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11. Hymenopterologen-Tagung in Stuttgart (03.-05.10.2014)

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KURZFASSUNGEN DER VORTRÄGE

Funktions- und Populationsspezifische Duftbouquets der Furchenbienen *Halictus rubicundus* und *Lasioglossum malachurum* und die Evolution von Fertilitätssignalen

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Eine der zentralen Fragen der Evolutionsbiologie beschäftigt sich mit der Evolution von Eusozialität und Koloniebildung bei Insekten. Eusoziale Insekten wie Termiten, Honigbienen, Ameisen oder Wespen weisen eine hochentwickelte, komplexe Form der Sozialität auf. Die eusoziale Lebensweise ist bei den meisten Arten obligat, was die Erforschung von Merkmalen, die mit der Evolution sozialer Lebensweise einhergehen, bei diesen Taxa erschwert. Die Furchenbienen (Hymenoptera: Halictidae) gelten dagegen als geeignete Modellorganismen zur Erforschung sozialer Lebensweise, da sie eine hohe Variabilität an Sozialverhalten zeigen, wobei innerhalb einer einzigen Art sogar solitäre und soziale Nester möglich sind.

Eine wichtige Voraussetzung für die Evolution sozialer Lebensweise bei Insekten ist die chemische Kommunikation. Sogenannte Fertilitätssignale dienen als Erkennungssignale der Königin und wurden bereits bei vielen eusozialen Insekten nachgewiesen, nicht jedoch bei primitiv eusozialen Furchenbienen. Das Ziel unserer Forschungsarbeit war es, kasten- bzw. populationsspezifische Unterschiede im Duftbouquet bei der sozial polymorphen Furchenbiene *H. rubicundus*, die sowohl in sozialen als auch in solitären Populationen vorkommt, zu charakterisieren und so neue Einblicke in die Evolution der Fertilitätssignale und der sozialen Lebensweise zu geben. Zudem wollten wir testen, ob die Distanzen im Duftbouquet zwischen Königinnen und Arbeiterinnen mit dem erreichten sozialen Niveau zweier Furchenbienenarten, *H. rubicundus* und der primitiv eusozialen Art *Lasioglossum malachurum*, korrelieren. Je höher das soziale Niveau einer Art ist, umso deutlicher sollten auch die Unterschiede in den Erkennungssignalen zwischen Arbeiterinnen und Königinnen sein. Daher vermuteten wir, dass auch die Distanzen in den Duftbouquets der Kasten bei *L. malachurum*, die ein höheres soziales Niveau als *H. rubicundus* aufweist, größer sind.

Um die kasten- und populationsspezifischen Unterschiede im Duftbouquet von *H. rubicundus* zu untersuchen und die Substanzen zu identifizieren, die zwischen Weibchen mit unterschiedlich entwickelten Eierstöcken und Weibchen sozialer oder solitärer Nester variieren, sammelten wir im Frühjahr und Sommer 2013 Extrakte der Cuticulaoberfläche und der Dufourdrüsen von nestgründenden und brutaktiven *H. rubicundus* Weibchen einer solitären Population in Nordirland (Belfast) sowie von nestgründenden und brutaktiven Königinnen und Arbeiterinnen zweier sozialer Populationen in Deutschland (Bonn und Hayingen).

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Mithilfe chemischer Analysen (Gaschromatographie und Massenspektrometrie sowie Gaschromatographie gekoppelt mit Elektroantennographie (GC-EAD)) fanden wir neben populationsspezifischen Unterschieden auch kastenspezifische Duftbouquets der Weibchen. Während nicht brutaktive Weibchen der sozialen und solitären Populationen teilweise Ähnlichkeiten aufwiesen, zeigten brutaktive Königinnen ein Duftbouquet, das sich von allen anderen unterschied. Dies könnte auf ein spezifisches Fertilitätssignal der Königinnen sozialer *H. rubicundus* Populationen hinweisen. Verschiedene Weibchengruppen, Kasten und Populationen unterschieden sich hauptsächlich in den relativen Anteilen an makrozyklischen Lactonen, Alkanen und Alkenen, welche mit der Ovarienentwicklung korrelierten. Die Bouquets dieser Substanzen haben daher vermutlich eine Schlüsselfunktion als Fertilitätssignal.

Darüber hinaus sammelten wir im Frühjahr und Sommer 2013 Extrakte der Cuticulaoberflächen von nestgründenden und brutaktiven *L. malachurum* Königinnen sowie Arbeiterinnen. Das in chemischen Analysen identifizierte Duftbouquet der *L. malachurum* Weibchen diente dazu, Distanzen im Duftbouquet zwischen Königinnen und Arbeiterinnen von *L. malachurum* und *H. rubicundus* zu vergleichen. Dabei konnten wir zeigen, dass die Distanzen artspezifische Unterschiede aufweisen. So waren die Distanzen im Duftbouquet von *L. malachurum* signifikant größer als die von *H. rubicundus*. Dieses Ergebnis ist mit individuenreicheren Kolonien und einem deutlich ausgeprägtem Königinnen- und Arbeiterinnenerkennungssignal bei *L. malachurum* erklärbar und spiegelt letztlich den höheren Status der Sozialität bei dieser Art wider.

Die Ergebnisse unserer Forschungsarbeit deuten darauf hin, dass bei den Furchenbienen ein spezifisches Duftsignal existiert, dass die soziale Lebensweise einer Art widerspiegelt. Ob dieses Signal letztlich durch Umweltfaktoren und/oder genetisch getriggert wird, muss noch weiter untersucht werden. Letztendlich stellen unsere Ergebnisse neue Erkenntnisse zu Fragen des sozialen Polymorphismus und der Kastenentwicklung bei Furchenbienen dar und erweitern so das Wissen um die Evolution sozialer Lebensweisen bei Insekten.

Bestäuberanlockung bei der Täuschorchidee *Cephalanthera rubra*

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Die Täuschorchidee *Cephalanthera rubra* wird von Männchen der auf Glockenblumen spezialisierten Scherenbienenart *Chelostoma rapunculi* bestäubt. Die Blüten produzieren keinen Nektar und imitieren die Farbe von Glockenblumen. Da hauptsächlich Männchen zur Bestäubung angelockt werden, sind Sexualtäuschung oder Rendezvousplatz-Mimikry zwei mögliche Mechanismen der Bestäuberanlockung. Unser Ziel war es, den Bestäu-

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bungsmechanismus bei *C. rubra* aufzuklären. Dazu haben wir Farbmessungen von Blüten durchgeführt, chemische und elektrophysiologische Analysen und Verhaltensexperimente.

Die Verhaltensexperimente, die im Flugkäfig durchgeführt wurden, zeigen, dass 1) Pentan-Extrakte von virginellen *C. rapunculi* Weibchen bei den Männchen Kopulationsversuche auslösten, nicht jedoch Blütenextrakte von *C. rubra*, 2) olfaktorische und visuelle Blütensignale von *Campanula trachelium* und *C. rubra* gleich attraktiv für blütennaive Männchen und Weibchen von *C. rapunculi* sind und 3) sowohl Männchen als auch Weibchen die Blüten besuchen. Farbmessungen ergaben eine große Ähnlichkeit des Farbspekrums von Glockenblumen und Orchideenblüten, während chemische Analysen zeigten, dass die Sexualpheromonkomponenten von *C. rapunculi* nicht von den Orchideenblüten produziert werden.

Ein Vergleich der Headspaceverbindungen von Glockenblumen und Orchideen ergab, dass die Orchideen neben anderen Verbindungen (*E*)-Conophtorin produzieren, ein Spiroacetal, welches von Glockenblumen produziert wird und in Biotests für die bestäubenden Scherenbienen eine Funktion zur Blütenerkennung hat. Diese Verbindung ist selten bei Pflanzen, kommt jedoch häufig bei Glockenblumen vor.

Unsere Ergebnisse zeigen, dass *C. ruba* die Bestäuber nicht durch Sexualtäuschung sondern Rendezvousplatz Mimikry anlockt. Weitere Untersuchungen werden im Moment durchgeführt, die zeigen sollen, welche Bedeutung Scherenbienen Weibchen bei der Bestäubung von *C. rubra* haben.

Gefördert durch die DFG

Morphometric analysis and taxonomic revision of *Anisopteromalus* Ruschka (Hymenoptera: Chalcidoidea: Pteromalidae) – an integrative approach

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We use an integrative taxonomic approach to revise the genus *Anisopteromalus*. In particular, we apply multivariate ratio analysis (MRA), a rather new statistical method based on principal component analysis (PCA) and linear discriminant analysis (LDA), to numerous body measurements and combine the data with those from our molecular analysis of Cytb and ITS2 genetic markers (on a subset of species) and all available published data on morphology, karyology, behavior, host associations, and geographic distribution. We demonstrate that the analysis of quantitative characters using MRA plays a major role for the integration of name-bearing types and thus for the association of taxa with names. Six species are recognized, of which two are new. For *Anisopteromalus calandrae* (Howard),

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a well-known, cosmopolitan parasitoid of stored-product pests, we have selected a neotype to foster continuity and stability in the application of this important name. The species was sometimes confused with its sibling species, *A. quinarius* Gokhman & Baur sp. n., another cosmopolitan species that is frequently encountered in similar environments. Finally, we discuss the influence of morphological artefacts on the multivariate analysis of body measurements.

Farbpräferenzen Stachelloser Bienen unter Berücksichtigung einzelner Farbattribute

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Trotz ihrer essentiellen Rolle als Bestäuber in den Neotropen gehören Stachellose Bienen zu den weniger gründlich untersuchten Bienen. Insbesondere das Farbensehen von Stachellosen Bienen ist weitgehend unerforscht. Für andere corbiculate Bienen, vornehmlich *Bombus terrestris* und *Apis mellifera*, konnte bereits mehrfach nachgewiesen werden, dass Arbeiterinnen verschiedene Attribute von Blütenfarben, wie vorherrschende Wellenlänge, Farbreinheit und Farbintensität verarbeiten können. Allerdings fehlen auch bei diesen Arten bisher aussagekräftige Studien, die die Bewertung einzelner Farbattribute und deren Einfluss auf die Ausprägung von Farbpräferenzen herausarbeiten.

In dieser Studie wurden zum einen Kenntnisse über das Farbsehen von Stachellosen Bienen gesammelt und zum anderen Einflüsse einzelner Farbattribute auf spontan gezeigte Farbpräferenzen untersucht. Hierzu wurden Farbpräferenztests an zwei Stachellosen Bienenarten (*Melipona mondury* und *M. quadrifasciata*) unter Anwendung einer neuartigen Methode zur Herstellung von Blütenattrappen durchgeführt. Bei dieser Methodik werden chromatische und achromatische Pigmentpulver in einer Art und Weise vermischt, die die Herstellung von vielen verschiedenen Testfarben, deren Farbattribute unabhängig voneinander variiert werden können, erlaubt. So ist es gelungen, Testfarben zu entwickeln, die beispielsweise eine konstante vorherrschende Wellenlänge und einen bestimmten Farbreinheitsgrad, aber variierende Farbintensitätsgrade aufweisen. Diese flexible Art der Herstellung von Testfarben bietet eine exzellente Grundlage um den Einfluss einzelner Farbattribute auf die Farbpräferenzen von Stachellosen Bienen zu untersuchen. Erfahrene Arbeiterinnen der beiden untersuchten Bienenarten zeigen ausgeprägte spontane Farbpräferenzen. Weiterhin scheint die Beurteilung der Farbattribute wesentlich komplexer als angenommen zu sein. So werden die gezeigten Farbpräferenzen vermutlich nicht durch ein einzelnes Farbattribut, sondern möglicherweise durch eine bestimmte Kombination von Farbreinheits- und Farbintensitätsgraden determiniert. Auch die Präferenz für Testfarben verschiedener vorherrschender Wellenlängen unterscheidet sich stark zwischen den untersuchten Arten. So zeigen Arbeiterinnen von *M. mondury* eine starke Präferenz für Testfarben im blauen Wellenlängenbereich, während *M. quadrifasciata* Samm-

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lerinnen gelbe Testfarben präferieren. Mögliche Ursachen, wie die Einbindung von Vorerfahrungen in die unterschiedliche Bewertung der präsentierten Testfarben, sollen diskutiert werden.

The cryptic *Bombus lucorum* species complex in Austria

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The taxonomy of the cryptic bumblebee species belonging to the *Bombus lucorum*-complex has been in disarray for several decades. However, the status of the three species in the group – *Bombus lucorum* and the closely related *Bombus cryptarum* and *Bombus magnus* – has recently become widely accepted. This is primarily due to investigations of nucleotide sequences and marking pheromones. In contrast, serious doubts remain concerning the validity of species identification based on morphology. Furthermore, there are indications that the species are morphologically indistinguishable, especially regarding queens and workers. Since species recognition has been traditionally difficult, our current knowledge of their autecology is muddled in a mire of unreliable literature data from hundreds of authors over the centuries. Almost no studies on the ecology of the species exist that are backed up by reliable species identification using biochemical methods. To rectify the problem in Austria, we collected 387 specimens of the species complex from all across the country, particularly the Austrian Alps. Using the reliable identification method based on a partial sequence of the mitochondrial COI gene, we conducted extensive distributional analyses on geographical patterns, altitudinal differences and habitat usage. Further, the distribution of the species was examined with respect to the climatic conditions of the collection localities. For this purpose we assigned mean annual air temperature and mean annual precipitation values derived from Austrian climate maps for 1971-2000 to each site where at least one specimen was collected. In addition, the assigned values were examined for differences between the investigated species.

Our results show that *Bombus lucorum* and *B. cryptarum* co-occur in several areas across the country. No evidence was found to verify the presence of *B. magnus* in Austria. Of the two species in Austria, *B. lucorum* was more common and widespread than *B. cryptarum*, which occurs mainly in the high mountains and is the predominant species above altitudes of 2100 m a.s.l. This pattern can be traced along the Austrian Alps. *B. cryptarum* occurs mainly in western Austria along the main ridge of the Alps, whereas it is very rare or absent in the lower mountains and foothills of the Alps of the eastern regions. Surprisingly, *B. cryptarum* is also present in wetlands in northern Austria. *B. cryptarum* is almost absent from woodlands and is relatively more abundant in scree areas. Furthermore, examination of the mean annual air temperature reveals distributional differences between *B. lucorum* and *B. cryptarum*. The prevailing tendency is that the habitat localities of *B. cryptarum* are significantly colder than those of *B. lucorum*. In contrast, the mean annual precipitation sum has seemingly no effect on the abundance of the species.

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Molecular phylogeny of cuckoo wasps: what can we learn from it?

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The family Chrysididae (Hymenoptera: Chrysidoidea) comprises about 3000 species of small brightly colored solitary wasps. Because they all exhibit parasitoid or cleptoparasite behavior, they receive the common name of “cuckoo wasps”. The family has been traditionally subdivided into four subfamilies: Chrysidinae, Amiseginae, Loboscellinae and Cleptinae, the first one of which is by far the most diverse and is also subdivided into 5 tribes (Kimsey & Bohart, 1990; Antropov, 1995). However, cuckoo wasps have not been well studied and we still know very little about their evolutionary history. Nevertheless, cuckoo wasps provide interesting taxa to test hypotheses about the evolution of chemical mimicry: it has been previously found that some cuckoo wasps exhibit cuticular hydrocarbon profiles that are more similar to their hosts than to those of closely related cuckoo wasp species (e.g., Strohm et al., 2008; Wurdack et al., submitted).

