



**XI International Symposium
on Mediterranean
Lacertid Lizards**

- 27 / 28 Sept. 2021 -

Abstracts

EDITED BY

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Logo

Flavia Grita



Preface

Starting its gestation during the 1st World Congress of Herpetology held in Canterbury (UK) 1989, the 1st Symposium on the Mediterranean Lacertid Lizards was born in Mytilini, Lesvos (Greece) in 1992. The idea of informally joining scientists, students and conservationists across the Mediterranean and beyond in a stimulating ambient has been so successfully that it has become a normal appointment every, more or less, three years. Faro (Portugal), 1995; Čres (Croatia), 1998; Maó, Menorca (Spain), 2001; Lipari (Italy), 2004; Mytilíni, Lesvos (Greece), 2008; Palma, Mallorca (Spain), 2010; Kope, (Slovenia) 2013; Limasol (Cyprus), 2016; Tel Aviv (Israel), 2018, were great opportunities to exchange scientific results, project ideas, conservation initiatives, recruit new enthusiastic students and, overall, enjoying what we are most passionate about studying Lacertid lizards in the Mediterranean and surrounding areas. This year we are back to Lipari although circumstances force it to be different from usual. The last 18 months have been complicated for all Lacertid researchers and conservationists as it has been for the all humanity, but we are still here to share the same spirit. This time, the online interactions should be sufficient to bring connect each other and share our results, ideas and projects in the hope that the next meeting will allow for closer interactions again. In the meantime, let's all share our findings on the Lacertid lizards together and are not ashamed to admit that we like them.

The Organising Committee



Mytilíni, 1992.



Programme

Monday 27 September 2021

09:00-09:10 OPENING

MORPHOLOGY SESSION

09:10 INVITED PLENARY LECTURE

Antigoni Kaliontzopoulou - *Universitat de Barcelona, Spain and CIBIO/InBIO, Porto, Portugal*

Lacertid lizards as models for understanding phenotypic evolution in Mediterranean ecosystems

10:10 Carolina Reyes-Puig, Urtzi Enriquez-Urzelai, Antigoni Kaliontzopoulou

Linking static allometries to macroevolutionary patterns in green lizards: a test for Rensch's rule

10:30 Renáta Kopena, Pilar López, José Martín

Morphology and sexual signals of male lizards *Lacerta schreiberi* may explain their space use and mating strategies

10:50 Enrico Lunghi, Marta Biaggini, Claudia Corti

Implementing the use of digital images in studies on lizards

11:10-11:20 COFFEE BREAK

11:20 Sabina E. Vlad, Danielle A. Klomp, Guillem Perez i de Lanuza, Zbyszek Boratyński, Miguel A. Carretero

Using scars to infer sexual selection in a polymorphic lizard

11:40 Hélder Cabo, Guillem Pérez i de Lanuza, Miguel A. Carretero

A functional approach to sexual selection, tested in wall lizards *Podarcis bocagei*

12:00 Irene Fernández-Rodríguez, Florentino Braña

Functional and allocation conflicts of autotomy and regeneration: an integrative approach with a lacertid lizard as a model

12:20-14:00 LUNCH BREAK



FUNCTIONAL ECOLOGY SESSION

- 14:00 Liran Sagi, Amos Bouskila
Demographic separation in populations of desert chameleons that live in spatial overlap
- 14:30 Anamarija Žagar, Veronica Gomes, Neftalí Sillero
Microhabitat use, activity and selected temperatures of sympatric *Iberolacerta horvathi* and *Podarcis muralis*
- 14:50 Urban Dajčman, Miguel A. Carretero, Rodrigo Megía-Palma, Ana Perera, Rok Kostanjšek, Anamarija Žagar
Shared blood parasite infections may drive competition dynamics in lacertids
- 15:20 Miguel A. Carretero, Julia Cao, Verónica Gomes, Neftalí Sillero, Guillem Pérez i de Lanuza, Rodrigo Megía-Palma
Infection of *Podarcis muralis* by haemogregarines suggests shift in host-parasite balance between colour morphs
- 15:40 Ferran de la Cruz, Guillem Pérez i de Lanuza, Enrique Font
Sexual selection and environmental conditions drive interpopulation differences in the design of a UV signal in wall lizards (*Podarcis muralis*)
- 16:00 Lekshmi B. Sreelatha, Zbyszek Boratyński, Miguel A. Carretero, Guillem Pérez i de Lanuza, Danielle A Klomp, Verónica Gomes, Pedro Andrade, Oleksandra Oskyrko
Do the colour morphs of European wall lizards differ in temporal trends of locomotion?
- 16:20-16:50 COFFEE BREAK**
- 16:50 Anamarija Žagar, Urban Dajčman, Rodrigo Megía-Palma
Biological interactions and traits of metabolism in two sympatric lacertids
- 17:10 Abderrahim S'khifa, Miguel A. Carretero, D. James Harris, Tahar Slimani
Ecophysiological conservativeness and size-mediated plasticity in the high mountain lizard *Atlantolacerta andreanskyi* confirm its vulnerability to climate change
- 17:30 Emiliya Vacheva, Borislav Naumov
A contribution to the knowledge on the diet and food preferences of *Darevskia praticola* (Reptilia: Lacertidae)



