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The Relationship Between the Type of Gas Exchange System and Behavioral Energetics in Six Arachnid Orders

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Arachnids exhibit striking diversity with respect to respiratory systems. Book lungs derived from book gills are the apparent ancestral condition, but tracheal lungs, “insect-like” trachea and cutaneous respiration have evolved independently. In other animal groups there is a strong relationship between the mix of aerobic and anaerobic metabolism used in “non-resting” behaviors and the type of respiratory system. Animals that use gills or lungs in conjunction with blood to move respiratory gases (vertebrates) typically mix aerobic and anaerobic metabolism during behaviors. Those that use “insect-like” tracheal respiration usually are strictly aerobic and CO2 production accurately reflects the energetics of a particular behavior. By contrast, when anaerobic metabolism is significant, CO2 production is not a quantitative measure of metabolism because pH changes associated with the accumulation of anaerobic products such as lactate drives CO2 from body fluids. Thus, CO2 exchange is the sum of CO2 produced by aerobic metabolism and additional CO2 driven from tissues. Moreover, there is also a period after activity ends when CO2 production becomes abnormally low as stores are rebuilt. We found for five species in four orders (Scorpiones, Solfugidae, Thelyphonida, Amblypygi and Araneae), which rely on blood lungs and hemolymph for gas exchange, that O2 consumption and CO2 production during recovery from forced activity are consistent with significant anaerobic metabolism. Therefore, CO2 is not an accurate measure of behavioral energetics. By contrast, in one tracheal species (an opilionid), the pattern was suggestive of metabolism that was largely, if not exclusively, aerobic.

New Mexico Linyphiidae: a preliminary look at species and response to precipitation patterns

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The arid southwestern U.S. is perhaps not considered a likely place to collect linyphiids, since they are associated more commonly with wetter habitats. However, they do occur at high elevations, along rivers, and even in drier areas during years of increased precipitation. In this presentation we focus on linyphiids collected from New Mexico, a state with biomes ranging from Chihuahuan Desert to the Rocky Mountains. Our presentation is in two parts: 1) species richness and collection localities known from NM museum material, and 2) habitat and precipitation associations for species from a long-term pitfall trapping program at Bandelier National Monument in north-central NM. In collections at UNM and NMSU we have specimens from about 70 species, including some large range extensions. Most areas of the state have not been sampled comprehensively, and we expect interesting distribution patterns, given the “sky island” effect of isolated mountains in the region. At Bandelier National Monument, 14 years of data from 3 elevations (piñon-juniper 1948m, ponderosa pine 2454m, and mixed-conifer 2712m) showed most species were collected between October and April and most were associated with mixed-conifer habitat. Abundance was low in the dry early 2000’s but numbers increased greatly with wetter conditions beginning in 2005. Dominant taxa were *Disembolus anguineus* (piñon-juniper), and *Helophora* sp., *Mermessus taibo* and *Pityohyphantes minidoka* (at the higher elevations). Because of their preferences for mesic microhabitats, linyphiids are good candidates for tracking regional climate change, especially winter precipitation. Current drought and wildfires increase the need to document the state’s diversity.

Molecular and mechanical comparisons of major and minor ampullate silks from cob-web weavers (Theridiidae)

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Orb-weaving spiders and their relatives (Orbiculariae) make at least five different types of task-specific silk that are synthesized in unique abdominal glands. These proteinacious fibers are all high performing materials in terms of strength and extensibility. We compared molecular and mechanical properties for silks synthesized in the major and minor ampullate glands of three cob-web weaving species (Theridiidae). We characterized full-length sequences of minor ampullate silk encoding genes (*MiSp*) from the Western black widow *Latrodectus hesperus* and the brown widow, *L. geometricus*, and partial sequences for the false black widow, *Steatoda grossa*. We additionally characterized partial major ampullate silk encoding genes (*MaSp1* and *2*) from *S. grossa* and compared to previously published *MaSp* sequences. Both *MiSp* and *MaSp* contain proline and alanine rich amino acid motifs associated with elastic β-spiral and crystalline β-sheet secondary structures, respectively. However, there are substantial differences in the proportions of these motifs among species and between proteins. We additionally performed mechanical testing of minor and major ampullate silk from each species. In general, minor ampullate silk is much more extensible than major ampullate silk, whereas major ampullate silk is stronger, tougher, and stiffer. Extensive variation among species within silk type also exists. For example, black widows have the strongest measured major ampullate silk while false black widows have the weakest. Variation in protein sequence is correlated with these differences in mechanical properties.

Sustainable Grazing: Effects of high-intensity, low frequency rotational cattle grazing on spider and arthropod communities

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Various sustainable grazing techniques have been developed for different landscapes, climates, and grazers. Attempts to measure their efficacy have produced a diversity of parameters, confounding accurate comparisons. Since arthropod communities associated with different grazers and grazing regimes are poorly known, understanding endemic arthropod biodiversity and community dynamics under different pasture management schemes may provide a metric allowing discrimination and diagnosis between various grazing plans to design those most sustainable. Thus, we initiated a study of the arthropod & spider communities inhabiting pastures under a sustainable rotational grazing schedule at a site well-positioned to assess temporal changes associated with rotational grazing and to directly compare with conventional grazing. Arthropod communities in pastureland paddocks at Polyface Farms (Swope, VA) under high-intensity, low-frequency rotational grazing, and three immediately adjacent continuously grazed pastures were sampled in 0.25-m2 areas by first suction-sampling vegetation for 1 minute. Then all vegetation was cut to ground level and searched for remaining arthropods. A second suction session sampled the exposed substrate. The substrate was subsequently hand-searched with aspirators for 15 person-minutes. The high-intensity, low-frequency grazing significantly reduced abundance of most arthropods, and overall mean taxonomic richness was decreased. Interestingly, acari and coleoptera abundances increased. Functional group analysis found that predator richness (mostly Araneae) was maintained more than other groups despite abundance declines. The arthropod community under rotational grazing had greater species diversity and evenness pre- and post-grazing than continuously-grazed pastures. Although abundances were significantly decreased, the overall proportional representations of major taxa were maintained pre-and post-grazing under rotational grazing.

