des Chauves-Souris De La Réserve De Biosphère Du Dja, Cameroun, le Véspère, (2):11-20.
3. **Zerguini M., Zizi A., 2013.** Mémoire de master, Université d'Abderrahmane Mira de Bejaia, *Etude Des Parasites Des Chiroptères Au Niveau De La Grotte d'AOKAS, Bejaia*, 2 p.
4. **Tatsuya A., James D. and William J., 2016.** *Spatial Gaps In Global Diversity Information And The Role Of Citizen Science*. Bioscience 66:393-400. Oxford University Press on behalf of the American Institute of Biological Sciences.

Geomorphometric approach to study inter- and intra-specific differences in wing morphology

By Juan Pellon, Ana Belén Ribadeneira and Madalitso Mwaungulu

INTRODUCTION

Assemblages of bats have been frequently studied in order to understand the rules that allow the coexistence of species; however, in most of the cases relationships have not been accurate evaluated to species level (Morin 2009). For example, for neotropical frugivorous bats, diet analysis has elucidate relations between genus of plants and bats, but the relations within the genus remain almost unknown (Sánchez & Giannini, 2018). Moreover, intraspecific relationships are important in all processes of populations, but also our knowledge about them still scarce. This means that it is necessary to evaluate more ecological aspects to understand better the assemblages of bats.

Geometric morphometrics analyze morphogical shapes using coordinates instead of linear measurements, allowing to discriminate patterns between species and individuals, representing a tool to study morphological differences among species of the same genus, as Schmeider *et al* (2014) demonstrated in tail relevance for *Myotis myotis* and *Myotis blythe* in maneuverability (Adams, Rohlf, & Slice, 2013; Parés-Casanova & de la Cruz, 2015), but also morphological differences among individuals of the same species.

Therefore, this study pretended to assess the advantages of the geometric morphometrics approach by evaluating the wind morphology differences in three cases: two interspecific comparison within two congeneric species (*Neoromicia nana/Neoromicia rendalli and Scotophilus andreweborii/Scotophilus trujilloi*) and an intraspecific comparison between two color phases in *Triaenops afer* (Orange/gray).

METHODS

For studying morphological differences among species of the same genera, *Neuromicia nana* and *N. rendali,* and *Scotophilus trujilloi* and *S. andrewewborii* were been used.

For studying morphological differences among individuals of the same species, to morphs (gray and orange) of *Triaenops afer* were been used.

To reach the objectives of this study, the methods of sampling were using mist nets in two different places, Jacaranda´s Hotel gardens and Diani Bay´s Resort gardens; and hand nets on one of the Three Sisters Caves.

To get the data of wing morphology for the species that were capture, they were identify and taken a picture of the wing on graph paper by kindly stretching the right wing until the elbow was fully extended as well as the feet (Figure 1.A.); from the pictures that were taken, the best was chosen of each individual of each specie for setup 13 landmarks (Figure 1.B.) using the software ImageJ. Each landmark were placed on strategic anatomical points: 1) shoulder, 2) elbow, 3) wrist, 4) thumb, 5) metacarpal – proximal phalangeal join on the second digit, 6) proximal – middle phalangeal join on the second digit, 7) distal tip of second digit, 8) metacarpal – proximal phalangeal join on the third digit, 9) proximal – middle phalangeal join on the third digit, 10) distal tip of third digit, 11) metacarpal – proximal phalangeal join on the fourth digit, 12) proximal – middle phalangeal join on the fourth digit, 13) distal tip of fourth digit (O'Mara, Bauer, Blank, Baldwin, & Dechnam, 2016).

All the coordinates determined by landmarks were analyzed using a principal component analysis (PCA) based on a covariance matrix; in addition the data were analyzed by canonical variate analysis using MorphoJ software.

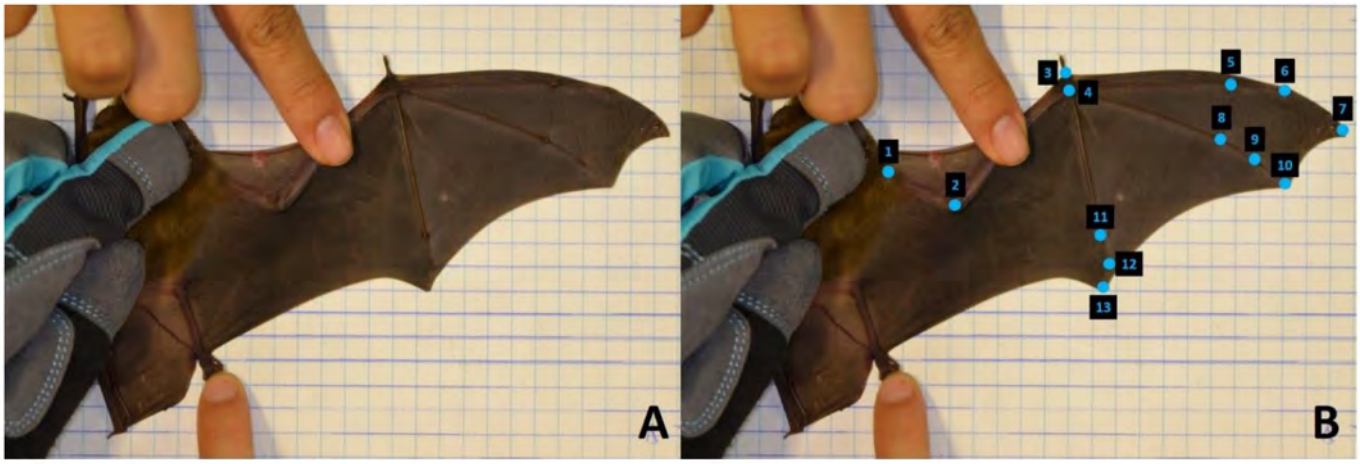


Figure 1. **Wing morphlogy of *Scotophilus trujilloi*.** A) *S. trujilloi* right wing showing the way to hold it to take the picture. B) *S. trujilloi* right wing with the 13 landmarks.

RESULTS

We took photos of seven Neoromicia nana, six Neoromicia rendalli, four Scotophilus andrewewborii, seven Scotophilus trujilloi and twelve Triaenops afer (7 gray and 5 orange).

Interspecific variation:

The PCA for *Neoromicia* slightly separate *N. rendalli* from *N. nana*, *N. rendalli* were more related with positive values of the two first components (Figure 2); and according to the CVA (Figure 3) both species are not related displaying a Mahalanobis distance of 9.5093. In regard to *Scotophilus*, PCA (Figure 4) showed that *S. trujilloi* is related with the positive values of the second component, while *S. andrewewborii*, with the negatives. However, in the PCA, one sample of *S. trujilloi* have a very different wing morphology, not related with the other individuals of *S. trujilloi and S. andrewewborii*. Similar to *Neromicia*, CVA (Figure 5) showed that both species are not related displaying a Mahalanobis distance of 4.1890.

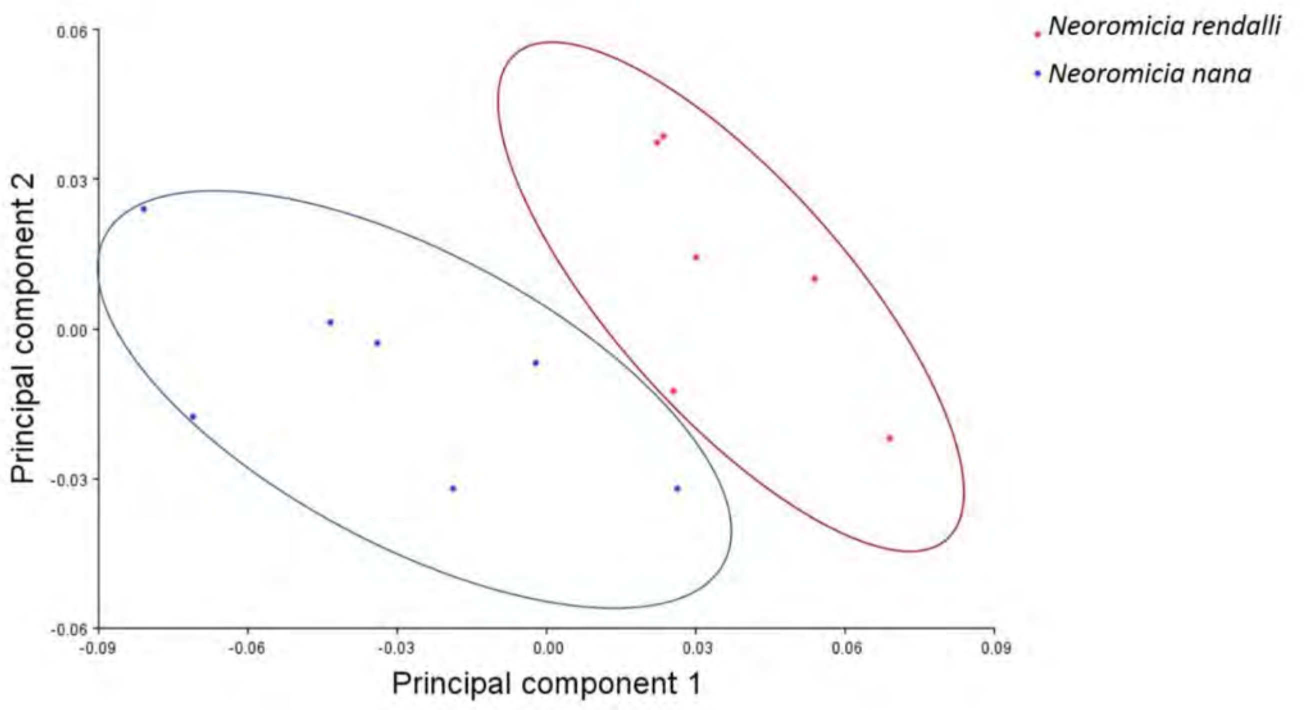


Figure 2. Neromicia´s PCA.

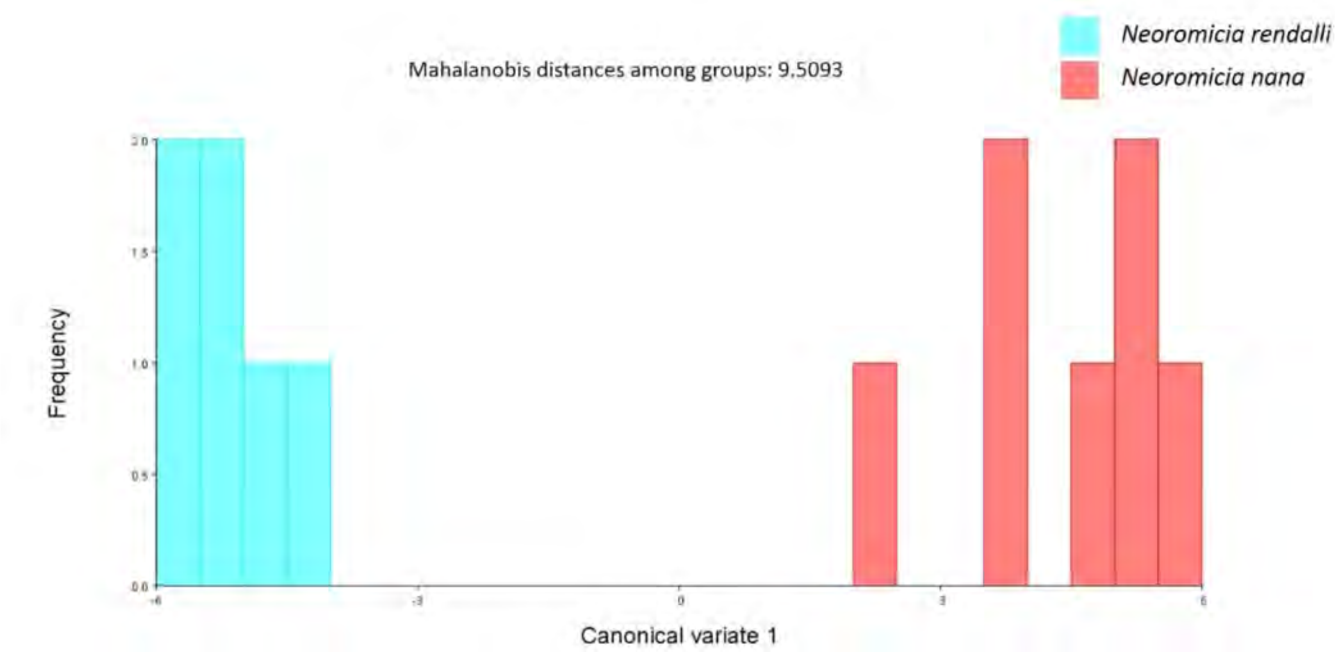


Figure 3. Neromicia CVA.

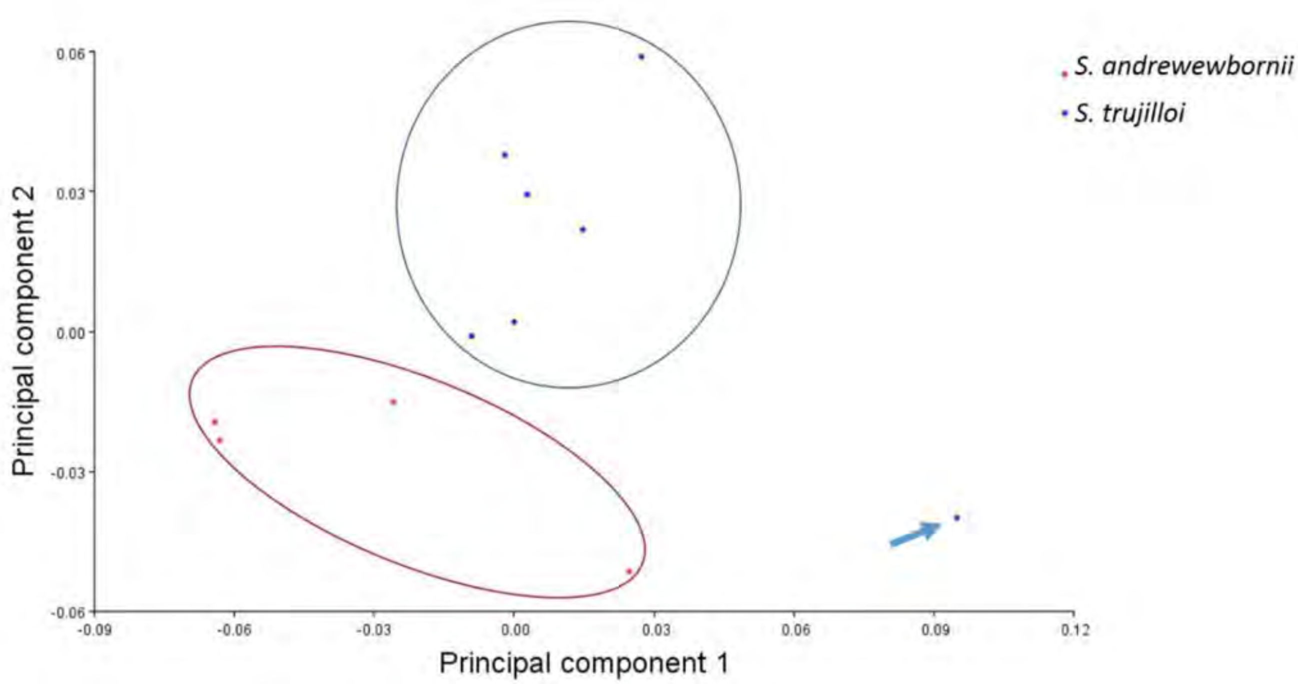


Figure 4. PCA Scotophilus.

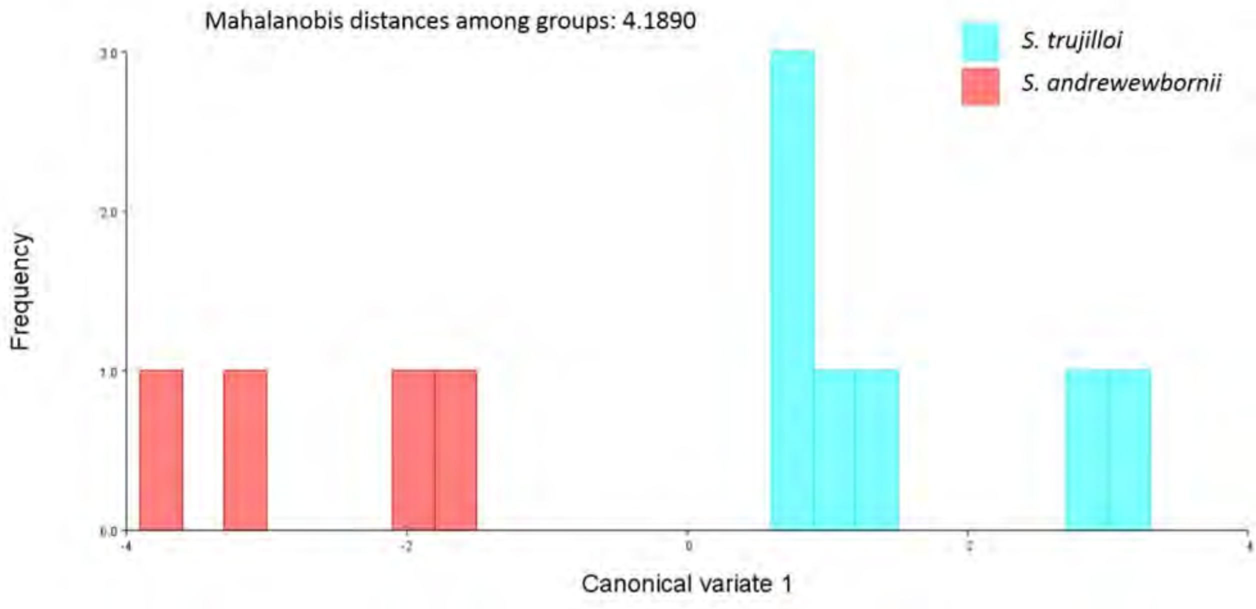


Figure 5. CVA Scotophilus

Intraspecific variation:

The PCA (Figure 6) and CVA (Figure 7) for the two phases of color in *Triaenops afer* did not display a separation between them, the distance Mahalanobis distance was 4.1890.