Tuesday 28 September 2021

EVOLUTION SESSION

09:00 INVITED PLENARY LECTURE

David Tarkhnishvili - *Ilia State University, Tbilisi, Georgia*

Speciation in rock lizards of the Caucasus: isolation and niche shift

10:00 André Vicente Liz, Dennis Rödder, Duarte Vasconcelos Gonçalves, Guillermo Velo-Antón, Philippe Geniez, Pierre-André Crochet, José Carlos Brito

Phylogeny and biogeography of the *Acanthodactylus scutellatus* species complex in North Africa

10:20 Catarina Rato, Neftalí Sillero, Francisco Ceacero, Enrique García-Muñoz, Miguel A. Carretero

A survival story: evolutionary history of the Iberian algyroides, an endemic lizard relict

10:40 Oleksandra Oskyrko, Lekshmi B. Sreelatha, Iolanda Silva-Rocha, Tibor Sos, Sabina E. Vlad, Dan Cogălniceanu, Tavakkul M. Iskenderov, Igor V. Doronin, Miguel A. Carretero

Molecular analysis of recently introduced populations of the Italian wall lizard (*Podarcis siculus*) in SE Europe and SW Asia confirm invasiveness at species level

11:00-11:30 COFFEE BREAK

CONSERVATION SESSION

11:30 Michele Chiacchio, Annegret Grimm-Seyfarth, Klaus Henle

Effects of ski-runs' habitat structure on the occupancy of *Zootoca vivipara*

11:50 Shahar Gofer, Amos Bouskila, Oded Berger-Tal

Thermal conditions determine lizards' response to oil contamination in a desert habitat

12:10 Oleksandra Oskyrko, Daniel Jablonski

The first comprehensive data on the distribution of lizards (Lacertidae) within the Southern Bug eco-corridor, Ukraine

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A functional approach to sexual selection, tested in wall lizards *Podarcis bocagei*

Hélder Cabo^{1,2,*}, Guillem Pérez i de Lanuza^{1,4}, Miguel A. Carretero^{1,2}

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Male lacertids bite conspecific females during copulation attempts but also bite other males during agonistic encounters. This type of behaviour results in temporary marks on both males and females which can serve as an indirect measure of the intensity of sexual selection. Scar pattern can be associated with population traits driving sexual selection (e.g. density, competition intensity), emerging from sexual selection (e.g. sexual dimorphism) or resulting from behavioural diversity (colour polymorphism). Here, inguinal copulation marks on females, and head and chest marks on males of *Podarcis bocagei* were quantified to indirectly infer the intensity of male choice on females and male-male competition across colour morphs and populations under different degrees of sexual dimorphism. In parallel, staged contests between *P. bocagei* males within the same population were performed in order to determine possible variation in aggression levels and the probability of success between morphs. Indeed, scar pattern varied between morphs and populations under different sexual selective pressures while aggression levels and the success in agonistic encounters as well as the number of interactions producing scars were not only associated to size and size disparity between the interacting males but also on their colour morphs. Methodological repercussions and significance for colour polymorphism are discussed.



Infection of *Podarcis muralis* by haemogregarines suggests shift in host-parasite balance between colour morphs

Miguel A. Carretero^{1,2,*}, Julia Cao¹, Verónica Gomes¹, Neftalí Sillero³, Guillem Pérez i de Lanuza^{1,4}, Rodrigo Megía-Palma^{1,5}

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Although host-parasite interactions result from an evolutionary arms race between host and parasite, the contemporary infection patterns within a given host species are shaped by the balance between parasitisation and other selective forces. While ontogeny and sex are already well known to affect parasitaemia levels in lacertid lizards, other host traits may be also involved. In particular, polymorphic species consisting of alternative discrete phenotypes (morphs) differing in several biological functions could represent different host-parasite balances. We tested this hypothesis by examining the infestation by haemogregarines of the common wall lizard, *Podarcis muralis*, a polymorphic lacertid encompassing up to three pure morphs (white, yellow, and orange) plus two mosaic morphs (orange-white and orange-yellow). Prevalence and intensity were recorded from two Pyrenean datasets: a) an extensive sampling of 161 lizards encompassing two northern slope populations with adults of both sexes and five colour morphs, and b) an intensive sampling of 60 adult males (20 of each pure morph) from a single population in the southern slope, which were analysed separately using Generalized Mixed-Models (GLMM). As expected, both infestation parameters depended on host-size (longer parasite exposure with age) and, in the extensive dataset, also on host-sex (males involved in reproduction more frequently and intensively parasitized). However, morph entered in all the parasitisation models for both datasets. In the extensive dataset, yellow



individuals regardless their sex and size tended to be less frequently infected than the other four morphs. In the intensive dataset, white individuals attained the highest prevalence and were the only morph increasing intensity with size. Considering that previous investigations on these polymorphic populations indicate that only the orange morph differs from the others in space use and hydric physiology while the yellow morph differs in behavioural personality, the current results suggest that variation in parasitisation across morphs is not due to different exposure to parasites or their vectors but to different host response and, hence, represents a genuine shift in host-parasite balance. The subjacent causes should be investigated with more populations and other polymorphic species.