Responses of burrowing wolf spiders to resource pulses: fire and rain interrupt endless sunny days in Florida scrub

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I wish to summarize a 26-year study of population-level responses of rare burrowing wolf spiders to two resource pulses, fire and flood. *Geolycosa xera archboldi* and *G. hubbelli* co-occur in xeric shrub habitat on the Lake Wales Ridge in south-central Florida. Annually for 26 years (1987-2012) I conducted censuses of both spiders in 15 permanent plots, each 10 x 10 m, primarily to determine whether the *Geolycosa* species, like many native plants and vertebrates, benefit from periodic burning of scrub. Previous studies show most spiders (80-90%) survive fires because they are protected deep in their burrows. Densities of both *Geolycosa* increased 3-5 fold within a year after two intense wildfires (May 1989 and February 2001), but thereafter their numbers declined because gaps of open sand quickly disappeared as the scrubby matrix re-sprouted and leaf litter accumulated. Curiously, the rate of decline in spider densities after the 2001 wildfire was precipitous compared to the 1989 burn. A post-hoc analysis showed that chronic flooding caused by 1.5 m of above-normal precipitation for 4 years in a row summer of 2001, an event that happens every 50 years or so, resulted in decimation of *Geolycosa* populations in most plots; the effect lasted two years.

Ultrastructure and functional significance of papillae on the pedipalps of camel spiders (Arachnida, Solifugae)

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Arachnids in the order Solifugae, commonly called "camel spiders," are peculiar desert dwelling arachnids whose biology is poorly known. They hold their pedipalps anteriorly while moving through the environment. Their pedipalps are covered in sensory setae. Males of certain species in the families Eremobatidae, Solpugidae, and Karschiidae have setal structures called papillae on the ventral surface of their pedipalps which are hypothesized to function as mechanoreceptors and possibly chemoreceptors. We used various microscopy techniques and specimens from the family Eremobatidae to elucidate the functional significance of these aberrant structures.

Molecular evidence for pest suppression potential and dietary selectivity in an epigeal spider community in winter wheat

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A predator's biological control potential is best understood by determining its diet breadth. Spiders have considerable pest suppression potential because they are often the most abundant group of predators in agricultural fields. We examined the feeding habits of an epigeal spider community in a winter wheat agroecosystem through PCR-based gut-content analysis, and correlated the results with prey availability. The epigeal spiders appeared to prefer Collembola over other suitable-sized prey and Collembola predation was correlated with web area. Small Diptera and Hymenoptera were also frequently encountered (Brachycera, Platygastridae), but were under-utilized in relation to their abundance. Considering their apparent rarity on the ground, aphid predation was surprisingly high and was not correlated with web size or prey availability. Out-of-web foraging was likely responsible for the levels of aphid predation recorded for at least two of the spider species. We conclude that the epigeal spider community encountered sufficient numbers of suitable prey (Collembola) to sustain their populations such that they were available to prey on pests during immigration into the crop. Our results demonstrate that these spiders are not truly polyphagous, but appear to specialize on jumping or slowly-crawling prey (Collembola and Aphididae, respectively). Given the frequency with which they prey on scarce aphids, epigeal spiders have the potential to delay possible exponential increases in aphid populations by helping (along with other predators) to suppress early-season aphid populations.

Arachnid Genomes and i5k: The 5,000 Arthropod Genome Project

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The i5K Insect and other Arthropod Genome Sequencing Initiative (http://arthropodgenomes.org/wiki/i5K) seeks to sequence 5,000 arthropod genomes in five years. The American Arachnological Society participated in the selection of arthropod genomes, resulting in commitments to sequence the genomes of *Centruroides sculpturatus, Loxosceles reclusa, Parasteatoda tepidariorum, and Latrodectus hesperus*. Assembling and annotating the genomes present major challenges and opportunities. Genome size is an important practical consideration, and efforts are underway to size the genome of the pseudoscorpion *Cordylochernes scorpioides*. I will describe the

initiative overall and suggest ways that arachnologists can participate and position additional taxa for sequencing.

Mutualism or parasitism: how endosymbiotic bacteria manipulate Linyphiid spider biology

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Sheet-weaving Linyphiid spiders are widely distributed, agriculturally important predators. Like the majority of insect taxa, spiders are host to a variety of maternally inherited endosymbiotic bacteria including *Cardinium*, *Rickettsia*, *Wolbachia*, and *Spiroplasma* that ensure their own transmission through the female germline either by manipulating host reproduction or conveying a facultative benefit. Depending upon selection pressures, the selfish interests of endosymbionts may be in concert or conflict with that of the host. Recent broad-taxa screening studies indicate that endosymbionts are particularly common among spiders; however, little is known about how these bacteria affect their spider hosts. To investigate the continuum of bacterial phenotypes in Linyphiid spiders, I reared two naturally-infected lines of the Linyphiid spider *Mermessus fradeorum*: one infected with *Wolbachia* and one superinfected with *Wolbachia* and *Rickettsia*. Superinfected *M. fradeorum* produced almost all female offspring, whereas *M. fradeorum* infected with only *Wolbachia* produced a male-biased sex ratio. The superinfected line was not parthenogenetic: mating was required for fertile eggsac production. Subsequent generations of superinfected progeny retained a strong female bias. The exact mechanism of reproductive manipulation is not yet clear, but we hypothesize that *Rickettsia* induces the female bias through male killing or feminization. Future chromosome observations will reveal if feminization of genetic males has occurred. The function of *Wolbachia* remains unclear, but curing of *Wolbachia* and *Rickettsia* will be undertaken to investigate the possibility of cytoplasmic incompatibility, as well as to evaluate the fitness costs or benefits induced by each of the symbionts.

Specificity of attraction to floral chemistry in a crab spider (*Misumenoides formosipes*)

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As knowledge of arachnid olfactory capabilities grows, the importance of chemical cues in foraging and mating systems is becoming more apparent. Olfactory cues could be especially beneficial to cursorial and ambush spiders living in structurally complex habitats. Field and olfactometer trials demonstrated that male *Misumenoides formosipes* (Thomisidae) are attracted to the floral scent of *Rudbeckia hirta*, but not to scents from *R. hirta* foliage or *Morus rubra* foliage. These males also showed no tendency to associate with *Daucus carota* inflorescences despite the fact that they commonly reside on them in the field. Female *M. formosipes* spent more time in an olfactometer arm with the *R. hirta* floral scent, although they did not move towards *R. hirta* inflorescences as a first choice over a control. The use of phytochemical cues by males to locate *R. hirta* inflorescences should increase encounters with potential mates as this is the substrate on which females in our population are found with the greatest predictability.