Knowledge of the phylogenetic relationship of these species and these subfamilies can help us to get insights into understanding whether and how chemical mimicry has taken place in the Chrysididae and whether or not there had been phylogenetic constraints in the evolution of cuticular hydrocarbon (CHC) profiles. Under the null hypothesis that no selection pressure acts on the evolution of CHC profiles, we would expect a molecular phylogeny to correlate with a phylogeny based on CHC profiles. Although all species are parasitoids or cleptoparasites of mainly solitary bees and wasps, different strategies are employed, and we have sufficient data to test different hypotheses. However, the first requirement for being able to test these hypotheses is to have a robust and accurate molecular phylogeny. Until now, this phylogeny was lacking. There have been previous attempts to build phylogenies based on morphological characters (Kimsey & Bohart, 1990) and nucleotide sequence data of a handful of genes (Niehuis & Wägele, 2004; Soon & Saarma, 2011), but either the cited phylogenies were restricted to a very specific species group (“Chrysis ignita group”, Soon & Saarma, 2011), or it comprehended a very limited sample size (Niehuis & Wägele, 2004).

We have built a molecular phylogeny based on 10 nuclear genes, which we selected among orthologous genes proposed by Hartig et al. (2012). To build this phylogeny, we used nucleotide sequences of 170 species of a total of 33 genera, the latter representing all subfamilies except Loboscellinae. All analyzed samples had been preserved in 100% ethanol. DNA was extracted, PCR amplified and Sanger sequenced following standard procedures at the ZMFK. Forward and reverse sequences were assembled and aligned using Geneious version 7.0.6. Closely related species were aligned and multiple alignments were built sequentially using consensus alignment in Geneious. Alignments were corrected by eye at each new alignment step. These alignments were subjected to Maximum Likelihood analysis in RAxML (Stamatakis, 2006) using a GTRGAMMAI model, both for each gene separately and for the concatenated exons (~ 4.500 nucleotide positions).

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The intron regions were only used to resolve internal nodes that could not be resolved otherwise.

Our phylogeny is, so far, the most extensive phylogeny conducted for the family Chrysididae. It provides many interesting findings: taxonomically it calls attention to certain taxa that were previously considered monophyletic but are, according to our results, very distantly related (e.g., several *Chrysura* species and *Hedychridium* species), whereas it also shows that the relationships between the genera within the tribe Chrysidini differ strongly with what the phylogeny based on morphology suggested (Kimsey & Bohart, 1990). However, for us the most interesting findings are those related to the biology of the species. Our phylogeny shows that all species specialized on parasitizing solitary bees group together and are of recent origin, indicating that host shifts might have taken place less often than it was previously thought. We hope that our phylogeny provides a general framework for testing many other interesting questions and hypotheses about the evolution of cuckoo wasps.

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Bestäubungsbiologie und Taxonomie der Breitblättrigen Stendelwurz *Epipactis helleborine*

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Epipactis helleborine (L.) Crantz (Orchidaceae), die Breitblättrige Stendelwurz, hat ein Verbreitungsgebiet, welches sich von Nordafrika über Asien und Europa erstreckt. Diese Orchidee lockt ihren Bestäuber, soziale Faltenwespen, teilweise mit Hilfe von Täuschungsmechanismen an. Die Blüten produzieren sogenannte „Green Leaf Volatiles" welche normalerweise von Pflanzen produziert werden, die von herbivoren Insekten, wie etwa Schmetterlingsraupen, gefressen werden. Wespen werden von diesen Duftstoffen angelockt und führen die Bestäubung der *E. helleborine* Blüten durch. *Epipactis helleborine* ist sehr variabel in Form, Größe und Farbausprägung der Blüten. Das hat zur Beschreibung von 30 Unterarten geführt. Wenn es sich hier um Taxa auf dem Artniveau handelt, so sollten Isolationsbarrieren auftreten, da Unterarten per Definition kein sympatrisches Vorkommen aufweisen. Studien, die sowohl die Mechanismen der Pflanze zur Anlockung von Bestäubern als auch die Wahrnehmung dieser Signale durch den Bestäuber beleuchten, wurden bisher nur selten durchgeführt. Das Ziel dieses Vorhabens ist, den taxonomischen Status und reproduktive Isolationsmechanismen der drei Taxa *E. helleborine helleborine*, *E. helleborine moratoria* und *E. helleborine minor* zu untersuchen und zu klären. Dazu wurden morphometrische- und chemische Analysen, Elektroantennographie und Biotests durchgeführt. Die Untersuchungen wurden sowohl an mehreren Freilandpopulationen als auch im Labor unter kontrollierten Bedingungen durchgeführt.

Die bisherigen Ergebnisse deuten darauf hin, dass sich die drei Taxa *E. helleborine helleborine*, E. *helleborine moratoria* und *E. helleborine minor* sowohl in ihrer Morphologie als auch in der Zusammensetzung des Blütenduftes unterscheiden. Mit Hilfe der gekoppelten Gaschromatographie und Elektroantennographie (GC-EAD) registrierten wir 13 elektrophysiologisch aktive Substanzen in den Headspaceproben der drei Taxa, die von Wespen wahrgenommen werden. Mithilfe von Massenspektrometrie konnte die chemische Struktur der Substanzen identifiziert werden. Der Vergleich der Duftbouquets zeigte, dass sich die Taxa nicht in der Duftqualität sondern in den Duftbouquets unterscheiden. In Biotests wurden *Vespula germanica* Arbeiterinnen vom Duft aller drei Taxa angelockt, bevorzugten jedoch die Nominatform *E. helleborine helleborine* gegenüber den anderen beiden Taxa. Die bislang vorliegenden Ergebnisse sprechen dafür, dass es sich bei *E. helleborine helleborine*, *E. helleborine moratoria* und *E. helleborine minor* nicht um Unterarten handelt.

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Function of plant extrafloral trichome secretions in nests of wool-carder bees, *Anthidium manicatum*

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Bees make use of plant substrates for nutritional purposes (pollen, nectar), but also for nest building. Megachilidae use a staggering array of plant-derived cell-building materials, including mortar made from plant leaves, fragments of plant leaves, resin, or plant hairs ('wool'). While some plant-derived materials have been hypothesized to protect provisions and brood against microbial decay, this has not been tested, and the factors driving diversification of nesting materials are unclear. Here, we investigated the protective effects of *Pelargonium* extrafloral trichome secretions which females of European wool-carder bees, *Anthidium manicatum*, smear on their brood cells. By breeding bees in cages with differential *Pelargonium* supply we generated brood cells with or without trichome secretions. Brood cells with trichome secretions were less attractive to chalcidoid parasitic wasps in Y-maze olfactometer tests. When exposed at sites where *A. manicatum* occurs in natural populations, brood cells smeared with trichome secretions were less affected by wasp-parasitation than those without trichome secretions. On the other hand, trichome secretions did not prevent the growth of mold on brood cells, and larval mortality due to microbial decay was almost non-existent even when brood cells were exposed to rainfall. We suggest that the use of plant trichome secretion for brood cell construction has more likely evolved as a response to chalcidoid wasp parasitation. Wasp parasitation may be an underestimated cause of the diversification of megachilid cell construction materials.

Patterns of relatedness within aggregations of the primitively eusocial halictid bee, *Lasioglossum malachurum* (Kirby 1802)

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Lasioglossum malachurum forms some of the most conspicuous nesting aggregations known for halictid bees in Germany, with up to a thousand or more nests in a characteristically clumped distribution. Inseminated females (gynes) overwinter away from their natal nest and return to their original aggregation to start a new one in the next spring. Those nests generally comprise a queen and, at our field sites around Tübingen, generally less than 10 workers that are a mix of full and half sisters. The question we address is whether nests that are located close together within an aggregation belong to foundresses that are closely related or not. In this study, a total of 178 workers, one worker per nest, from four aggregations around Tübingen were genotyped with 14 microsatellite loci to determine genetic relatedness. Geographic distances between their nests were measured in order to investigate the relationship between relatedness and distance within and between aggregations. Results from this study will allow us to determine patterns of natal dispersal and to infer the processes (kin cooperation or kin competition) that might drive dispersal in *L. malachurum*.

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Chromosomes of parasitoid Hymenoptera: what can they tell us?

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Karyotypes of more than 450 species of parasitic wasps have been examined up to now. However, this value constitutes just about 0.05% of the number of described species of parasitoid Hymenoptera. Since females of parasitic wasps are generally diploid and males of these insects are normally haploid, chromosomal study can provide data on sex ratios of immature stages of parasitoid Hymenoptera. Moreover, species identification of these stages by their karyotypes is also possible in natural populations. The haploid chromosome number (n) varies from n = 3 to n = 23 in parasitic wasps. The highest n values are characteristic of certain Ichneumonidae and Braconidae (n = 21 and 23 in *Perithous scurra* (Panzer) and *Fopius arisanus* (Sonan) respectively), and the lowest ones are found in a few unrelated Chalcidoidea (n = 3 in *Encarsia protransvena* Viggiani (Aphelinidae), *Brachymeria intermedia* (Nees) (Chalcididae) and *Perilampus ruschkai* Hellén (Perilampidae) as well as in a member of the genus *Aphidius* Nees (Braconidae)). The distribution of species by the chromosome number is bimodal with the two distinct peaks at n = 6 and 11. Although the general model of karyotype evolution in parasitic wasps remains relatively stable during the last decade, new data continue to provide important information on the patterns of chromosomal variation in certain taxa. For instance, first karyotypic data for a few families and subfamilies, such as Agaonidae (n = 5-6 in the genera *Ceratosolen* Mayr and *Blastophaga* Gravenhorst respectively) and Homolobinae (Braconidae; n = 6 in *Homolobus infumator* (Lyle)), were published since 2010.

Chromosomal study led to discovery of more than 20 groups of cryptic species of parasitoid Hymenoptera. For example, our karyotypic investigation of a supposedly well-known parasitoid of a wide array of coleopteran stored-product pests, *Anisopteromalus calandrae* (Howard) (Pteromalidae), revealed that some strains of this species had = 7, whereas the others had n = 5. Further research has demonstrated that this name harbored two different cosmopolitan species, which were fully isolated from each other in terms of reproduction. Moreover, these species also have alternative life-history strategies which are best interpreted in terms of the r/K continuum. Furthermore, differences in life-history features between these parasitoids correlate with the corresponding characteristics of their preferred hosts. In addition, the species with n = 5 appeared to be new to science and was later described as *A. quinarius* Gokhman & Baur. These results, together with a number of similar cases, also call for wider application of chromosomal analysis to parasitoid stocks cultivated for both industrial and laboratory use, and this kind of analysis can therefore provide means of express identification of particular strains.

Karyotypic study can become a very important method of determining numbers of linkage groups in parasitoid Hymenoptera. This method is especially valuable in cases where certain chromosomes are small or relatively inert in terms of genetics, like e.g. B chromosomes. Recent data suggest that these elements are substantially more abundant among parasitic wasps than it was previously supposed. Specifically, we detected up to six B chromosomes per diploid karyotype in *Pnigalio gyamiensis* Myartseva & Kurashev (Eulophidae), whereas two chromosomes of that kind found in the chromosome sets of *Pnigalio agraules* (Walker) and of a particular strain of *Aphidius ervi* Haliday is the next highest

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number of B chromosomes in parasitoid Hymenoptera. Although these chromosomes often carry sex-ratio distorters in parasitic wasps, this is probably not the case in *P. gyamiensis*, thus providing a possible explanation for accumulation of B chromosomes in this species.

Differential staining (mostly C- and AgNOR-banding) was performed on chromosomes of a number of parasitoid species. C-banding reveals constitutive heterochromatin, whereas AgNOR-banding visualizes nucleolus organizing regions (NORs) on chromosomes. Segments of pericentromeric and telomeric heterochromatin are the most characteristic of parasitoid Hymenoptera. Moreover, NORs are always localized on both homologous chromosomes of the diploid chromosome set. Both these characteristic groups of chromosomal segments, especially NORs, can vary even between closely related species. Nowadays, traditional banding methods are complemented with base-specific fluorochrome banding. Without any pretreatment, AT-specific fluorochromes (e.g. DAPI or Hoechst 33258) usually produce homogeneous staining on chromosomes of parasitoid Hymenoptera, sometimes except for NORs, which, in turn, are stained with GC-binding fluorochrome dyes (chromomycin A_3).

Fluorescence *in situ* hybridization (FISH) is becoming an efficient tool used for detection and localization of various DNA sequences on chromosomes of parasitic wasps. Using this approach, we were able to map 45S and 18S rRNA genes in a few members of the superfamilies Ichneumonoidea (Ichneumonidae: *Ichneumon amphibolus* Kriechbaumer), Cynipoidea (Cynipidae: *Diplolepis rosae* (Linnaeus)), and Chalcidoidea (Eulophidae: *Entedon cioni* Thomson, *E. cionobius* Thomson; Eurytomidae: *Eurytoma robusta* Mayr, *Eu. serratulae* (Fabricius), *Eu. compressa* (Fabricius); Torymidae (*Torymus bedeguaris* (Linnaeus)). We have also proposed the first model of evolution of the number and chromosomal localization of rDNA clusters in parasitoid Hymenoptera. Although the number of rDNA sites within the latter group can vary from one to six per haploid karyotype, the amount of rDNA clusters generally correlates to the chromosome number. Moreover, we have demonstrated absence of the canonical insect telomeric repeat, TTAGG, in the above-mentioned superfamilies, suggesting the total lack of the $(TTAGG)_n$ motif in parasitic wasps, apart from most aculeate Hymenoptera. We believe that FISH, including chromosome painting, as well as related techniques (e.g. chromosome microdissection) will be widely used in the future to facilitate genome assembly in parasitoid Hymenoptera, as it is already being done for some other insects.

Methods of immunochemistry can also reveal various aspects of chromosomal composition. For example, methylation profiles of particular chromosomes can be visualized. We have performed this study on chromosomes of *Entedon cionobius* and *E. cioni* using antibodies to 5-methylcytosine. These fluorochrome-labeled antibodies revealed distinct positive signals in the telomeric regions of most chromosomes, although a few weaker centromeric and interstitial signals could also be seen.

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Prey stage availability and sex allocation in *Ampulex fasciata*

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Ampulicidae or cockroach hunting wasps are solitary ectoparasitoids of cockroaches of which most taxa are of tropical origin. The body size of these kinds of haplo-diploid insects is clearly determined by prey or host size. When wasp's fitness increases more with body size in females than in males, mothers are expected to allocate daughters on larger hosts. The latter hypothesis of conditional sex allocation was investigated in a strain of *Ampulex fasciata* from Central-Europe. *A. fasciata* is unique being the only species in the genus with postglacial populations in northern localities north of the Alps. The occurrence of *A. fasciata* is highly associated with the Ectobiinid forest cockroach *Ectobius sylvestris*, sometimes accompanied with the dusky cockroach *E. lapponicus*.

Adult male and female cockroaches as much as the larger nymphal stages are captured for oviposition whereas smaller nymphs are ignored. Moreover, captured low quality preys may still be rejected for oviposition and are only used for host-feeding. An improved statistical model, designed by Wellings et al. (1986), showed that emergence sex-ratios (ESRs) of *A. fasciata* show a significantly male bias in smaller hosts. This shift in the ESRs was attributable to maternal decisions based on the potentially consumable parts of the prey. Progeny mortality was found to be low in almost all prey stages. Hence, differential progeny mortality does not play a significant role in the sex-ratio shift.

Wasp's body size, as expected, increases with host size. Remarkably, individual female progeny was found significantly larger than male offspring when both developed on equal host resources (calculated as the consumable body parts). In nature the most advantageous prey stages to optimize progeny body size are available for the first generation of *A. fasciata* from the second half of May until early August. A (partially) non-diapausing, small second generation and an even smaller third generation have to be satisfied to reproduce on less favourable preys. Due to this low resource availability the mother wasps are supposed to contribute extremely male-biased investment ratios later in the season.

Effects of habitat area, connectivity and management on snailshell-nesting bees

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The effects of habitat loss and fragmentation on wild bee populations are still not fully understood. Availability of resources, top-down regulation and exchange of individuals between metapopulations should influence population sizes of bees. Whereas floral resources for wild bees have been considered in research and conservation management, nesting resources are largely neglected. Snail shells are the exclusive nesting cavities for

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several *Osmia* species and provide a good but until now unused tool to study driving factors of bee population dynamics. We investigated the effects of habitat area, connectivity and local management of semi-natural grasslands on populations of snailshell-nesting bees. We monitored snail shell colonization on 23 calcareous grasslands in northern Bavaria by providing empty snail shells of different sizes (large *Helix*, medium *Cepaea* and small *Helicella* and *Zebrina* shells) as nesting resources. Additionally we recorded flower visits of wild bees during May and June which is the main flight period of the abundant snail shell nesting species.