Effects of ski-runs' habitat structure on the occupancy of *Zootoca vivipara*

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Despite the rich biodiversity, montane and alpine areas are intensively threatened by climate change and land-use modifications, such as the construction and maintenance of ski-resorts. In this study, we used multi-season occupancy analysis to investigate occupancy and colonization/extinction probability of *Zootoca vivipara* at two distinct spatial scales in Paneveggio-Pale di San Martino Nature Park and local ski-resorts in Trentino (IT). Specifically, we investigated the distribution of the species within the landscape and its habitat-use strategies within ski-runs. The landscape-level analysis showed how *Z. vivipara* occupancy is mainly driven by distance from a water source and vegetation height, while the extinction process is caused by long-term climatic trends, such as previous summer precipitation and winter mean temperatures. On the other hand, the habitat-level analysis showed that *Z. vivipara* occupancy on ski-runs increases closer to the ecotone, while removal of bushes leads to an increasing extinction risk. Overall, our results from the landscape-level analysis confirm the importance of humid area for the species, while the habitat-level ones indicate a strong dependance on the habitat surrounding the ski-runs. The lizards seem to prefer ski-runs cutting through forested areas over those surrounded by meadows. There, they focus their presence toward the edge of the ski-runs where they can take advantage of both the richer availability of natural refuges found outside the margins of the ski-runs and the more open area of the ski-runs for thermoregulation. These behaviors are in line with that of other reptiles' habitat-use strategies and provides new insights on the effects of ski-runs on alpine fauna.



Shared blood parasite infections may drive competition dynamics in lacertids

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We set out to analyze the haemogregarine blood parasites infecting two competing lizard species, *Iberolacerta horvathi* and *Podarcis muralis*, in syntopic and allotopic populations with the idea of observing potential differences in their parasite prevalence and infection intensity. Host species, in our case lizards, may differ in their ability to fight of parasitic infection and this ability might be further impacted by other ecological dimensions, such as competition, that influence their behavioral and physiological state. We confirmed parasitic infection with haemogregarine parasites belonging to the genus *Karyolysus* in both species. Using the 18S rRNA gene, we identified six new *Karyolysus* haplotypes clustering with other Central and Eastern European samples, and shared between both lizard hosts. We detected infections by haemogregarines at all sampled sites and over 50% individuals were parasitized. Overall, *I. horvathi* was more frequently and also more intensely parasitized than *P. muralis*. Males of both species tended to be more frequently infected and showed a higher infection intensity. In line with the hypothesis of a higher susceptibility to parasites under competition, we observed higher infection rates in *I. horvathi* when syntopic with *P. muralis*. This pioneering study sheds light on the complex ecological interaction between competing lizards. Further studies are needed to understand the role of parasites in systems of sympatric host species.



Sexual selection and environmental conditions drive interpopulation differences in the design of a UV signal in wall lizards (*Podarcis muralis*)

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Studying variation in the design of a signalling trait is important as it may give us clues to the underlying selective processes and the type of information revealed by the signal. Male European wall lizards (*Podarcis muralis*) have conspicuous ultraviolet (UV)-blue patches in their flanks that are displayed during social interactions. In this study, we use spectrophotometric data from ca. 2000 adult males from 56 Pyrenean populations to examine intra- and inter- population variability of this coloration. Overall, we found a relationship between UV-blue patch variables (hue, chroma, luminance, area, number of patches) and morphological traits related to male quality (SVL, head size, body weight). We also found that variation in UV-blue patches is associated with inter-population differences in sexual dimorphism and environment (altitude, cloudiness, temperature seasonality). These results agree with previous work showing that UV-blue patches may act as condition-dependent signals providing information on male resource holding potential, but also highlight that these signals vary geographically, as signallers adjust them in response to social and environmental conditions.



Functional and allocation conflicts of autotomy and regeneration: an integrative approach with a lacertid lizard as a model

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Life-histories are shaped by decisions about the phenology and distribution of the limited energy and materials that organisms acquire and metabolically process. Allocation conflicts may arise when more than one trait simultaneously require energy or materials from the same storage, leading to a competition between traits and to a potential allocation trade-off. Autotomy, which is the ability to self-induce the shed of a body part in response to threats, is commonly used by lizards as an antipredator mechanism. The regeneration of the detached parts evolved in many cases to allow the restoration of the lost capacities after autotomy, but it may trade-off with other highly demanding processes like reproduction or growth. The balance between the costs and benefits of these two adaptations is the key to their selection, and integrating these different approaches is essential for the interpretation of their evolution. Under such framework, we investigated the different costs of autotomy and regeneration using the wall lizard *Podarcis muralis* as a model, approaching to the multiple aspects that may be affected. Adult wall lizards showed decreased locomotor performance after tail loss, but these capacities were apparently restored after the completion of caudal regeneration. Adult individuals also altered their behavior, intensifying pattern with antipredator significance that likely diminish the probability of detection by predators. Regarding the energy costs of regeneration, tailless hatchlings showed lower body growth rates than non-regenerating ones, particularly when facing situations of resources scarcity. Moreover, caudal regeneration caused a reduction in the concurrent reproductive investment of adult females, which was greater under an income breeder than a capital breeding strategy. Besides, the amount of regenerated tail was negatively correlated with the investment in reproduction. Ultimately, the resolution of these costs and trade-offs may vary between species and ontogenetically within the same species (e.g., juveniles vs. adults).