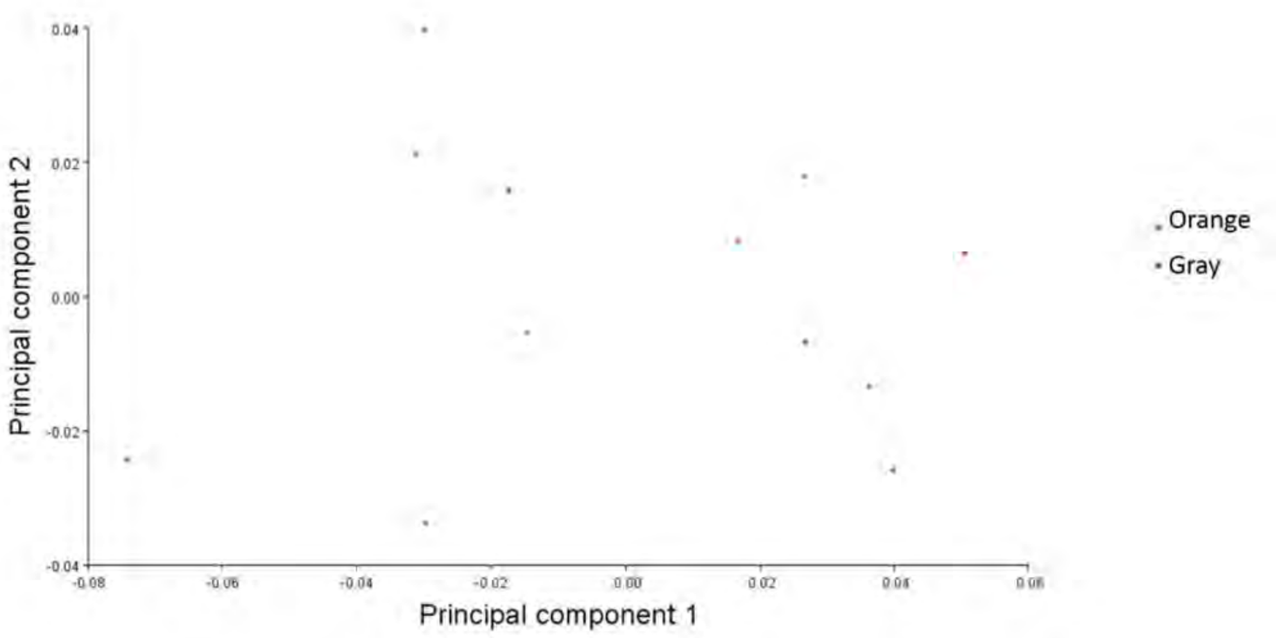


Figure 6. PCA Triaenops afer.

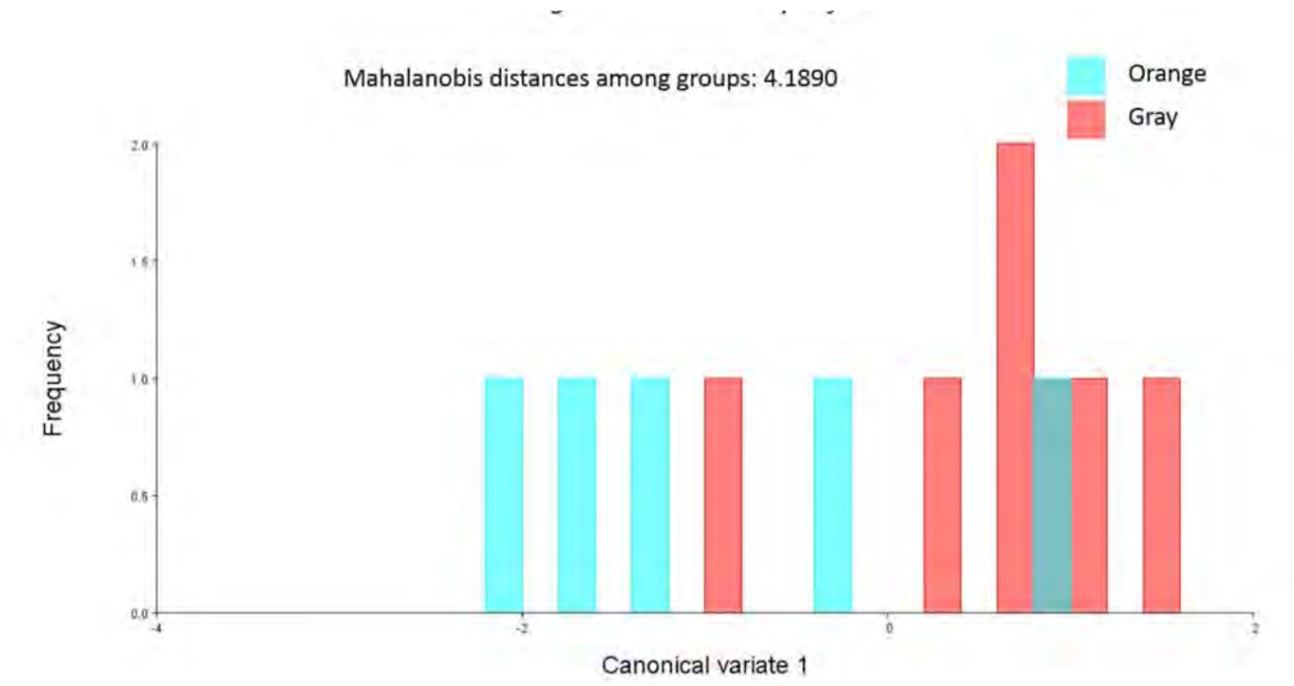


Figure 7. CVA Triaenops afer

DISCUSION

Wing morphology is known to be related with the feeding habits of bats and birds. For example between insectivorous bats, the wing morphology differs according their feeding strategies, high-flying insectivorous bats have small, pointed wings which give good agility, high flight speeds and low cost of transport; while bats that have a foraging activity among vegetation (incluiding gleaners) have very short and rounded wingtips, and often relatively short, broad wings, giving good manoeuvrability at low flight speeds (Norberg & Rayner 1987). Bats of other feeding guilds, contrast a lot with the insectivorous wing design of that of insectivorous. For example, carnivores have relatively large wing areas as their foraging strategies consist on perching, hunting and gleaning. Also, other factors can influence wing adaptations, such as migration (as they have to fly with a foetus or young) (Norberg 2012).

Morphology have an important effect in the behavior of bats, for example high flight speed correlates with high wing loading, and good manoeuvrability is favoured by low wing loading, characteristics important for insectivorous bats (Norberg 1994). Even between species of the genus Rhinolophus the geometric morphometric approach allowed to study their relationships (Schmieder et al. 2015). Also the differences in morphology are closely related with the echolocation calls of bats, being an important aspect in the ecology of insectovorus bats (Manciona et al. 2012).

Therefore, the differences between the species two congeneric species of Neoromicia and Scotophilus could be closely related to their feeding habits and hence their echolocation. This could be an important factor that can explain how very similar species can coexist in the same ecosystems, as they display a niche partining. In regard to Triaenops afer, the color is not usually correlated with modifications on the morphology in animals, but it is related with echolocation (Brigham & Cebek 1989). In this case, geometric morphometric approach did not allow us to study phenotypic variations within a population.

CONCLUSION

Our study on the applications of the geometric morphometric approach on the analysis of wing morphology displayed differences between the two groups of congeneric species (*Neoromicia nana/Neoromicia rendalli and Scotophilus andreweborii/Scotophilus trujilloi*), however in an intraspecific level it did not display differences (*Trianops afer*). It is necessary to test similar questions using more samples to get more accurate results.

REFERENCES

Adams, D. C., Rohlf, F. J., & Slice, D. E. (2013). A field comes of age: geometric morphometrics in the 21st century. *Hystrix, the Italian Journal of Mammalogy*.

O'Mara, M. T., Bauer, K., Blank, D., Baldwin, J. W., & Dechnam, D. K. (2016). Common Noctule Bats Are Sexually Dimorphic in Migratory Behaviour and Body Size but Not Wing Shape. *PLOS ONE*.

Parés-Casanova, P. M., & de la Cruz, S. (2015). A Classification of Feline Skulls by Means of Geometric. *Global Journal of Animal Scientific Research*, 65-71.

Sánchez, M. S., & Giannini, N. P. (2018). Trophic structure of frugivorous bats un the Neotropics: emergent patterns in evolutionary history. *Mammak review*, 90-107.

Norberg, U. M. (2012). Vertebrate flight: mechanics, physiology, morphology, ecology and evolution (Vol. 27). Springer Science & Business Media.

Norberg, U. M., & Rayner, J. M. (1987). Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions of the Royal Society of London. B, Biological Sciences, 316(1179), 335-427.

Norberg, U. M. (1994). Wing design, flight performance, and habitat use in bats. Ecological morphology: integrative organismal biology, 1, 205-239.

Schmieder, D. A., Benítez, H. A., Borissov, I. M., & Fruciano, C. (2015). Bat species comparisons based on external morphology: a test of traditional versus geometric morphometric approaches. PloS one, 10(5).

Mancina, C. A., García-Rivera, L., & Miller, B. W. (2012). Wing morphology, echolocation, and resource partitioning in syntopic Cuban mormoopid bats. Journal of Mammalogy, 93(5), 1308-1317.

Morin, P. J. (2009). Community ecology. John Wiley & Sons.

Brigham, R. M., & Cebek, J. E. (1989). Intraspecific variation in the echolocation calls of two species of insectivorous bats. Journal of Mammalogy, 70(2), 426-428.

Acoustic identification key to the bats of coastal Mombasa

By Quincy Augustine, Claude Mande, Jean Michael Mutebi

Introduction

Bats are perhaps the most unusual and specialized in all the mammals (Jones and Teeling 2006). They have mastered the evolutionary art of flight at night through echolocation. Over the years, biologists have gathered their knowledge on bats through unique survey methods such as mist netting, harp traps and hand traps. These methods may seem outdated but can still be very effective. Currently, biologists have added acoustic systems to aid in the presence and in most cases identification of bat species. Using acoustic systems has improve the effectiveness and offers enormous potential in studies of ecology, behaviour, taxonomy, and conservation.

Many bat species differ from each other in functional ways, and specific diversity tends to be correlated to habitat functioning (Petchey and Gaston 2006). Depending on habitat structure, bat species have characteristic echolocation pulses which can be used to classify them into broad guilds or sonotypes. Hence, identifying temporal and spatial shifts in soundscapes, acoustic monitoring can be used to assess how species are affected by environment state (Burivalova et al. 2019).

By adding acoustic systems, biologists are more properly equipped in the identification of bat species. However, using the appropriate instruments can better aid to that success. Presently, there are a wide variety of instruments that are used. Even though many biologists may have their personal preference of acoustic system to use, their effectiveness is highly questionable. Analysing the data received can be difficult at times due to the lack of resources pertaining to acoustic recordings of bats. This leads to our main objective which was to create an acoustic recording key for East African Bats.

Methods

Acoustic Devices

There were three devices used in the acoustic surveys. They were the 4th generation Song Meter (SM4) Recorder by Wildlife Acoustics and Audiomoth by Open Acoustics Devices as shown in picture 1 and 2 respectively. The SM4 is fully waterproof with dimensions of 218 mm in height, 186 mm in width, 78 mm in depth and weighs 2.9 lbs with batteries. Its recording technology is built with a Two-channel, 16-bit PCM .wav files or compressed.w4v files and recording bandwidth of 20Hz – 48Hz (Wildlife Acoustics 2019). It also supports sample rates between 8000 and 96000 samples per second on one or two channels (Wildlife Acoustics 2019).

With regards to Audiomoth, the device is compact with dimensions of 58 mm in height x 48 mm width x 15 mm in depth (Open Acoustics Devices 2019). The device is built with an EFM32 Gecko processor and records at rates from 8,000 to 384,000 samples per second. The compact device is also capable recording at sample rates of up to 384kHz (Open Acoustics Devices 2019).

The Echo Meter Touch 2 PRO by Wildlife Acoustics was used. The dimensions of the device are 48 mm in width, 35 mm in length and 11.7 mm - 18.0 mm in height. It is built with a rugged polycarbonate housing with an integrated acoustical horn and has a maximum frequency recording of 192 kHz (Wildlife Acoustics 2019). It also has a sampling rate of 256k or 384k samples per second at 16 bits (Wildlife Acoustics 2019).

Fieldwork for release calls recordings

The key to the echolocating calls for the bats of coastal Mombasa is based on the recordings of bats captured in mist nets during the nights of January 16^{th} to 18^{th} in the Diani beach of Mombasa, Kenia (4º15'44.32"S 39º35'52.77"E) and the Fikirini caves. Three active acoustic microphones (Echo meter touch 2 pro from wildlife Acoustics, Inc.) were used to record each bat, also, data files in wav. format were created using the software Echometer touch (Wildlife Acoustics, Inc.). Each recording session required one person releasing a bat and three persons recording with devices, each one of them holding a microphone at a distance of 10 or 3 meters (depending on the species), and, in order to increase the chances of recording the echolocating calls, two recorders where located at an angle of around 45º left and 45º right of the releasing bat and one in front of it. To prevent interference from free flying bats, releases where done only after knowing from the detectors that no other bats where flying around at that moment.

Data analysis

A total 322 files where obtained; nevertheless, due to the lack of quality of the majority of files, three files were inspected for each species looking for the file that best qualified for a correct description of each species echolocation pulses; furthermore, three pulses where analyzed within each file always choosing pulses of different size. The description of the echolocating calls includes the following parameters: Shape of the pulse (Sp), Frequency of maximum energy (FME), Minimal frequency of pulse (Fpmin) and Maximal frequency of pulse (Fpmax).

Results

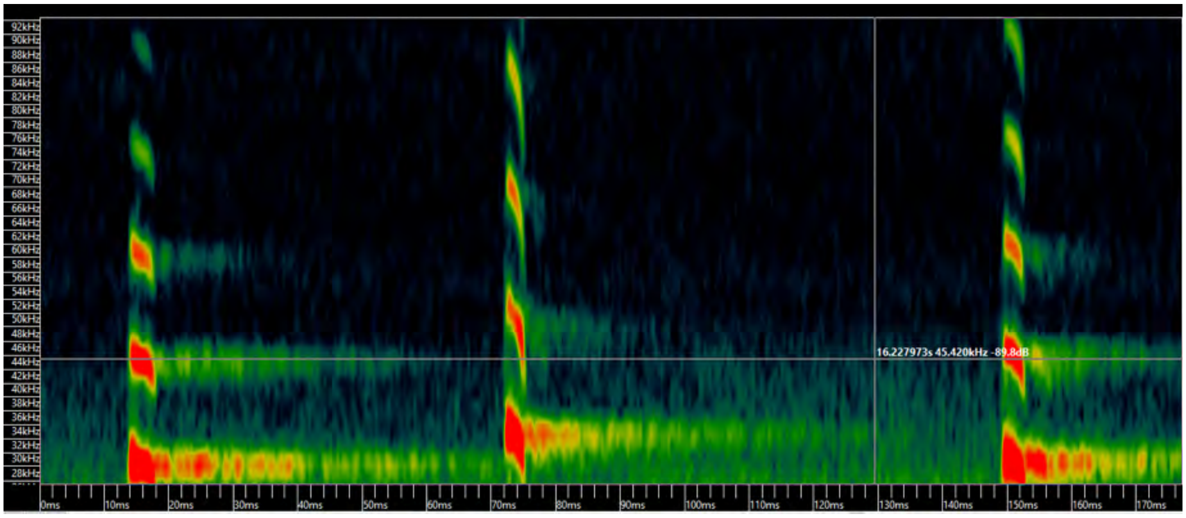
Key for release calls

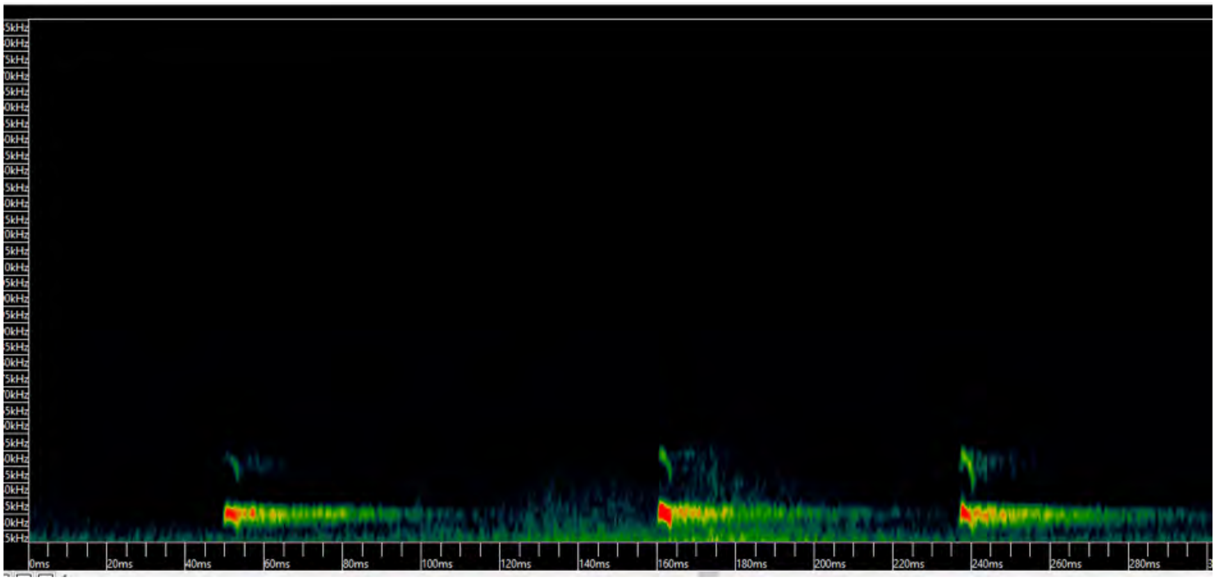
1. Shape as hockey stick: Miniopteridae and Vespertilionidae
2. Shape staple: Rhinolophidae
3. Shape angle: Hipposiridae

