

# TALK ABSTRACTS

## 2019 ANIMAL BEHAVIOR CONFERENCE

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Organized alphabetically by presenter last name. Presenter last names are shown in bold.

### **CHRONIC STRESS INDUCES SEX-SPECIFIC DENDRITIC REORGANIZATION IN MEDIAL PREFRONTAL CORTEX OF ADULT RATS THAT EXPERIENCED SOCIAL INSTABILITY IN ADOLESCENCE**

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Women are more susceptible to many stress-linked psychological disorders, including depression and posttraumatic stress disorder. Dysfunction of prefrontal cortex is implicated in many of these disorders. Thus, understanding how stress may differentially influence prefrontal cortex in males and females may shed light on the neurobiological underpinnings of these disorders. Chronic stress induces sex-specific changes in rodent medial prefrontal cortex. For example, apical dendrites of adult male rats retract after 10 days of chronic stress, which is followed by outgrowth after 7 days of rest. Conversely, apical dendrites of stressed female rats exhibit minimal changes throughout the post-stress period. However, little is known about how stress in adolescence affects these sex-dependent stress-induced changes in adulthood. As adolescence is an important period for HPA axis development and synapse maturation, stress during this time could alter later stress-induced changes in the adult brain. We examined dendritic remodeling in the prelimbic region of medial prefrontal cortex of rats that had experienced social instability stress in adolescence, followed by chronic restraint stress with or without a rest period in adulthood. Brains were collected either one day after chronic restraint or after 7 days of rest, and were stained using a Golgi-Cox method. Dendritic length and spine density analyses revealed a retraction of apical dendrites and an increase in mushroom spine density in chronically stressed male rats given a rest period. Chronically stressed female rats given a rest period experienced outgrowth of apical dendrites and a decrease in mushroom spine density. Both sexes experienced an increase in thin spine density following a rest period after chronic stress. These results corroborate previous evidence of sex-dependent stress-induced changes in mPFC and suggest that stress during adolescence may modulate stress-induced dendritic changes in adulthood.

### **COGNITIVE IMPAIRMENT RESULTING FROM DOXORUBICIN, CYCLOPHOSPHAMIDE, AND DOCETAXEL TREATMENT**

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Breast cancer is the most commonly diagnosed cancer among women and it is estimated that about 30% of newly diagnosed cancers in women will be breast cancers. While advancements in treating breast cancer have led to an average 5-year survival rate of 90%, many survivors experience cognitive impairments as result of chemotherapy treatment. Which include acute and delayed deficits in memory, learning, attention, processing speed, concentration, visuospatial skills, and executive function. Doxorubicin, Cyclophosphamide, and Docetaxel (TAC) are commonly administered as treatments for breast cancer. The purpose of this study is to investigate the effects of a clinically relevant regimen of TAC on cognition, cytokine regulation, and dendritic structure in the hippocampus of females. 12-week-old female C57BL/6 mice received 4 weekly intraperitoneal injections of saline or a combination of Doxorubicin + Cyclophosphamide followed by 4 Docetaxel injections. Four weeks after the last injection we tested for cognitive impairments of the animals in the Y-Maze test. TAC treated mice were not able to distinguish between the 3 arms and spent approximately the same amount of time in novel and familiar arm during the retention trial. Next animals were tested for hippocampus dependent cognitive

performance in the Morris water-maze. All animals were able to locate the visible and hidden platform locations. Saline-treated animals showed spatial memory retention in the probe trial and searched significantly longer in the target quadrant than in any other quadrant. However, a significant memory impairment was observed in the TAC-treated animals who did not demonstrate a preference for any of the quadrants on day 3. We are currently performing Golgi staining, licking behavior, and cytokine analyses in order to quantify: changes in dendritic complexity and arborization, cognitive dysfunction, and changes in pro-inflammatory, cytokine dysregulation.