Thermal conditions determine lizards' response to oil contamination in a desert habitat

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On December 2014, 'Avrona Nature Reserve, a unique, hyper-arid habitat in southern Israel, was polluted by crude oil from a severed pipeline. Surveys in the reserve following the spill event found that some species of local lizards avoid oil, while other closely related species were found more frequently on oil polluted areas. These results raised the question: why do these species react differently to oil polluted soil? We examined three species (two nocturnal geckos – *Stenodactylus doriae* and *Stenodactylus sthenodactylus*, and one diurnal lizard – *Acanthodactylus opheodurus*) in semi-natural arenas divided into quarters containing natural and oil polluted soils. We placed petri dishes with varying amounts of food (mealworm) on each quarter, and underground heating pads in clean quarters (heating operated according to the experimental balanced design). We measured how soil type, thermal conditions and food availability interact to shape lizards' habitat preferences by videotaping each arena 24 hours a day for six days and calculating how much time each lizard spent in each micro-habitat. We found that species responded differently to the treatments. *S. doriae* and its sister species *S. sthenodactylus* both spent more time on clean heated areas, and less time on oil and clean unheated areas. *A. opheodurus* showed no apparent preference for any micro-habitat. Food availability did not affect *Stenodactylus* species, while *A. opheodurus* stayed slightly more in shelter when we provided more food on oil. Our results illuminate the mechanisms underlying how animals cope with sudden disturbances and the possible impacts of oil spills on ectothermic species in desert areas.



Lacertid lizards as models for understanding phenotypic evolution in Mediterranean ecosystems

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Lizards have long been used as major model organisms for understanding how phenotypes evolve, and lacertids are no exception. The diverse community of lacertids that inhabit the Mediterranean Basin is outstanding in several aspects: occupying the dynamic structural habitats and climatic environments of the area, they have diversified in the numerous islands of the Mediterranean and surrounding continental areas, in close coexistence with human activities. Under the influence of these special conditions, they have evolved a variety of body sizes, shapes, and colours, with particularities that may characterize entire species or clades, but that frequently also appear within very short timescales. All these characteristics provide remarkable examples for addressing how morphological diversity evolved, making lacertids an emblematic component of the Mediterranean fauna. Here, I will review how linking comprehensive data on morphological variation to its functional consequences, and combining this with information on environmental factors and on the genetic background of populations and species, we gain a better understanding of how the unique characteristics of Mediterranean ecosystems have shaped lacertid phenotypic diversity across individuals, populations and species.



Morphology and sexual signals of male lizards *Lacerta schreiberi* may explain their space use and mating strategies

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The movement patterns and space use of animals can reveal the social relationships and mating behavior of a species. This study investigated the home-range size of male Iberian green lizards (*Lacerta schreiberi*), the intra- and intersexual overlapping between home ranges and their relationship with sexual signals. We aimed to analyze how the characteristics of the morphological and sexual signals of an individual can influence its space use and the consequence of home range size and overlapping. We found that males with more traits signaling dominance (i.e., more intensive UV-blue throat coloration and relatively greater heads) used larger home-ranges, while males with higher α -tocopherol (= vitamin E) content in chemical signals and with higher number of femoral pores use smaller home-ranges. Males using bigger home ranges overlap not only with more females but more males. However, the presence of bite hurts on the body was not explained by the size of the home-range, neither by the number of overlapping males, but a positive marginal significant relationship was found between the presence of the bite hurts and the dominance of the overlapping males and a positive tendency with the size (age) of the males. The size of home-ranges did not affect the condition of the individuals; however, males with higher vitamin E content in femoral secretion and with higher number of femoral pores, as well as males overlapping with males with larger relative head sizes, were in poorer condition. Males with higher vitamin E content in chemical signals and with higher number of femoral pores moved in smaller areas, avoiding males with more intensive UV-blue throat coloration but overlapping with better quality (greener-backed) females. Results of home-range overlapping of males and females may suggest the existence of two different reproductive tactics of males regarding their space use. Males with larger home-ranges overlapped with more females, likely increase reproductive success by mating with a higher quantity of females. In contrast, males with smaller home-range areas preferred



overlapping females with greener dorsal coloration, so these males likely increase reproductive success by mating with fewer females but of higher quality. Potentially similar reproductive success with different tactics may be one of the factors that play a role in maintaining multiple sexual signals in males of this species.



Implementing the use of digital images in studies on lizards

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There is increasing use of digital images in zoological and ecological studies, as well as for digitization of museum collections. High-quality images have multiple advantages: they can be handled over and over again without disturbing the individual, they can be “ready-to-use” everywhere at any time, and they can provide additional information that would otherwise be difficult to access. Thanks to their relatively small size, many species of amphibians and reptiles are particularly suitable to record high-quality images; however, specific tests on feasibility and potential uses are still scarce. Here the results of our test on the potential use of digital images to study *Podarcis* lizards are shown. We used as model individuals of *P. siculus* from Tuscany (Italy). We captured 14 lizards in May 2021 with a noose. Individuals were photographed in an on-site portable photo studio that allows to record standardized images. We took two pictures: one from the dorsal view and one from the ventral view. We used a post-hoc method to measure the snout-vent length (SVL) from ventral images. Using the same method, we estimated the SVL from the dorsal view and evaluated its reliability. We then evaluated the potential use of a specific software that extrapolates information on individual coloration.