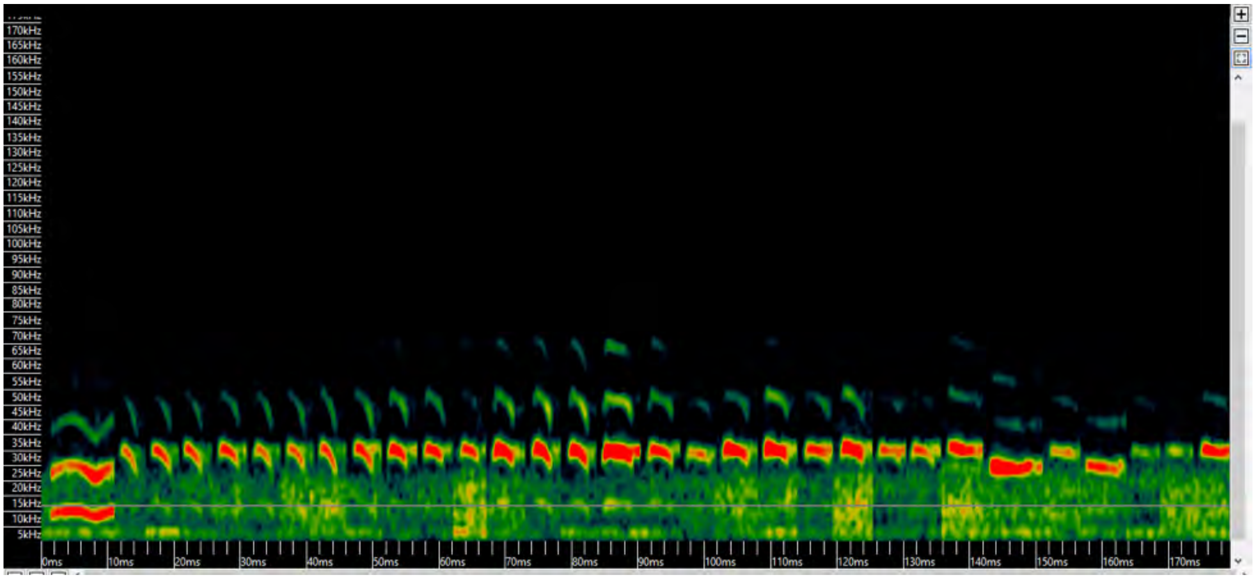
    i.

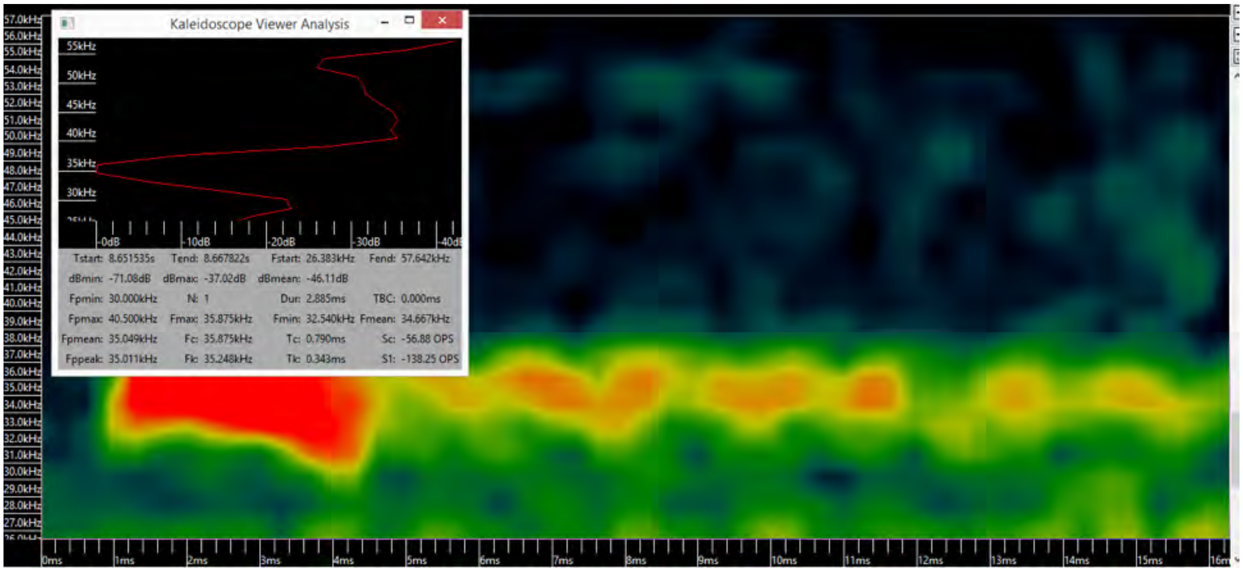
Coleura afra

Species	Fppeak	Fpmin	Fpmax
Coleura afra	34.734	30.685	38.425
Coleura afra	35.06	30.685	39.574
Coleura afra	34.746	30.685	39.574
	34.85 (34.734-35.06)	30.69	39.19(38.425-39.574)



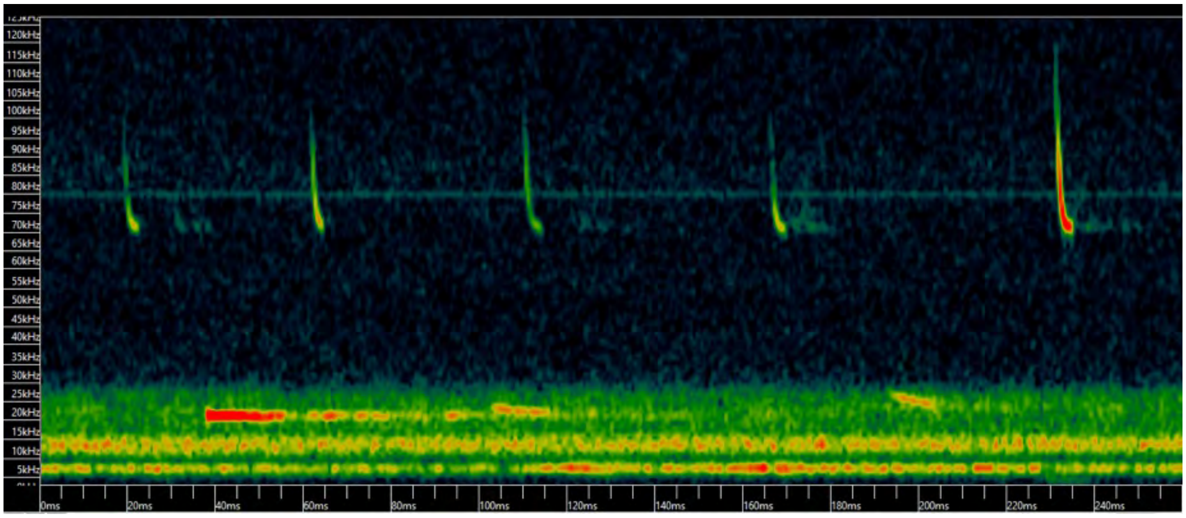


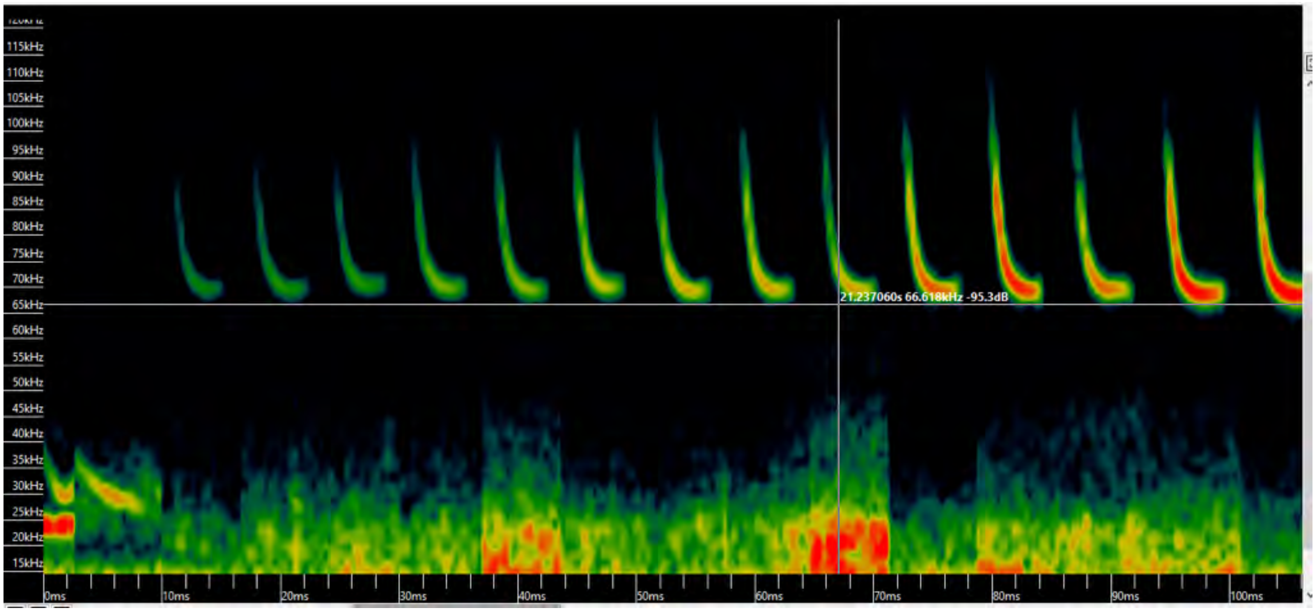


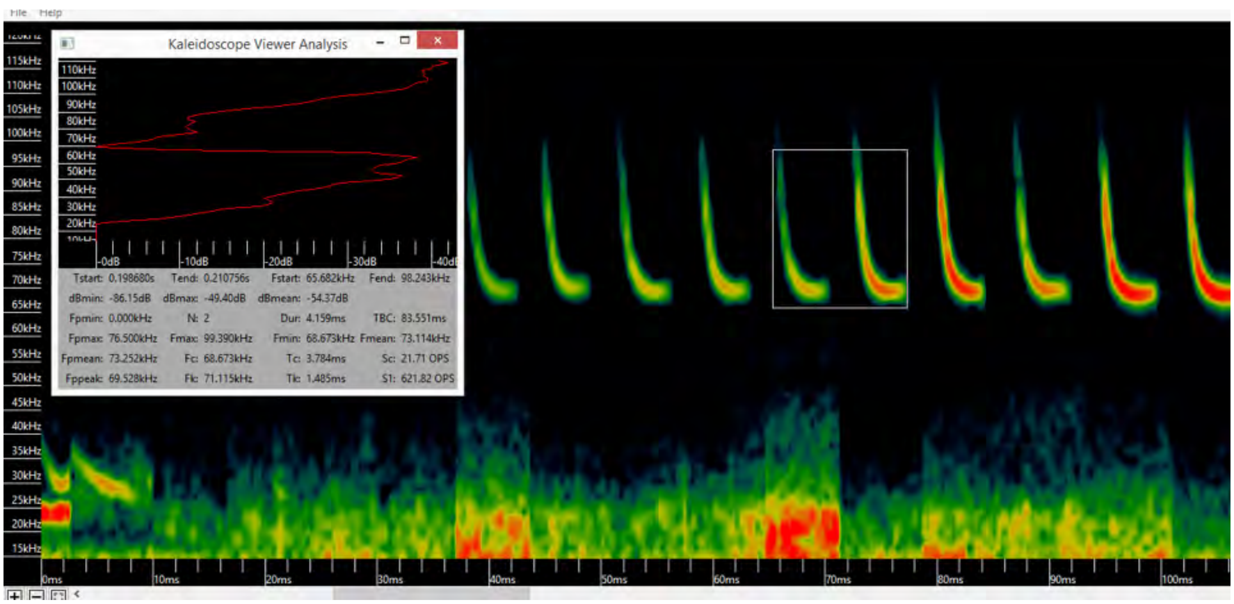

Kaleidoscope Viewer Analysis
Tstart: 8.651535s Tend: 8.667822s Fstart: 26.383kHz Fend: 57.642kHz
dBmin: -71.08dB dBmax: -37.02dB dBmean: -46.11dB
Fpmin: 30.000kHz N: 1 Dur: 2.885ms TBC: 0.000ms
Fpmax: 40.500kHz Fmax: 35.875kHz Fmin: 32.540kHz Fmean: 34.667kHz
Fpmean: 35.049kHz Fc: 35.875kHz Tc: 0.790ms Sc: -56.88 OPS
Fppeak: 35.011kHz Fk: 35.248kHz Tk: 0.343ms S1: -138.25 OPS

Neoromicia Nana

Species	Fppeak (khz)	Fpmin (khz)	Fpmax (khz)
Neoromicia nana	72.99	71.12	96.24
Neoromicia nana	71.74	71.12	102.34
Neoromicia nana	71.85	71.12	120.18
	72.19(71.74-72.99)	71.12	106.25(96.24-120.18)

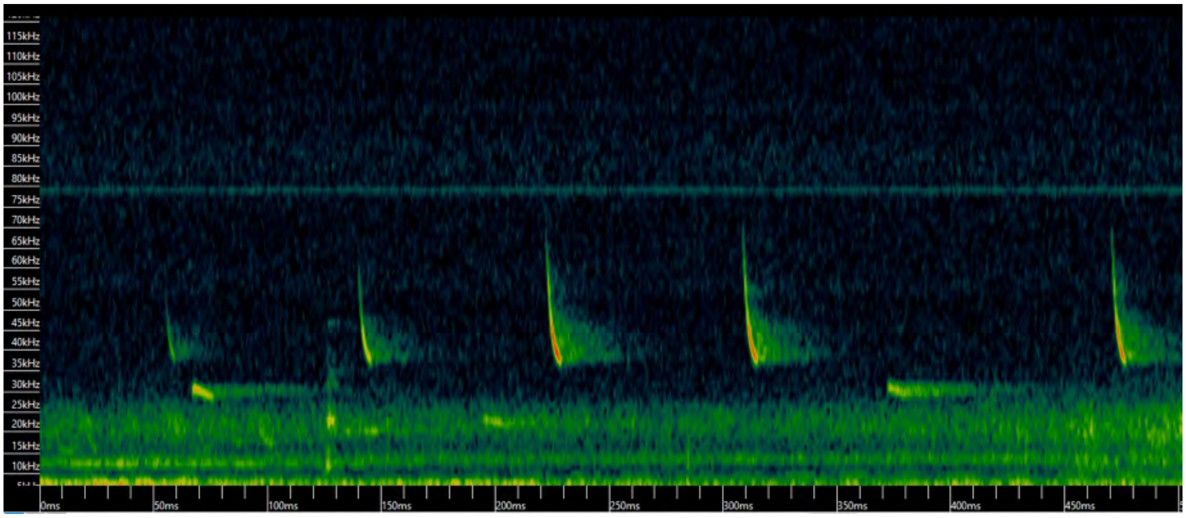


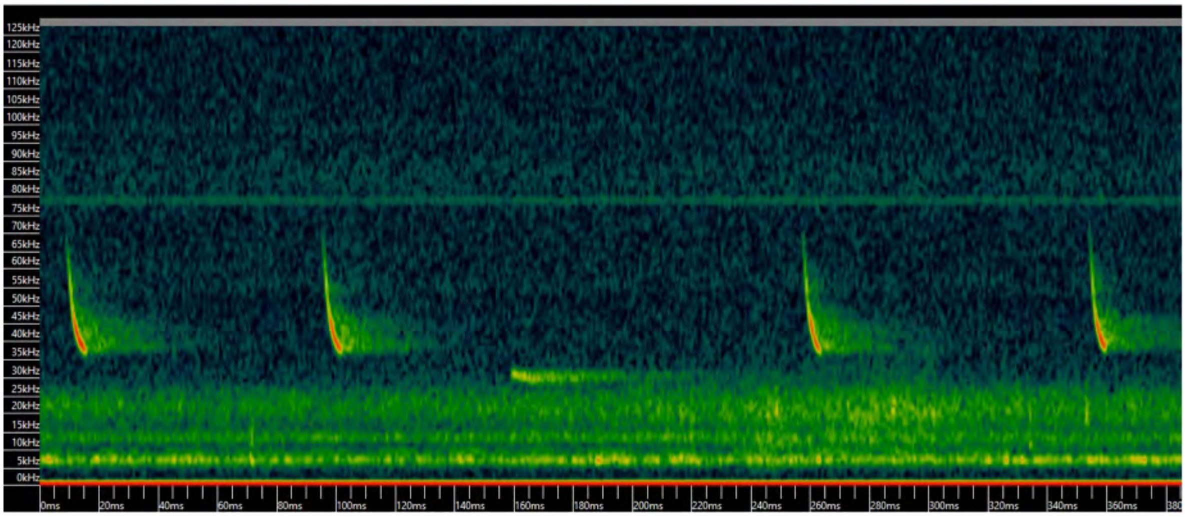

115kHz
110kHz
105kHz
100kHz
95kHz
90kHz
85kHz
80kHz
75kHz
70kHz
65kHz
60kHz
55kHz
50kHz
45kHz
40kHz
35kHz
30kHz
25kHz
20kHz
15kHz
21.237060s 66.618kHz -95.3dB
0ms
10ms
20ms
30ms
40ms
50ms
60ms
70ms
80ms
90ms
100ms