## DEVELOPMENT OF NEW FOOD-SHARING RELATIONSHIPS AMONG NONKIN VAMPIRE BATS

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In an individualized animal society, social bonds can foster cooperation and enhance survival and reproduction. Cooperative bonds often exist among kin, but nonkin can also develop high-investment cooperative bonds that share similarities with human friendship. How do such bonds form? One theory suggests that strangers should ‘test the waters’ of a new relationship by making small initial cooperative investments and gradually escalating them with good partners. This ‘raising-the-stakes’ strategy is demonstrated by human strangers in short-term economic games, but it remains unclear whether it applies to helping in a natural long-term social bond. Here we show evidence that unfamiliar vampire bats (*Desmodus rotundus*) selectively escalate low-cost investments in allogrooming before developing higher-cost food-sharing relationships. We introduced females from geographically distant sites in pairs or groups and observed that bats established new reciprocal grooming relationships, and that increasing grooming rates predicted the occurrence of first food donations, at which point grooming rates no longer increased. New food-sharing relationships emerged reciprocally in 14% of female pairs, typically over 10-15 months, and developed faster when strangers lacked alternative familiar partners. A gradual grooming-to-sharing transition among past strangers suggests that ‘raising the stakes’ might be more evident when tracking multiple cooperative behaviors as new relationships form, rather than measuring a single behavior in an established relationship. ‘Raising the stakes’ could play a similar underappreciated role across a broader spectrum of social decisions with long-term consequences, such as joining a new social group or forming a long-term pair-bond.

## EVIDENCE FOR THE ALLOCENTRIC REPRESENTATION OF REFUGE LOCATION IN WHIP SPIDERS (ARACHNIDA: AMBLYPYGI)

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Whip spiders are nocturnal, tropical and subtropical predators that navigate back to a refuge after a night of activity. Navigation by whip spiders in structurally complex habitat, like a rainforest, is hypothesized to be under integrated, multisensory control. To explore how various sensory cues contribute to their navigation abilities, we performed a controlled laboratory experiment with the Costa Rican whip spiders *Paraphrynus laevifrons* and *Phrynus pseudoparvulus*. In particular, subjects were placed into a circular arena that contained a shelter, visual, olfactory and tactile cues. After an initial period to establish shelter fidelity subjects were tested in a series of pre-dawn displacements, where their subsequent movements were video recorded. The displacements were associated with no cue manipulation (controls), removal of either the visual or olfactory cue, or removal of the shelter. In the absence of the shelter subjects spent more time in its original location than in other control shelter locations in the arena, which suggests that subjects formed an allocentric, spatial representation of the shelter location that did not depend on stimuli intrinsic to the shelter. Additionally, the results of other analyses suggest that light cues play a particularly important role in the efficiency of whip spider return paths to the shelter.

## THE EFFECTS OF MUSHROOM BODY LESIONS ON HOMING OF *P. MARGINEMACULATUS*

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Arachnids in the order Amblypygi have mushroom bodies that are relatively larger than those of any other studied arthropod. It is hypothesized that these brain structures process and integrate multimodal sensory inputs that support their ability to navigate complex terrain at night to return to a home shelter in their natural habitats. This can be simulated in the lab to assess how environmental cues are used to navigate to a shelter. In this study, the protocerebrum of *P. marginemaculatus* was mechanically lesioned to elucidate consequences associated with disruption of the mushroom bodies. Lesioned and sham treated subjects were observed in a circular arena that contained a shelter and various visual, olfactory, and tactile stimuli. Each subject was allowed to roam freely in the arena over three nights, where it readily adopted the artificial shelter, and, then displaced to one of four different locations along the arena wall. Their paths were video tracked to determine how ablation of the mushroom bodies alters various aspects of their navigation routes. Brains were dissected and imaged with confocal microscopy to relate the extent of lesion damage with deficits in the ability of individuals to use sensory stimuli to navigate to a home shelter.

## PARENTAL CARE IN A POISON FROG OFFERS INSIGHTS INTO THE RELATIONSHIP BETWEEN LIFE-HISTORY AND OFFSPRING-PARENT COMMUNICATION

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Studying a trait across distantly related lineages affords opportunities to test and refine hypotheses for that trait's evolution. Behaviors expressed by free-living offspring, seemingly to encourage further investment by parents (i.e., begging), are particularly well-studied in birds, but occur in diverse lineages, including poison frogs. Recent advances in knowledge about the life-history of one frog, *Oophaga pumilio*, provide context for understanding why offspring-parent communication might evolve in this species (i.e., in which information parents might be interested). These frogs provide post-hatching care to their young, including regular provisioning with trophic eggs upon which tadpoles are entirely dependent and, this care is costly to females in terms of both current and future reproductive effort. The information content of putative begging displays by tadpoles is consistent with the hypothesis that parental life-history drives the evolution of offspring solicitation displays, and highlights the importance of taxon-specific factors in shaping both the payoffs of parental care and the potential payoffs of attending to offspring signals. These findings offer support for the established, but underappreciated, hypothesis that offspring signals evolve to reveal the high quality (i.e., fitness prospects) of senders, and highlight the need for more complex hypotheses about the evolution of offspring-parent communication.