The first comprehensive data on the distribution of lizards (Lacertidae) within the Southern Bug eco-corridor, Ukraine

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Ukraine, especially in the southern lowland parts, is one of the least studied countries in Europe in terms of the distribution of reptiles. Today many reptile species' populations are declining on a global level. Therefore, the availability of reliable distribution maps is an important component in reptile conservation research. Our study was conducted within the Southern Bug eco-corridor in the steppe zone, Ukraine. The Southern Bug River eco-corridor of the steppe zone is located in the south of Ukraine, Mykolaiv Oblast (Province). It is one of the least known territories in Ukraine and Europe. In this study, we report on the first comprehensive study on the distribution of lizards in this area. This study provides distribution data for 12 species of reptiles in this territory, of which 4 species of lizards, namely *Eremias arguta*, *Lacerta agilis*, *Lacerta viridis*, *Podarcis tauricus*. We compiled 425 records for lizards from published literature (58), from public databases (21), and from field surveys we made in 2016–2020 (346). All records were mapped on to a grid of 10×10 km, representing the 294 cells of the studied area. We present new distributional data for *P. tauricus*. The northernmost populations of *P. tauricus* were so far recorded in the vicinity of Mykolaiv. However, we found new populations further north during our investigations (60–80 km north of the previous reports). For all the other species, our records add new localities that fall within areas where these reptiles were previously reported. Historical records of *E. argumentta* reported from the northern part and along the Southern Bug River to the Black Sea coast. But we found this species only in the south of the region. We hypothesize that we did not find the species in the north because previously suitable habitats have been planted with forests in the 1990s. We observed *L. agilis* relatively rarely and had significant gaps in the distribution in parts of the oblast. Most of the individuals of this species have been observed near fields, gardens or pastures. The most abundant species was *L. viridis* with the highest number of sightings,



probably because it is an easily detectable species. Also, this species represented by numerous records per grid cell showed higher values in the percentage of observations in comparison to the percentage of occupied grid cells. The frequency distribution lizards of specific grid occupancy rates (number of grid cells by number of species and records) was higher in the north-central part of the oblast and around the city of Mykolaiv. Species richness and Shannon's H' index show that herpetofauna diversity was higher in the areas along the Southern Bug River. This can be because most of this area is part of the Buzk's Gard National Nature Park which experiences low anthropogenic impact. This implies that the Southern Bug eco-corridor is a territory of interest for future conservation activities in Ukraine. In general, our data provide the basis for future biogeographical and ecological studies and conservation priorities.



Molecular analysis of recently introduced populations of the Italian wall lizard (*Podarcis siculus*) in SE Europe and SW Asia confirm invasiveness at species level

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The introduction of alien species is a global threat to biodiversity. In recent decades, many reptile species have been introduced outside their native ranges, mostly through passive transportation of goods or garden plants, but also intentionally associated with pet trade. Reptiles can withstand long periods of starvation and desiccation, and many use small cavities as refuge, which increases their chances of being passively transported and allows both short- and long-distance range expansion. Among the European reptiles, repeated introductions of the Italian wall lizard *Podarcis siculus* have been reported. Molecular evidence taking advantage of the structured phylogeography of the species in its native range suggests single, separate origins of introduced populations. As such, from its native distribution in the Italian Peninsula, Sicily and the north Adriatic coast, it has been introduced in Corsica, Sardinia, Menorca, in islands and coastal areas of the eastern Adriatic Sea apparently since long date. Besides these regions, scattered introduced populations are also known from the Iberian Peninsula, Southern France, Switzerland, Turkey, Great Britain, Greece, United States and Canada. Very recently, several additional introductions have been reported in Romania (Bucharest and Alba Iulia),



Russia (Sochi) and Azerbaijan (Baku). We generated sequences of the mtDNA gene cytochrome-b of samples from two of the introduced populations (Alba Iulia and Baku) and analyzed them together with published sequences from across the species' native and introduced range to determine its origin and likely introduction pathway. Phylogenetic analysis (Bayesian inference) suggest that the Romanian lizards originate from Feniglia, Italy, while the population from Azerbaijan is admixed including two distinct haplotypes, one similar to the haplotypes found in Sicily (Syracuse) and the other present across the southern Italian Peninsula. Overall, our results further demonstrate that *P. siculus* as a whole is able to establish outside of its native range even under different climatic conditions and for the first time they also suggest that repeated human transport is promoting lineage admixture. Therefore, documenting the origin and pathways of introduction and monitoring the expansion of the alien populations are needed to implement more effective prevention and management strategies at a global scale.



A survival story: evolutionary history of the Iberian algyroides, an endemic lizard relict

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The Iberian algyroides (*Algyroides marchi*) is a lacertid lizard with one of the narrowest distribution ranges in continental Europe, restricted to a minute area in the Subbaetic mountains in SE Spain. Due to specific habitat requirements, this species is considered threatened by climate change and habitat degradation. Here, an improved and time-calibrated multilocus phylogenetic analysis, combining two mitochondrial, three nuclear markers as well as a battery of 12 microsatellite loci, was performed. Moreover, ancestral changes in effective population size were determined under Approximate Bayesian Computation (ABC) analysis. In parallel, past, present and future habitat suitability was inferred using Ecological Niche Models (ENMs). The diversification of *A. marchi* in the Iberian Peninsula began during the Upper-Pleistocene around 0.10 Mya. However, during the Last Interglacial the species had much larger suitable habitats along NE Iberia and/or the Cantabrian region. Indeed, ABC analysis indicates that not the Last Interglacial, but instead the Last Glacial Maximum led to a population bottleneck followed by a recovery/expansion. The footprint of this complex evolutionary history is reflected today in six monophyletic lineages, with little genetic differentiation and geographic coherency. This pattern most likely arises from the climatic oscillations during the Pleistocene, leading to a complete range shift and secondary contact,



with very divergent haplogroups in sympatry and exchanging genes. Finally, the ENMs predict a considerable future retraction and shift in the area suitable for the species, which should be taken into account for conservation policies.