Diversification on the Bare Hills of Granite

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Thirty-four biodiversity hotspots have been recognized by Conservation International; this designation is based on two criteria, floristic richness and habitat loss. The rich arthropod heritage, including arachnid diversity, found in these regions is frequently under-assessed. Southwestern Australia is one of the global hotspots. A distinctive feature of the region is an extensive system of granite outcrops. Our research focuses on the pseudoscorpion fauna that is restricted to this terrestrial archipelago. When our work commenced, only one described species, *Synsphyronus elegans*, had been recorded from the outcrops and it was known only from its type locality. Currently, *Synsphyronus* Chamberlin(Garypidae: Pseudoscorpiones) comprises 31 described species in Australia and New Zealand. We visited over 100 outcrops in southwestern Australia during three field seasons; populations were found on two-thirds of the granite islands. Additionally, lineages were sampled in each of the four biomes in Australia; sixteen described species are included in this study. Evolutionary relationships between lineages were inferred using molecular data. Gene trees were reconstructed for four nuclear markers (elongation factor 1-alpha, actin 5C, internal transcribed spacer regions, and wingless) using multiple phylogenetic methods. Three major clades were recovered; the outcrop taxa are not monophyletic. Deep genetic divergences across small spatial scales exist between some outcrop populations. Southwestern Australia harbors a rich *Synsphyronus* fauna. Species level diversity on the outcrops is greater than the four presently described endemic species. Similarly, many of the non-outcrop lineages cannot be assigned to described species. *Synsphyronus* is a successful genus; its diversity is clearly underestimated.

Effects of immune stress on multimodal sexual signaling of *Schizocosa ocreata* wolf spiders

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Theory suggests that male signals and secondary sexual traits may serve as honest indicators of immune function in female mate assessment. Male *Schizocosa ocreata* wolf spiders exhibit multiple condition-indicating traits (foreleg tufts, courtship vigor) used as criteria in female mate choice, but the direct and/or indirect effects of immune stress on these sexual signaling traits is unknown. To evaluate the effects of immune stress on sexual signaling, immature males were infected with a bacterial pathogen (*Pseudomonas aeruginosa*) and were assessed at maturity for several fitness-related measures. Fluctuating asymmetry (FA) in male foreleg tufts (secondary sexual characters) was significantly greater in spiders subjected to bacterial infection. Adult mass and body condition indices were significantly lower among infected individuals than uninfected (control) individuals. In addition, we examined whether females can detect infection status via chemical cues in male silk. Females were significantly more receptive and showed more receptivity displays towards a courting male video stimulus when uninfected male silk was placed in front of the screen than infected male silk. Females also spent significantly more time on uninfected male silk than infected male silk. These results indicate that immune stress from bacterial infection significantly reduces overall body condition and negatively impacts key indicator traits (leg tufts), potentially reducing mating success. These results also show that it may be possible for females to detect infection via male silk cues. Ongoing research will investigate further the role of immune stress on sexual selection in this species.

Reproductive partitioning and task specialization in social spiders

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Reproductive partitioning is a key component of social organization in groups of cooperative organisms. In colonies of permanently social spiders of the genus *Stegodyphus* less than half of the females reproduce, while the rest perform suicidal allomaternal care. Theory suggests that reproductive skew is a product of contest competition within colonies, leading to size hierarchies where only the largest females become reproducers. Alternatively, reproductive skew is an adaptive strategy

whereby reproduction is differentiated in order to maximize colony survival and production through inclusive fitness benefits of allomaternal care. We investigated the effect of competition on within-group body size variation over six months in *Stegodyphus dumicola*, by manipulating food level and colony size. We found no evidence that competition leads to increased size asymmetry within colonies, suggesting that contest competition may not be the mechanism leading to reproductive skew. Within-colony body size variation was high already in the juvenile stage, and did not increase over the course of the experiment. This is consistent with the hypothesis of adaptive reproductive skew mediated by processes shaping body size variation at an early stage, facilitating task specialization within colonies. We suggest that reproductive skew in social spiders may be an adaptation to sociality. Colony benefits would arise by ensuring that some females become reproducers while their offspring benefit from allomaternal care provided by non-reproductive helpers.

Neuroendocrine control of molting in the scorpion *Heterometrus swammerdami*

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Neuroendocrine control of molting in scorpions is time tested from the past 430 million years. Scorpions are considered as the first air breathing and land dwelling animals on our planet earth. The scorpion brain assumes a central role in the whole process of molting. In *Heterometrus swammerdami*, specialized neurons in the protocerebrum synthesize the brain hormone, and communicate with the other neural organs like the subesophageal ganglion, hypocerebral ganglion, and the rostral and frontal ganglia. After receiving the neuronal and hormonal cues, the subesophageal ganglion of the scorpion is able with its own neurosecretory cells, to communicate with the functionally similar structure to that of prothoracic gland of pterygote insects. This analog - the blind end organ, in turn , transports the synthesized active biological principle, to various targeted regions of the body through the blood cells (oenocytes). These are responsible for the further development and growth of organs. Through the feedback mechanism, the brain is kept informed about the internal milieu, and the attainment of sexual maturity. The scorpion *Heterometrus swammerdami* undergoes periodic molting until it reaches adulthood. The structural analogs of the prothoracic gland and corpus allatum complex of insects are compared with those of scorpion in the present study. The neuroendocrine control of molting and the involvement of counterparts of ecdysone, neotenin and the feedback control mechanism in the molting phenomenon of the scorpion *Heterometrus* are discussed in this communication.

Ecological implications of diel rhythm in aggressiveness in *Anelosimus studiosus* (Araneae: Theridiidae)

Thomas C. Jones, Chelsea R. Ross, J. Colton Watts, Darrell Moore, Edith Seier & Michele L. Joyner
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Ecologically, spiders are both predators and prey. Behaviorally they must balance being bold enough to capture prey while being wary enough to avoid potential predators. However, the relative adaptiveness of boldness and wariness can change with context, such as hunger level, reproductive status, or changes associated with the daily cycle. In this study, we explore the relationship of aggressiveness to reproductive state, and observe if aggressiveness changes over the daily cycle, in the spider *Anelosimus studiosus*. We test the hypotheses that (A) brooding females will be more aggressive than non-brooders, and (B) that aggression level will fluctuate over the course of a day, reflecting relative abundance of prey and/or potential threats. Spiders were entrained to a 12:12 LD cycle in the lab, and we observed their responses to simulated predator attacks at four hour intervals over four days. We also monitored activity levels for four days under 12:12 LD conditions. Finally, we sampled flying insect densities in the spider's natural habitat every three hours for two days. We found that these spiders showed robust nocturnal activity, and that females which had produced broods were more aggressive than those which had not. We also found that aggression levels of non-brooding females changed significantly over the course of a day in a pattern similar to the daily fluctuations in density of both prey and parasitoid wasps.