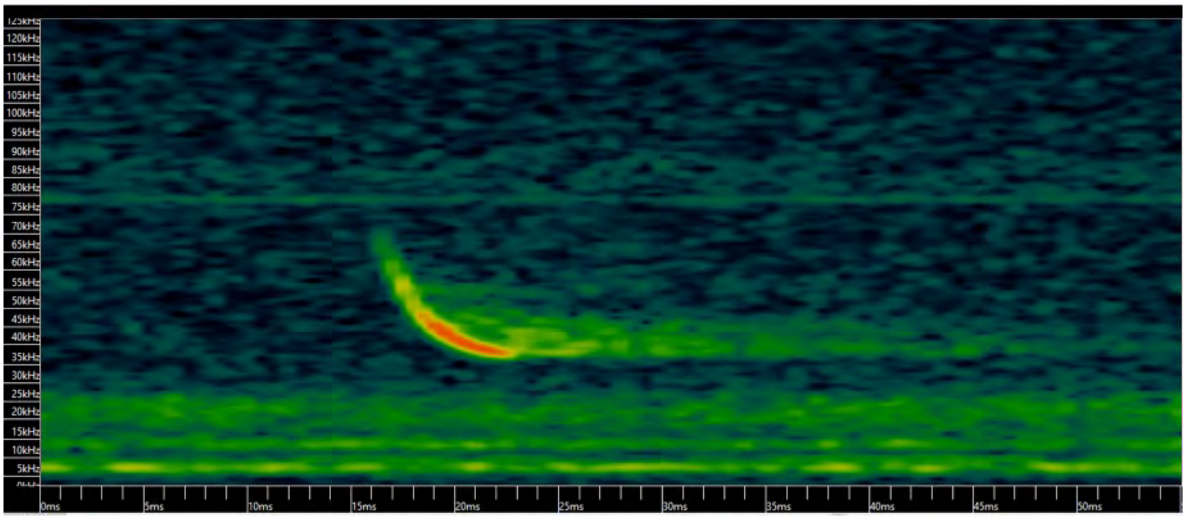

File Help
Kaleidoscope Viewer Analysis
110kHz
100kHz
90kHz
80kHz
70kHz
60kHz
50kHz
40kHz
30kHz
20kHz
-0dB
-10dB
-20dB
-30dB
-40dB
Tstart: 0.198680s Tend: 0.210756s Fstart: 65.682kHz Fend: 98.243kHz
dBmin: -86.15dB dBmax: -49.40dB dBmean: -54.37dB
Fpmin: 0.000kHz N: 2 Dur: 4.159ms TBC: 83.551ms
Fpmax: 76.500kHz Fmax: 99.390kHz Fmin: 68.673kHz Fmean: 73.114kHz
Fpmean: 73.252kHz Fc: 68.673kHz Tc: 3.784ms Sc: 21.71 OPS
Fppeak: 69.528kHz Fk: 71.115kHz Tk: 1.485ms S1: 621.82 OPS
115kHz
110kHz
105kHz
100kHz
95kHz
90kHz
85kHz
80kHz
75kHz
70kHz
65kHz
60kHz
55kHz
50kHz
45kHz
40kHz
35kHz
30kHz
25kHz
20kHz
15kHz
0ms
10ms
20ms
30ms
40ms
50ms
60ms
70ms
80ms
90ms
100ms

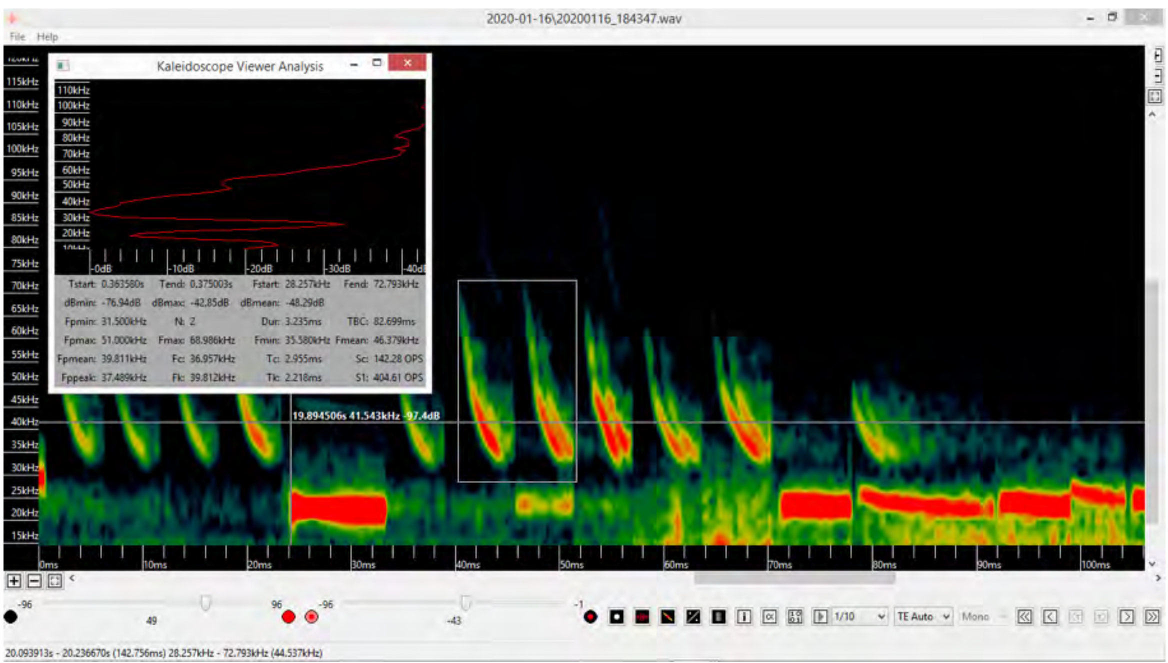
Scotoecus hirundo

Species	Fppeak	Fpmin	Fpmax
Scotoecus hirundo	38.89	35.41	60.95
Scotoecus hirundo	39.043	35.41	69.97
Scotoecus hirundo	38.99	35.41	71.25
	38.97(38.89-39.043)	35.41	67.39(60.95-71.25)



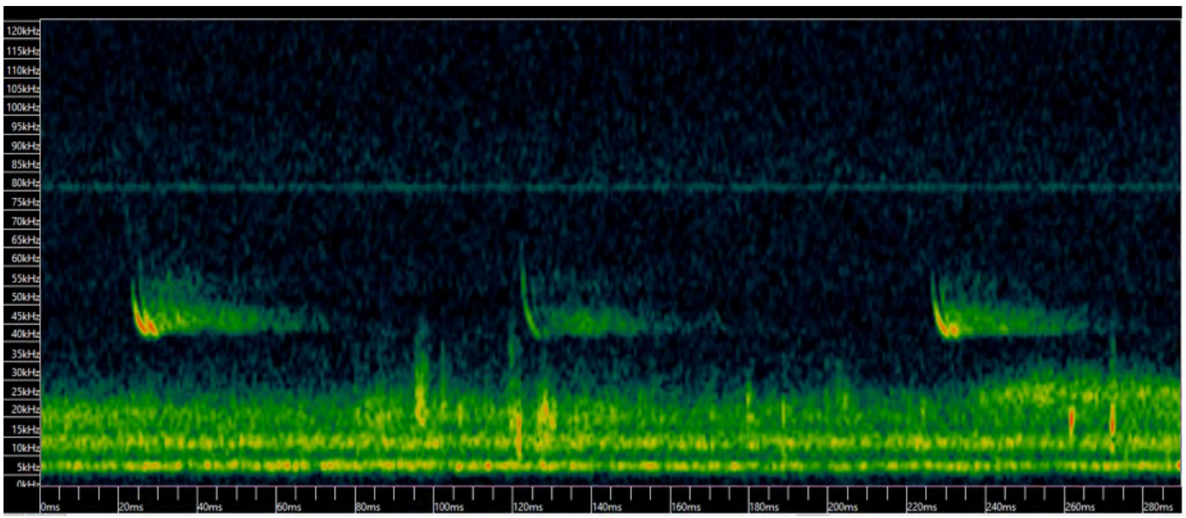


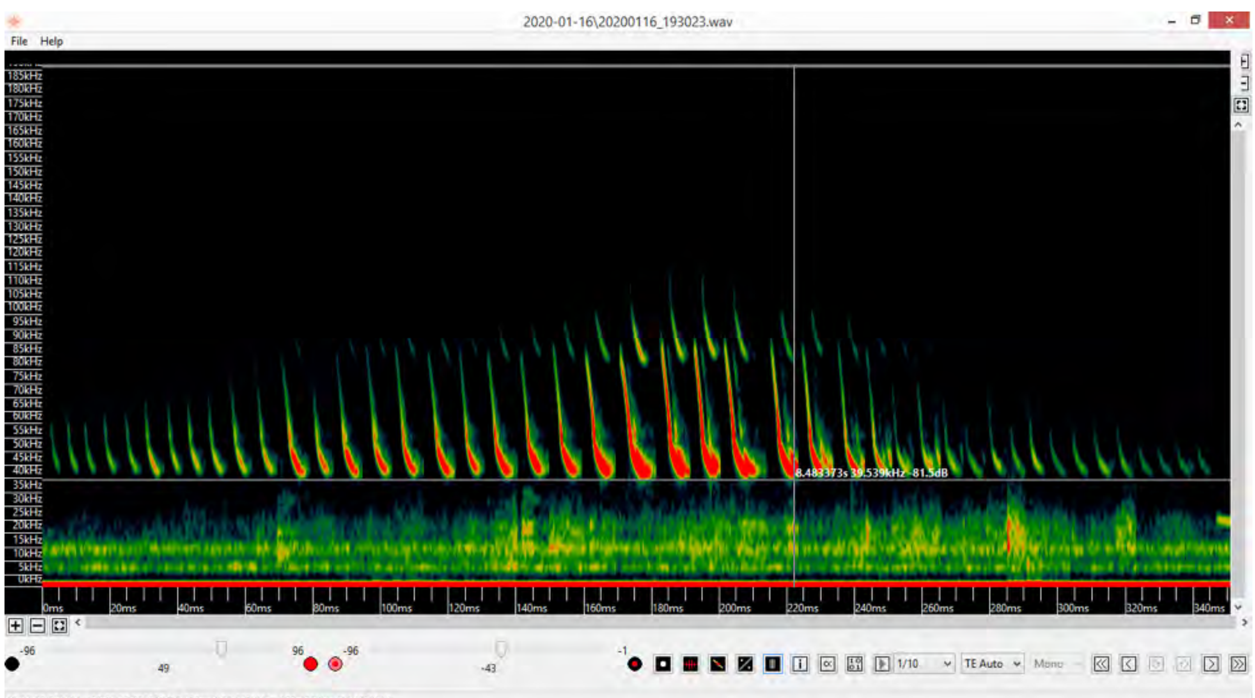

120kHz
115kHz
110kHz
105kHz
100kHz
95kHz
90kHz
85kHz
80kHz
75kHz
70kHz
65kHz
60kHz
55kHz
50kHz
45kHz
40kHz
35kHz
30kHz
25kHz
20kHz
15kHz
10kHz
5kHz
0ms 5ms 10ms 15ms 20ms 25ms 30ms 35ms 40ms 45ms 50ms

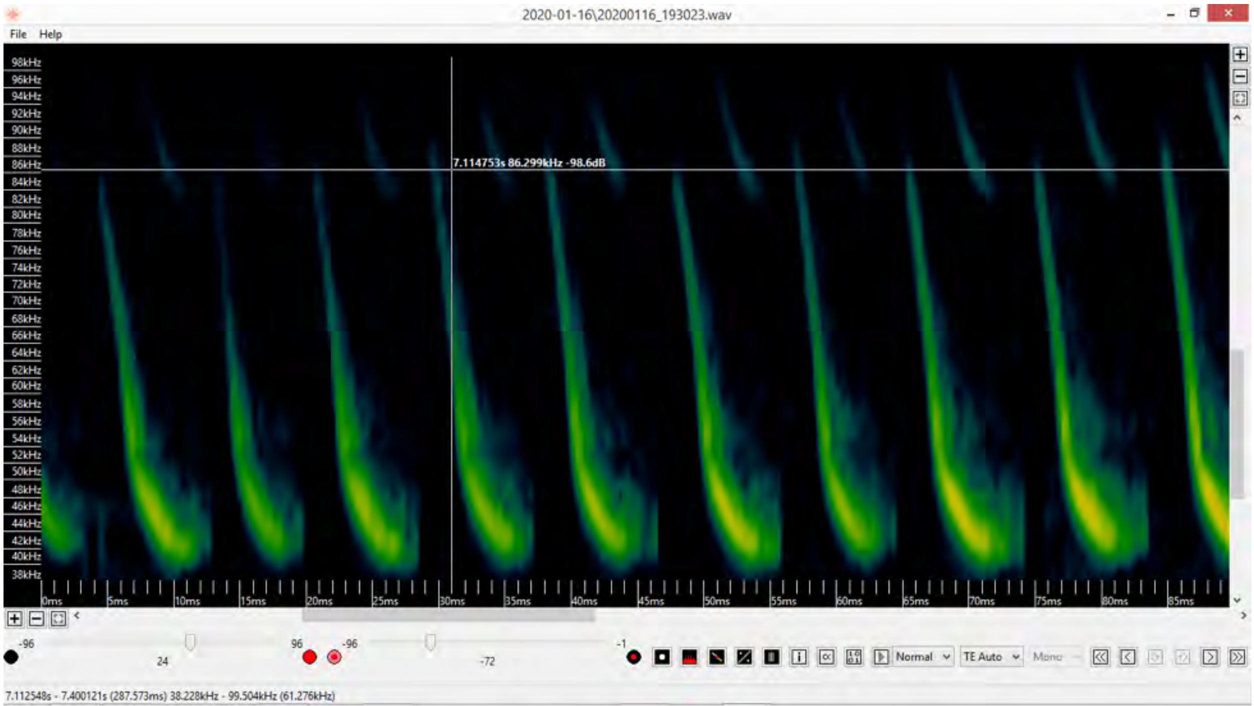

2020-01-16\20200116_184347.wav
File Help
Kaleidoscope Viewer Analysis
Tstart: 0.363580s Tend: 0.375003s Fstart: 28.257kHz Fend: 72.793kHz
dBmin: -76.94dB dBmax: -42.85dB dBmean: -48.29dB
Fpmin: 31.500kHz N: 2 Dur: 3.235ms TBC: 82.699ms
Fpmax: 51.000kHz Fmax: 68.986kHz Fmin: 35.580kHz Fmean: 46.379kHz
Fpmean: 39.811kHz Fc: 36.957kHz Tc: 2.955ms Sc: 142.28 OPS
Fppeak: 37.489kHz Fk: 39.812kHz Tk: 2.218ms S1: 404.61 OPS
19.894506s 41.543kHz -97.4dB
0ms 10ms 20ms 30ms 40ms 50ms 60ms 70ms 80ms 90ms 100ms
1/10
TE Auto
Mono
20.093913s - 20.236670s (142.756ms) 28.257kHz - 72.793kHz (44.537kHz)