Linking static allometries to macroevolutionary patterns in green lizards: a test for Rensch's Rule

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The increase in sexual dimorphism (SD) with body size in male-biased clades, or decrease in female-biased ones, is known as Rensch's Rule (RR). RR has been almost exclusively examined for size and not for other characters, despite being initially formulated for a diversity of traits. The trend of increased SD with increasing body size represents a case of evolutionary allometry, and it has been linked to sexual selection. Similarly, sexual differences in intraspecific static allometry have been associated with the tendency to exaggerate the relative size of body parts under sexual selection. As such, intraspecific allometric variation could underlie RR. Here we evaluate RR in different body parts of green lizards (*Lacerta* and *Timon*) and examine whether intraspecific allometries shape the evolutionary allometry of SD. We quantified five morphological traits: body size (SVL), head size (HS), trunk length (TRL), forelimb (FLL), and hindlimb length (HLL). To assess RR we carried out a phylogenetic generalized least-squares analysis between SD and species size. Additionally, we tested if sexual differences in intraspecific allometric slopes contributed to RR. We found a positive relationship between SD in SVL and HS relative to species size, consistent with RR. By contrast, SD of HLL exhibited a negative relationship with species size. The difference in slopes between the sexes had no contribution. This is the first detailed evaluation of RR in traits other than body size. By doing so we confirm RR for body and head size and explore the relevance of sexual selection in producing macroevolutionary trends.



Ecophysiological conservativeness and size-mediated plasticity in the high mountain lizard *Atlantolacerta andreanskyi* confirm its vulnerability to climate change

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Atlantolacerta andreanskyi is a small lacertid lizard endemic to Morocco, where it is found in the mountains of the High Atlas (2200-3500 m). Its populations display a disjointed distribution across 440 km, consisting of phylogenetic lineages separated since the Miocene, suggesting a species complex. To determine whether this deep evolutionary divergence has promoted shifts in fundamental niche, but also if there is ecophysiological plasticity, preferred temperatures (T_{pref}) and evaporative water loss (EWL) were examined in adult males and females from three populations of the central and western High Atlas. Results revealed no differences in T_{pref} across populations but lower thermal preferences in (pregnant) females. In contrast, EWL varied between populations but not between sexes. In both cases, sexual patterns remained similar between populations and differences disappeared after accounting for body size. Importantly, T_{pref} and EWL traded-off although with a common trend across populations. These results suggest that ecophysiology remains mostly conservative within this species complex and that hydric ecology, more closely associated with body size, is more flexible than thermal ecology. The decrease of lizard size with altitude, in agreement with life history trends with seasonality observed in other mountain lizards, cannot be interpreted in terms of ecophysiological adaptation since low altitude populations are the most exposed to dehydration. Overall, the ecophysiological conservativeness of this endemic species confirms its vulnerability to climate change. In this context, the low altitude populations are the most exposed and local management measures should be focused on preventing dehydration through the conservation of vegetation and water bodies.



Demographic separation in populations of Desert Chameleons that live in spatial overlap

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Almost all individuals of the desert subspecies of the common chameleon in Israel, *Chamaeleo chamaeleon musae*, do not survive after their first reproductive season, about a year from birth. Annual life spans are not very exceptional among desert lizards, but when combined with semelparity (death following reproduction) and the long incubation period (11 months) this may lead to sub-population separation in *C. c. musae*. The first sub-population hatches in odd years and reproduces in even years, while the second – hatches in even years. As a consequence of this temporal separation, the populations rarely mix. There are not many cases of sympatric speciation, and temporal separation is seen only in insect and Pink Salmon. In this case we have the opportunity to understand a rare mechanism that may explain sympatric speciation and apply to other species with a similar life-history. Our field records include 1081 individuals in 1551 observations during the last 12 years in Holot Mash'abim, Negev, Israel. We checked the survival rate of the chameleons using the program MARK under the 'robust design'. The survival decreases rapidly in the first months after hatching in all years. The survival up to the end of the first year, after egg laying, is 1.8%. Reaching a second reproduction season is even more rare – only 0.1% survive. This confirms that there is almost a full separation between the two sub-populations. Yearly survival depends on rain and evaporation, leading to variations in the number of offspring in the next generation. These variations seem to persist throughout the years, further suggesting of the separation. These results show that the unique biennial life cycle in *C. c. musae* can result in demographic separation into two distinct sub-populations and may lead to sympatric speciation.



Do the colour morphs of European wall lizards differ in temporal trends of locomotion?