Almost a quarter of recorded flower visits were made by snailshell-nesting *Osmia* species. Three species were found nesting in the offered snail shells and colonization rate varied highly between grasslands and species. Habitat area had a positive effect on the population size of the habitat specialist *Osmia aurulenta*, whereas the more generalist species *Osmia bicolor* was positively influenced by habitat connectivity. Local grazing intensity affected the availability of nesting resources by higher destruction rates of snail-shells on more often grazed grasslands. We conclude that large and connected habitats benefit bee populations in fragmented landscapes. Management regimes should take into account potential negative effects of intensive grazing on specific nesting resources of specialized bee populations in semi-natural grasslands.

Insights into the phylogeny of the endemic oil-collecting bee genus *Rediviva* based on nuclear and mitochondrial data

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The bee genus *Rediviva* represents a remarkable example of co-evolution with its main host plant *Diascia*. Bees of this South African genus have evolved elongated forelegs, a bizarre and remarkable morphological adaptation, in order to collect floral oil from flowers of *Diascia* host plants. Leg length of *Rediviva* bees varies not only within the genus (range: 6-26 mm) but also from population to population within a species; morphological studies have revealed a significant correlation between the length of the bees' forelegs and the oil-producing spurs of its local host *Diascia*, strongly supporting the idea of co-evolution. Genetic data underlying this co-evolutionary process are lacking, yet would give insights into the targets of selection and the lability of evolutionary change. A prerequisite to investigate the evolution of variance in leg length within *Rediviva* and test for co-evolution is to reconstruct the phylogeny of this bee genus. Previous analyses on melittid bees suggest *Rediviva* to be paraphyletic, but more thorough analyses including more species are needed to substantiate this finding; phylogenetic relationships on the species level have not yet been resolved. Here, I present results from my phylogenetic analyses based on six nuclear markers and the mitochondrial COI gene fragment. Firstly, my results provide a better understanding of the evolution of the genus *Rediviva* and, secondly, they will help to investigate the genetics of a noticeable phenotypic trait – elongated front legs – that results from the reciprocal evolution of two interacting species.

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How landscape related resource diversity boosts bee fitness

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Bees are major pollinators of many crop plants, and recent declines in native bee populations raise concerns about the stability of global food production. Bees themselves need a choice of resources (nectar, pollen and resin) from a variety of plants. But how plant diversity at the landscape level affects foraging behaviour and ultimately colony fitness in social bees is yet largely unexplained.

We studied the influence of plant diversity on long term colony development of the perennial Australian stingless bee *Tetragonula carbonaria* (Apidae: Meliponini) in different landscapes. We placed 48 bee colonies at 12 study sites, representing three landscape types with increasing levels of plant diversity: plantations, forests and suburban gardens. We compared foraging behaviour across landscapes over six seasons. Changes in colony weight and brood reproduction were monitored over two years to assess overall colony fitness. Samples of honey and pollen storages were analysed for nutritional quality and compared between landscapes.

Despite pronounced differences in plant diversity, we found general foraging patterns to be largely similar across landscapes. Diversity of pollen collected and overall resource intake was highest in gardens, but low in forests and plantations. Nutritional quality of honey was highest in gardens, whereas pollen quality was equally high in gardens and plantations. Colony growth rates and reproduction were consequently highest in gardens, but highly variable in forests and plantations.

Our findings confirm the importance of resource availability, diversity and composition in determining colony growth and hence fitness of social bees. However, highest resource diversity is not necessarily associated with large natural habitats and gardens may have a surprisingly high conservation value for bees.

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Suandrena and *Micrandrena* species of the Canary Islands and the Madeira Archipelago – new taxonomic, phylogenetic and biogeographical aspects

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The Canary Islands and the Madeira Archipelago are characterised by many endemic plant and animal species, among them also bee species (Hohmann et al. 1993, Kratochwil et al. 2008). In the following, species of the subgenera ***Suandrena*** and ***Micrandrena*** will be compared by detailed morphological analysis, followed by an evaluation of their taxonomic rank and phylogenetic/biogeographical relationships.

Suandrena: Taxonomic aspects: Warncke (1968) defined *A. maderensis* Cockerell, 1922 (Madeira), as nominate species and considered besides *A. m. portosanctana* Cockerell, 1922 (Porto Santo), two other taxa as subspecies of *A. maderensis*: *A. m. notata* Warncke, 1968 (Canary Islands), and *A. m. fratella* Warncke, 1968 (Morocco). Later, Warncke (1974) revised the classification of *A. m. fratella* and regarded this subspecies as a subspecies of *A. cyanomicans* Pérez, 1895. Dylewska (1983) regarded *A. m. notata* as synonymous to *A. cyanomicans* and *A. m. fratella* as synonymous to *A. leucocyanea* Pérez, 1895. According to our studies all subspecies of *A. maderensis* (including *A. m. fratella*), defined by Warncke (1968, 1974), differ in many morphological features (e.g. for females: body length, labrum process, clypeus and propodeum structure, flagellum and wing colour, puncturing of mesoscutum and scutellum, pubescense of clypeus, genal area, propodeal corbiculae, metasoma). Therefore these subspecies have to be upgraded to species rank. Phylogenetic/biogeographical aspects: Porto Santo is geologically the oldest island (14 million years) of the Madeira Archipelago. Much younger are Madeira (4.6) and Desertas Islands (3.6). Concerning the geological age of the different islands, it is hypothesised that the eldest one, Porto Santo, was colonised before the existence of Madeira. All in all the probability is high that *A. fratella* or one of its ancestors colonised first Porto Santo (or stepping-stone islands which today are under sea-level) and developed to the endemic *A. portosanctana*. Later Madeira was colonised by *A. portosanctana*, which developed to Madeira's own endemic species, *A. maderensis*. Based on the larger distance from mainland, the time of colonisation of Porto Santo by *A. fratella* (or an ancestor of this species) might have been later than the colonisation of Fuerteventura and Lanzarote. *A. fratella* or one of its ancestors also colonised Fuerteventura and Lanzarote (Canary Islands) and evolved to *A. notata* (limited in its distribution to Fuerteventura and Lanzarote). Fuerteventura, locus typicus of *A. notata*, is the eldest island of the Canary Archipelago (23.5 million years), followed by Lanzarote (15.5) and Gran Canaria (14.5). Tenerife is geologically much younger (7.5), the youngest islands being those situated furthest westward: La Gomera (1.7) and El Hierro (1.2). We do not support the interpretation of Dylewska (1983), that *A. m. fratella* is synonymous to *A. leucocyanea* Pérez, 1895, and *A. m. notata* is synonymous to *A. cyanomicans*. There are some indications, that *A. cyanomicans* is a phylogenetically younger taxon, which probably evolved from *A. fratella*, one of its ancestors or a closely related species.

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Micrandrena: Taxonomic aspects: There is an analogous situation in the case of the subspecies of the *A. wollastoni* group. First described by Cockerell (1922) (specimens collected from Madeira), Warncke (1968) differentiated *A. wollastoni* into four subspecies: the nominate taxon *A. w. wollastoni* Cockerell, 1922 (Madeira, Porto Santo), and, for the Canary Islands, *A. w. acuta* Warncke, 1968 (Tenerife, La Palma), *A. w. gomerensis* Warncke, 1993 (El Hierro [?], La Gomera) and *A. w. catula* Warncke, 1968 (Gran Canaria). According to several morphological differences we separated *A. dourada* Kratochwil & Scheuchl, 2013 (Porto Santo), from *A. wollastoni* Cockerell, 1922, as a species of its own (Kratochwil & Scheuchl 2013). The subspecies of the former *A. wollastoni* of the Canary Islands can be distinguished also by several morphological features (e.g. for females: length of body, wings, clypeus, stigma, propodeum; facial fovea index, colour of, e.g., paraocular area, tibial scopa, tergites 5 and 6, labrum process structure). Therefore the three subspecies of the Canary Islands should be upgraded to species rank: *A. acuta* (Warncke, 1968), *A. gomerensis* (Warncke, 1993) and *A. catula* (Warncke, 1968); Kratochwil & Scheuchl in prep. Phylogenetic aspects: Concerning several morphological features *A. dourada* (Porto Santo) and *A. catula* (Gran Canaria) show a close morphological relationship to each other and to *A. tiaretta* Warncke, 1974. *A. gomerensis* and *A. acuta* can be interpretated as taxa evolved from the potential ancestor *A. catula* on islands much younger than Gran Canaria. Biogeographical aspects: *A. tiaretta* is distributed in southern Spain, North Africa, Israel and Syria. Both islands, Porto Santo and Gran Canaria, are characterised by a similar age of origin. So the probability is high that *A. tiaretta* (or an ancestor of this species) colonised from mainland the islands Porto Santo and Gran Canaria. A taxon of the former *A. wollastoni* group is missing in Fuerteventura and Lanzarote, although both islands could have served as important stepping stones. Another *Micrandrena* species ocurring there is *A. spreta* Pérez, 1895. *A. spreta* shows high similarity to *A. tiaretta* too. At present, no comprehensive morphological analysis of *A. spreta* and *A. tiaretta* exists. The same is true for *A. lineolata* Warncke 1968, a second *Micrandrena* species occurring in Tenerife: *A. lineolata* is distributed in the Cañadas and the Teno region and according to Warncke (1968) is closely related to *A. wollastoni*.
The endemic *Suandrena* and *Micrandrena* species of the Canary Islands and the Madeira Archipelago are models for the colonisation processes and species diversifications on oceanic islands.

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The fossil history of Chalcidoidea and the use of Synchroton X-ray microtomography for their visualization

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Chalcidoidea are a diverse and biologically important group of predominantly parasitoid wasps. The evolutionary history of the superfamily is largely unknown mainly because their rich fossil record has never been comprehensively studied. Here, the first overview of the fossil history of Chalcidoidea is presented based on more than 1.000 fossils from Cretaceous, Eocene and Miocene ambers. Previously unrecognized specimens from Lebanese amber significantly increase the minimum age of the superfamily to about 130 million years. The phylogenetic relationships of these stem group representatives to extant Chalcidoidea are discussed. Chalcidoidea already exhibited a broad diversity in the Lower Cretaceous. Recently discovered fossils from Burmese amber (~99 mya) help dating the crucial transition from endo- to ectoparasitoidism. The minimum ages of further biological transitions are presented based on new fossil records of various chalcidoid families and subfamilies. The new fossils provide important calibration points for molecular dating studies and constitute a rich source of phylogenetic data.

For the morphological investigations of the minute chalcidoid specimens digital microscopes are used as well as Synchrotron-based X-ray microtomography (SR-µCT). SR-µCT facilitates three-dimensional visualization of the non-translucent, millimeter-sized samples. As a non-destructive imaging technique, it has become established as an important tool for entomologists to examine insect morphology. The ability to picture three-dimensional specimens without reflections and distracting particles is of great value for morphological studies on extinct species in amber. The resulting “virtual insects” can be made widely accessible to the scientific community, a clear benefit especially in the case of valuable type material that may become lost or degraded in storage over time. Several tomographic scans of fossil Chalcidoidea in different types of amber were performed at the ANKA Synchrotron Radiation Facility of Karlsruhe Institute of Technology. The investigations showed that amber inclusions often consist merely of an imprint of the original insect. In some cases, however, internal anatomical structures, such as musculature and apodemes, are remarkably well preserved and may provide new insights into phylogenetic relationships.

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Discovering hidden biodiversity in *Lasioglossum* (*Dialictus*) and its relationship to habitat loss

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Over the past two decades, there has been increasing awareness of the threat that a decline in pollinators might have for pollination, an important 'ecosystem service' in terrestrial habitats. Most attention has been focused on the honey bee (*Apis mellifera*), though the 'pollinator crisis' likely also affects other species of bee, for which taxonomic identity and conservation status are poorly known in hyperdiverse tropical regions such as Mesoamerica. In conjunction with pesticide misuse, disease transmission and pollution, habitat loss and fragmentation have been suggested as leading causes of reduced pollinator populations and loss of biodiversity. To investigate the impact of habitat loss on bee populations in Mesoamerica, we collected and analysed 1089 individuals of *Lasioglossum* spp. (subgenus *Dialictus* and *Evylaeus*) from 21 sites across a gradient of land-use intensity on the Yucatán Peninsula, Mexico. The taxonomy of *Lasioglossum* and, in particular, of members of the subgenera *Dialictus* and *Evylaeus*, from Mesoamerica remains unresolved. We aimed to delineate species in our samples using an integrated taxonomic approach incorporating morphological, mitochondrial and nuclear DNA data. Our morphological data and mitochondrial DNA 'barcodes' suggest nine species. These data are also partially supported by nuclear DNA (genes: Opsin and Elongation Factor 1-alpha). On the basis of these data and additional morphometric measures of wings and body characters, we developed a dichotomous key for the identification of *Lasioglossum* (*Dialictus* and *Evylaeus*) species and tested its utility in additional specimens. Two *Lasioglossum* (*Dialictus*) taxa were selected to assess the genetic diversity of populations of these bee species so as to test the idea that habitat destruction and fragmentation leads to a loss of intraspecific genetic diversity. These analyses will reveal how well populations are interconnected and help inform policy and practice aimed at conserving them and the important ecosystem service of pollination that they perform.

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Vergleich des Blütenbesuchs-, Paarungs- und Brutfürsorgeverhaltens zweier palaearktischer Artkomplexe der Pollenwespengattung *Celonites* (Hymenoptera: Vespidae: Masarinae)

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Innerhalb der Pollenwespengattung *Celonites* bildet die *C. abbreviatus*-Gruppe ein gut begründetes Monophylum, das derzeit sieben westpalaearktische Arten umfasst (MAUSS 2013). Die *C. abbreviatus*-Gruppe sensu RICHARDS 1962 besteht aus zwei Artkomplexen, dem *C. abbreviatus*-Komplex und dem *C. afer*-Komplex, die sich auffällig in der Ausbildung der Behaarung auf der Stirn unterscheiden (MAUSS 2013). Bei Arten des *C. abbreviatus*-Komplexes ist die Stirn dicht mit am Ende knopfartig verdickten Sammelborsten besetzt, die eine Kopfbürste zur Aufnahme von Pollen aus nototriben Blüten bilden (SCHREMMER 1959, MÜLLER 1996). Eine solche Kopfbürste fehlt den Vertretern des *C. afer*-Komplexes. Dies lässt erwarten, dass sich die Vertreter beider Gruppen zumindest hinsichtlich der genutzten Pollenquellen und des Blütenbesuchsverhaltens unterscheiden. Detaillierte Untersuchungen zur Bionomie wurden bisher nur für einen Vertreter des *C. abbreviatus*-Komplexes veröffentlicht, nämlich den auch in Mitteleuropa vorkommenden *Celonites abbreviatus* (SCHREMMER 1959, BELLMANN 1984, 1995, MÜLLER 1996, AMIET & MAUSS 2003, MAUSS 2006). Demgegenüber war die Lebensweise von Vertretern des *C. afer*-Komplexes bisher weitgehend unbekannt.

Unser Ziel war es deshalb möglichst viele bionomische Merkmale von *Celonites fischeri* und *C. afer* zu erfassen, die gemeinsam den *C. afer*-Komplex bilden, und mit den Merkmalen von *C. abbreviatus* zu vergleichen. Dazu wurden an *C. fischeri* umfangreiche Freilanduntersuchungen vom 20.5.-30.5.2013 auf Zypern durchgeführt. Ergänzende Beobachtungen zum Blütenbesuch von *C. afer* wurden in den Jahren 2007, 2011, 2012 und 2014 in Marokko gemacht.