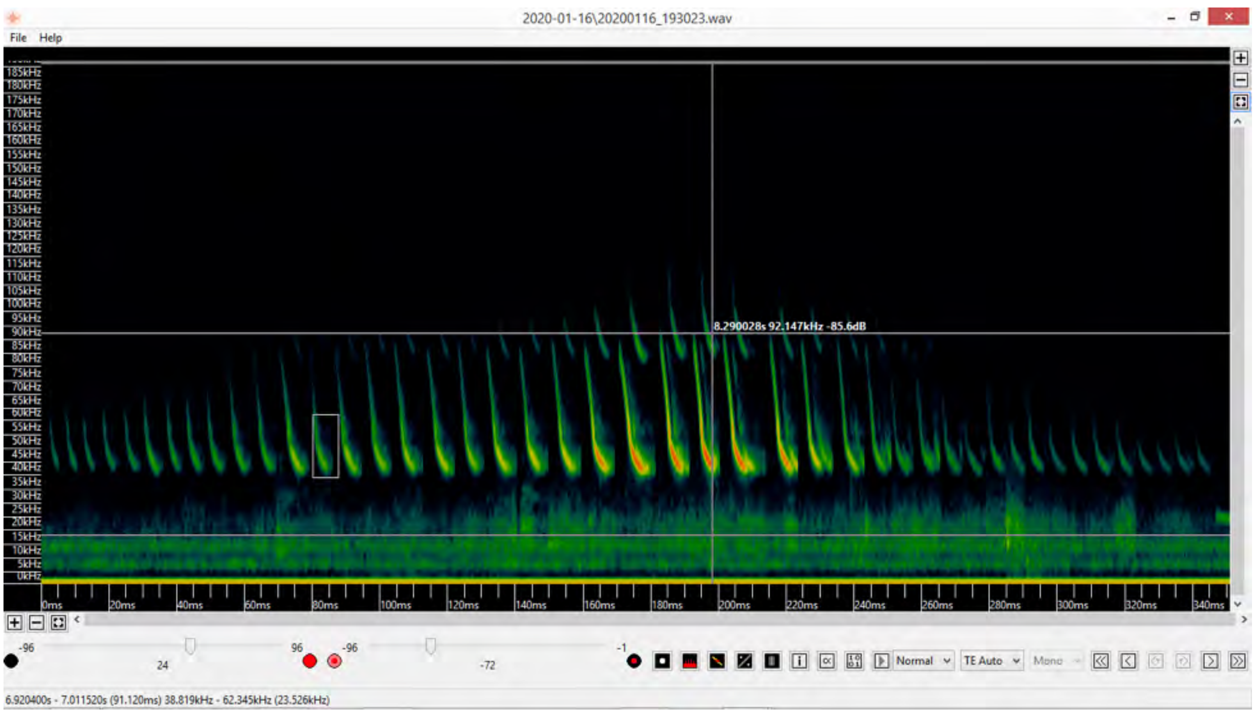
Scotophylus trujilloi

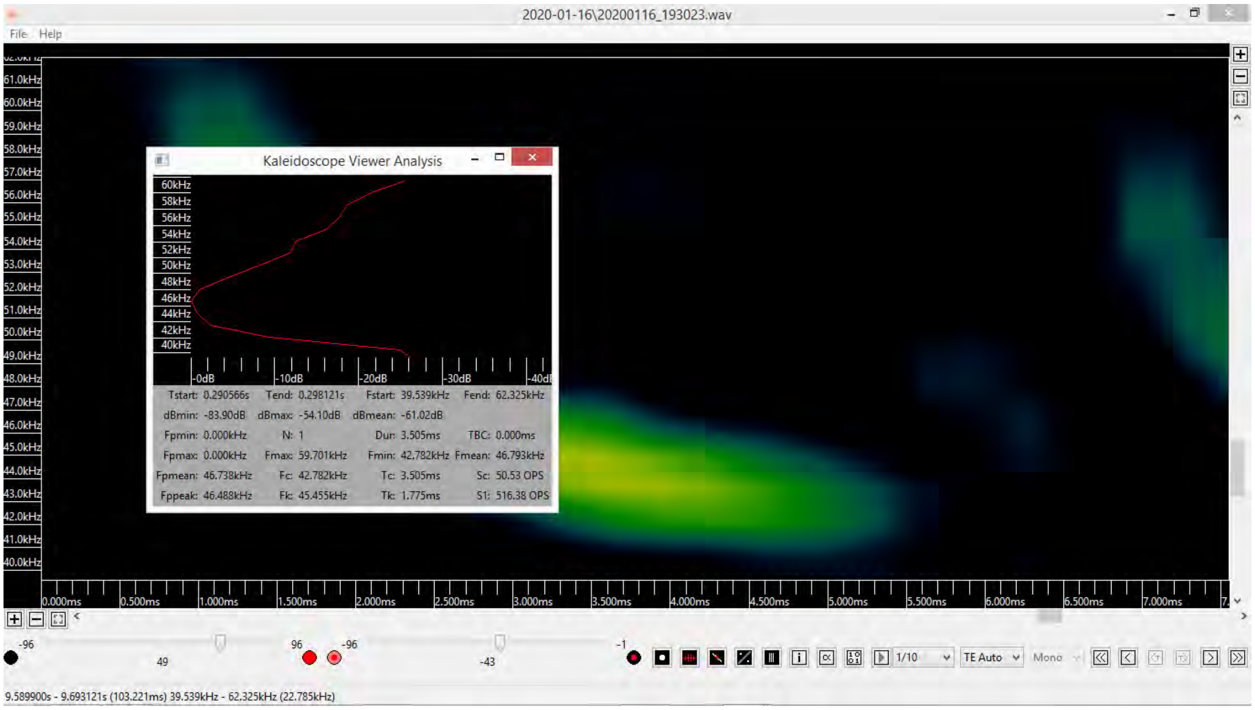
Species	Fppeak	Fpmin	Fpmax
Scotophilus trujilloi	43.95	40.69	56.97
Scotophilus trujilloi	45.94	40.69	66.5
Scotophilus trujilloi	43.046	40.69	58.83
	44.31(43.046-45.95)	40.69	60.77(56.97-66.50)





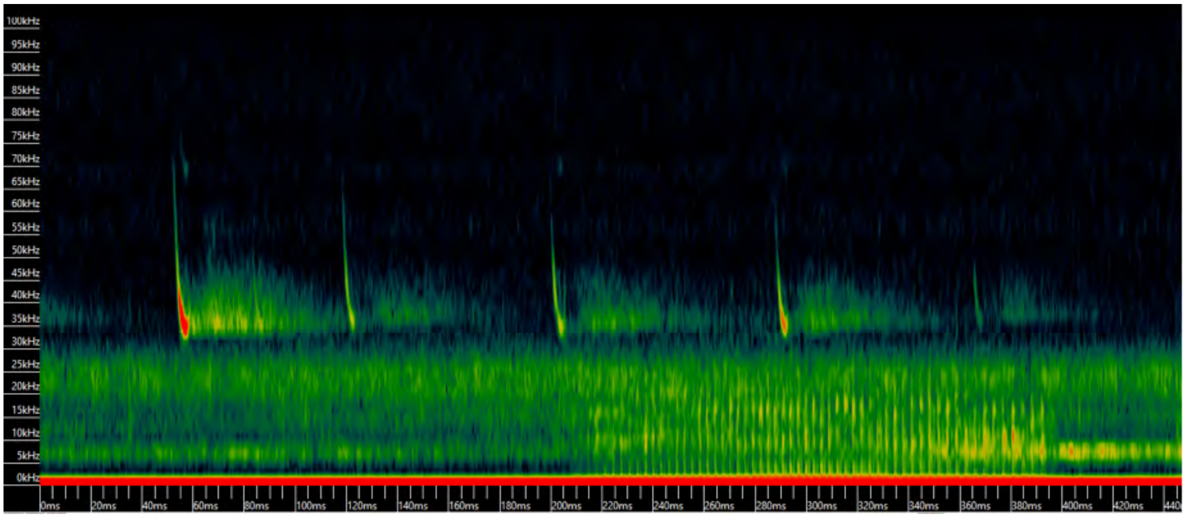

2020-01-16\20200116_193023.wav
File Help
7.114753s 86.299kHz -98.6dB
Normal
TE Auto
Mono
7.112548s - 7.400121s (287.573ms) 38.228kHz - 99.504kHz (61.276kHz)

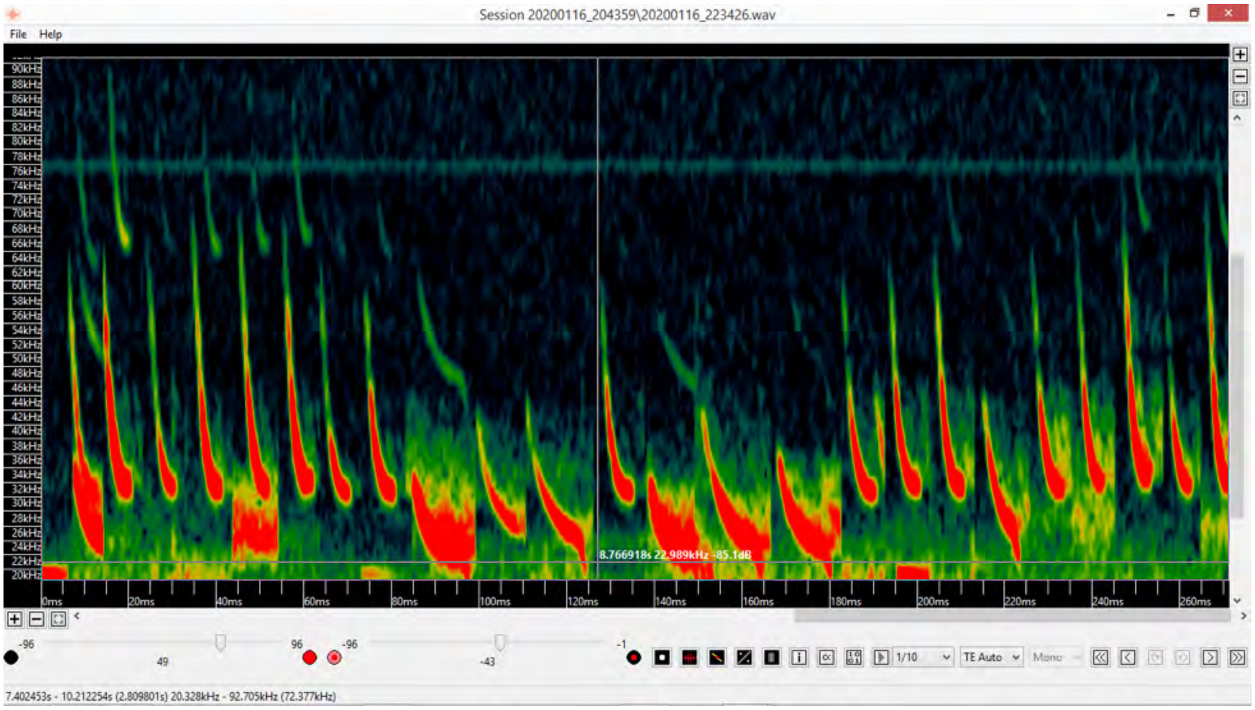

2020-01-16\20200116_193023.wav
File Help
8.290028s 92.147kHz -85.6dB
Normal
TE Auto
Mono
6.920400s - 7.011520s (91.120ms) 38.819kHz - 62.345kHz (23.526kHz)

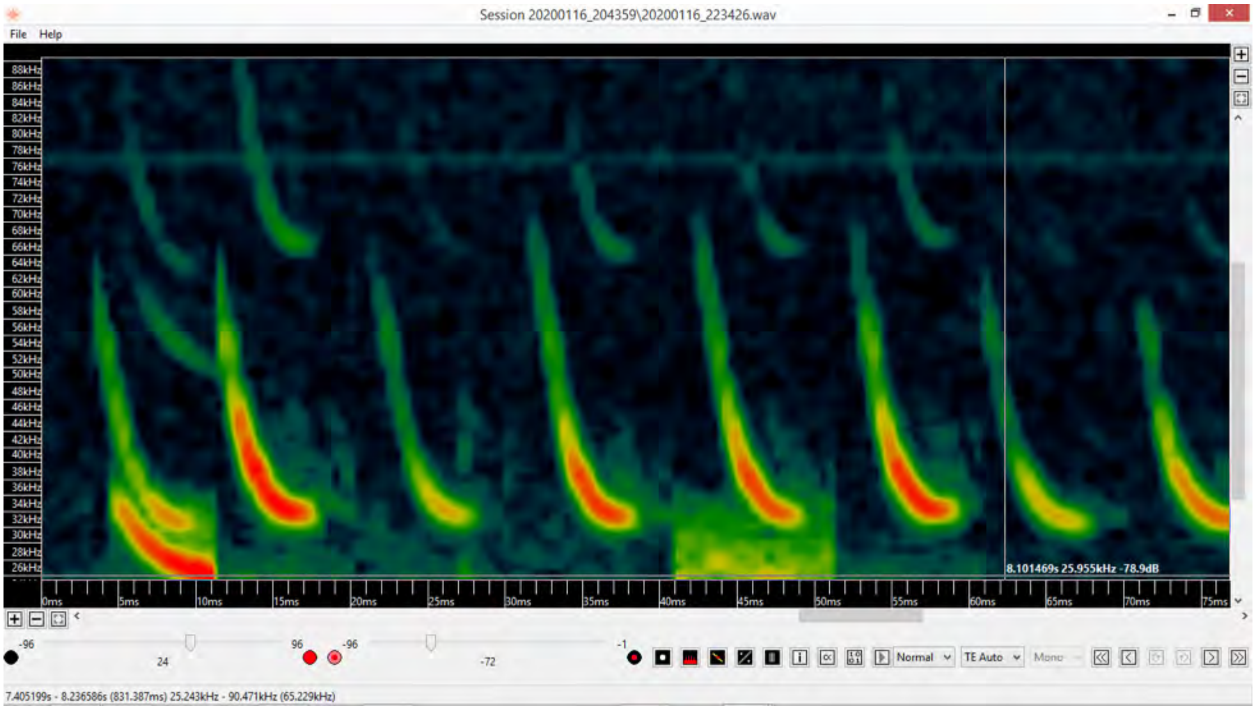

2020-01-16\20200116_193023.wav
File Help
Kaleidoscope Viewer Analysis
Tstart: 0.290566s Tend: 0.298121s Fstart: 39.539kHz Fend: 62.325kHz
dBmin: -83.90dB dBmax: -54.10dB dBmean: -61.02dB
Fpmin: 0.000kHz N: 1 Dur: 3.505ms TBC: 0.000ms
Fpmax: 0.000kHz Fmax: 59.701kHz Fmin: 42.782kHz Fmean: 46.793kHz
Fpmean: 46.738kHz Fc: 42.782kHz Tc: 3.505ms Sc: 50.53 OPS
Fppeak: 46.488kHz Fk: 45.455kHz Tk: 1.775ms S1: 516.38 OPS
9.589900s - 9.693121s (103.221ms) 39.539kHz - 62.325kHz (22.785kHz)

Scotophyllus andrewborri

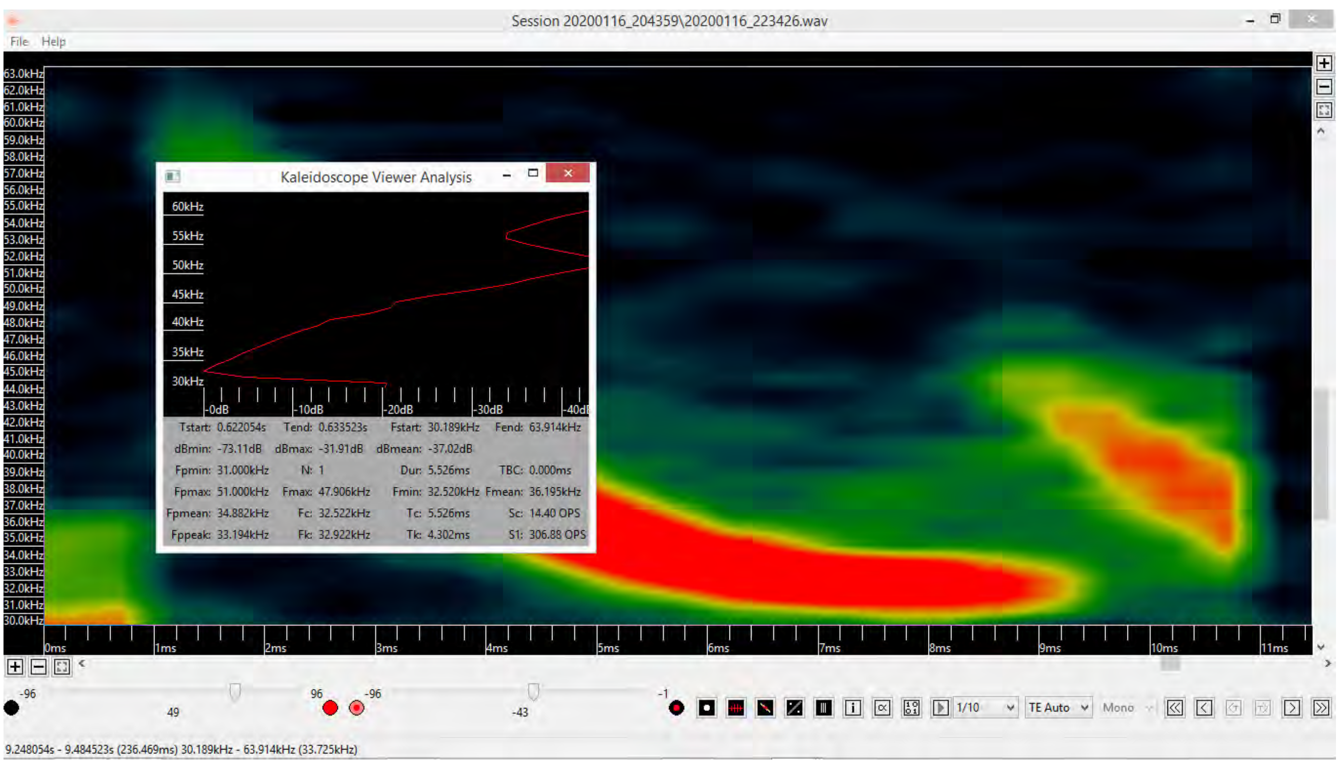
Species	Fppeak	Fpmin	Fpmax
Scotophilus andrewborii	34.52	31.71	49.58
Scotophilus andrewborii	34.62	31.71	60.54
Scotophilus andrewborii	35.96	31.71	69.95
	35.03(34.52-35.96)	31.71	60.02(49.58-69.95)