## INVESTIGATION OF MULTIMODAL SENSORY INTEGRATION FOR FACILITATION OF SHELTER DISCRIMINATION IN AMBLYPYGI (ARTHROPODA: ARACHNIDA)

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Amblypygi are a nocturnal order of arachnids that live in tropical and subtropical regions. These animals have specialized appendages-antenniform legs-that process olfactory, mechanosensory, and chemosensory cues. These sense organs are used by amblypygids to navigate to and recognize a home shelter after a night of foraging. It is hypothesized that this ability is supported by multi-modal integration across a number of sensory modalities. To test this hypothesis, an experiment was carried out to determine whether providing both olfactory and tactile stimuli would facilitate shelter discrimination compared to the availability of one cue alone. Subjects, *Phrynus marginemaculatus*, were allowed to wander freely in an arena that contained an accessible (+) and inaccessible (-) shelter, where the two shelters were cued by a distinct combination of olfactory and tactile stimuli. They were then tested in a

small arena with a floor that was divided into two sections equally covered by each configured stimulus pair. Preference scores, based on occupancy in the two sections of the test arena, were used to measure the strength of shelter recognition. Preliminary results suggest that, as expected from the hypothesis, pairing of an olfactory and tactile cue does enhance the ability of amblypygids to recognize a shelter.

## **HORMONAL RESPONSES TO BOTH REAL AND SIMULATED SOCIAL CHALLENGES IN A COMPETITIVE FEMALE BIRD**

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In many vertebrate species, males respond to competitive interactions by rapidly elevating testosterone (T) levels in circulation. Though there is growing evidence that aggression can also be adaptive for females, and that females can synthesize and respond to T, we still lack a full understanding of how females hormonally respond to social challenges. Tree swallows (*Tachycineta bicolor*) are an ideal system in which to explore this issue because females compete for limited nesting cavities, and their aggression is at least partly mediated by T. Here, we measured circulating T levels in pre-laying females that were exposed to 30-min simulated territorial intrusions, compared to stage-matched controls. In a separate experiment conducted after initial territory establishment, we experimentally reduced the availability of nesting cavities, allowing us to compare T levels in females experiencing real social instability to those of controls. Results suggest that female tree swallows do not elevate T levels in circulation after behaving aggressively toward real or simulated competitors. This apparent lack of T elevation stands in sharp contrast to prior work showing that females are physiologically capable of elevating T (i.e. to GnRH) during this same breeding stage. Collectively, these results provide new insight into how females do (or do not) respond to social competition, raising new questions as to whether females socially modulate other hormones as an adaptive response to social challenges.

## **THE PIGMENTARY BASIS OF EGGSHELL MIMICRY IN INDEPENDENT AVIAN HOST-PARASITE SYSTEMS**

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Hosts of avian brood parasites often use visual cues to reject foreign eggs, and several lineages of brood parasites have evolved mimetic eggshell coloration and patterning to circumvent host recognition. What is the mechanism of parasitic egg color mimicry at the chemical level? Here I review our current understanding of these mechanisms in three evolutionarily independent lineages of egg-mimetic host-parasite systems. Mimetic egg coloration in 3 genets of the Common Cuckoo is achieved by depositing similar concentrations of colorful pigments into their shells as their hosts. The mechanism of parasitic egg color mimicry at the chemical level in the poorly studied host-parasite system of the Neotropical Striped Cuckoo and one of its hosts, the Rufous-and-white Wren is that of perceptual similarity, but not chemical parallelism. Finally, eggshell ground color mimicry in the Cuckoo Finch and its Tawny-flanked Prinia host is again shared chemical composition and concentrations of the two avian eggshell pigments in some but not in other color morphs of the host and parasite eggshells. Similarity of host-parasite eggshell appearance, therefore, can but need not always be paralleled by a quantitative chemical match to generate effective visual mimicry of the eggs in avian host-parasite interactions.