Contact function explains negative allometries of copulatory structures

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Sexual traits vary greatly in how they scale relative to body size -- i.e., their static allometry. Some traits scale proportionally with body size (isometry), while others scale more steeply (positive allometry) or more shallowly with body size (negative allometry). Genitalia present the most consistent allometric pattern among animals, showing predominantly negative allometries. This pattern may be explained by selection on genitalia through their function either as contact courtship devices or as sperm transfer devices. The contact-courtship hypothesis predicts that non-genitalic male structures that contact females during copulation will scale shallowly with body size like genitalia, while the sperm-transfer hypothesis predicts that they will not. Here we test these predictions with *Leiobunum vittatum* (Arachnida: Opiliones) harvestmen, in which males grip females with the tarsi of their pedipalps and certain legs during copulation. We measured these traits as well as genitalia, body size and structures not used in copulation, and we calculated their allometric slopes. We found that the tarsi of the legs and pedipalps that grasp females during copulation had distinctly shallower allometric slopes than non-contact segments of the same appendages. Furthermore, they also had shallower slopes than tarsi of non-contact legs. These results support the hypothesis that genitalia scale shallowly because of their role in contact courtship. We discuss implications for selection on the scaling of trait size relative to body size.

Hello pretarsus! A journey through the internal morphology of the distal segment of a spider leg

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In the last century much research has been conducted on the comparative morphology of walking appendages among Chelicerata. A leg consists of several podomeres connected by joints. The distal podomere is the pretarsus, a plate-like structure connected to the rim of the tarsus by transverse bicondylar joints, which permits a levation-depression motion. In spiders, the pretarsus consists of a sclerotized claw lever, which sometimes bears the unpaired claw and is connected to the pair claws by a membrane and sometimes associated with two tenant plates. The pretarsal levator arises from the dorsal surface of the metatarsus and inserts on the dorsal rim of the pretarsus, whereas the pretarsal depressor arises from the dorsal surface of the metatarsus and tibia and inserts on its ventral rim. Our current knowledge of pretarsus conformation and function is well known for only one species, *Phidippus audax* (Salticidae). In our study, we attempt to increase this data set by examining the pretarsus of several taxa, with an emphasis on haplogyne spiders, in order to find new phylogenetic characters. Our preliminary results show that the pretarsal levator and depressor consist of two strands, and that the first continues underneath the membrane between the paired claws and inserts dorsally on the anterior face of the claw lever. The distal end of the pretarsal levator may be single or bifurcated, straight or swollen, whereas that of the depressor could be wide or tubular, and may insert underneath the claw lever or through a posterior ventral hole in it.

Massively parallel signature sequencing reveals novel genes associated with silk production in the Western black widow, *Latrodectus hesperus*

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Spiders produce task-specific fibers in unique abdominal glands, such as the dragline silk synthesized in major ampullate glands and outer egg casing silk, which

originates in tubuliform glands. These fibers are composed primarily of one or more structural proteins. For instance, *MaSp1* and *MaSp2* constitute dragline silk, and *TuSp1* forms egg casing. Our goals were to identify the relative expression of structural proteins in the major ampullate glands and to identify other potential genes involved in silk synthesis. We created libraries of 3' anchored, 20 base pair "tags" from genes expressed in the cephalothoraxes and major ampullate glands of two adult females. We sequenced at least five million tags from each library, which resulted in 32,111 unique tags that had more than one count per million in at least two of the four libraries. In order to determine genes associated with the tags, we compiled a database of published genes (368) and generated an additional 260 sequences from a whole female black widow cDNA library. Of the 268 tags that matched a gene, 62 were significantly more abundant and 41 were significantly less abundant in major ampullate glands than in cephalothoraxes. Genes highly expressed in major ampullate glands included the structural proteins known to be in dragline silk, *MaSp1* and *MaSp2*, as well as other structural proteins such as TuSp1. An additional 21 protein coding genes were more abundant in major ampullate glands than cephalothoraxes, representing a plethora of novel genes that are likely important for silk synthesis.

Rediscovery of *Tengella perfuga* and Description of the Male

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Tengella perfuga Dahl (1901) has remained poorly known since Dahl's original description of two female syntypes. With the male heretofore undescribed its classification has been uncertain, and it has been sometimes placed in synonymy with the better known *T. radiata* (Kulczynski). With males undescribed, an unknown natural history and a vague type locality ("Sud Amerika?") it would seem unlikely this spider would be easily rediscovered. However, recent collecting in Nicaragua resulted in discovery of *T. perfuga* populations with adult males, females and various life stages. *Tengella radiata* populations were also discovered which allowed for comparison between species. We confirm that *T. perfuga* is a valid species, redescribe the species, including the first description of the male, document the distribution, designate a lectotype and compare the species with *T. radiata*.

Natural History Notes On Dahl's Lost Species, *Tengella perfuga* Dahl, and Comparison with *T. radiata* (Kulczynski)

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During a recent field trip to Nicaragua the natural history and habitat of the poorly-known *Tengella perfuga* Dahl was observed. Previously known only from Costa Rica, we also discovered *T. radiata* (Kulczynski). Here we present field and laboratory observations and comparisons of web structure and density, feeding behavior, and courtship between *T. perfuga* and *T. radiata.* Despite considerable similarity morphologically, the two species differ in their behavior and habitat preference.