Sowohl *Celonites fischeri* als auch *C. afer* sind wahrscheinlich eng oligolektisch und nutzen ausschließlich Pflanzen der Gattung *Echium* (Boraginaceae) als Nektar- und Pollenquelle. Die Pollenaufnahme erfolgt bei beiden Arten direkt durch das Fressen von Pollen aus den sternotriben Antheren, was von bürstenden Bewegungen der Vorderbeine unterstützt werden kann. Die Weibchen beider Arten verfolgen dabei eine bisher von Pollenwespen nicht bekannte Pollensammelstrategie. Sie zwängen ihren Kopf in Blüten hinein, die gerade erst im Aufblühen begriffen sind und deren Corolla noch weitgehend geschlossen ist, und gelangen so an die noch nicht frei zugänglichen Antheren. Diese Strategie könnte eine Anpassung an die Konkurrenz um Pollen durch Bienen darstellen, die *Echium*-Pollen am Exoskelett sammeln. Im Gegensatz zu den Vertretern des *C. afer*-Komplexes sind, soweit bekannt, alle Taxa des *C. abbreviatus*-Komplexes mit Lippenblütlern (Lamiaceae) assoziiert, die nototribe Blüten besitzen. Pollen wird von Imagines des *C. abbreviatus*-Komplexes mit Hilfe der spezialisierten Sammelborsten auf der Stirn indirekt aus den nototriben Antheren aufgenommen und dann mit Hilfe der Pollenkämme an den Vorderbeinen von der Stirn zur Mundöffnung transportiert (SCHREMMER 1959, MÜLLER 1996). Die unterschiedliche Stirnbehaarung in beiden Artkomplexen lässt sich

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also auf Anpassungen an den unterschiedlichen Bau der Blüten zurückführen, die sie als Pollenquellen nutzen. Dabei ist es unklar, ob die spezialisierte Stirnbehaarung erst in der Stammlinie des *C. abbreviatus*-Komplexes entstanden ist oder ob die Sammelborsten in der Stammlinie des *C. afer*-Komplexes reduziert wurden. In anderen bionomischen Merkmalen besteht weitgehende Übereinstimmung zwischen *C. fischeri* und *C. abbreviatus*:

Bei beiden Arten patrouillieren die Männchen an Blüten der jeweiligen Nahrungspflanzen auf der Suche nach Weibchen. Das Kopulationsverhalten und auch die Kopuladauer stimmen bei beiden Arten weitgehend überein. Männchen übernachten in charakteristischen Schlafgemeinschaften, die sich über mehrere aufeinander folgende Nächte immer wieder am selben Platz bilden.

Die Nester bestehen bei beiden Arten aus mehreren aneinander grenzenden Lehmzellen, die in Gruppen oberirdisch an Steinen oder Pflanzenstängeln angebaut werden und am Ende mit einer gemeinsamen Erdschicht überzogen werden können. Das Nestbauverhalten eines über drei Tage fokal beobachteten Weibchens von *C. fischeri* ähnelte in hohem Maße dem eines Weibchens von *C. abbreviatus*, das von BELLMANN (1984) untersucht wurde. Ein deutlicher Unterschied bestand aber in der Dauer der Verproviantierungsphase, die bei *C. abbreviatus* nur 0,5 Tage, bei *C. fischeri* aber 1,5 Tage in Anspruch nahm, obwohl die Anzahl der Pollensammelflüge, die zur Verproviantierung einer Brutzelle durchgeführt wurden, annähernd gleich war. Dies ist darauf zurückzuführen, dass die Pollensammelflüge bei *C. fischeri* deutlich länger dauerten als bei *C. abbreviatus*. Die gesteigerte Verproviantierungsrate bei *C. abbreviatus* weist auf eine höhere Sammeleffizienz hin, die auf die indirekte Pollenaufnahme mit der spezialisierten Stirnbehaarung zurückzuführen sein könnte.

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Effects of an insect growth regulator and its solvent on honey bee (*Apis mellifera* L.) queen viability and brood development

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The insect growth regulator fenoxycarb, e.g. used for pest control in orcharding, disturbs larval development into adults and frequently leads to queen loss in honeybee (*Apis mellifera* L.) colonies. Here, we tested whether queens are affected by fenoxycarb and/or by its solvent dimethyl sulfoxide (DMSO), relating to egg eclosion and brood development. Damaged brood could explain the elimination of queens by worker bees. Small bee colonies were fed with (i) sucrose solution (control group), (ii) sucrose-DMSO solution, and (iii) sucrose-fenoxycarb-DMSO solution, respectively. For evaluating egg eclosion combs with newly-laid eggs were transferred into an incubator until hatching. For testing differences in brood development depending on food supply and brood care by workers a transfer experiment was conducted. Therefore, hives were grouped pairwise (five partners per group) as follows: a) control and another control hive, b) control and fenoxycarb-DMSO treated hive, c) control and DMSO treated hive, d) fenoxycarb-DMSO and another fenoxycarb-DMSO treated hive, and e) DMSO and another DMSO treated hive, respectively. New and empty combs were added to each colony and, after oviposition, changed with the egg containing comb of the appropriate partner-hive. Brood development was recorded every fourth day until hatching. Experiments were conducted in 2012 with the groups a), b), and e) and in 2013 with all groups a) to e).

No significant differences were found in egg eclosion between the different treatments. However, by trend, there is a higher mortality of eggs from fenoxycarb exposed queens than of eggs from queens of the other groups. In the transfer experiment survival curves of

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brood showed significant differences between brood from control hives (group a) and brood exposed to fenoxycarb (group b, d) and DMSO (group c, e), respectively. Brood only nourished with sucrose developed best, followed by brood exposed to DMSO. Fenoxycarb exposed brood developed worst.

The results point out that fenoxycarb treatment has an adverse effect on brood development, possibly explaining queen loss. This effect is not significant for DMSO treatment. Besides, brood survival curves indicate a nurse bee-mediated effect on development of brood reared under exposure to fenoxycarb as well as to DMSO, previously assumed as non-toxic solvent.

Does pathogen spillover from managed bees represent a threat to wild bees?

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Examples of pathogen spillover, the transfer of pathogens from one group of organisms to another, are widespread in nature and encompass a wide range of plants and animals, including us humans. There is growing evidence that pathogen spillover also occurs between managed bees, including managed honey bees (*Apis mellifera*) and managed bumble bees (*Bombus* spp.), and wild bees and other insects. Our recent data from Great Britain suggest that viruses thought to be restricted to honey bees are commonly found in bumble bees; the distribution of genetic variants of one common viral family, deformed wing virus (DWV), suggests frequent and on-going transfer from managed honey bees to wild bumble bees (Fürst et al. 2014 Nature 506: 364-366). As well as presenting these and related datasets, I shall address the extent to which pathogen spillover represents a threat to wild bees, and how this threat can be minimised. As a potential cause of bee decline, pathogen spillover is of considerable relevance for the conservation of our native fauna and deserves closer scrutiny.

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"False Ants" from the Cretaceous (Hymenoptera: Chrysidoidea: Falsiformicidae)

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Falsiformicidae (= false ants) are an enigmatic family of aculeate wasps described by Rasnitsyn based on two individuals, male and female, from Cretaceous Siberian (Taimyr) amber. Discussing the morphological similarities of Falsiformica cretacea, at that time the only species in the family, with 'Bethyloidea' (= Chrysidoidea), Scolioidea, and Formicoidea Rasnitsyn suggested the Falsiformicidae to be a potential sister lineage to Formicidae s.lat. Due to the state of preservation of the only two specimens, the female lacks most of the head while the male lacks the wings, parts of the mesosoma, and the metasoma, the enigma of the phylogenetic position of the Falsiformicidae remained.

In recent years about 40 additional Cretaceous fossil falsiformicid wasps, belonging to several undescribed species, have been excavated, originating from Charentese amber, Pyrenean amber, Burmese amber, Spanish amber, and Lebanese amber. The new fossils do not only give proof for an extensive distribution of the family during the Cretaceous. Careful examinations of the external morphology of these fossils clearly demonstrate the chrysidoid nature of Falsiformicidae which is consequently transfered to Chrysidoidea implying a convergent evolution of the features of ants (e.g. the presence of a well-defined metasomal nodus). The results of a preliminary family level cladistic analysis of the Chrysidoidea support a close relationship of Falsiformicidae and Bethylidae.

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The phylogeny of jewel wasps (Chalcidoidea) – new insights from transcriptome sequencing

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Chalcidoidea (jewel wasps) are among the most species rich, ecologically important and biologically diverse groups of terrestrial organisms. An estimated 500,000+ species are currently provisionally placed in 23 families and 83 subfamilies. Chalcidoidea are nested in the Proctotrupomorpha, a large monophyletic taxon that includes also gall wasps and relatives (Cynipoidea), and other speciose parasitoid superfamilies (e.g., Platygastroidea, Diaprioidea).

Major patterns in the evolution of Chalcidoidea include their extreme morphological diversification, shifts in mode of parasitoid lifestyle (egg to larval or pupal parasitoidism, endo- to ectoparasitoidism, primary- to hyperparasitoidism), rates of morphological and genetic evolution, and host specificity, and multiple secondary returns to phytophagy. A robust phylogeny is needed to address the question how and when this enormous diversity of species and biological and morphological traits has evolved.

In the framework of the Hymenoptera subproject of 1KITE (www.1kite.org), we sequenced the transcriptome of 44 species of the Proctotrupomorpha (34 chalcids from 16 families, 10 other proctotrupomorphs), three additional species are still in progress. This taxon sampling is obviously unsuited to cover the whole diversity of chalcid wasps but will be extremely useful to generate a robust "backbone tree" of the large subgroups of Chalcidoidea that has been proven to be very difficult to infer with the previous datasets. Here, we present first results inferred from phylogenetic analysis of 4,565 single-copy orthologous genes with more than 2 million amino acid sites.

Blowing in the wind – wind direction dependent positioning of orchid bees during perfume exposition

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Neotropical orchid bees are well known for the males' behavior of visiting a number of floral and non-floral sources to collect the emitted fragrances, which are then stored in the

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bees' specialized hind leg pouches. Eventually a species-specific perfume bouquet is accumulated. Mating occurs at non-resource based territories in the forest understory where males perch and display on tree trunks or other vertical structures. Using a series of stereotypical behaviors, the bee exposes small amounts of its perfume, undertaking regular patrol flights and then returning to the central perch. The perfume is thought to act as pheromone analog with male and female conspecifics approaching the perch site from downwind. It is as yet unclear which factors govern the choice of the perch site and the positioning of the territorial male on the perch during perfume exposition. Here, we measured characteristics of over 300 display perches of euglossine males (diameter, slope of surrounding terrain) and recorded the male's position on the perch (height of display, orientation in relation to wind and illumination) in La Gamba, Costa Rica. Perch diameter and perching height were different between species. In all species the bees' orientation on the perch was tightly linked to wind direction (downwind) but not to illumination. Cage experiments with artificially changed wind directions clearly proved that male bees evaluate the wind direction and orient themselves downwind on their perch. Being positioned on the leeward side of their perch may help to distribute their perfume, but it is also the prime position to be seen by conspecifics approaching anemotactically against the wind. Our findings further strengthen the hypothesis that the perfume acts as pheromone analog for attracting conspecifics to display sites.

The bumblebees of Vorarlberg (Austria)

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As of 2011, research on bumblebees in large areas of Vorarlberg (Austria) was underrepresented. Although, more than 6,000 specimens belonging to 35 different *Bombus* species (out of a total of 46 species across Austria) had been collected at over 370 localities, mainly below 2,000 m a.s.l. The goal of this study was to complement the distribution data of the bumblebees of Vorarlberg. In addition, a survey of different ecological factors was conducted. From July 1 to August 30, 2012, more than 3,500 specimens belonging to 27 species of the genus *Bombus* were observed in Vorarlberg. The individuals were collected at 407 localities at altitudes ranging from 400 to 2,780 m a.s.l., using a transect method. Based on the collected data, an analysis of diversity, altitudinal preferences, habitat preferences, flower visiting habits and associations of the different bumblebee species was conducted. The data showed the highest abundance of bumblebees within the altitudinal range from 1,000 to 2,400 m a.s.l. Furthermore, the data allowed for the classification of the different species with reference to their altitudinal distribution. Tall herbaceous vegetation represented the habitats with the highest bumblebee abundance by a substantial margin. Diversity indices were calculated for different altitudinal levels and habitat type groups, using the Shannon-Wiener index. The highest diversity was observed at altitudes between 1000 to 2400 m a.s.l. Humid habitats showed the lowest number of species of all habitat type groups. Collected data revealed that the most frequently visited flowering plant taxa were *Aconitum* spp., *Cirsium spinosissimum* and *Trifolium pratense*. An analysis of flower visits with reference to functional floral types indicated that compo-

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site and lipped floral types were most often visited by bumblebees and that the different *Bombus*-species could be divided into two groups of guilds. The oligolectic species *Bombus gerstaeckeri*, which actually only visits flowers of the genus *Aconitum* could also be documented on *Cirsium spinosissimum*. Distribution maps are provided for all species, also taking into account historical data. The first records of *Bombus alpinus* and *Bombus flavidus* in Vorarlberg since 1931 and 1938, respectively, are remarkable.

Insights into the systematic relationships of a European fossorial bee species complex in the subgenus *Hoplandrena*

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Andrena is a genus of solitary bees containing more than 1500 currently known species split into approximately 100 subgenera. Several studies have addressed the systematics and phylogeny of *Andrena*, but many taxonomic questions remain open. A Palearctic species complex from the subgenus *Hoplandrena*, which is known as *Andrena jacobi* group, is a good example as it exhibits taxonomic problems which have been frequently discussed in the literature, with between 2-5 species described in recent keys to the group (namely: *rosae*, *stragulata*, *carantonica/jacobi/scotica*, *trimmerana* and *spinigera*). We counter the unresolved taxonomy of this group with an integrative taxonomical approach as morphological and behavioural analyses alone seem to be insufficient. We used mitochondrial and nuclear gene sequences as genetic markers to underpin the taxonomic status of morpho-species and to reveal phylogenetic relationships of taxa in this group. Here, we present a combination of genetic and morphological data of specimens from different European locations to give insights in the structure of the *Andrena jacobi* group.

Pattern of relatedness in an aggregation of a social sweat bee, *Lasioglossum laticeps* (Hymenoptera: Halictidae)

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Individuals normally behave more altruistically and less competitively towards relatives because they share a high proportion of their genes. By helping a relative to reproduce, an individual may pass on more of its genes to the next generation and increase its inclusive fitness (Hamilton, 1964). Limited dispersal increase relatedness but it also increases local competition among relatives, potentially compromising the benefits of kin cooperation. As a consequence, dispersal may evolve to avoid kin competition for limited resources. In the present study, we aimed to determine patterns of dispersal of a social sweat bee *Lasioglossum laticeps* by examining relatedness of females from adjacent nests. A total of 61 females from 54 nests of one aggregation in front of the main Institute for Zoology building at Halle (Saale) were analyzed at 10 microsatellite loci to study the correlation between

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genetic and geographic distance. If dispersal in this species is limited, a positive correlation between genetic and geographic distances is expected, described as a pattern of isolation by distance. If dispersal is promoted to avoid kin competition no correlation is expected. Preliminary results show a lack of correlation, suggesting that establishment of new nests at every generation is independent, at least at the small scale of the single aggregation we analysed *Lasioglossum laticeps* may possess a mechanism of natal dispersal and nest founding that avoids kin competing for limited nesting resources such as the maternal nest.

Mechanische florale Filter für Bienen: Kraftmessungen an dorsiventralen Blüten

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Dorsiventrale Blüten wie jene in der Familie der Fabaceae verfügen über Eigenschaften, die mechanische Schranken für bestimmte Blütenbesucher darstellen und schwächeren Insekten wie Schwebfliegen oder der Westlichen Honigbiene *Apis mellifera* den Zugang zu Nektar oder Pollen versperren, also als florale Filter wirken. Mechanische florale Filter könnten den Reproduktionserfolg von Pflanzen maßgeblich beeinflussen indem sie Nektar- und Pollendiebe ausfiltern, während vornehmlich Bestäubern der Eintritt in die Blüte möglich ist. Bisher wurden wenige Pflanzenarten hinsichtlich ihrer Blütenkräfte und wenige Bienenarten hinsichtlich korrespondierender Kräfte untersucht. Es ist daher nicht bekannt ob florale Filter durch Kraft auch für weitaus stärkere Bienen als *Apis mellifera* existieren.