Session 20200116_204359\20200116_223426.wav
8.766918s 22.989kHz -85.1dB
7.402453s - 10.212254s (2.809801s) 20.328kHz - 92.705kHz (72.377kHz)

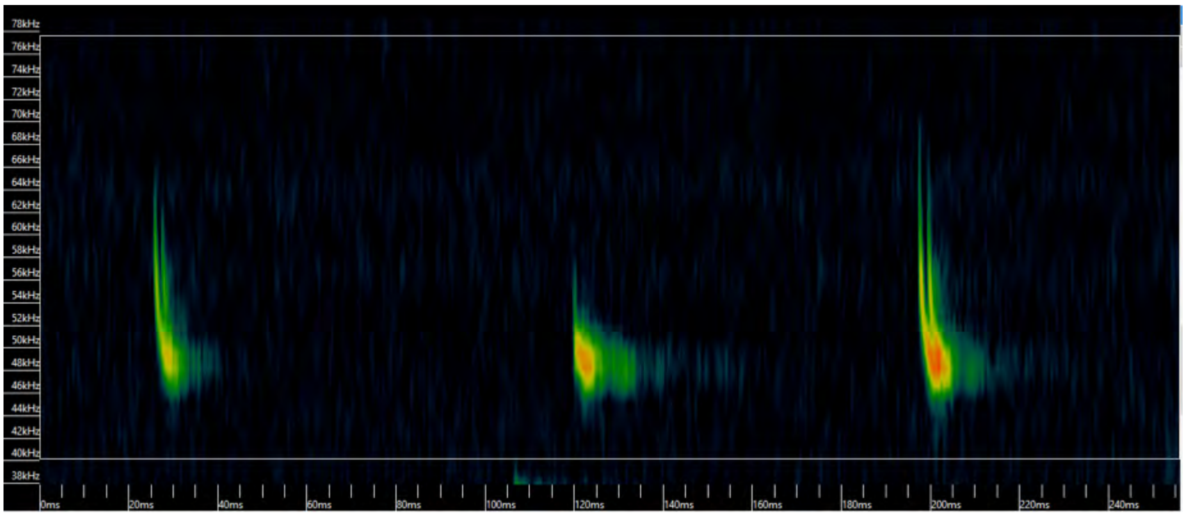

Session 20200116_204359\20200116_223426.wav
8.101469s 25.955kHz -78.9dB
7.405199s - 8.236586s (831.387ms) 25.243kHz - 90.471kHz (65.229kHz)

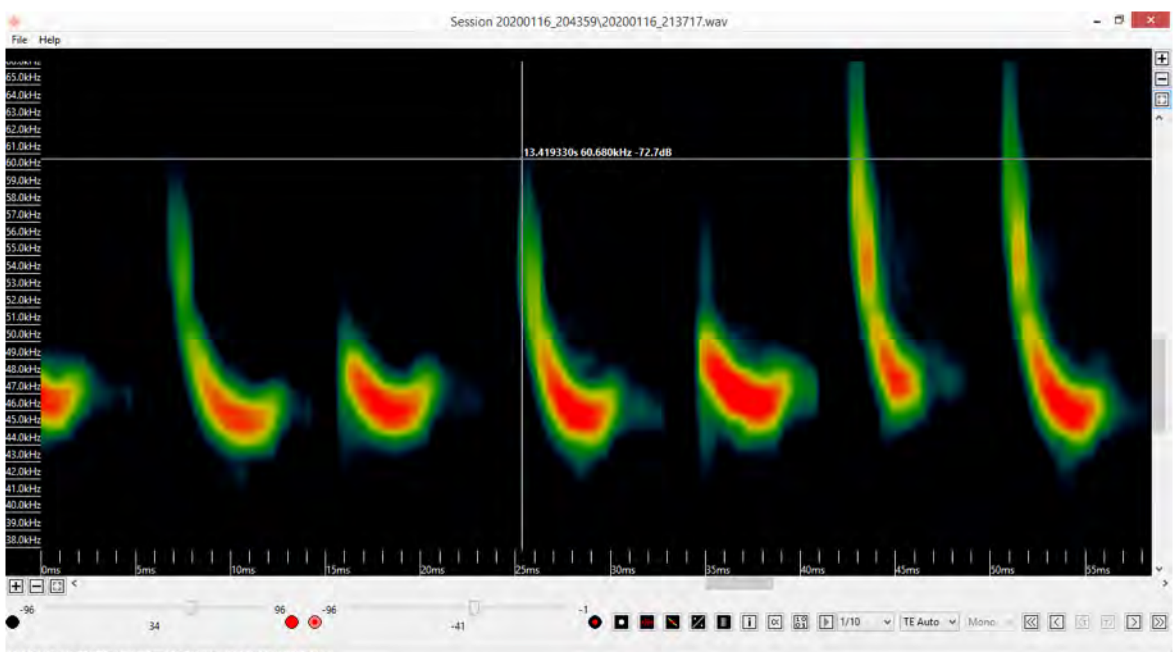

2020-01-16\20200116_203430.wav
File Help
5.098964s 49.592kHz -66.5dB
4.836564s - 5.443517s (606.953ms) 22.785kHz - 55.623kHz (32.838kHz)


Session 20200116_204359\20200116_223426.wav
File Help
Kaleidoscope Viewer Analysis
Tstart: 0.622054s Tend: 0.633523s Fstart: 30.189kHz Fend: 63.914kHz
dBmin: -73.11dB dBmax: -31.91dB dBmean: -37.02dB
Fpmin: 31.000kHz N: 1 Dur: 5.526ms TBC: 0.000ms
Fpmax: 51.000kHz Fmax: 47.906kHz Fmin: 32.520kHz Fmean: 36.195kHz
Fpmean: 34.882kHz Fc: 32.522kHz Tc: 5.526ms Sc: 14.40 OPS
Fppeak: 33.194kHz Fk: 32.922kHz Tk: 4.302ms S1: 306.88 OPS
9.248054s - 9.484523s (236.469ms) 30.189kHz - 63.914kHz (33.725kHz)

Neoromicia rendali

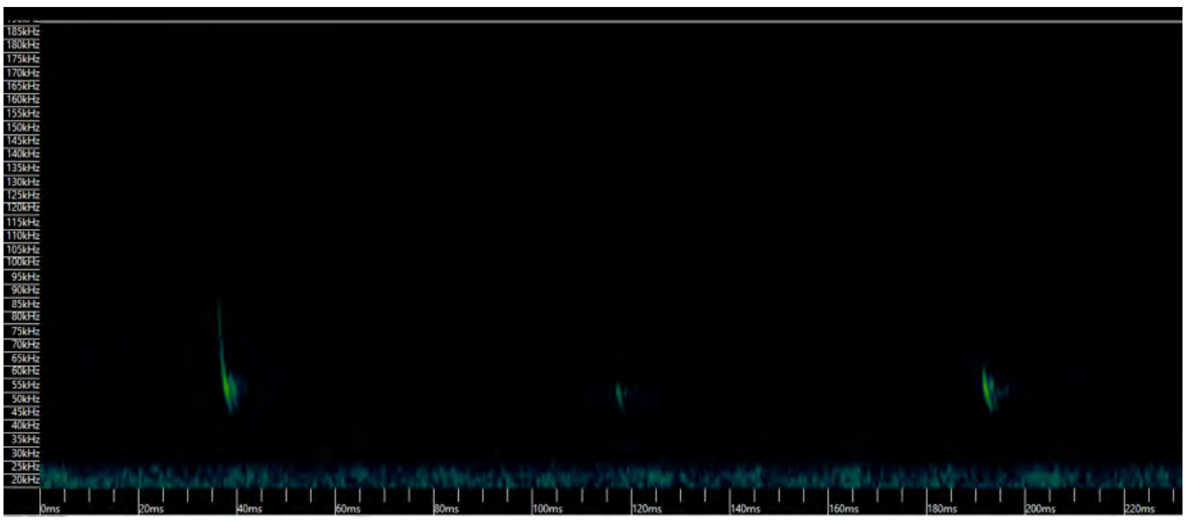
Species	Fppeak	Fpmin	Fpmax
Neoromicia rendalli	49.24	45.35	66.67
Neoromicia rendalli	48.57	45.35	58.07
Neoromicia rendalli	48.63	45.35	70.7
	48.81(49.24-48.57)	45.35	65.15(70.70-58.07)

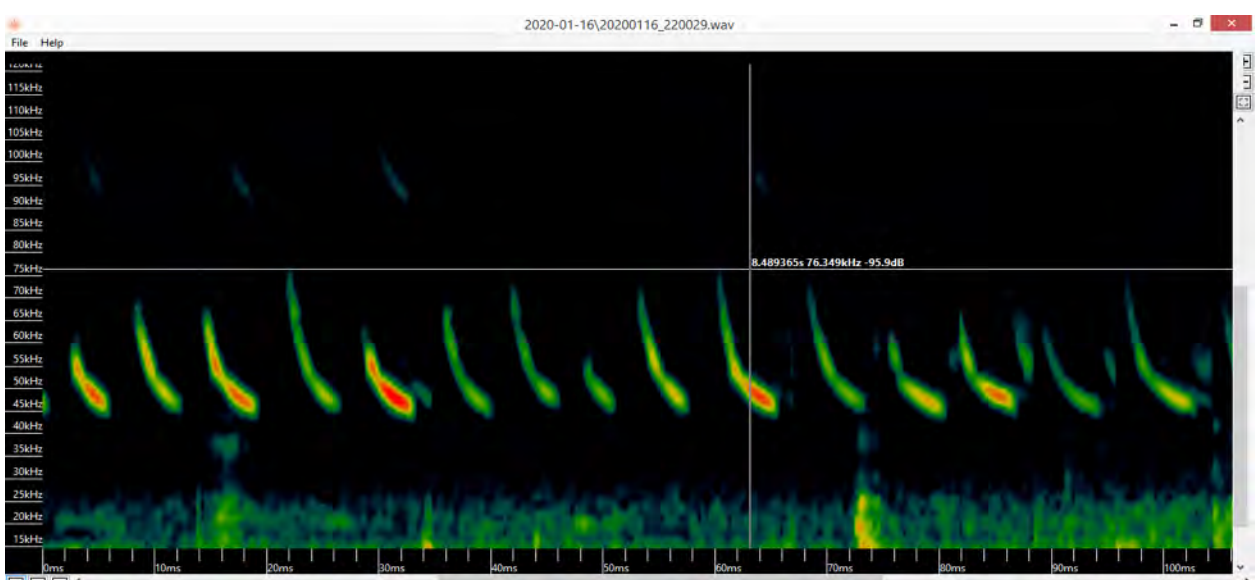


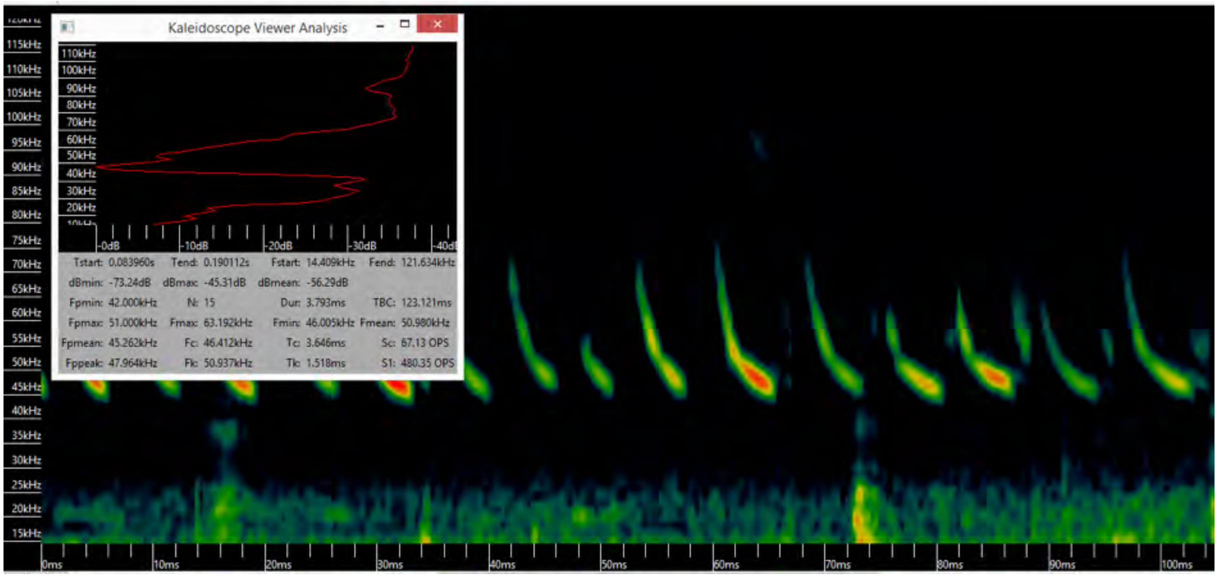


Pipistrellus reppellii

Species	Fppeak (khz)	Fpmin (khz)	Fpmax (khz)
Pipistrellus rueppellii	55.73	47.54	88.61
Pipistrellus rueppellii	54.075	47.54	59.5
Pipistrellus rueppellii	56.65	47.54	64.033
	55.49(54.075-56.65)	47.54	70.71(59.50-88.61)