Testing a Rapid Assessment Protocol for Spiders in Nantucket Sandplain Grassland and Coastal Heathland

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We have been developing a Rapid Assessment Protocol (RAP) for spiders and other invertebrates in which randomly located 0.01 ha plots are intensively sampled within a standard 0.25 ha site, with the goal of providing richness estimates that are comparable across studies and locations. We tested this RAP in sandplain grassland and coastal heathland on Nantucket Island, Massachusetts in two different seasons (June and August) by comparing the RAP collection to a collection of spiders from the same area sampled using standard methods of pitfall trapping and plotless beat/sweep samples. The June samples comprised 124 spiders from 23 species (RAP) and 314 spiders from 58 species (Standard Methods), and the August samples comprised 414 spiders from 30 species (RAP) and 47 spiders from 24 species (Standard Methods). The June RAP found 37% of the estimated species present and added four species to the seasonal list. The August RAP captured 71% of the estimated species present and added 18 species to the seasonal list. The August collection also added three species to the species list that were not caught at any other time of the year. Both RAP tests required approximately 65% less time than the standard collections and pitfall trapping when counting time collecting, travelling, and processing. The RAP can result in a substantially similar species list from a much more rapid and efficient sampling effort, although this efficiency may be offset to some extent by a susceptibility to fluctuations in daily weather or collecting conditions.

Using PCR to reveal a spider-dominated leaf-litter food web

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The application of PCR to food-web research has the potential to greatly advance our understanding of the structure and dynamics of food webs. Using the spider-dominated leaf-litter food web as a model system, this research project utilizes Real-Time PCR to reveal the predator-prey interactions between major taxa within a forest-floor arthropod community. Our model web consists of 20 nodes. Real-Time PCR is used to examine the gut contents of ten focal predators (families of spiders) for the DNA of eight non-predacious prey taxa, two non-spider predator taxa, and the DNA of the other nine spider families. Through a combination of litter-sifting and hand-collection, over 5000 spiders have been collected from field sites located within the Palos region of the Forest Preserve District of Cook County (Chicago, IL). DNA is extracted from the gut contents of these spiders and Real-Time PCR is used to identify the prey item(s) that each spider has consumed. To date, over 6000 interactions have been examined between the 20 taxa that make up this model food web. Preliminary results demonstrate that it is possible to detect prey DNA from 12 different prey taxa, including other spiders. Based on this data, a quantitative food web has been constructed that elucidates the structure and interaction pathways within this spider-dominated arthropod community.

Are the viscous prey capture threads of araneoid orb-webs adapted to different humidity regimes?

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Viscous threads that form the sticky prey capture spirals of araneoid orb-webs feature regularly spaced droplets, each comprised of a glycoprotein glue core that is covered by aqueous material and supported by axial fibers. This glycoprotein is a viscoelastic solid, whose extensibility facilitates the summation of adhesion from multiple droplets and dissipates energy of prey impact and struggle. Low molecular weight compounds in the aqueous material make the droplet hygroscopic, causing its volume to change with relative humidity (RH). As RH increases some of this absorbed water is taken up by glycoprotein, causing its extensibility to increase. We measured the features and responses of viscous droplets of two large orb-weavers, *Argiope aurantia* and *Neoscona crucifera*, at 20%, 37%, 55%, 72%, and 90% RH. *Argiope aurantia* droplet extension increased linearly with RH; whereas that of *N. crucifera* increased exponentially. The volume specific extension of *A. aurantia* glycoprotein reached a maximum value at 55% RH and then declined, whereas that of *N. crucifera* increased exponentially through the RH range. As humidity increased the stress on droplet filaments at maximum extension, as gauged by axial line deflection, decreased in *A. aurantia*, but increased exponentially in *N. crucifera*. These differences suggest that *A. aurantia* threads are adapted to low and intermediate RH environments, whereas *N. crucifera* threads are adapted to a broader RH range and may be optimized for higher RH. The hygroscopicity of a droplet's aqueous coat appears to play a crucial role in this adaptation, perhaps complimented by changes in

glycoprotein molecules.

Neurochemical Levels Correlate with Population Level Differences in Social Structure and Individual Behavior in the Polyphenic Spider*, Anelosimus studiosus*

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Anelosimus studiosus is a socially polyphenic spider. Individuals can be classified as social/tolerant or solitary/aggressive. These behavioral differences are associated with considerable variation in social structure. Here, we begin to examine the physiological differences that may underlie the behavioral dimorphism in this species and possible implications for the evolution of sociality. Octopamine is a neurotransmitter that has been found to elevate aggression in invertebrates. Serotonin has been shown, in some cases, to interact antagonistically with octopamine. We used High Pressure Liquid Chromatography with Electrochemical Detection to quantify levels of these neurochemicals among adult females from social (multi-female) and solitary (single-female) webs in east Tennessee. A subset of spiders was scored for individual social tendency. We found that higher octopamine levels are associated with a greater degree of aggression and intolerance, both at the individual level and the population level, while higher levels of serotonin are found in multi-female colonies and social individuals.

Tarsal flexor system and sexually dimorphic tarsal glands in gonyleptoid harvestmen (Opiliones, Laniatores)

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Appendicular characters such as intrinsic musculature have remained an important aspect of evaluating and explaining the hypothesized phylogenetic relationships among arachnid orders. In the present study, I examine the general tarsal morphology for laniatorid harvestmen (Opiliones) and describe a novel system of retinacular structures, termed the tarsal flexor system, which functions to maintain close apposition between the tendon and internal ventral surface of the cuticle to provide mechanical advantage for tarsal flexion and other movements of the tarsus. I discuss this system with regards to other lineages of Opiliones, especially those that exhibit prehensility of the tarsus (i.e., Eupnoi), as well as other orders of Arachnida. Additionally, I compare the sexually dimorphic tarsal glands among gonyleptoid families and discuss phylogenetic implications based on recently hypothesized relationships within this superfamily.

Iterative evolution of increased behavioral variation characterizes the transition to sociality in spiders and proves advantageous

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The evolution of group living is regarded as a major evolutionary transition and is commonly met with correlated shifts in ancillary characters. We tested for associations between social tendency and a myriad of abiotic variables (e.g., temperature, precipitation) and behavioral traits (e.g., boldness, activity level, aggression) in a clade of spiders that exhibit highly variable social structures (genus *Anelosimus*). We found that, relative to their subsocial relatives, social species tended to exhibit reduced aggressiveness towards prey, increased fearfulness towards predators, reduced activity levels, and tended to occur in warm, wet habitats with low average wind velocities. Within-species variation in aggressiveness and boldness was also positively associated with sociality. We then assessed the functional consequences of within-species trait variation on reconstituted colonies of four test species (*A. eximius, A. rupununi, A. guacamayos, A. oritoyacu*). We used colonies consisting of known ratios of docile/fearful versus bold/aggressive individuals and group foraging success as a measure of colony performance. In all four test species, we found that groups composed of a mixture of docile/fearful and aggressive/bold individuals outperformed monotypic groups: (1) mixed groups were more effective at subduing medium and large sized prey, and (2) mixed groups collectively gained more mass during shared feeding events. Our results suggest that the iterative evolution of depressed aggressiveness and increased within-species behavioral variation in social spiders is advantageous, and could be an adaptation to group living that is analogous to the formation of morphological castes within the social insects.