Wir untersuchten die von Blütenbesuchern aufzuwendenden Kräfte an Schiffchenblüten der Familien Fabaceae und Polygalaceae sowie an den Maskenblumen des Löwenmäulchens *Antirrhinum majus* und Echten Leinkrauts *Linaria vulgaris* mithilfe eines digitalen Kraftmessgerätes und verglichen die Werte mit den Ergebnissen eigener und aus der Literatur bekannten Kraftmessungen an Bienen. Beobachtungen der Blütenbesucher dienten dazu das Spektrum ihrer Möglichkeiten bei Auslösung von Blütenmechanismen besser zu erfassen.

Es zeigte sich, dass Blüten sämtlicher untersuchter Arten nennenswerte Kräfte aufweisen. Diese liegen in einem Bereich von circa 20 bis 120 mN und damit zum Teil oberhalb der Maximalkräfte kleinerer Bienenarten. Je nach Messposition an den Blüten und Faktoren wie deren Alter und Turgeszenz-Zustand aufgrund unterschiedlicher Bewässerung differiert die Höhe aufzubringender Kräfte deutlich. Die Kräfte können näherungsweise unter Anwendung des Hebelgesetzes berechnet und als Drehmoment angegeben werden. Unterschiedlich große Individuen der Erdhummel *Bombus terrestris* und der Ackerhummel *Bombus pascuorum* überwanden mechanische Schranken gemäß ihrer Erfahrung mit unterschiedlichem Erfolg. Laborhummeln der Erdhummel *Bombus terrestris* waren schwächer als ihre freilebenden Artgenossen und nicht fähig Blüten der Breitblättrigen Platterbse *Lathyrus latifolius* auszulösen.

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Die Ergebnisse legen nahe, dass florale Filter durch Kraft in Kombination mit der Erlernbarkeit von Blütenmechanismen den Erfolg des Blütenbesuchs bestimmen, entsprechend aber manche opportunistischen Blütenbesucher wie *Bombus pascuorum* nur geringfügig einschränken. Kleinere oder jüngere Individuen der Ackerhummel und Erdhummel vermögen ihre physischen Nachteile mithilfe erlernter Bewegungsabläufe zu kompensieren, um hohe Blütenkräfte durch Ausnutzung des Hebelprinzips zu überwinden. Ein mittelstarker Blütenmechanismus wie der von *Polygala myrtifolia* stellt aufgrund seiner Komplexität auch für ausreichend starke Bienen, die gemäß ihrer maximalen Kräfte zu dessen Öffnung befähigt wären, einen wirksamen floralen Filter dar. Mechanische florale Filter wären demnach als Filter durch Kraft oder Filter durch Blütenkomplexität zu definieren.

Hohe Kräfte die Blütenbesucher für einen erfolgreichen Blütenbesuch aufbringen müssen und im Stande zu leisten sind können in Zusammenhang mit bestimmten Blütenkonstruktionen als wechselseitige Spezialisierung gewertet werden wie z. B. im Falle des Blasenstrauchs *Colutea* und besuchenden Blattschneiderbienen der Gattung *Megachile*. Die blütensteten Solitärbienen bestäuben effizient und über längere Distanzen hinweg, wobei sie die zur Öffnung der Blüten benötigte Technik beherrschen. Im Gegensatz zu Generalisten, deren Bewegung und Positionierung auf der Blüte individuell variiert und das Ergebnis eines Lernprozesses ist, erscheinen sie weniger flexibel in ihren Bewegungsabläufen. Vogelbestäubte Blüten wie jene der Gattung *Strelitzia* wären ebenfalls als mechanische florale Filter für Bienen interpretierbar. Nachfolgende Untersuchungen könnten auf die Reproduktionsraten von Pflanzenarten mit kraftinduzierten Blüten oder den denkbaren Zusammenhang zwischen aufzuwendenden Kräften und Menge der Belohnung für Blütenbesucher zielen.

Genetic differentiation in the socially polymorphic sweat bee *Halictus rubicundus* (Hymenoptera: Halictidae)

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Eusociality is a life-history strategy characterized by reproductive division of labour between one queen who monopolizes reproduction and her many daughter workers, who forgo reproduction and cooperatively take care of the brood. One of the consequences of this extreme reproductive skew concerns the effective population size (Ne), the number of individual in a population that contribute genes to the next generation. Ne is expected to be reduced in social species, because the reduced number of reproductive individuals per colony. *Halictus rubicundus* is a socially polymorphic halictid bee, which exhibits solitary behavior in colder regions of its range and social behavior in warmer ones. In this study, I have analyzed patterns of coding sequence polymorphisms (mtDNA, COI) and nuclear DNA patterns of genetic diversity (13 microsatellite loci) from x solitary and y social populations across Germany and the British Isles to test the prediction of a reduced Ne in social populations of *H. rubicindus* when compared with Ne in solitary populations.

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Morphometric differentiation of populations of the parasitoid wasp *Lariophagus distinguendus* (Hymenoptera: Chalcidoidea: Pteromalidae)

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The parasitoid wasp *Lariophagus distinguendus* (Förster) (Chalcidoidea: Pteromalidae) parasitizes larvae of about 20 different host species, most of them Coleoptera. Some of these hosts, for instance the drugstore beetle *Stegobium paniceum* (L.) (Anobiidae) or the granary weevil *Sitophilus granarius* (L.) (Dryophthoridae), are important pests of stored products, such as rice and wheat. Recent research revealed that various strains of *Lariophagus distinguendus* differ regarding their innate and learned host preferences for each of the two host species mentioned above. Crossbreeding furthermore indicates that some strains are sexually and reproductively isolated. Additionally, molecular analyses show distinct differences indicating that the various strains belong to two separate species, which prefer either *Sitophilus* or *Stegobium* as host.

In the course of a taxonomic revision of the *L. distinguendus* species complex we also performed a morphometric analysis to enable a morphological diagnosis of the putative cryptic species. We measured 27 characters of 171 specimens from 10 different strains and analysed the data using multivariate ratio analysis (MRA). MRA comprises a set of statistical tools based on principal component analysis (PCA) and linear discriminant analysis (LDA). Yet by using MRA size and shape and their correlation (allometry) can be examined independently, which is essential for taxonomic studies.

The results show that the two species are morphometrically significantly different, but still overlapping in their range. From a morphological perspective, one would not necessarily consider them as different species. However, the combination of our morphometric data with the biological and behavioural data and molecular data (COI, ITS2, CAD as well as several introns) reveals two separate species within the *Lariophagus distinguendus* species complex. The two *Lariophagus*-species thus seem to have followed different evolutionary trajectories than the closely related *Anisopteromalus calandrae* (Howard) and its recently described sibling species, *A. quinarius* Gokhman & Baur (Pteromalidae). These occupy the very same ecological niche and use the same hosts as the two *Lariophagus*-species, but are not only genetically, but also morphologically clearly differentiated.

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KURZFASSUNGEN DER POSTER

Do Bumblebees (Hymenoptera: *Bombus*) benefit from the Agri-Environmental-Measure "Extensification of Grassland"?

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North-Rhine-Westphalia (cofunded by the EU) provides payments to farmers who subscribe to environmental commitments, i.e. no use of chemical fertilizer and pesticides. Most studies monitoring the effects of grassland extensification dealt with botanical parameters or bird communities. However, data on invertebrate communities are still missing. The aim of this research project is to analyse the effects of grassland extensification on Bumblebees. Therefore Fields managed after the Agri-Enviromental-Measure (AEM) are compared to a Control-Group (CTL), which are managed without commitments and with fields being managed after the commitments of Contractual-Nature-Conservation (CNC), which are not fertilised and often only cut once per year.

The investigations were conducted in 2013 and 2014 in the Eifel and the Süderbergland (NRW, Germany) on 24 grasslands of varying intensity (10 AEM, 10 CTL, 4 CNC). The abundance of the species is recorded every three weeks from April to October along transects (250 m / 25 min). In addition, various habitat parameters are determined to characterize the landscapes.

In 2013, we recorded 297 bumblebees from 5 species. In 2014 we found at least 4 additional species. The most dominant bee-species were *Bombus lucorum* (n = 109), *B. lapidarius* (n = 94) and *B. pascuorum* (n = 87). These are all euryoecious species. With increasing density of flowering plants, we observed an increase in the number of bumblebees. This is mainly due to the abundance of the long distance foraging *B. lucorum* and *B. lapidarius* that require an abundant offer of suitable flowering plants. This offer is provided by the AEM-grasslands with a mass flower of clover (*Trifolium* spec.) in June and July. However, the number of bee species tends to increase on the extensively used grasslands (AEM, CNC). This effect is stronger in the Süderbergland than in the Eifel.

The preliminary results indicate a minor influence of the Agri-Environmental-Measure on the composition of bumblebee communities. Based on the results, suggestions on the evaluation and improvement of the Agri-Environmental-Measure "Extensification of Grassland" will be made.

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Pollinator attraction in the sexually deceptive orchid *Ophrys leochroma*

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The flowers of the genus *Ophrys* mimic the sex-pheromones of virgin females of their pollinators and thereby attract males, which attempt to copulate with the flower labellum, for pollination. In general each *Ophrys* species attracts only one pollinator species through visual and species-specific chemical cues. This specific relationship is the main mechanism of reproductive isolation. Previous studies on pollinator attraction in *Ophrys* flowers revealed that only certain compounds in the odor bouquets are responsible for eliciting pseudocopulation in the males. These studies have mainly been performed with *Andrena* pollinated *Ophrys* species where mixtures of saturated and unsaturated hydrocarbons do play a role in pollinator attraction. To gain further insight on pollinator attraction in other non-*Andrena* pollinated *Ophrys* taxa we are investigating how long-horned bee pollinated *Ophrys* species attract their pollinators.

The *O. tenthredinifera* complex occurs over the whole Mediterranean region and comprises 12 closely related species. In former studies it was shown that *O. dimidiata* flowers and virgin females of *Eucera dimidiata* attract males with polar compounds that can be found on the cuticle surface of virgin females and in labellum extracts of flowers. The aim of our investigations was to study in a further *Ophrys*-system which compounds of *O. leochroma* play a role for male attraction of their pollinator *E. kullenbergii*.

We collected odor samples of virgin females and of orchid flowers that were used to perform chemical (gas chromatography, mass spectrometry (GC-MS)) and electrophysiological (gas chromatography with electroantennographic detection (GC-EAD)) analyses and behavioral experiments. The field work was performed during the blooming season of *O. leochroma* in March of 2013 and 2014 in Neapoli (Crete, Greece). In chemical analyses we found 132 chemical compounds in the surface extracts of virgin females of *E. kullenbergii* and 108 chemical compounds in the labellum extracts of *O. leochroma*. By GC-MS we identified straight chain alkanes and alkenes with 11-32 carbon atoms. In electroantennographic analyses we found 9 electrophysiologically active compounds in female surface extracts and 18 electrophysiologically active compounds in the labellum extracts that released reactions in the male antennae. They were identified as aldehydes, furthermore benzyl alcohol, octanol and dodecanoic acid. In addition we identified hydrocarbons. Some of the compounds occurred in common in orchids and female bees.

In bioassays that we performed with surface extracts of virgin females, labellum extracts, polar and unipolar fractions and synthetic mixtures of GC-EAD active compounds we found that polar fractions of female surface extract and labellum extract elicited significantly higher number of male reactions, amongst them pseudocopulatory attempt with the dummy bee than the solvent control. The synthetic mixtures consisting of electrophysiologically active compounds of female and flower extracts released in males approaches and pouncing, however, no pseudocopulatory attempts. The reason therefore could be

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that some compounds are still missing in the mixture as was shown in further electrophysiological analyses. Further behavioral experiments are necessary to test a more complete synthetic mixture of the GC-EAD active compounds.

In summary our results show that polar compounds do play a role in *Eucera* pollinated *Ophrys* species of the *O. tenthredinifera* complex. Additional research is needed to understand how they contribute to premating isolation in these orchid species.

Antennal sensitivity to floral scents of *Campanula*: A comparative study of polylectic and oligolectic bees

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The pollen diet provided by bees to their offspring varies greatly. While some species collect pollen on several plants irrespective to their phylogenetic relatedness (polyleges), others collect pollen only on plants within a genus or family (oligoleges). Floral scents play a central role in any bee-plant interaction. To locate flowers, polylectic bees are assumed to rely on compounds commonly found as floral scent constituents. Oligolectic bees, on the other hand, might rely on unusual compounds to recognize unambiguously host flowers. *Campanula* flowers are visited by polylectic and oligolectic bees, and their flower scent bouquets are composed of both typical and unusual compounds (i.e. spiroacetals). In this scenario, we hypothesized that: 1) Oligoleges and polyleges respond similarly to typical flower volatiles; 2) *Campanula* oligoleges are highly sensitive to *Campanula* specific compounds, whereas species that are not specialized on *Campanula* are not, and 3) *Campanula*-specialists are more sensitive to the floral scent bouquet of *Campanula* than the other species. In order to compare the antennal sensitivity to flower volatiles of *Campanula* spp., we performed electroantennographic analyses (EAG) with three *Campanula* oligoleges (i.e. *Chelostoma rapunculi*, *C. campanularum*, and *Osmia mitis*), two polylectic bees (*Bombus terrestris* and *Andrena bicolor*), and one *Ranunculus oligolege* (*C. florisomne*). We tested typical flower volatiles, i.e. 2-phenylethanol, linalool and (E)-ß-ocimene (common in *Campanula* species too), and five spiroacetals at four different concentrations. Additionally, we tested headspace samples of *R. acris* and *C. trachelium*. The results show that the antennal sensitivity to the typical flower scent compounds was similar among pollen diets. In contrast, the sensitivity to the unusual spiroacetals was significantly higher in *Campanula*-specialists in comparison to polylectic species, but not to *Ranunculus*-specialist *C. florisomne*. In terms of sensitivity of individual species to the different compounds, we found that 2-phenylethanol, linalool and (E)-ß-ocimene are perceived by most of the species at concentrations of 10-7 (100 µg/L). In the case of spiroacetals, *Campanula*-specialist, as well as *Ranunculus*-specialist, were able to detect concentrations as low as 10-9 (1 µg/L), whereas polylectic species either did not detect (*B. terrestris*) or only detected them in high concentrations of 10-3 (100 mg/L; *A. bicolor*). Finally, we found that antennal responses of *Campanula*-specialists are stronger to headspace samples of their host flowers compared to polylectic species, but not to *C. florisom-*

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ne. The results indicate that *Campanula oligoleges* evolved highly sensitive receptors for specific scents of their host flowers. Newly-emerged females of *C. rapunculi* are known to use spiroacetals for host-flower recognition and our results strongly indicate that this might also be true for other *Campanula*-oligoleges. The impressively high sensitivity to spiroacetals might help bees to locate and recognize host flowers even from great distances. The study also shows that polylectic bees, which are not that selective in pollen diet, possess olfactory receptors that signalize flowers as a whole. In contrast to our hypothesis, we found that the *Ranunculus* oligolege *C. florisomne* is as sensitive as *Campanula* oligoleges towards spiroacetals. Since *C. florisomne* shares common *Campanula*-specialist ancestors with the two other *Chelostoma* species investigated here, we believe that the receptors for spiroacetals would be a pleisiomorphic trait. Altogether, these results have a strong significance in the evolution of pollen diet among bees.