## **ARTIFICIAL LIGHT AT NIGHT DISRUPTS THE BEHAVIOR AND PHYSIOLOGY OF CRAYFISH**

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A significant amount research exploring the impacts of light pollution and artificial lighting at night has focused on vertebrates. The lack of literature on invertebrate species, especially aquatic invertebrates, is an important gap in knowledge. Aquatic invertebrates are often keystone species; thus, any changes within the organisms themselves can severely affect entire ecosystems. We investigated how properties light at night had altered the physiology and behavior within two different aquatic invertebrates, the virile crayfish (*Faxonius virilism*) and rusty crayfish (*Faxonius rusticus*). Data was collected for ten weeks at

the University of Michigan Biological Station (UMBS) in Pellston, MI. Behavioral data was measured as the amount, duration, and maximum intensity of agonistic interactions. Hemolymph was obtained to quantify the stress levels within the crayfish as a physiological response. Exposure to a higher intensity of light and the presence of ultraviolet light induced a behavioral trend, resulting in shifted social interactions within both species of crayfish. Due to the importance of freshwater ecosystems and the role crayfish play as a keystone species, examining how crayfish are impacted from ecological light pollution is imperative to maintaining the health of aquatic ecosystems.

## **USING PLAYBACK EXPERIMENTS TO INVESTIGATE SPECIES DISCRIMINATION IN A HYBRIDIZING POPULATION OF BLUE-WINGED AND GOLDEN-WINGED WARBLERS**

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Species recognition is crucial for reproduction in birds and is usually aided by species-specific vocalizations or songs. When ranges of closely related species overlap, cross-species learning may occur, eliminating the associations with signals necessary for species discrimination. In 2017 and 2018, we recorded mismatched and atypical songs in Blue-winged (*Vermivora cyanoptera*, BWWA) and Golden-winged Warblers (*V. chrysoptera*, GWWA) in a hybrid contact zone at Fort Drum Military Base in upstate New York. Here, we investigate species discrimination in that hybrid contact zone. Given the intensity of introgression in this region, we hypothesized that GWWA and BWWA show limited or no species discrimination by song. We used playback experiments to test the responses of focal males identified by song phenotype to simulated conspecific and heterospecific male intruders. We presented pre-recorded songs of GWWA and BWWA, as well as atypical songs, in randomized order to males of both species. We ran a principal component analysis on vocalizations, closest approach, and number of perch changes to find overall response scores and then ran linear mixed models with song phenotype and playback treatments as predictors, PC1 and PC2 as overall responses, and male identity as a random effect. BWWA and GWWA responded to playbacks of both conspecific and heterospecific songs, but whereas BWWA responded similarly to all playbacks, GWWA responded less to BWWA song. Our study suggests weak or limited species discrimination by song in winged warblers.

## **THE INFLUENCE OF PAIRING STATUS ON YELLOW WARBLER RESPONSES TO SIMULATED THREATS TO THE NEST**

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Nest defense is a costly behavior, thus its extent should reflect the perceived risk to the nest and the value of the contents. Yellow Warblers use referential seet calls to warn mates of nearby brood parasitic Brown-headed Cowbirds. Most seet calls are produced during the laying or incubation stages of nesting, because the risk of brood parasitism is greatest during these stages. How then, do Yellow Warblers without a mate or nest respond to playbacks that simulate parasitic and other threats? We presented playbacks of cowbird chatter, seet calls, Blue Jay calls (nest predator), and Wood Thrush (non-threatening sympatric control) to both paired and unpaired Yellow Warbler males during the breeding season and measured behavioral responses. Pairs that were actively guarding territories but not building nests or gathering food for chicks were assumed to be laying or incubating eggs, while unpaired males were assumed not to have a nest. We found that pairing status of males was related to their response to playbacks that simulated threats to a nest. Paired males responded quicker and vocalized more than unpaired males towards playbacks of Brown-headed Cowbird and Blue Jay, both which threaten nest success. Our data also show that Yellow Warbler males discriminate between these playbacks and adjust their responses based on the extent of current investment in nesting.