Behavior in the spider nursery

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The desert spider, *Agelenopsis aperta*, has been a model organism, exemplary of an aggressive syndrome. In this study, we investigated juvenile behavior during early feeding bouts that would occur while sibs are clustered in the immediate vicinity of the female parent's web-site. We examined the behavior paired juvenile sibs exhibited during weekly feeding bouts to determine whether contest competition (competes for prey), scramble competition (attacks only prey offered to it, ignoring the other sib) or cooperation (joint capture and subsequent feeding) occurs during this period of group-living. We found significant familial variation in the nature of the behavioral interactions juveniles exhibited during the feeding bouts. Despite the fact that food levels were biased against contesting prey, contest behavior predominated and evidence of the exhibition of despotic behavior will be presented. Note, however, that injurious behavior was extremely rare and likely the result of misidentification.

Modeling encounter rates within a wolf spider communication network

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Multimodal signals have likely evolved to compensate for environmental constraints inherent to complex habitats, but animals that utilize multimodal signals experience many selection pressures that could affect the evolution of signaling behavior. The risks to senders and intended receivers are primarily related to signal exploitation by social and/or interceptive eavesdroppers. One key factor necessary for understanding the influence of unintended receivers on signal evolution is to establish a realistic estimate of interaction rates within the social, or communication, network. We explored interaction rate estimates using a common model of multimodal communication,

the brush-legged wolf spider, *Schizocosa ocreata* (Araneae: Lycosidae). Male behavior, distance traveled, and interactions with conspecifics and heterospecifics were observed across multiple field seasons. Behavior and distance data was combined with field measurements of the active space of visual and seismic courtship, and used in modified ideal gas equations to estimate mobile active space and interaction rates for males during the peak mating season. Estimates were compared to observed interaction rates from the field to explore their utility in further studies of multimodal signal evolution.

Herbicide and predator exposure during mating have contrasting effects on egg production in the wolf spider, *Pardosa milvina*

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In many ways, exposure to anthropogenic chemicals is analogous to encountering predators: sub-lethal exposure can shift the behavior or aspects of the life history of the target species. Previous work demonstrated that the wolf spider, *Pardosa milvina* (Araneae, Lycosidae), reduces its activity both in the presence of chemotactile cues from the larger wolf spider, Hogna helluo (Araneae, Lycosidae), and in the presence of glyphosate-based herbicide. Here we tested the hypothesis that exposure to these two stressors while mating would affect eggsac production. Virgin males and females were introduced to field enclosures that were treated with glyphosate, water, predator cues, or nothing. They were left to interact with one another for 24 hrs. and then returned to the laboratory where they were maintained until death Fewer of the females from containers with predator cues produced eggsacs and they took longer to produce eggsacs than controls. Glyphosate had no effect on the likelihood of producing eggsacs but exposed animals produced eggsacs more quickly than controls. Predator- and herbicide-stressed females produced smaller first eggsacs than did control females but subsequent eggsacs did not differ among treatments. Females that mated in the presence of herbicide produced more eggsacs in their lifetime whereas females mating with predator cues present produced fewer eggsacs than their unstressed counterparts. Hence these two common stressors have different impacts on the reproductive biology of the spider and the collective impact of predator cues seems to have greater negative consequences to reproductive output than exposure to a common herbicide.

Spatiotemporal interactions in a carnivorous plant-spider community

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Spatial pattern can have significant effects on interactions between species. In particular, the presence of sessile predators likely influences mobile predators with the reciprocal also a possibility. In this study, we documented the spatial distribution of sundews (*Drosera brevifolia*), a carnivorous plant in a wet prairie habitat in Kentucky. We used sticky traps to measure the plant's potential dietary overlap with web-building spiders and PCR-based molecular gut-content analysis to assess predation levels by the spiders. We found the highest densities of sundews in the northern portion of the plot with lower densities either in the southern portion, or where spider websites were most abundant. We observed seasonality in sundew size and distribution with the highest cover and largest sundews earlier in the season, which decreased over time and recovered later in the season. Sixteen spider species were observed, the most common being *Neoantistea agilis* (Araneae: Hahniidae). Prey activity-density varied seasonally, being highest in the southern area, intermediate at spider websites, and lowest in the northern area containing the highest sundew densities. We found high levels of predation by spiders on the most common prey taxon, Collembola, which was neither seasonally structured nor correlated with prey abundance. Our results indicate that the composition of prey at sundew or spider microsites is similar, but that areas with higher densities of sundews potentially reduce available prey making these sites lower quality for other predators. Further study will target understanding the effects of other environmental gradients driving the interactions in these multi-kingdom carnivorous communities.

Prey sharing and communal living in two species of African tarantula: *Heterothele villosella* and *Hysterocrates gigas*

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Sociality is well documented in many different animal taxa including spiders, but it has rarely been explored in tarantulas. This study examined sociality in two species of African tarantula: the Cameroon Red Tarantula (*Hysterocrates gigas*) and the Tanzanian Dwarf Chestnut Tarantula (*Heterothele villosella*). In captivity, juveniles of both species have been documented sharing prey items or cluster feeding. Overall our goals were to compare the frequency of cluster feeding between species and to document any changes over time and with successive molts. Tarantulas were housed in communal groups and we manipulated group size, prey mobility (live vs. pre-killed) and prey size to determine how these factors would influence social feeding occurrences. *H. villosella* had significantly higher occurrences of cluster feeding events but were also more likely to cannibalize tankmates. When cluster feeding occurred, *H. villosella* often had all group members in the cluster whereas *H. gigas* had only one cluster feeding event with all group members. Cluster feeding was not affected by prey mobility or prey size. Group size had no effect on latency to feeding. Prey mobility and size did significantly affect latency to feeding, with groups given live prey and smaller prey items feeding more quickly. Overall *H. villosella* responded to prey more quickly and *H. gigas* often did not feed, particularly in the large prey size groups. Growth rates were not affected by group size, prey mobility or prey size.