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Coexistence of distinct colour morphs within the same species, colour polymorphism, is a common phenomenon in the animal kingdom. Previous studies have indicated that *Podarcis muralis*, the European wall lizard, exhibits five genetically determined colour morphs; yellow (Y), orange (O), white (W), yellow-orange (YO) and white-orange (WO). Current evidence suggests that maintenance of color polymorphism in natural populations is not only regulated by sexual selection acting on social interaction and mating, but also by natural selection on alternative behavioural personalities association to colour morphs. Here, we tested whether the color morphs of European wall lizards (both pure and mixed) exhibit temporal changes in their reaction to exposure to a novel environment. We conducted 15min long trials of a novel environment test (Open Field Test) in different populations of *P. muralis* from two separated Pyrenean regions, Val d'Aran and Cerdanya. The results suggest a general picture where alternative morphs differ in locomotion and locomotion in the novel environment differently during the trial duration. In overall, our results represent a relevant contribution to understand the maintenance of colour polymorphism in natural populations.



Speciation in rock lizards of the Caucasus: isolation and niche shift

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Most common speciation pattern includes several consequential or parallel stages. Incipient species / evolutionary lineages usually arise under conditions of geographic isolation, as a result of combination of gene drift and natural selection. This stage may continue until the lineages reach stage of full prezygotic isolation, or come into secondary contact. In the latter case, they either assimilate or form tension hybrid zone, where selection favors characters decreasing probability of hybridization (reinforcement). Species that reached sufficient level of prezygotic isolation may compete for resources, which causes niche shift and character displacement.

Rock lizards (*Darevskia*) are highly speciose monophyletic genus (33 nominal species) with the most of species concentrated in the western part of the Caucasus Ecoregion. Georgia, a country with the area of ca. 68,000 km², has 16 nominal rock lizard species – unusually high diversity for a non-tropical region. Up to nine species, including two parthenogens, can be found within a 35 km long transect in central Georgia. These species show different degree of spatial shift, and provide a good example for testing hypotheses about association of the time of divergence and isolation mechanism.

There are five different types of spatial shift between different species of *Darevskia*: (1) allopatry; (2) parapatric distribution with a contact zone; (3) shift along the altitudinal gradient; (4) shift of microhabitats / character displacement; (5) full or partial sympatry, no mutual avoidance. The question is whether the type of the shift is correlated with the time of the divergence. The analysis of the distribution of the species suggests that indeed it is. In particular, the most closely related, sister species (such as *D. rudis*, *D. obscura*, *D. valentini*, *D. portschinskii* and *D. bythinica*; *D. saxicola*, *D. brauneri*, *D. szczyrbaki*, *D. lindholmii*) are either allopatrically or parapatrically distributed. Less closely related forms, such as *D. mixta* and *D. caucasica*, show altitudinal shifts; even less related *D. mixta* and *D. derjugini*, or *D. caucasica* and *D. derjugini* coexist in the same location but shift microhabitats and show character displacement. Finally, more distant species may coexist in the *same habitat*; however there are clear signs of niche shift even between very distant species, such as *D. parvula* and *D. clarkorum*. In the present talk, I am trying to explain this phenomenon.



A contribution to the knowledge on the diet and food preferences of *Darevskia praticola* (Reptilia: Lacertidae)

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The Meadow lizard (*Darevskia praticola* s.l.) is the only representative of the genus *Darevskia* in Europe, with very limited distribution, including NE Serbia, S Romania, Bulgaria, NE Greece, European Turkey, SW Russia, and NW Georgia, and therefore, one of the less-studied European lizard species. The species occurrence in Bulgaria is very sporadic and it can reach up to 1000 – 1100 m a.s.l. The Meadow lizard is a species with a very limited spatial niche, which showed great attachment to deciduous forests (mostly oak forests). No detailed data of the diet of the Meadow lizard was previously available.

For the purpose of the study we investigate a total of 180 faecal samples from *D. praticola* s.l. Among them, 136 from adults (70 male and 66 female) and 44 immature Meadow lizards. A comparison among sex and age groups was made and also one between the consumed prey and the available resources. Food selectivity was analysed by comparing the faecal samples with trap samples on the basis of abundance of individuals from particular operational taxonomic unit (OTU) and the electivity was described by the indices of Ivlev and Vanderploeg & Scavia. Total number of OTUs registered in the faecal samples was 23. The average number of invertebrates found in the faecal pellets was 3.46 and the maximal number – 15. The prey composition in the diet of the Meadow lizard contains mainly arthropods (insects and spiders) and the most abundant prey were Araneae, Auchenorrhyncha and Coleoptera. Total number of OTUs registered in the pitfall traps was 25. Most abundant OTUs were Formicidae, Aranea and Coleoptera. According to the electivity indices none of the OTUs were highly preferred by *D. praticola*. The highest values for both indices were observed for Hymenoptera (excl. Formicidae) in immatures and for Blattodea for males but abundance in faecal samples for both OTUs were very low (respectively 6,38% and 5,2%). On the other hand, with lowest values of the indices (close to -1) were Formicidae for all sex/age groups.



Differences in food preferences can be found between adults and subadults in *D. praticola*, while differences in trophic preferences among males and females were insignificant. The lack of clear differentiation between males and females could be a result of their similar size and locomotor ability. In conclusion, our results reveal that *Darevskia praticola* s.l. is a generalist and it shows no food specialization due to its very narrow spatial niche.