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Untersuchungen zur Attraktivität von mit Leuchtfarben lackierten Farbschalen

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UV-reflektierende Farben werden als besonders attraktiv für Hymenopteren beschrieben (Droege 2006, Stephen und Rao 2005) und für den Einsatz beim Fang mit Farbschalen empfohlen. Westphal et al. (2008) benutzen Leuchtfarben der Marke Spavar um im UV-reflektierende Farbschalen zu erhalten und Schindler et al. (2013) empfehlen ebenfalls die Verwendung dieser Farben.

Bei den durchgeführten Untersuchungen wurde die Attraktivität von mit Spavar Leuchtfarben (Spavar 3107 Leuchtblau, Spavar 3104 Leuchtgelb und Spavar 3108 Leuchtweiß, Spray – Color GmbH, Merzenich, Deutschland) lackierten Farbschalen mit der von mit RAL Farben (1021 Rapsgelb, 9010 Reinweiß und 5010 Enzianblau) versehenen Farbschalen verglichen und die Reflexion der Farben mit einem Reflexionsmessgerät (USB 4000 Ocean Optics GmbH, Ostfildern, Deutschland) gemessen (Abb. 1).

Nach unserer Definition beschreibt der Begriff „UV-reflektierend“ eine Farbe, welche Licht im Wellenlängenbereich von etwa 100-380 nm reflektiert. Bei keiner der verwendeten Sprühfarben konnte eine Reflexion im UV-Bereich gemessen werden. Die Leuchtfarben unterscheiden sich von den RAL Farben vor allem durch eine mehr als 100%ige Reflexion im sichtbaren Bereich und verstärken so die Reflexion des sichtbaren Farbtons. Dies deutet darauf hin, dass die Leuchtfarben fluoreszierende Eigenschaften besitzen; UV-Licht wird also von den Leuchtfarben nicht reflektiert, sondern absorbiert und in einem höheren Wellenlängenbereich wieder emittiert.

An zwei Standorten im Botanischen Garten der Heinrich-Heine-Universität Düsseldorf wurden die Sets an 4 Untersuchungstagen im Juni 2014 vergleichend getestet. Hierzu wurden sie mit Wasser und einem Tropfen Tween (Polysorbat 20) als Detergenz gefüllt und in Höhe des Blütenhorizontes aufgestellt. Um Wechselwirkungen zwischen den Farb-

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schalen zu unterbinden, wurden die Außenseiten der Farbschalen mattschwarz lackiert und zwischen den einzelnen Farbschalen ein Mindestabstand von 5 m eingehalten (Droege et al. 2010). In Intervallen von 30 Minuten fand eine Kontrolle der Schalen statt. Dabei wurden die gefangenen Insekten entnommen, determiniert und nach erfolgter Trocknung wieder frei gelassen.

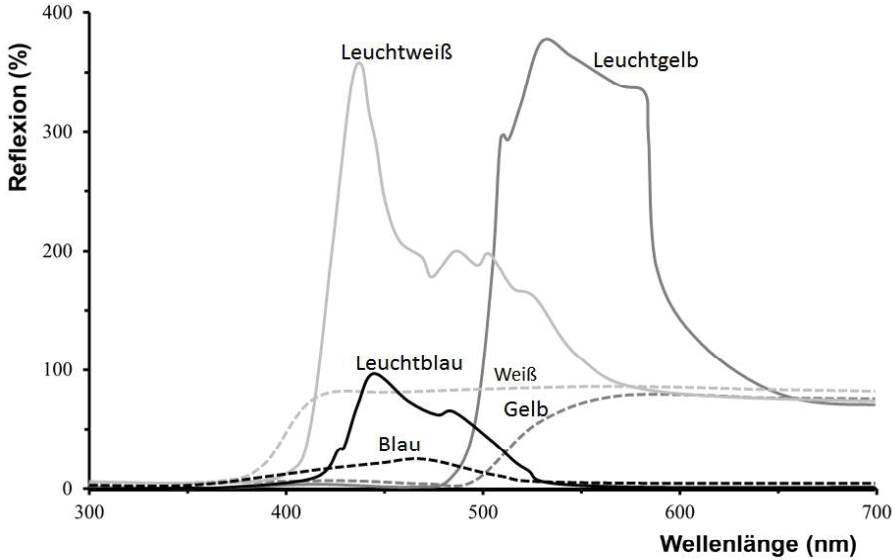

Abb. 1: Spektrale Reflexion der getesteten Farben im Vergleich zu Bariumsulfat als Weißstandard.

Die mit Leuchtfarben lackierten Farbschalen waren in unserem Versuch attraktiver für Bienen und Dipteren als die mit RAL Farben lackierten Farbschalen. Am deutlichsten unterschieden sich die Fängigkeit von Gelb und Leuchtgelb, gefolgt von Weiß und Leuchtweiß. Zwischen der Fängigkeit von Blau und Leuchtblau konnte kein signifikanter Unterschied nachgewiesen werden. Leuchtgelb und Gelb unterscheiden sich auch am deutlichsten, Leuchtblau und Blau hingegen am wenigsten in ihrer Intensität (Abb. 1). Die Attraktivität einer Leuchtfarbe im Vergleich zur jeweiligen Nichtleuchtfarbe war also umso größer, je größer der Unterschied in der Farbintensität war. Der Gebrauch von mit Leuchtfarben lackierten Farbschalen führte in unserem Versuch zu einer signifikanten Erhöhung der Anzahl der gefangenen Hymenopteren und wird empfohlen.

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Die Bedeutung von Blütensignalen bei der Wirtspflanzenerkennung der Sandbiene *Andrena bicolor*

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Oligolektische Bienenarten sammeln ihren Pollen und Nektar nur auf wenigen Pflanzenarten, die nahe miteinander verwandt sind. Um ihr enges Spektrum an Wirtspflanzen zu erkennen sind sie auf spezifische Blütensignale angewiesen, die nur diese Pflanzen besitzen. Diese können sowohl visueller als auch olfaktorischer Art sein. In dieser Arbeit wurde untersucht, auf welche Blütensignale die bivoltine Sandbiene *Andrena bicolor*, deren zweite Generation vornehmlich auf *Campanula* sammelt, reagiert. Hierzu wurden zwei-Wahl Experimente mit blütennaiven als auch mit blütenerfahrenen Bienen der ersten und zweiten Generation mit *Taraxacum officinale* und *Campanula trachelium* durchgeführt, wobei visuelle oder olfaktorische Signale einzeln und in Kombination getestet wurden. Des Weiteren wurden chemische und elektroantennographische Analysen mit Headspaceproben von Blüten beider Pflanzenarten durchgeführt. Die Ergebnisse von Wahlexperimenten zeigten, dass *A. bicolor* Weibchen hauptsächlich auf visuelle oder eine Kombination aus visuellen und olfaktorischen Signalen reagieren, wobei keine Bevorzugung von *C. trachelium* gegenüber *T. officinale* vorhanden ist. Die elektroantennographischen Analysen ergaben, dass *A. bicolor* auf Verbindungen die sehr häufig als Blütenduftstoff zu finden sind (e.g. trans-β-Ocimen, Linalool, 2-Phenylethylacetat) aber nicht auf *Campanula* spezifische Duftstoffe (z.B. Spiroacetale) reagiert. Unsere Ergebnisse sprechen dafür, dass *A. bicolor* nicht auf *Campanula* Blüten spezialisiert ist. Die bislang vorlegenden Veröffentlichungen zur Oligektie von *A. bicolor* beruhen lediglich auf Feldbeobachtung. Der Grund dafür, dass *A. bicolor* Weibchen der zweiten Generation häufig auf Glockenblumen beobachtet wurden, könnte daran liegen, dass diese blühen, wenn die Flugaktivität der Weibchen beginnt, und dass sie große Mengen an leicht zugänglichem Pollen bzw. Nektar bieten.

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Using bumblebee chemical footprints to assess flower visitation in the field

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For the past decades abundance and diversity of wild pollinator species was declining for reasons mostly unknown. Intensification of land use and competition with domestic honeybees are suspected stressors that have the potential to influence the resource availability for a wide range of flower visitors.

We investigated how these two stressors may affect wild bumblebees, *Bombus*, on 46 grassland plots (Swabian Alb, Germany) in the Biodiversity Exploratories project. Plots were chosen to represent a land-use gradient and differed in honeybee abundance. Abundance and floral resource use of bumblebees were measured via two different methods. We conventionally conducted censuses of foraging bees along flower transects (three times per plot). Additionally, we extracted (with hexane) and quantified (by GC/MS) long-chain cuticular hydrocarbon (CHC) deposits ("footprints") of bumblebees on flowers. Such CHCs remain on flowers in near-unchanged quantities for up to 48h and thus present a cumulative measure of bumblebee visitation (Witjes and Eltz, Journal of Chemical Ecology 35: 1320-1325). This method allows collecting large numbers of samples quickly at the end of a day.

A first analysis of census data showed a negative correlation between honeybee abundance or land-use intensity and the proportion of visits by bumblebees to bumblebee-attractive plant species. Currently, chemical footprint samples are being analysed, and we will investigate whether CHC footprints lead to similar answers concerning honeybee abundance and land-use intensity. Using both methods will allow us to evaluate and compare the two methods. This will help us to assess the influence the two stressors have on wild pollinators.

Die Rolle von *Wolbachia* bei der reproduktiven Isolation der Erzwespe *Lariophagus distinguendus*

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Die Mechanismen der ökologischen Artbildung sind vielfältig und nach wie vor heiß diskutiert. Die Lagererzwespe *Lariophagus distinguendus* (Pteromalidae) eignet sich durch ihre hohe Nachkommenzahl bei gleichzeitig kurzem Generationszyklus besonders gut zur Untersuchung von Artbildungsprozessen. Die parasitoide Wespe, die auch zur Schädlingsbekämpfung eingesetzt wird, gilt als Generalist und verschiedene Käferlarven dienen ihr als Wirt.

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In früheren Studien konnte festgestellt werden, dass bei *L. distinguendus* eine Auftrennung der Arten bereits begonnen hat und unterschiedliche Wirtsrassen existieren. So entwickeln sich die beiden Stämme Ravensburg (RAV) und Pforzheim (PFO) an unterschiedlichen Wirten: RAV bevorzugt die Larven des Brotkäfers *Stegobium paniceum* als Wirte, PFO parasitiert v.a. die Larven des Kornkäfers *Sitophilus granarius*. Es ist bereits bekannt, dass zwischen den beiden Stämmen eine teilweise bzw. vollständige reproduktive Isolation existiert, jedoch sind die Mechanismen unklar. Als möglicher Mechanismus für sympatrische Artbildung wird bei Insekten die Infektion mit Bakterien der Gattung *Wolbachia* diskutiert. Ungefähr ein Fünftel der Insekten ist von *Wolbachia* befallen und es ist bekannt, dass diese Bakterien in die Reproduktion ihrer Wirte eingreifen. Unter anderem kann es bei den Wirtsinsekten zu Parthenogenese, Feminisation und dem Absterben männlicher Nachkommen kommen. *Wolbachia* ist außerdem für das Phänomen der cytoplasmatischen Inkompabilität (CI) verantwortlich, bei der die paternalen Chromosomen nach der Fertilisation verloren gehen, was bei haplodiploiden Organismen zu ausschließlich männlichen Nachkommen führt.

Um zu untersuchen, ob *Wolbachia* und cytoplasmatische Inkompabilität eine Rolle bei der reproduktiven Isolation zwischen den beiden *L. distinguendus* Stämmen PFO und RAV spielen und damit zur Artaufspaltung beitragen, wurden die Wespen mit Antibiotika (Tetracyclin) behandelt und Kreuzpaarungen durchgeführt. Dabei stellte sich unter anderem heraus, dass RAV Weibchen auch nach einer Behandlung mit Antibiotika keine weiblichen Nachkommen mit behandelten PFO Männchen zeugen, während dies bei behandelten PFO Weibchen mit behandelten RAV Männchen möglich ist. *Wolbachia* Bakterien scheinen daher einen Einfluss auf die Isolation zwischen den beiden Stämmen zu haben. Allerdings müssen noch weitere Mechanismen existieren, die eine erfolgreiche Fortpflanzung zwischen RAV Weibchen und PFO Männchen verhindern. Durch molekulare Untersuchungen der in den verschiedenen Stämmen vorhandenen Bakterien soll in naher Zukunft ein Überblick über die *Wolbachia* Prävalenz bei *L. distinguendus* gewonnen werden und die Rolle der Bakterien bei der Artbildung geklärt werden.

Pollen schützt sich mit Stacheln vor dem Sammeln durch corbiculate Bienen

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An Blüten von Stockrosen kann man beobachten, dass Honigbienen und Hummeln den in großer Dichte am Körper anhaftenden Pollen bei der Umlagerung in die Corbiculae verlieren, so dass sich in und unter den Blüten große Mengen an Pollen ansammeln. Pollen der Stockrose *Alcea rosea* ist recht groß mit einem Durchmesser von 123.47 ± 4.32 µm (n = 11) und weist im Unterschied zu vielen anderen Pollenkörnern Stacheln auf. Die durchschnittliche Anzahl der Stacheln pro Pollenkorn beträgt 153 ± 18 und die durchschnittliche Länge der Stacheln beträgt 11.81 ± 0.58 µm wie anhand von lichtmikroskopischen Aufnahmen ermittelt wurde. Mittels licht-und rasterelektronen-mikroskopischer Aufnahmen an

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Stockrosen- und Hibiskus-Pollen konnte gezeigt werden, dass die Stacheln im Unterschied zum Rest der Pollenkörner nicht mit Pollenkitt bedeckt sind.

In Laborversuchen haben wir die Hypothesen getestet, dass der Pollen giftig ist oder Bitterstoffe enthält, die die Bienen veranlassen, ihn nicht zu sammeln, oder dass der Pollen durch mechanische Eigenschaften geschützt ist vor dem Sammeln durch diese Bienen. Für die Versuche wurde Stockrosenpollen unterschiedlich manipuliert; einerseits wurde durch Waschen in n-Hexan der Pollenkitt entfernt, andererseits wurde durch 30-minütiges Vortexen zusammen mit einem Plasikkügelchen die Stacheln abgebogen; als Kontrolle wurde natürlicher, von Hand gesammelter Pollen getestet. Die Chemische-Abwehr-Hypothese nimmt an, dass Pollen mit Pollenkitt, wo toxische Inhaltsstoffe vermutet werden, nicht gesammelt wird, Pollen ohne Pollenkitt dagegen schon. Die Mechanische-Abwehr-Hypothese nimmt an, dass das Abbiegen der Stacheln ausreicht, um den Pollen für Bienen nicht sammelbar zu machen. In den Versuchen wurde nicht-manipulierter und manipulierter Pollen der Stockrose in Pipetten-Spitzen eingefüllt und zur Verbesserung der Attraktivität zusammen mit Blüten ohne Staubgefäße in einem Flugkäfig Arbeiterinnen der Dunklen Erdhummeln (*Bombus terrestris*) angeboten. Die 10 getesteten Hummeln buzzten die Blütenattrappen, aber sammelten natürlichen Pollen der Stockrose nicht, dagegen sowohl Pollen mit abgebogenen Stacheln als auch Pollen ohne Pollenkitt. In einem weiteren Kontrollexperiment wurde mit Bitterstoffen (Chininsulfat) versehener Kiefer-Pollen (*Pinus mugo*) zunächst gesammelt, aber dann meist wieder abgestreift. Zusatzversuche zeigten, dass Hummeln sogar chemisch inerte Pollensurrogate wie Glaspulver sammeln und legen nahe, dass das Fehlen von Lockstoffen im Stockrosen-Pollen nicht die Ursache dafür sein kann, dass er von corbiculaten Bienen nicht gesammelt wird.