Evolution of the chelicera: a *dachshund* domain is retained in the deutocerebral appendage of Opiliones (Arachnida)

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The proximo-distal axis of the arthropod leg is patterned by mutually antagonistic developmental expression domains of the genes *extradenticle*, *homothorax*, *dachshund*, and *Distal-less*. In the deutocerebral appendages (the antennae) of insects and crustaceans, the expression domain of *dachshund* is typically reduced. By contrast, the *dachshund* domain is entirely absent in the deutocerebral appendages of spiders, the chelicerae. It is unknown whether loss of *dachshund* expression in the spider chelicera is associated with the two-segmented morphology of this appendage, or whether all chelicerates lack the *dachshund* domain in their chelicerae. We investigated gene expression in the harvestman *Phalangium opilio*, which bears the plesiomorphic three-segmented chelicera observed in “primitive” chelicerate orders. Consistent with patterns reported in spiders, in the harvestmen chelicera *homothorax*, *extradenticle*, and *Distal-less* have broadly overlapping developmental domains, in contrast with mutually exclusive domains in the legs and pedipalps. However, unlike in spiders, the harvestman chelicera bears a distinct expression domain of *dachshund* in the proximal segment, the podomere that is putatively lost in derived arachnids. These data suggest that a tripartite proximo-distal domain structure is ancestral to all arthropod appendages, including deutocerebral appendages. As a corollary, these data also provide an intriguing putative genetic mechanism for the diversity of arachnid chelicerae: loss of developmental domains along the proximo-distal axis.

Patchy and mismatched cues: *Pardosa milvina* activity and survival influenced by two predators

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Most prey species coexist with multiple predators that present different levels of predation risk. The wolf spider *Pardosa milvina* (Araneae: Lycosidae) detects and responds to chemotactile cues (i.e., silk, feces, excreta) deposited by predators traveling through the environment. We tested the responses of *Pardosa* to cues from the larger wolf spider *Hogna helluo* and the ground beetle *Scarites quadriceps* (Coleoptera: Carabidae), which use distinctly different hunting modes. We examined changes

in *Pardosa* activity and survival when different combinations of predator cues were present. We also used short and long food deprivation periods for *Hogna* and *Scarites* to investigate the role of hunger on the strength of response shown by *Pardosa*. Responses to cues from *Hogna* (decreased activity) were generally stronger than those from *Scarites* (increased activity). When simultaneously exposed to cues from both predators, *Pardosa* either responded only to *Hogna* cues or seemed to average its response to *Hogna* and *Scarites* cues alone. There was a significant effect of predator (i.e., *Hogna* and *Scarites*) food deprivation period on *Pardosa* behavior, with stronger effects seen at the higher hunger level. The type of predator cue present in the predation trials only had a significant effect on *Pardosa* survival when predators were at high hunger levels. Furthermore, *Pardosa* seemed to prioritize chemotactile information over visual and vibratory information when evaluating predation risk. Overall, it is clear that *Pardosa* is capable of integrating information from multiple predators and the potential risks they pose.

***Dictyna/Emblyna*, To-mae-to/To-mah-to**

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Females of the genera *Dictyna* and *Emblyna* represent an identification challenge , especially when collected without conspecifics. The two genera represent a morphologically similar, and likely closely related group which were considered to be of a single genera in the most useful identification publication, Chamberlin and Gertsch 1958. In an attempt to create an identification aid for females without conspecifics, internal female reproductive structures were examined. From an initial set of 34 species, representing all but one species group proposed by Chamberlin and Gertsch, it was found that the shape of the copulary tubes, location of the spermatheca, and location and shape of the external fovea all aided correct identification. These initial 34 species were also phylogenetically examined with a small morphologic data set, as well as general morphologic characters, and there is some evidence that the proposed species groups may represent artificial groups. This is an initial summary, as it is hoped that the project will be expanded to cover all *Dictyna* and *Emblyna* covered in Chamberlin and Gertsch.

The effects of perceived operational sex ratio and male density on mate-choice plasticity in a wolf spider, *Schizocosa ocreata* (Hentz)

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Theory predicts that female mate preferences will vary depending on operational sex ratios (OSRs) in the population and/or the overall density of males. In the brush-legged wolf spider, *Schizocosa ocreata*, males typically mature in the field two weeks prior to females, which may allow females to assess potential mate availability before maturation to adulthood. Previous studies have shown that juvenile exposure affects adult female preference for male foreleg tufts, a secondary sexual characteristic. We used video playback in the lab to simulate changes in male density and sex ratio that females experience as penultimate instar juveniles. A full-factorial design, in which juvenile females were exposed to videos of one or three courting males at a frequency of once every two days or twice per day, was used for exposure. As adults, females were presented videos of courting males with small or large tufts. Female receptivity toward males with large tufts increased significantly with the cumulative number of males that females were exposed to as juveniles. Additionally, results suggest that a male-biased OSR plays a greater role in increasing female selectivity for males with large tufts than male density does. This study adds to the growing body of literature that suggests that invertebrates demonstrate plasticity in their mate choice decisions depending on their social environment.

Acoustic and seismic signal production in *Gladicosa gulosa* wolf spiders.

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Many wolf spiders produce complex multimodal (visual/seismic) signals, while others rely entirely on seismic vibration, making them excellent models for testing hypotheses about the evolution of signaling behavior. The “purring” wolf spider *Gladicosa gulosa* has been widely overlooked in previous research, though early studies suggest that males of this species produce an airborne signal during courtship. The method of production of this airborne signal and its potential adaptive value is unknown. We examined acoustic/vibratory communication in *G. gulosa*. Using Laser Doppler Vibrometry and sensitive microphones, we recorded and characterized the components of male courtship. Results suggest that courtship displays by males of this species involve both airborne (acoustic) and seismic (vibration) signals, and that the components of these complex signals are produced by both stridulation and percussion mechanisms. However, the airborne component of the signal is fully ablated on a non-vibrating surface. Our data suggest that the airborne component of courtship in this species may be the indirect result of vibration of the substratum during courtship. We suggest that substrate resonance may play a role in production of the airborne signal, which could potentially have adaptive consequences in this species.