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Phylogeny and biogeography of the *Acanthodactylus scutellatus* species complex in North Africa

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Deserts and arid regions are perceived as homogeneous spaces poor in biodiversity. Yet, this contrasts with considerable endemism and the high degree of genetic structure observed in some species inhabiting the Sahara Desert, which have been frequently attributed to progressive aridification and climatic oscillations during the Plio-Pleistocene. Lizards of the *Acanthodactylus scutellatus* complex are among the most conspicuous representatives of the Saharan xeric fauna. The complex is composed of seven currently recognised species: *A. aegyptius*, *A. aureus*, *A. dumerilii*, *A. longipes*, *A. scutellatus*, *A. senegalensis*, and *A. taghitensis*. Despite being a promising model to assess historical biodiversity dynamics in arid regions, no comprehensive study on the evolutionary history of the complex has been performed to date. Our study addresses the phylogenetic relationships, potential cryptic diversity, and inter-specific contact zones within the *A. scutellatus* complex. Two mitochondrial markers and one nuclear gene were used to infer phylogenetic relationships and identify cryptic lineages, while species' ecological models based on climatic and remote-sensing variables were used to estimate potential contact zones. Phylogenetic relationships among species were generally recovered with good support. However, the lack of distinction between *A. dumerilii* and *A. senegalensis* calls for a taxonomic reassessment. The presence of



several highly-divergent lineages, particularly around mountain areas, reveals a high degree of cryptic diversity within the complex. Ecological models suggest a series of contact zones where potential inter-specific hybridization remains unstudied. This work contradicts the “empty-desert” conception and underlines the existence of still unexplored diversity across the Sahara.



Using scars to infer sexual selection in a polymorphic lizard

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In lacertid lizards, interactions during the breeding season and agonistic encounters within the activity season result in temporal body marks, which usually disappear within the following shedding. The polymorphic European wall lizard (*Podarcis muralis*) displays alternative ventral colours, encompassing up to three pure morphs (white, yellow, and orange) plus intermediate morphs. Within the same population, morphs have different frequencies and vary in microhabitat use, home range size and success in staged agonistic encounters, fact which was often interpreted in the light of sexual selection.

Based on digital images taking during the breeding season of 2018, we indirectly inferred (i) the intensity of male choice on females and (ii) male-male competition across multiple populations from Central Pyrenees under different environmental conditions and with variable morph frequency. The analysis of the frequency of body marks (inguinal copulation marks on females, and chest and head scars on males) considering population, sex, morph and body size based on Generalized Linear Mixed-Models (GLMM) revealed a complex interplay between natural and sexual selection, with scar intensity varying with both population and morph. If correctly recorded, scar patterns may represent a promising tool for recording and analysing large amounts of relevant data for life history, ecology and evolution.



Biological interactions and traits of metabolism in two sympatric lacertids

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We analyzed the relationship between biological interactions, namely competition and parasite-host interaction, and traits of metabolism in two competing lacertid lizards. We obtained samples from allotopic and syntopic populations of *Podarcis muralis* and *Iberolacerta horvathi* from Southern Slovenia and in a single season. The phenotypic parameters of lizards analyzed were (i) potential metabolic activity (PMA) as a proxy of the metabolic performance capacity, (ii) total haemoglobin concentration (Hb) as a proxy of limiting factor for metabolic capacity, and (iii) the antioxidative capacity, using the catalase activity (CAT) as a measure of enzymatic potential for buffering oxidative stress. CAT is related to both the metabolic rate and the availability of hemo group. Results showed that there was no evident effect of competition (syntopy) on the phenotypic expression of metabolic (PMA) or antioxidative capacity (CAT). *P. muralis* lizards had higher Hb measured under syntopy. We did not find any significant relationship between haemoparasite intensity and the metabolic traits investigated (PMA, CAT or Hb). This study provides foundational information for future exploration of the effects of competition on metabolic traits of lizards.



Microhabitat use, activity and selected temperatures of sympatric

Iberolacerta horvathi and *Podarcis muralis*

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Lizards live in a thermally heterogeneous environment and use thermoregulation through behavior and physiology to maintain body temperatures within a narrow thermal range during their activity. Lizards' microhabitat selection is driven by many factors, being thermoregulatory behavior one of the most important ones. Reversely, the thermal environment will amongst other factors have an effect on effective thermoregulation. In syntopic populations of potentially competing species, habitat selection will also be influenced by avoiding interactions; subtle differences in microhabitat use may be detected. We studied microhabitat selection, activity and selected temperatures in *Iberolacerta horvathi* and *Podarcis muralis* under allotopic and syntopic conditions. We used novel geo-location techniques with a low error, registered environmental temperatures with temperature data-loggers and performed spatial analyses using geostatistics (interpolations). Results showed that more generalist species (*P. muralis*) exhibits a more generalized use of microhabitats and thermal space and is active for a longer period of the day than the more specialist species, *I. horvathi*. Allotopic *I. horvathi* site was characterized with low environmental temperatures (Te) that allowed restricted activity time. This corroborates its high-altitude eco-physiology as an adaptation to thermally restricted environments. Syntopic site that supports both species was characterized by the highest range microhabitat types and Te, which suggests that both, habitat and spatial thermal heterogeneity may be an important factor promoting species coexistence.



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