Die Ergebnisse zeigen, dass Stacheln von Pollen einen mechanischen Schutz vor dem Sammeln durch corbiculate Bienen bieten, da diese ihn nicht in den Höschen kompaktieren können. Die Befunde lassen sich gut Beobachtungen von oligolektischen Bienen an Malven und anderen Blüten mit stacheligem Pollen zuordnen, die Pollenkörner in einer lockeren Beinbehaarung oder mit dem gesamten Körper ins Nest transportieren. Wir vermuten, dass Interaktionen zwischen dem hydrophoben Pollenkitt und den Pollenkitt-freien Stacheln dazu führen, dass der Pollen sich nicht für den Transport in den Corbiculae verstauen lässt. Weitere Experimente sollen zeigen, ob Blütenpflanzen stacheligen Pollen gezielt einsetzen, um corbiculate Bienen zum Verzicht auf das Pollensammeln zu bewegen. Zudem soll die Rolle regurgitierten Nektars beim Sammeln von stacheligem Pollen näher untersucht werden.

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The energy plant *Silphium perfoliatum* L. (Asteraceae) as a late pollen resource for the honey bee *Apis mellifera* L.

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Pollen is an essential protein resource for the nutrition of the honey bee *Apis mellifera* L., especially for the larval diet (Crane 1990). Malnourishment is considered to be one of the reasons for the so-called Colony Collapse Disorder that could be observed in the last decades in North America and Europe (Staveley et al. 2013). Not only the quantitative amount of food, but also the quality of pollen is important for bee health (Di Pasquale et al. 2013). Reasons for food shortage are the decline of semi-natural habitats and agricultural intensification (Decourtye et al. 2010). Cultivation of energy crops was recently criticized to aggravate this problem (BfN 2009). Measures to make agricultural production more bee-friendly are the implementation of flower strips and the use of bee pastures (Decourtye et al. 2010). In that context, the cup plant *Silphium perfoliatum* L. (Asteraceae) is under consideration to diversify the production of energy plants for biogas. The flowering period of *S. perfoliatum* extends to the late growing season from July to September. It could therefore be a valuable pollen resource for the brood-rearing of winter bees. The aim of our present study is to quantify the amount of pollen produced by *S. perfoliatum* as well as to survey to what extent the pollen is used by honey bees.

In 2012 we collected samples for pollen analyses of *S. perfoliatum* that was planted in 2010 at the experimental site of the TLLat Dornburg. Withal, we differentiated between the degree of stem branching (termed 2nd, 3rd and 4th order), omitting the main branch (1st order). 20 inflorescences per order from individual plants were used to count the number of disk florets (staminate) and ray florets (pistillate) per inflorescence. 10 of these inflorescences were randomly selected for quantitative analyses of pollen using a haemocytometer (c.f. Dafni 2005, modified). Each sample consisted of the pollen from 5 disk floretsin 100µL deionised water. Pollen production of the different orders of stem branching was compared using analysis of variance (one-way ANOVA, beforehand Levene's test for homogeneity of variance) and Bonferroni post-hoc test. Calculations were done with R (version 3.1.0, R Development Core Team 2014).

In the same year we analysed the pollen foraging of honey bees at 5 different sites in Lower Saxony (rural districts of Emsland, Osnabrück, Verden, Stade, Region Hannover). Pollen was collected from bee hives which were placed at the margins of *S. perfoliatum* fields planted in 2011, using pollen traps over a period of 2 days per record. 1-3 records were realized during the flowering period. Analyses were conducted according to Vergara Lopez et al. 2013 (modified). Pollen of the tribe Heliantheae (*Silphium* and *Helianthus*) as well as all other pollen with a weight portion >3% were determined to species or genus level or classified to types.

S. perfoliatum produced on average 15,800 pollen per disk floret (n=30) and 134 disk florets per inflorescence (n=60).The number of pollen per disk florets in the 2nd order was significantly higher than in the 3rd ($p < 0.05$) and 4th ($p < 0.01$) order. The number of disk florets per inflorescence did not vary significantly between orders. At the experimental site

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Dornburg the cup plant developed on average 49 inflorescences per stem (n=90, 6-106) and 14 stems per plant (n=90, 8-32). Pollen-ovule ratio within an inflorescence was about 85,000:1.

Foraging behavior of honey bees varied strongly between sites and records. Weight portion of pollen from the Heliantheae was on average 21% (n=12, 1-55%). Other major pollen resources originated either from semi-natural habitats or agricultural crops or both: E.g., pollen of the *Sinapis*-Typ was found in two sitesin the 3rd record (84 and 94%), indicating that fields with this type of green manure were close by. At another site *Echium* and *Phacelia* represented 28% of the pollen each, indicating the presence of flower strips as agri-environmental scheme. In contrast, in 5 records out of 3 sites *Calluna vulgaris* was the dominant pollen type. Here, heather was found within a distance of 3km, partly in areas under nature conservation.

The results show that *S. perfoliatum* could be a valuable supplement to existing pollen resources for honey bees, but they also show that the cup plant might be less attractive in comparison to other mass-flowering plants, irrespective of being agricultural or wild plants.

In further studies, we will quantify the pollen production of more branching degrees (5th and 6th order). Qualitative analyses of the pollen will follow. Moreover, we are going to examine samples from bee hives that were placed at a distance of about 500m from the fields of *S. perfoliatum*.

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Blühflächen für Wildbienen – Welche Mischung und welche Pflege soll es sein?

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Um dem Verlust der Biodiversität in den Europäischen Agrarlandschaften entgegen zu wirken, wurden in verschiedenen Ländern Agrar-Umweltprogramme ins Leben gerufen. In diesem Rahmen wird in Österreich die Anlage und Pflege von „Nützlings- und Blühstreifen", „Biodiversitätsflächen" oder „Bienenweiden" gefördert. Ziel dieser Studie ist es, unterschiedliche Ansaat-Mischungen und verschiedene Pflegemaßnahmen in Hinblick auf eine Optimierung dieser Flächen als Lebensraum für Wildbienen zu vergleichen.

Im niederösterreichischen Marchfeld, einem intensiven Ackerbaugebiet, wurde dazu in einem Versuch, der 2009 angelegt wurde, eine landwirtschaftlich übliche „Wildäsungsmischung" (10 Pflanzenarten wie zum Beispiel Klee-Arten, *Phacelia*, Sonnenblume) mit einer „Blühmischung" (87 autochthonen Wildkrautarten) verglichen (n=8). Außerdem wurde auf Flächen, auf denen 2007 eine „Blühmischung" angesät wurde, 2011 ein Pflegeversuch mit den Varianten „Bodenbearbeitung mit Scheibenegge", „Bodenbearbeitung mit Scheibenegge und Nachsaat" und „keine Bearbeitung" durchgeführt (n=4). Die Wildbienen wurden an jeweils sieben Tagen zwischen Mitte April und Ende September in den Untersuchungsjahren 2012-2013 entlang von Transekten erfasst. Zusätzlich wurde die Vegetation nach der Methode von Braun-Blanquet erhoben.

Der Vergleich der beiden Mischungen zeigte in beiden Jahren einen signifikanten Unterschied der Individuenhäufigkeiten der Wildbienen zu Gunsten der „Blühmischung". Der Vergleich der Artenzahlen unterschied sich erst im zweiten Untersuchungsjahr signifikant. Als verantwortlich für das bessere Abschneiden der „Blühmischung" zeigte sich die signifikant höhere Pflanzenartenzahl mit einem hohen Blütenreichtum, der für die Blühmischung bis in den September hinein prägend war.

Beim Bearbeitungsversuch zeigte die Auswertung der Wildbienen in beiden Jahren keine signifikanten Unterschiede. Tendenziell niedrigere Werte der Bienenartenzahlen und Häufigkeiten der Variante „ohne Bodenbearbeitung" spiegelt eine signifikant höhere Deckung mit konkurrenzstarken Pflanzen (vorwiegend *Calamagrostis epigejos*), die eine Reduktion des Blütenreichtums mit sich brachte, wieder.

Die Ergebnisse zeigen die Bedeutung artenreicher Ansaatmischungen und von Pflegevarianten, die zumindest einen teilweisen Neustart der Blühflächen nach einigen Jahren mit sich bringen, für die Förderung von Wildbienen.

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Intraspecific and interspecific competition in the parasitoid wasp *Nasonia vitripennis*

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The ectoparasitoid wasp *Nasonia vitripennis* is an emerging model organism for various fields of research. Among others, it is used for evolutionary and behavioral studies. To learn more about the discrimination behavior of *N. vitripennis*, the present study focuses on intra- and interspecific competition.

Wildtype *Nasonia vitripennis* which were collected from baits on carrion in the park of Hohenheim (Stuttgart, Germany) were offered host pupae of the blow-fly *Lucilia sericata* parasitized by competitors one day or four days before. A red-eyed mutant strain (STDR) of *N. vitripennis* served as intraspecific competitor and the gregarious ectoparasitoid wasp *Dibrachys cavus* which was collected in the same location was used as interspecific competitor. One parasitized and one unparasitized host pupa were presented to one female wt-*N. vitripennis* and the location of the test female was checked every 15 minutes for a duration of 6 hours. While wildtype *N. vitripennis* females showed significant discrimination against host pupae parasitized by conspecifics, no significant avoidance could be found of host pupae parasitized by *D. cavus* females.

Additional tests were performed to investigate the oviposition behavior under direct competition in a confined space. For these tests the competing wasp (STDR-*N. vitripennis* or *D. cavus*) was placed in a 1 ml Eppendorf tube with one host pupa for 24 hours. One and four days later, one wildtype *N. vitripennis* female was placed in the same tube for 24 hours. Host pupae were dissected right after oviposition to check for the number of eggs and newly hatched larvae, and four days after oviposition to check for the number of older larvae. In addition, the number of emerged adult wasps was counted after 25 days. While significantly less eggs were laid by wt-*N.vitripennis* on pupae parasitized by conspecifics four days before, no significant reduction of eggs was found on pupae parasitized by *D. cavus*. Four days after oviposition of the second female, a significant reduction was found in the over all number of larvae as compared to the controls under conditions of intraspecific and interspecific competition. The number of emerging adults was likewise reduced in *N. vitripennis* in intraspecific competition. In contrast, interspecific competition lead to a significant reduction of both wasp species when *N. vitripennis* was allowed to parasitize one day after *D. cavus*. Parasitization of *N. vitripennis* four days after *D. cavus* had no significant effect on the offspring of *D. cavus*, but significantly reduced the offspring number in *N. vitripennis*.

Taken together, these results indicate that *N. vitripennis* is able to discriminate against hosts previously parasitized by conspecific females but not against hosts parasitized by heterospecific females. It is discussed that discrimination of hosts parasitized by conspecifics is enabled by chemical cues.

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How do bumblebees assess the protein content of pollen?

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Besides fat and carbohydrates, protein represents one of the most important macronutrients for bees. It is exclusively obtained from floral pollen and serves as a source for amino acids which are used for the individual's own protein biosynthesis. As both excessive and deficient amounts of protein are detrimental to bees, they should be able to assess the protein content of pollen of different plant species to guarantee an optimal protein supply for themselves as well as their brood. Assessment could be achieved either at the individual or (in the case of social bees) at the colony level. However, it is yet unknown whether or how bees can assess the protein content of pollen.

In this study, we examined whether, and if so, how individuals of the buff-tailed bumblebee (*Bombus terrestris*) do perceive the protein content of food. Therefore, bumblebees were trained using PER conditioning in an olfactory and chemotactile setup using unwashed and washed pollen as well as the milk protein casein. In an absolute conditioning experiment, we tested whether the bees could generally perceive the tested substances. In a subsequent differential conditioning approach, we investigated their ability to discriminate between different substances as well as different concentrations of these substances.

Both casein and pollen could be learned and thus be perceived by bumblebees. They were further able to discriminate between casein and pollen in the olfactory setup, but failed to discriminate different concentrations of the same substances. However, when the bees could touch the substances with their antennae they could also discriminate between different concentrations. Bumblebees are thus able to discriminate between different protein concentrations using contact chemosensory perception, which enables them to individually regulate protein intake.

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Horizontal transfer of *Wolbachia* in bees (Anthophila)

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Wolbachia is an alpha-proteobacterium which occurs in many groups of arthropods and in filarial nematodes. The bacteria can enhance their vertical spread (mother to offspring) through different manipulation mechanisms, e.g. male killing, feminization or cytoplasmic incompatibility. Similar strains of *Wolbachia* can appear in quite different animal taxa and distantly related *Wolbachia* strains might be found in the same taxon. This observation suggests frequent horizontal transmissions of *Wolbachia* between host taxa. However, the mechanisms of such a transfer are so far not understood.

In this study, we aim to investigate a potential way for horizontal *Wolbachia* transfer through oral uptake of infected pollen by larvae of the solitary bee *Osmia bicornis* (red mason bee). This common bee is naturally *Wolbachia* free and uses pre-existing hollows for nesting. By providing prepared reed (*Phragmites*) to a large population of mason bees, we were able to collect around 2,000 nest chambers of *Osmia bicornis*. Half of these chambers were infected by adding a *Wolbachia* suspension to the pollen. During the summer months the nests were stored, in order to enable normal development of the larvae. Cells containing cocoons were opened and the adult bees have checked for the presence of *Wolbachia* bacteria by PCR. Furthermore, *Wolbachia* specific antibodies and CLSM (confocal laser scanning microscopy) are used to localize potential *Wolbachia* cells in invaded host cells.

The influence of protein quality in diets on individual bumblebees and colonies

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Pollination by bumblebees plays a major role in natural ecosystems and agricultural landscapes. Hence, the observed decline of these pollinators is alerting. Little is known about the causes of this decline, but it is likely correlated with the changing availability of flowering plants and thus food availability caused by land-use intensification. Recent studies demonstrated that longevity, immune-activity and fitness of bumble bee colonies are influenced by food quality. Furthermore bumblebees collect pollen of significantly higher protein content than honeybees. However, little is known about the optimal nutrient ratio (e.g. protein to carbohydrate ratio, P:C) for bumblebees or about potential consequences of deviations from this ratio.

We fed worker groups of 10 animals (“micro colonies”) and queen-right colonies with brood (“macro colonies”) of the buff-tailed bumblebee (*Bombus terrestris*) with different protein-carbohydrate-concentrations, to investigate the preferred P:C ratio. Protein was

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provided as pollen, the milk protein casein or amino acids. Carbohydrates were provided as sucrose. The preferred P:C ratio selected by bumblebees was examined in two-choice experiments. Colonies were allowed to select between two different protein concentrations. In a second experiment, we tested how specific P:C ratios affect longevity and breeding behavior. In part of the experiments, we used cellulose as surrogate to standardize food consistency of different P:C concentrations. In of the other experiments, colonies were fed pure pollen-sucrose-blends without cellulose. In the first set of experiments, colonies preferred food with a high protein content. Furthermore, workers' survival increased with protein content. However, cellulose seemed to have a negative effect on *B. terrestris*. Colonies fed with food containing cellulose, all larvae died within 10 days, indicating that cellulose is an unsuitable surrogate for bumblebees. In the second set of experiments, colonies preferred a P:C ratio of approximately 1:8. We observed only minor deviations from this ratio in our experiments, suggesting that bumblebees adapt their foraging behavior to achieve a P:C ratio that is optimal for their colonies.

Longevity, nesting and breeding behavior of workers in micro colonies also increased with an increased pollen-/protein-content. Survival of individuals fed with casein was lower compared to individuals fed with pollen. Survival was lowest when fed a diet of pure sucrose. Consequently, a balanced protein to carbohydrate ratio as well as an adequate amount of protein is essential for both adult bumblebees and entire colonies.

First description of the queen of *Solenopsis saudiensis* Sharaf & Aldawood (Hymenoptera: Formicidae) with a key to species of Saudi Arabia based on queen caste

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Abstract
The queen of *Solenopsis saudiensis* Sharaf & Aldawood 2011 is described for the first time from Riyadh, Kingdom of Saudi Arabia. A key to the two Saudi Arabian species of the genus is presented based on the queen caste. This key is the first for Arabian ants based on queens. Some ecological and biological notes are also given.

Keywords
Arabian Peninsula, Middle East, Palearctic region, date palm, taxonomy, ants.