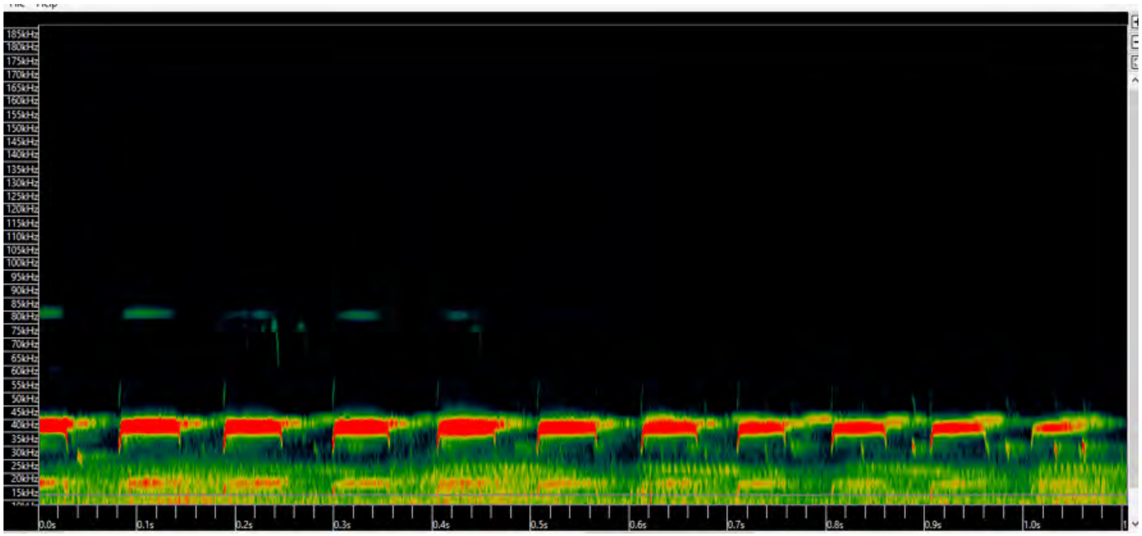


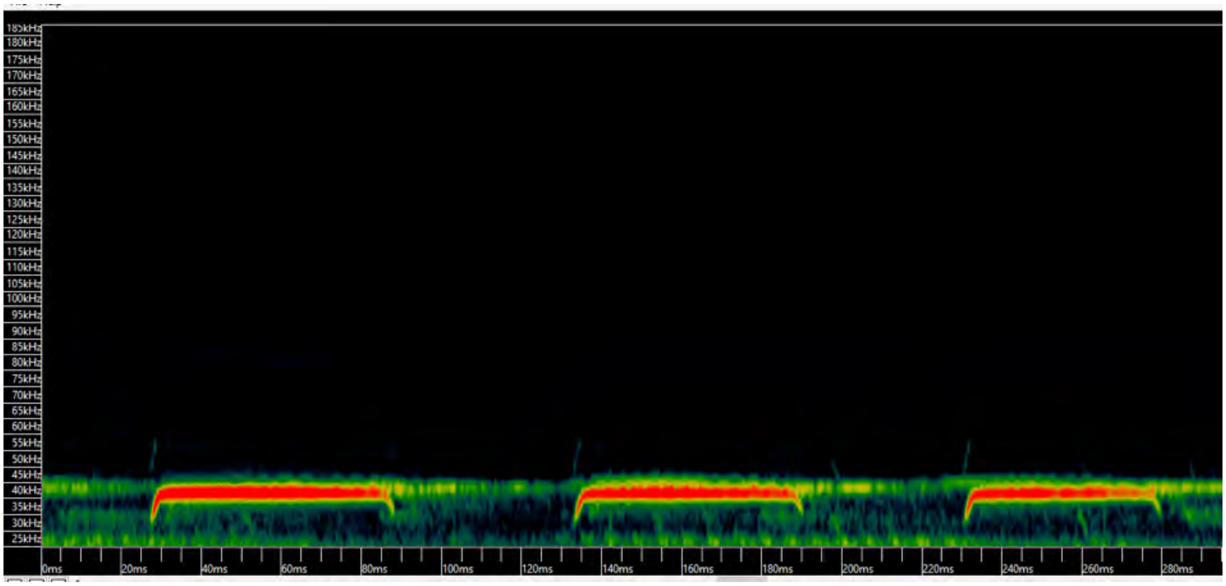


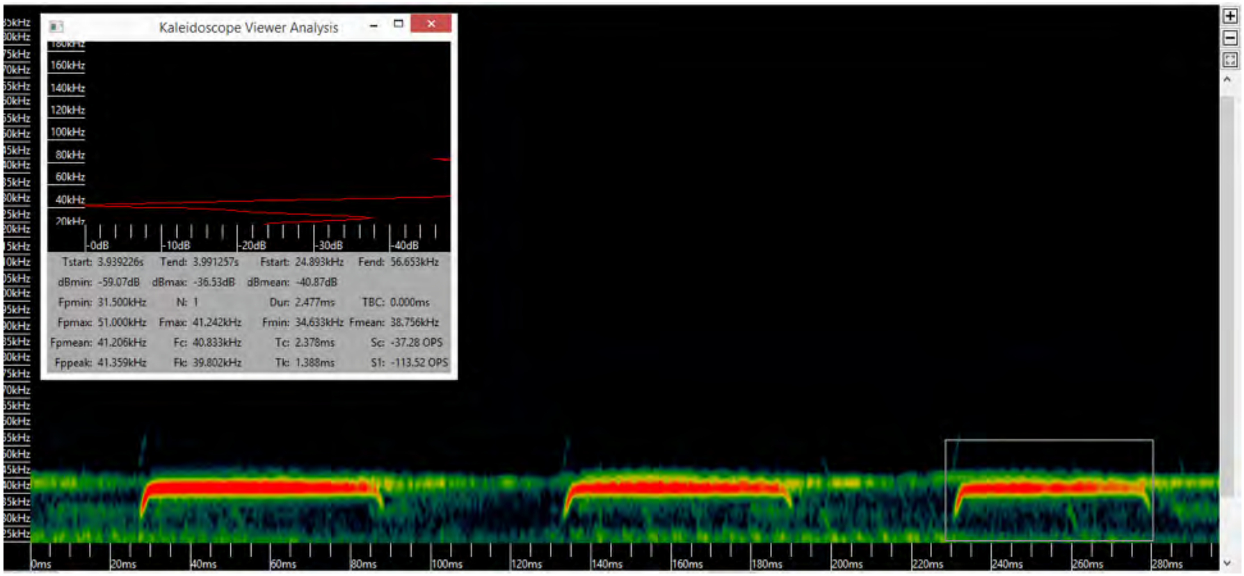

Kaleidoscope Viewer Analysis
Tstart: 0.083960s Tend: 0.190112s Fstart: 14.409kHz Fend: 121.634kHz
dBmin: -73.24dB dBmax: -45.31dB dBmean: -56.29dB
Fpmin: 42.000kHz N: 15 Dur: 3.793ms TBC: 123.121ms
Fpmax: 51.000kHz Fmax: 63.192kHz Fmin: 46.005kHz Fmean: 50.980kHz
Fpmean: 45.262kHz Fc: 46.412kHz Tc: 3.646ms Sc: 67.13 OPS
Fppeak: 47.964kHz Fk: 50.937kHz Tk: 1.518ms S1: 480.35 OPS

Rhinolophus eloquens

Species	Fppeak (khz)	Fpmin (khz)	Fpmax (khz)
Rhinolophus eloquens	41.424	32.015	45.597
Rhinolophus eloquens	41.398	32.015	45.597
Rhinolophus eloquens	41.359	32.015	44.627
	41.39(41.424-41.398)	32.02	45.27(44.627-45.597)

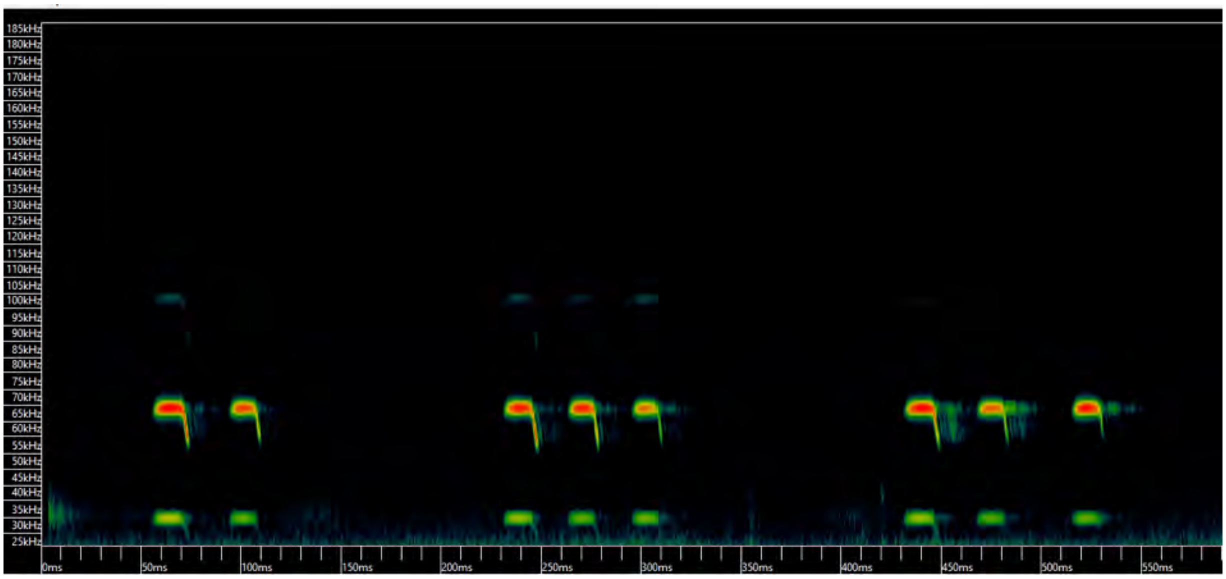


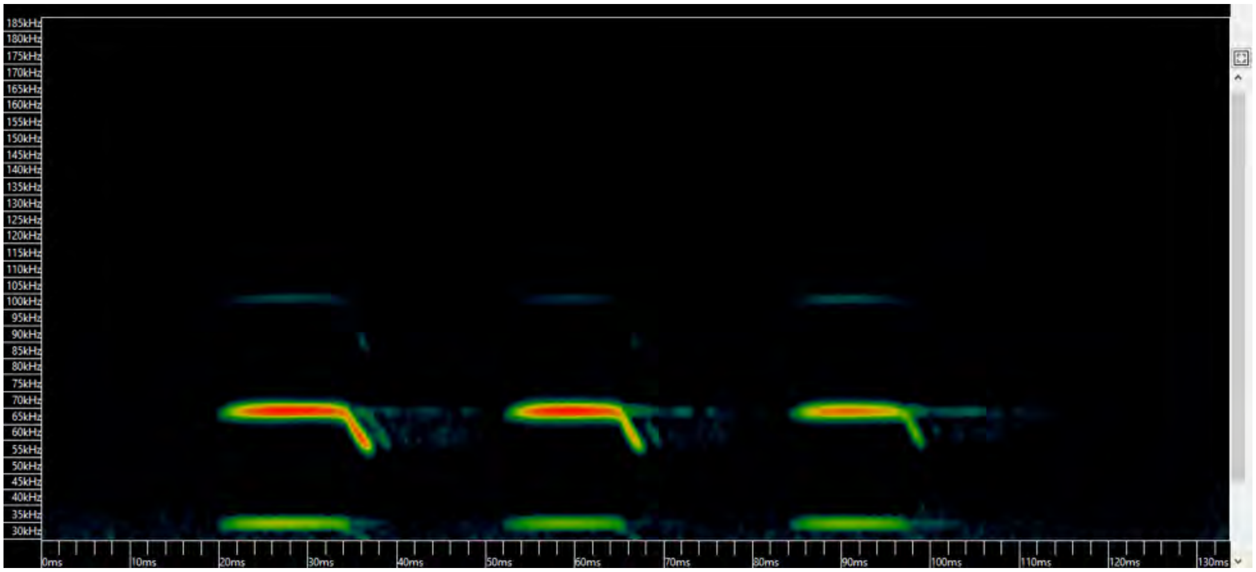


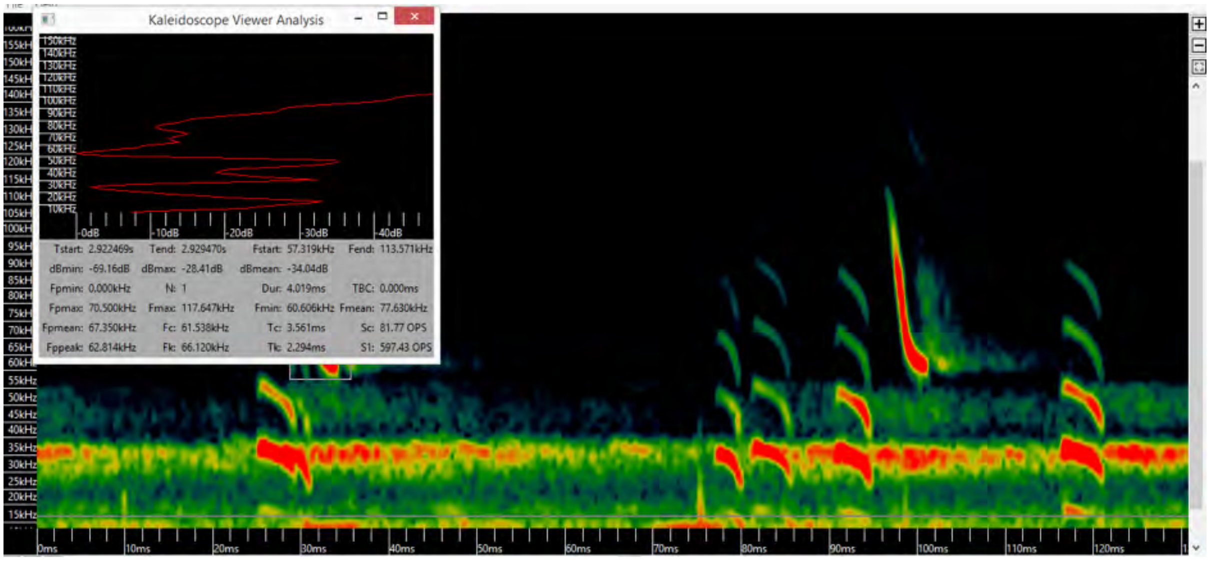

Kaleidoscope Viewer Analysis
160kHz
140kHz
120kHz
100kHz
80kHz
60kHz
40kHz
20kHz
-0dB
-10dB
-20dB
-30dB
-40dB
Tstart: 3.939226s
Tend: 3.991257s
Fstart: 24.893kHz
Fend: 56.653kHz
dBmin: -59.07dB
dBmax: -36.53dB
dBmean: -40.87dB
Fpmin: 31.500kHz
N: 1
Dur: 2.477ms
TBC: 0.000ms
Fpmax: 51.000kHz
Fmax: 41.242kHz
Fmin: 34.633kHz
Fmean: 38.756kHz
Fpmean: 41.206kHz
Fc: 40.833kHz
Tc: 2.378ms
Sc: -37.28 OPS
Fppeak: 41.359kHz
Fk: 39.802kHz
Tk: 1.388ms
S1: -113.52 OPS
0ms
20ms
40ms
60ms
80ms
100ms
120ms
140ms
160ms
180ms
200ms
220ms
240ms
260ms
280ms

Macronycteris vittata

Species	Fppeak (khz)	Fpmin (khz)	Fpmax (khz)
Macronycteris vittata	68.641	55.879	72.084
Macronycteris vittata	68.703	55.879	72.364
Macronycteris vittata	68.652	55.879	71.805
	68.67(68.652-68.703)	55.88	72.08(71.805-72.364)







Discussion

Echo location calls vary between and within species of different families, the overlap in frequencies also makes the identification of species. Environmental factors and physiological factors also affect the quality of the calls causing variations that makes identification cumbersome, therefore it is essential to critically observe echolocation calls of a particular species, in comparison with different calls of the same to capture those variations.

Release calls were used in this case and it is obvious that capture and handling process imposes stress to the animals thereby giving alterational calls that can be difficult to match. However, if proper techniques are applied in the characterisation of calls, species identification is made easy.

Measurements are taken from the harmonic with maximum concentration of energy, which is usually the first or second harmonic of any bat pulse.

The frequency of maximum activity also termed as frequency of maximum energy was obtained from the power spectrum. And this distinctively stands out between species. To avoid baises, average frequencies and maximum frequencies were documented for reference. And although the FME can vary between species, ranges of expected frequencies were noted as terms of reference.

The minimum frequency also recorded from the power spectrum is an outstanding variable that largely differs in all species but usually specific for every species. The minimum frequency is the frequency recorded above the background noise.

The maximum frequency recorded from the power spectrum is the frequency of greatest intensity, and this was comparatively measured in different pulses of any single bat species

Conclusion

The main limitation in regarding the use of bat echolocation calls to identify species is that many species have calls that overlap in frequency and similar shape of pulse which means that, in some cases, bats recorded in an acoustic devise can only be identified up to family level.

In order to correctly identify species using key, accuracy is essential in order to become a successful tool for its purpose, overlapping in measurements of any parameter will raise the probability of misidentification.

Acknowledgment

This field study would not have been possible without support from a number of people. Firstly, we would like to thank all the lecturers for their input and guidance throughout this process. Secondly, we would like to acknowledge the members of the team who worked extremely hard in setting the devices and analysing the data, despite the short time. Thirdly, we like to thank Adrià López-Baucells for all his hard work in teaching us the use of acoustic devices in bat research and conservation.

Literature Cited

Wildlife Acoustics, 2019. Retrieved from: https://www.wildlifeacoustics.com/

Open Acoustics Devices, 2019. Retrieved from: https://www.openacousticdevices.info/audiomoth

Jones, G. and Teeling, E. C. 2006. The evolution of echolocation in bats. TRENDS in Ecology and Evolution Vol.21 No.3 149-156.

Burivalova, Z., E. T. Game, and R. A. Butler. 2019. The sound of a tropical forest. Science 363:28–29.

Hill, A. P., P. Prince, J. L. Snaddon, C. P. Doncaster, and A. Rogers. 2019. AudioMoth: A low-cost acoustic device for monitoring biodiversity and the environment. HardwareX 6:e00073.

Petchey, O. L., and K. J. Gaston. 2006. Functional diversity: Back to basics and looking forward. Ecology Letters 9:741–758.

Drivers of Ectoparasite diversity and abundance in Paleotropical bats

By Diniz U.M., L.F Gomez, F.G. Gnali, I.A Raji

Abstract

The variables that underlie the diversity and abundance of ectoparasites of paleotropical bats are poorly known, especially in under sampled areas such as East Africa. Because ectoparasite specialization patterns and host preference are highly correlated to disease dynamics within bat populations, identifying the factors that shape bat-parasite networks is a conservation priority. We sampled bat-ectoparasite interactions from three localities in Kenya to assess the drivers of parasite diversity and abundance in east African bats, using body size, roosting habit and sex as explanatory variables. Twelve bat species were captured during the three nights, from which three interacted with at least one of five ectoparasite morphospecies. The two closest related species interacted with the same parasite species only. Moreover, body size had a clear, exponential effect on parasite diversity and abundance. The large cave-roosting bat *Rousettus aegyptiacus* interacted with most species and showed the highest amount of individual parasites, especially females. However, nor roosting habit, neither sex showed a significant relationship with ectoparasite diversity and abundance, indicating that our limited sampling effort might have negatively influenced our results. Here, we identified at least one significant variable underlying ectoparasite diversity and abundance and highlight the necessity of an increased sampling effort to unveil further driving factors for this interaction.

Keywords: Bat, Ectoparasites, Mist-netting, Cave, Roosting

Introduction

Ectoparasites are mostly known as vectors of pathogens and usually occur on a restricted number of hosts (Hopla *et al.,* 1994; Reeves *et al.*2004). They can be found in large aggregations or in small groups and are present on almost all species of mammals, including bats. There is evidence that most ectoparasites share coevolutionary ties with their hosts as they remain in the host for most of their lifetime or only briefly leave (Czenze & Broders, 2011). Many ectoparasites are present on their hosts all year round whereas others are only present during different reproductive stages of the host's such as gestation or lactation (Czenze & Broders, 2011). Bat roosting dynamics affect ectoparasite diversity and abundance in bat species while at the same time, these ectoparasites may also affect their host fitness (Dick & Patterson, 2006). They usually cause disorders in bats, such as irritability, skin necrosis and other infections (Hopla *et al.,* 1994).

The specificity of ectoparasites present in different bat species is strongly influenced by the ecology and behaviour of both the bat and the parasite (Brooks & McLennan, 1993). Therefore, variation in ectoparasite diversity is a response to a large set of environmental variables such as roosting preferences, temperature, humidity, bat colony size, inter and intraspecific interactions, etc. As well as individual variation in body size, weigh, sex and age. However, there are very few documented studies about bat ectoparasites in East Africa, thus the aim of our study is to provide insights into the drivers of ectoparasite diversity and abundance in Paleotropical bats. For this study, we tested four different hypotheses: 1) Closely related bat species interact with similar ectoparasite species. 2) Body size is related to ectoparasite diversity and abundance. 3) Abundance and diversity of ectoparasites is influenced by sex. 4) Different roosting habits influence ectoparasite diversity in bats.