Singing in the rain: Seismic signaling of spiders on sodden substrates

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Communication in complex environments poses challenges of potential signal loss, but some wolf spiders may compensate using multimodal signaling. Courtship of male *Schizocosa ocreata* (Hentz) is multimodal, consisting of visual and vibratory (seismic) signals. Previous studies have shown that efficacy of seismic communication varies with transmission properties of leaf litter microhabitat substrates. Because the 2011 field season had record-breaking levels of rainfall, we wondered whether adverse environmental conditions might dampen spider communication, and if leaf moisture affects seismic signals and mating success. We tested vibration transmission properties of wet vs. dry leaves using playback of both pure frequency tones and spider vibration signals. Dry leaves transmitted test tones and spider signals clearly, but wet leaves did not, obscuring signal structure across all frequencies. While wet leaves had higher levels of noise overall, dry leaves had higher signal to noise ratios. In addition, in dry leaves, signal amplitude may increase in a limited range of frequencies, suggesting potential for differences among leaves in resonance and/or signal filtering. Males courted females on wet and dry leaves equally, but mating success was significantly greater on dry leaf litter. Male spiders used significantly more visual signals (waves and arches) on wet leaves. Results suggest that although environmental conditions (e.g., heavy rains during the breeding season) can influence efficacy of individual signaling modes and negatively impact mating success, behavioral flexibility in multimodal signaling may compensate for constraints on communication.

The brown widow spider invasion of southern California: Assessment of egg parasites, microhabitat, and envenomation risk

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Within the last decade, the non-native brown widow spider, *Latrodectus geometricus*, became well established in southern California such that it is now a very common urban pest species around homes. Because of its characteristic spiked egg sac and ubiquitous nature, homeowners are very familiar with this new invading species, are

concerned about its toxicity and request control measures to contain populations. We investigated several aspects of brown widow's natural history in this new environment. First, because egg sacs of native western black widows, *L. hesperus*, are occasionally infested with parasites, we examined brown widow egg sacs to determine if 1) these parasites would cross over to brown widow sacs, 2) if so, to what degree and 3) could this be expanded into a biocontrol program. We dissected 3,739 brown widow egg sacs with the most common biocontrol possibility being a 2% infestation by the egg predator chloropid fly, *Pseudogaurax signatus*. Second, we examined the microhabitat selection of brown widows. There is considerable environmental variation in southern California habitat including urban homes, landscaped parks, natural areas, and agricultural property. We collected brown widows and noted their location. Most brown widows were found within 1 meter of the ground, were very common around urban homes and urban landscapes such as parks (including predominantly in playground equipment) and were rare or absent from natural and agricultural areas. Of note, some of their habitat choice (under curled lips of potted plants, in recessed handles of garbage cans) increased their potential for human envenomation.

Assessment of foraging-site quality by a sheet-weaving spider

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The utilization of micro-sites by web-building spiders is a classical study in behavioral ecology, and provides important insights into the behavior of foraging predators. Traditionally, research has treated site utilization as consisting of two components — site selection (the initial decision to utilize a site) and site tenacity (the decision of how long to remain in the selected site). However, site utilization in the field is a complex behavioral process, and a dynamic, conceptual model of spider foraging behavior is needed to accurately understand this process. We ran two-way behavioral choice assays in a controlled, laboratory setting with constant monitoring throughout an entire nocturnal period to document and characterize the responses of foraging linyphiid spiders (*Mermessus fradeorum* (Berland)) to cues from their main prey item, Collembola. Spider responses to prey cues indicated a surprisingly sophisticated site-evaluation process, consisting of several dichotomous decisions made across a series of behavioral phases, encompassing the search for foraging sites and the construction of webs. Each phase of the process entails an increased investment of silk into the foraging site, suggesting that sheet-weaving spiders continuously evaluate the quality of foraging sites and regulate web construction accordingly to avoid wastage of silk. Additionally, the impact of prey cues differed across behavioral phases, indicating that other, non-prey-related cues (such as microhabitat structures and microclimates) are incorporated at specific stages in the decision-making process. These results provide new insights into the ecology of sheet-weaving spiders and the evolution of the sheet web.

The effects of recreational trails on cursorial spiders in California coastal sage scrub habitat.

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We investigated the effects of recreational trails on cursorial spider communities in Point Mugu State Park located in Southern California. This is part of a larger study that included all cursorial arthropods and adult Diptera. Along three trails we placed three pairs pitfall trap arrays with one near the trail and the other 100m into the habitat. The pairs were placed at the trailhead, 500m along the trail, and 1000m along the trail. We sampled for two weeks in November 2004, April 2005, and June 2005. We collected 2109 spiders in 25 families in 51 genera. We analyzed our data at two ecological levels, a coarse level using community summary indices (species richness, species diversity, and number of individuals) and a fine level that compared the relative abundance of specific species using Bray-Curtis dissimilarity indices and permutational MANOVA. There was no impact of position on trail on spider species richness, spider abundance, Shannon's H', or Simpson's diversity index. This is in contrast to the entire data set of all cursorial arthropods and adult Diptera where the abundance of individuals and species richness was greater closer to trails than trapping points 100 m from the trail and in the native habitat. At the fine level, we found that spider communities were significantly different across the three trapping dates and that trails were also significantly different from one another. Additionally, spider communities at the three distances from the trailheads were also different and that there was a trail by distance interaction.

Male-specific (*Z*)-9-tricosene stimulates female mating behaviour in the spider *Pholcus beijingensis*

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Chemical signals play an important role in spider sexual communication, yet the chemistry of spider sex pheromones remains poorly understood. Chemical identification of male-produced pheromone mediating sexual behaviour in spiders has also not been reported before. This study aimed to examine whether chemically mediated strategies are used by males of the spider *Pholcus beijingensis* for increasing the probability of copulation. Based on data from gas chromatography–mass spectrometry (GC–MS) analysis, electroantennography (EAG) assay and a series of behavioural tests, we verified that (*Z*)-9-tricosene is a male-specific compound in the spider *P. beijingensis*. This compound acts as an aphrodisiac: it increases the likelihood that a female will mate. Mate-searching males release (*Z*)-9-tricosene to stimulate sexual behaviour of conspecific females. In the two-choice assay, however, sexually receptive females show no preference to the chambers containing (*Z*)-9-tricosene. This indicates that the male pheromone of *P. beijingensis* is not an attractant per se to the conspecific females. This is the first identification of a male-produced aphrodisiac pheromone in spiders.