Introduction
Solenopsis Westwood, 1840 is one of the largest ant genera in the subfamily Myrmicinae including 193 species (Bolton 2013), distributed worldwide in tropics and warm temperate regions (Brown 2000, Guénard *et al.* 2010). Workers of the genus *Solenopsis* can be recognized by the characters mentioned by Ettershank (1966), Bolton (1994), Sharaf *et al.* (2009) and Sharaf & Aldawood (2012).The queen character states follow the definitions of Ettershank (1966) & Bolton (1994): Larger than the conspecific worker. Antennae frequently 11-segmented, less often 10-segmented, with a 2-segmented club and, usually, one more antennomere than their workers; head of generalized form; propodeum strongly

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rounded; petiole node broader than in the worker; postpetiole broadly attached to the gaster.

The first contribution on the Arabian *Solenopsis* was published by Collingwood & Agosti (1996) describing three species, *S. omana* from Oman and *S. sumara* and *S. zingibara* from Yemen. A year later, *Solenopsis geminata* (Fabricius, 1804) was reported from the UAE (Collingwood *et al*., 1997). The genus was recorded for the first time from Kingdom of Saudi Arabia (KSA) (Sharaf & Aldawood 2011) by the species *S. saudiensis* from Riyadh region based on worker caste. Recently, the genus was revised for the Arabian Peninsula (Sharaf & Aldawood 2012) recognizing six species, *S. elhawagryi*, *S. geminata*, *S. omana*, *S. saudiensis*, *S. sumara* and *S. zingibara*. *Solenopsis elhawagryi* was described from southwestern Mountains of KSA based on worker and queen castes. The authors presented a key to the Arabian species supported by automontage and Scanning Electron Micrographs and redescribed the worker caste of *S. sumara*. Recent materials of *S. saudiensis* including two queens and several workers were collected by the second author (S.S.) from King Saud University campus. Herein we describe the queen caste of *S. saudiensis* for the first time from the type locality, and the first key to the two known species from KSA based on queens will be presented.

Material and Methods

Abbreviations:

- TL = Total Length; the outstretched length of the ant from the mandibular apex to the metasomal apex.
- HW = Head Width; the maximum width of the head behind eyes in full face view.
- HL = Head Length; the maximum length of the head, excluding the mandibles.
- CI = Cephalic Index (HW x 100/HL).
- SL = Scape Length, excluding basal neck.
- SI = Scape Index (SL x 100/HW).
- EL = Eye Length; the maximum diameter of the eye.
- ML = Mesosoma Length; the length of the mesosoma in lateral view, from the point at which the pronotum meets the cervical shield to the posterior base of the propodeal lobes or teeth.
- PL = Petiole Length; the maximum length measured in dorsal view, from the anterior margin to the posterior margin.
- PW = Petiole Width; maximum width measured in dorsal view.
- PPL = Postpetiole Length; maximum length measured in dorsal view.
- PPW = Postpetiole Width; maximum width measured in dorsal view.

All measurements are in millimeters and follow the standard measurements (Bolton 1987).

Results

***Solenopsis saudiensis* Sharaf & Aldawood, 2011 (Figs 1-3)**

Measurements of Queen: TL 3.32-3.57; HL 0.53-0.55; HW 0.46-0.50; SL 0.33-0.35; EL 0.12-0.17; ML 1.00-1.07; PL0.22- 0.25; PW 0.20-0.22; PPL 0.17-0.18; PPW 0.25-0.27; Indices: SI 70-72; CI 87-91 (n=2).

SAUDI ARABIA, 2 dealated queens, Riyadh, King Saud University Campus, 24.713863° N, 46.62557° E, 660 m.a.s.l., 04.iv.2014*(S. Salman leg.)*; King Saud University Museum of Arthropods (KSMA), College of Food and Agriculture Sciences, King Saud University, Riyadh, KSA.

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Description

Colour uniformly dark brown, antennae, mandibles and legs clear yellow. Head slightly longer than broad with feebly convex sides and weakly concave posterior margin; scapes and funiculus with subdecumbent pubescence; masticatory margin of mandibles armed with four teeth decrease gradually in size from apex to base; median anterior clypeal margin concave; eyes large (EL 0.24-0.36x HW), with about 18 ommatidia in the longest row. Mesosoma robust, in dorsal view elongate and clearly bilaterally compressed; propodeal spiracle circular; propodeal dorsum about twice longer than propodeal declivity in profile. Petiole with a relatively long peduncle; petiolar dorsum in profile short with a long curved anterior margin and straight vertical posterior margin. Postpetiole in profile slightly lower than petiole; postpetiole in dorsal view slightly broader than petiole. Sculpture: cephalic dorsum smooth and shining; area between antennal insertions faintly longitudinally striated; mesosomal dorsum superficially sculptured slightly shining; mesosomal sides smooth and shining; propodeal dorsum very faintly transversally striated; petiole and postpetiole superficially sculptured and dull; Gaster superficially granulate and slightly shining; Pilosity: cephalic dorsum with abundant long yellow hairs; eyes with several projecting yellow hairs among ommatidia; mesosoma, petiole, postpetiole and gaster with abundant long yellow hairs.

Key to species of the genus *Solenopsis* in Saudia Arabia based on queens

Smaller species, TL 3.32-3.57; HL 0.53-0.55; HW 0.46-0.50; SL 0.33-0.35; ML 1.00-1.07; PPL 0.17-0.18; eyes small, with about 18 ommatidia in the longest row; postpetiole without a small tooth-like process; propodeal dorsum about twice longer than propodeal declivity in profile; mesosoma in dorsal view elongate and clearly bilaterally compressed; mesosomal dorsum and gaster superficially sculptured, slightly shining; petiole and postpetiole superficially sculptured and dull…….....***saudiensis***

- Larger species, TL 4.30; HL 0.75; HW 0.65; SL 0.47; ML 1.40; PPL 0.25; eyes very larger, with more than 25 ommatidia in the longest row; postpetiole with a small distinct anteroventral tooth-like process which bears few long setae; propodeal dorsum as long as propodeal declivity in profile; mesosoma in dorsal view robust, broad and not bilaterally compressed; entire body smooth and shining (Figs. 4-6)……***elhawagryi***

Ecological notes

Two queens and several workers were found nesting in soil at the base of a date palm tree. Specimens were collected by sifting the soil which was a mixture of sandy loam with much decaying organic materials. Dense lawn was also exist around tree trunk. This area is a part of gardens of King Saud University Campus and irrigation is carried out regularly so soil has a significant degree of humidity. Several workers were observed foraging in area about a meter from the nest.

Distribution

Since the description of *S. saudiensis* the authors carried out extensive collecting efforts to clarify species distribution. As a result the species was recorded from several places in Riyadh region and the data of the new are as follow:

Rawdet Khoureim (Riyadh), 25°22'986''N, 47°16'712''E, 559m, 13.I.2014 (2); Saudi Arabia, Riyadh, Alhayer, 24°16'48.7N,46˚45'57.1E (3).

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1

2

3

Figures 1-3:
Solenopsis saudiensis, Queen
1 body in profile
2 body in dorsal view
3 head in full-face view
(antweb.org, CASENT0914333).

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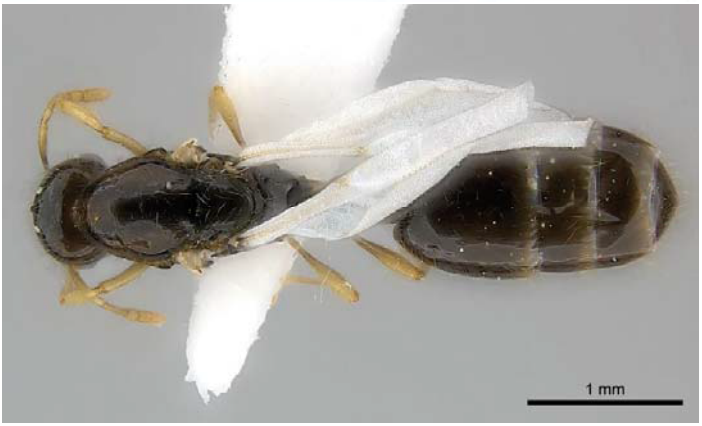
4



5

6

Figures 4-6:
Solenopsis elhawagryi Sharaf & Aldawood, Queen
4 body in profile,
5 body in dorsal view,
6 head in full-face view,
(antweb.org, CASENT0217361).

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Discussion

With description of the queen of *S. saudiensis*, the queen castes of the two *Solenopsis* species in KSA became known, consequently, we find it useful to provide a key to the two species based on queens. We intended to present a key to the queens of the Arabian *Solenopsis, S. geminata* (Fabricius, 1804), *S. sumara* Collingwood & Agosti*, S. zingibara* Collingwood & Agosti*, S. omana* Collingwood & Agosti but this would not be possible because the latter three species were only known from worker castes. According to the collecting efforts sinces description of *saudiensis* it is confirmed that its distribution is confined to date palm plantations in the desert central region of Saudi Arabia whereas *S. elhawagryi* is confined to wild *Acacia* forests in the mountains of southwestern Saudi Arabia. We hope in the future we can collect males and queens of the Arabian species and by accumulation of sexual caste materials it would be possible to provide keys.

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Frühe Reproduktionsschranken in einer Population der Juwelwespe *Nasonia vitripennis*

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Die Entstehung neuer Arten erfolgt über verschiedene Zwischenstufen wie z.B. Wirtsrassen, wobei zu Beginn die Auseinanderentwicklung von Populationen steht. Bei Populationen, welche sich noch in einer frühen Phase der Artbildung befinden, ist zu erwarten, dass das Ausmaß der reproduktiven Barrieren noch sehr gering ist. Zur Untersuchung dieser Hypothese wurden Tiere der parasitoiden Erzwespe *Nasonia vitripennis* (WALKER 1836) einer lokalen Population untersucht, welche Anzeichen für eine Aufspaltung in die beiden Habitate Vogelnester und Aas aufweist.

In Versuchen zur Reaktion auf Habitatgerüche zeigte sich, dass manche Zuchtlinien ausschließlich den Geruch ihres Ursprungshabitates bevorzugten, während andere Linien auf beide Habitatgerüche reagierten. Dies deutet auf eine beginnende ökologische Auftrennung hin. Paarungsversuche sollten Aufschluss darüber geben, ob bei den Tieren aus Vogelnestern und Aas bereits eine sexuelle Isolation vorliegt. Männchen und Weibchen von Zuchtlinien aus unterschiedlichen Habitaten wurden miteinander verpaart („Hetero"-Paarung) und die Weibchen auf Wirte gesetzt. Das Vorkommen von Paarungen, das Auftreten von weiblichen Nachkommen in der F1-Generation als Anzeichen für eine erfolgreiche Befruchtung, sowie die Dauer des männlichen Balzverhaltens vor und nach der Paarung sowie die Dauer der Kopulation wurden aufgezeichnet. Paarungsversuche mit Tieren aus dem gleichen Habitat dienten als Kontrolle.

Die Versuche zeigten, dass es bei allen Kombinationen gleichermaßen zu Paarungen kam und eine erfolgreiche Befruchtung stattfand. Wurden allerdings Tiere aus zwei unterschiedlichen Habitaten verpaart, so führte dies zu einer signifikanten Verlängerung des Balzverhaltens vor der Kopulation. Darüber hinaus nahm die Kopulation bei Tieren aus verschiedenen Habitaten weniger Zeit in Anspruch. Für das männliche Balzverhaltens nach der Kopulation konnte kein signifikanter Unterschied verzeichnet werden. Diese Ergebnisse deuten darauf hin, dass noch keine sexuelle und reproduktive Isolation vorliegt. Jedoch akzeptieren Weibchen die Männchen aus dem jeweils anderen Wirtshabitat weniger bereitwillig und die Männchen müssen daher länger um die Weibchen werben.

Zusammengenommen deuten die Ergebnisse darauf hin, dass bei *N. vitripennis* die Auseinanderentwicklung einer natürlichen Population in den Anfängen beobachtet werden kann. Dabei treten zunächst unterschiedliche Präferenzen für Wirtshabitate und eine abnehmende Akzeptanz bei den Weibchen für Männchen aus anderen Wirtshabitaten auf.

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Dr. Heiko Bellmann

***17.3.1950, †7.3.2014**

Foto: F. Gusenleitner

Mit dem Tod von Heiko Bellmann verliert die Stuttgarter Hymenopterologen-Tagung einen regelmäßigen Teilnehmer, der durch seine mit hochkarätigen Makrofotos bestückten Vorträge das Programm bereichert hat. So stellte er bei der 2. Hymenopterologen-Tagung 1996 die „Binnendünen, ein hochgradig gefährdeter Lebensraum für Aculeaten“ vor, und bei der 7. Hymenopterologen-Tagung 2006 referierte er über „Gallwespen und ihre Gallen (Hymenoptera, Cynipidae)“. Im Rahmen der 10. Hymenopterologen-Tagung 2012 präsentierte Heiko Bellmann in seinem Vortrag die „Wildbiene des Jahres 2013“.

Auch die öffentliche Vorstellung der „Wildbiene des Jahres 2014“ am Staatlichen Museum für Naturkunde Stuttgart übernahm er gerne. Als Mitglied des Kuratoriums „Wildbiene des Jahres“ und Mitarbeiter im Arbeitskreis Wildbienen-Kataster stellte er sowohl sein Fachwissen als auch seine hervorragenden Makrofotografien zur Verfügung, um die Öffentlichkeitsarbeit für die Wildbienen zu unterstützen. Mit den Bienen beschäftige er sich bereits in seiner Doktorarbeit, die er an der Universität Ulm über die Ethologie mitteleuropäischer Bauchsammlerbienen anfertigte und im Jahr 1979 abschloss. An der Universität Ulm lehrte und forschte Heiko Bellmann seit 1975. Aber er war nicht nur als Wissenschaftler tätig, sondern machte sich insbesondere als Autor einer Vielzahl von Naturführern und Bestimmungsbüchern, die teilweise ins Französische, Spanische, Niederländische oder Polnische übersetzt wurden, einen Namen. Seine Leidenschaft für die Makrofotografie resultierte in einem umfangreichen Bildarchiv, auf das er zurückgreifen konnte, um seine Bücher und Vorträge zu illustrieren.

Dabei waren es nicht nur die Hymenopteren, sondern fast alle Insektengruppen sowie Spinnen aber auch Pflanzen, die Heiko Bellmann fotografierte. Er verfügte über eine enorme Kenntnis sowohl der mitteleuropäischen als auch der mediterranen Tier- und Pflanzenwelt. Durch seine Publikationen und Vorträge weckte er bei vielen Menschen das Interesse an der Natur und brachte ihnen die meist wenig beachteten bis unbeliebten Insekten und Spinnen näher. Nicht nur für Insektenfreunde sondern auch für Studierende und in den Berufen der Umwelt- und Biowissenschaften sowie Land- und Forstwirtschaft Tätige ist das von JACOBS/RENNER begründete Standardwerk „Biologie und Ökologie der Insekten“ unentbehrlich geworden. Das Autorenteam Heiko Bellmann und Klaus Honomichl führten dieses seit 1996 als Taschenlexikon oder als CD-ROM-Lexikon fort. Im Jahr 2007 erschien die 4. Auflage, die sich durch die Vielzahl attraktiver und hochwertiger Makroaufnahmen von Heiko Bellmann auszeichnet.

In Gesprächen mit Heiko Bellmann war stets die Begeisterung für seine Studienobjekte zu spüren. Deren Besonderheiten und Schönheit fotografisch zu dokumentieren war das Eine, daneben galt sein Interesse aber auch ihrer Biologie und ihrem Verhalten. Durch

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seine Arbeit hat Heiko Bellmann einen essenziellen Beitrag zur Artenkenntnis erbracht und damit Grundlagen zum Schutz der einheimischen Arten und deren Biodiversität geschaffen.

Heiko Bellmann verstarb unerwartet und viel zu früh kurz vor seinem 64. Geburtstag. Er und sein Werk bleiben unvergessen.

Dr. Karin Wolf-Schwenninger, Stuttgart

Der Naturfotograf Heiko Bellmann in Aktion, Istrien 1989.
Foto: Joachim Holstein

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