Materials and methods

This study was conducted at Diani Beach in Mombasa. Bat and their ectoparasites were collected by setting out mistnets in Jacaranda resort, Diani Bay resort, and in the three sister's cave in Mzizima, Kwale county Kenya from the 16th to the 19th of January 2020.

Bat and Ectoparasite Survey were carried out by setting mistnets in Jacaranda Resort (S 4^{0}15\`43\`\`, E $39^{0}$35\`52\`\`) and Diani Bay Resort (S 4^{0}15\`42\`\`, E $39^{0}$35\`30\`\`) and also a visit to the Three Sisters cave in Mzizima, Kwale county Kenya (S 4^{0}36\`51\`\`, E $39^{0}$21\`16\`\`). Bats were trapped in three different roosting sites; one cave and two open space roost from 16th to 19th of January 2020. Mists net of various lengths were used for the bat capturing. These mist nets were operated on two consecutive trapping nights and cave was visited on the third night. Species, sex, forearms, weight of individual bat were determined (Meester & Setzer, 1971; Kingdon, 1997; Webala *et al.,* 2004). Bodyweight-forearm ratio (WFR) was calculated for each individual as a proxy for body size (Robbie & Umponstira,2014).

All the bats captured each night were thoroughly and systematically surveyed in the hand and ectoparasites were carefully checked using headlamps and collected using a pair of stainless steel pointed tweezers and preserved in 70% ethanol (Czenze, & Broders, 2011). The bats were entirely examined; the patagium was outstretched for proper check, the ears were examined internally at the base of the tragus and around the pinna, the fur was also examined by systematically blowing on the dorsal and ventral sides of the bat. Ectoparasites were identified using simple hand lenses magnifier based on morphology to family level. For each bat individual, parasite diversity and abundance were calculated.

A quadratic regression was performed to assess the effect of body size on ectoparasite diversity and abundance. Additionally, a Student`s t-test was used to test for differences in parasite diversity and abundance among sexes and roosting habit, i.e. cave-dwelling bats or foliage-dwelling bats, here referred to as ``open`` environment bats. All statistical analyses were performed in R v. 3.6.0 (R Core Development Team, 2020)

Results

Bat and parasite species

A total of 56 bats from 12 species were captured during sampling, from which 11 were captured within caves and 45 in open environments (Tab. 1). Fifty-four ectoparasites of five species were found on the body of captured bats. Parasites belong to the families Streblidae, Nycteribiidae (Diptera) and Ixodidae (Arachnida: Ixodida) (Fig. 1). Only eight bats (14.3%) from three species of bats carried at least one individual parasite, i.e. *Rousettus aegyptiacus*, *Neoromicia nana* and *Neoromicia randalli*. *Rousettus aegyptiacus* interacted with most species of parasites (n=5), while *Neoromicia nana* and *Neoromicia randalli* shared only one parasite species (Fig. 2).

Table 1. Bat species captured and their roosting environment in Kenya, East Africa.

Family	Bat species	Individuals captures	Type of roosting environment
Emballonuridae	Coleura afra	6	
Macronycteridae	Macronycteris vittatus	1	
Nycteridae	Nycteris thebaica	1	Cave
Pteropodidae	Rousettus aegyptiacus	3	
	Epomophorus wahlbergi	4	
	Epomophorus minimus	4	
Vespertilionidae	Neoromicia nana	11	
	Neoromicia randalli	7	

Pipistrellus mepellii	1	
Scotoecus hirundo	4	Open
Scotophilus andrewbori	4	
Scotophilus trujilloi	10	

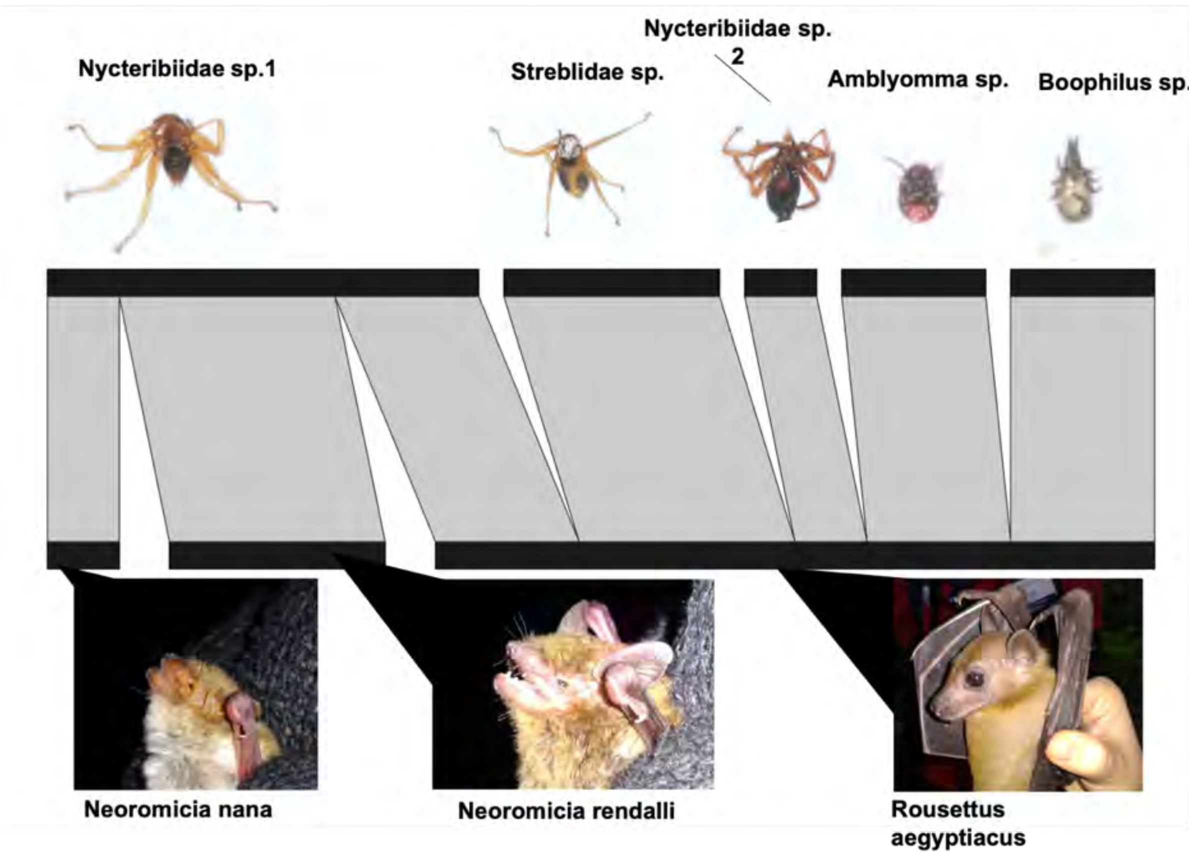


Figure 1. The interaction network of bats and ectoparasites in Kenya, East Africa. Link width represents interaction strength.

Drivers of parasite diversity and abundance

There was a significant, exponential effect of body size on both ectoparasite abundance (F=15.27, R^2=0.38, $p < 0.0001$) and diversity (F=12.15, R^2=0.32, $p < 0.001$) (Fig. 2). Moreover, ectoparasite abundance and diversity were not affected by roosting habit (abundance: t=1.72, df=10.07, p=0.12; diversity: t=1.80, df=10.15, p=0.10) nor sex (abundance: t = 0.79, df = 24.49, p = 0.44; diversity: t=0.24, df=50.83, p=0.81. (Fig. 3, 4).

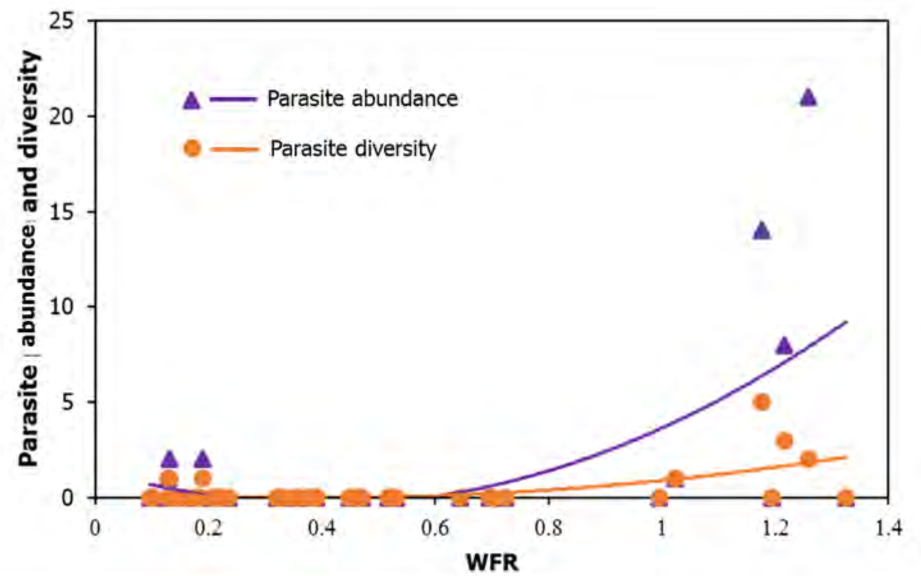


Figure 2. The effect of body size (WFR) on ectoparasite diversity and abundance on bats from Kenya, East Africa. Trendlines represent the fitting of the quadratic regression.

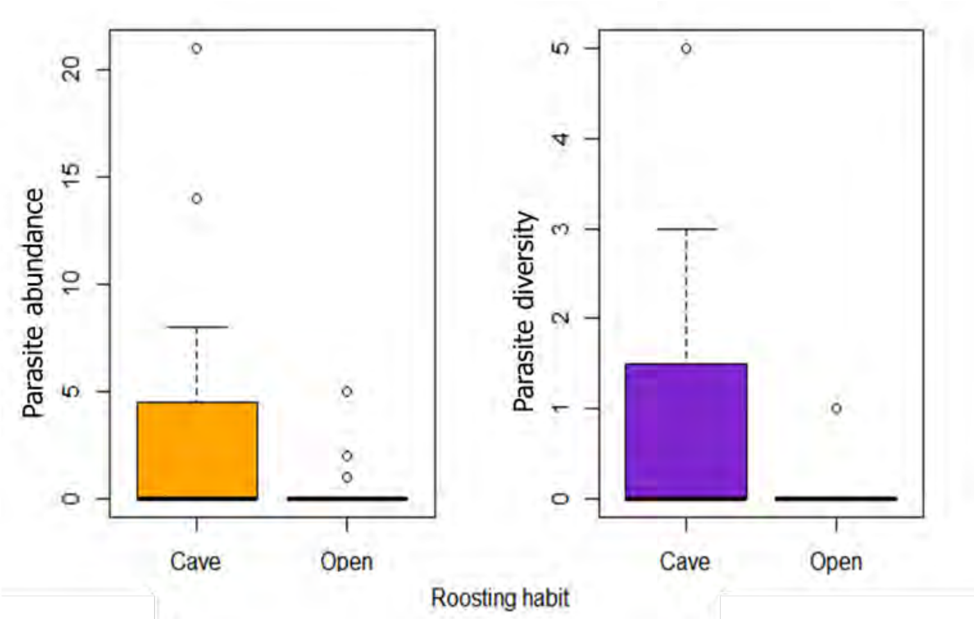


Figure 3. Differences in bat ectoparasite abundance and diversity in relation to roosting habit in Kenya, East Africa.

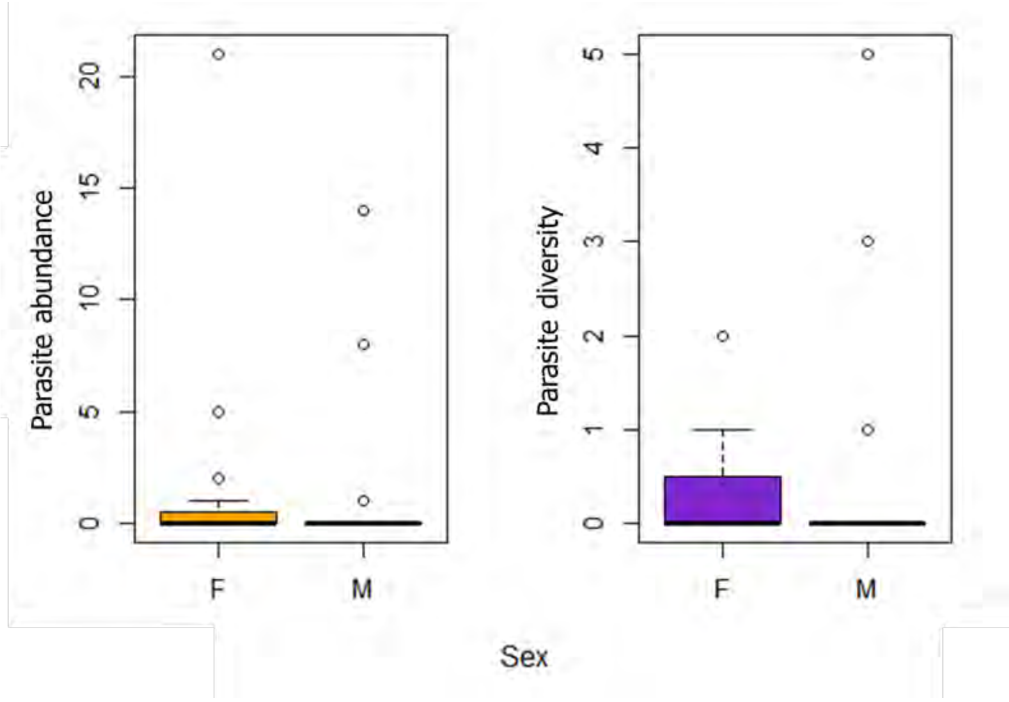


Figure 3. Differences in bat ectoparasite abundance and diversity in relation to sex in Kenya, East Africa.

Discussion

Our results partially support the proposed hypothesis for this study, as parasite diversity among bats was correlated to the phylogenetic proximity among bats and to body size, but not to roosting habit nor sex. Closely related bat species showed a tendency to share similar ectoparasite species, as seen between *Neoromicia nana* and *Neoromicia rendalli*, indicating that ectoparasites may show a preference to certain variables related to morphology or physiology that are correlated to bat phylogeny (Giorgi *et al.,* 2004). According to the literature, there are different environmental features and linkages related to the prevalence of ectoparasite species in bats that can extend from their immediate environment which is the host, to the surrounding ecosystem where the host lives (Patterson *et al.*, 2007). Roosting biology of bats should therefore influence the abundance and diversity of ectoparasites. However, in our study, certain ectoparasites do not seem to discriminate between roosting sites, affecting both cave-dwelling and foliage-dwelling bats, such as Nycteribiidae 1. This can indicate that bat gregariousness is likely not an important factor in its dispersal ability, as it has been proposed for many other bat-fly species (Patterson *et al.*, 2007). Sex differences were also not observed, indicating the formation of dense maternity colonies by females may also not lead to an increased dispersal potential for parasites.

However, a lack of detectable difference between treatments may be due to a limitation in sampling size, as only eight infected bats were captured from three sampling nights. An evidence to this is the cave-roosting *Rousettus aegyptiacus,* which showed to carry most parasites and to interact with most species. A better assessment is therefore required to describe the diversity of interaction between bats their parasites in the paleotropics.

References

Brooks, D. R. & Mclennan, D. A. 1993. *Parascript: parasites and the language of evolution*. Smithsonian Institution Press, Washington, DC. 429 pp.

Burgin CJ, Colella JP, Kahn PL, Upham NS (2018). How many species of mammals are there *J Mammal.* (2018) 99:1-14. doi: 10.1093/jmammal/gyx147

Czenze, Z. J., & Broders, H. G. (2011). Ectoparasite community structure of two bats (Myotis lucifugus and M. septentrionalis) from the Maritimes of Canada. *Journal of parasitology research*, *2011*.

Giorgi, M. S., Arlettaz, R., Guillaume, F., Nusslé, S., Ossola, C., Vogel, P., & Christe, P. (2004). Causal mechanisms underlying host specificity in bat ectoparasites. *Oecologia*, *138*(4), 648-654.

Hopla, C. E., Durden, L. A., & Keirans, J. E. (1994). Ectoparasites and classification. *Revue scientifique et technique-Office international des epizooties*, *13*(4), 985-1034.

Patterson, B. D., Dick, C. W., & Dittmar, K. (2008). Parasitism by bat flies (Diptera: Streblidae) on neotropical bats: effects of host body size, distribution, and abundance. *Parasitology Research*, *103*(5), 1091-1100

Reeves, W.K., L.A. Durden, M. Iwakami, K.J. Vince, and R.R. Paul. 2015. Rickettsial diseases and ectoparasites from military bases in Japan. J. Parasitol. 101: 150–155.

R Development core team (2020) R: A language and environment for statistical computing. 11 Vienna: The R Foundation for statistical computing

Webala, P. W., Oguge, N. O., & Bekele, A. (2004). Bat species diversity and distribution in three vegetation communities of Meru National Park, Kenya. *African Journal of Ecology*, *42*(3), 171-179

Weterings, R, Umponstira, C. (2014) Bodyweight-forearm Ratio, Cranial Morphology and Call Frequency Relate to Prey Selection in Insectivorous Bats. Electronic Journal of Biology 10(1): 21-27

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