## **PHENOTYPIC INTEGRATION WITH TESTOSTERONE DIFFERS BY SEX AND BREEDING STAGE IN SEX-ROLE REVERSED SPECIES**

Across vertebrates, testosterone (T) is considered a key player in the hormonal regulation of phenotypic traits related to reproductive success. While sexually selected traits are widespread in both males and females, their regulation by androgens may be divergent between the sexes. In particular, empirical and theoretical research suggests that high levels of circulating T may not explain behavioral variation in female aggression, potentially because high T can interfere with maternal care. For species in which males conduct parental care and females aggressively defend territories (i.e. sex-role reversed), these constraints may not be as relevant, but it is not clear if T explains aggression in males or females. We examined this question in sex-role reversed male and female Northern Jacanas (*Jacana spinosa*) in Panama. We simulated territorial intrusion to measure aggression and baseline circulating T levels in both sexes. Males were more aggressive than females, but there were no significant differences in T between the sexes. Aggressive behavior was not correlated with T for either males or females. However, T related to breeding stage for both sexes - incubating males had lower T than males not actively conducting parental care, and females observed copulating had lower T than those not actively breeding. Similarly, breeding stage influenced the co-variation T with phenotypic traits important for reproduction and territorial competition. In copulating females, T positively co-varied with body mass, ovary mass, and wing spur length, whereas in males that were not breeding, T positively co-varied with body mass and testis mass. Overall, copulating females had the strongest phenotypic integration, and incubating males had the weakest. These findings suggest that the integration of T with phenotypic traits may be constrained by male parental care in jacanas, and that the sexes may differ in the mechanisms regulating the expression of competitive traits.

#### EFFECTS OF REDOX MODIFIER MNTNBUE-2-PYP ON COGNITION AND HIPPOCAMPAL PHYSIOLOGY FOLLOWING CHEMOTHERAPY

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Chemotherapy treatment for breast cancer can induce cognitive impairments which often involve environmental influences such as oxidative stress. The brain, as a whole, is susceptible to oxidative stress due to its high energy requirements, limited anaerobic respiration capacities, and limited antioxidant defenses. The goal of the current study was to determine if the manganese porphyrin SOD mimetic MnTnBuOE-2-PyP (MnBuOE) could ameliorate the effects of doxorubicin, cyclophosphamide, and paclitaxel (AC-T) on mature dendrite morphology and cognitive function. 3-month-old female C57BL/6 mice were given intraperitoneal injections of chemotherapy followed by subcutaneous injections of MnBuOE. One day following the last injection, a cohort was sacrificed to examine the immediate molecular effects of the treatments including proteomic analysis of the hippocampus and plasma cytokine levels. 4 weeks following chemotherapy treatment a second cohort was tested for hippocampus-dependent cognitive performance in the Morris water maze and motor coordination with the fluid licking tests. Immediately after testing, brains were collected for Golgi staining and molecular analyses. Proteomic analysis revealed 272 significantly deregulated proteins. Canonical signaling pathways that were commonly altered included synaptic long-term depression, protein ubiquitination, and fatty acid oxidation. Plasma cytokine analysis revealed a significant increase of IL-4 in the AC-T + MnBuOE treated group. MnBuOE treatment protected spatial memory during the Morris water-maze. MnBuOE + AC-T showed spatial memory retention during all probe trials. AC-T treatment alone significantly impaired spatial memory retention in the first and third probe trial (no platform). AC-T treatment decreased dendritic length in the CA1 and DG areas of the hippocampus that was normalized upon MnBuOE treatment. We are currently performing western blot analyses for neurogenesis and microglial activation markers.

## **TADARIDA BRASILIENSIS ADJUSTS ECHOLOCAION CALLS TO DETECT CAVE OPENING: EVIDENCE FOR BIMODAL SENSING IN BATS**

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While both bats and dolphins use sonar to get a picture of their environment, both have visual acuity and the ability to perceive objects through vision. The ability to integrate information from vision and echolocation has been widely studied in dolphins and other cetaceans with studies suggesting that cetaceans use multimodal sensing to improve accuracy and target identification. While little is known about the extent to which bats integrate vision and echolocation, bats are known to exhibit behavioral changes when vision is obstructed compared to environments where ambient lights allows for use of visual cues. This suggests that like cetaceans, bats may integrate vision with echolocation when sensing their environment. In this study, we examined how Brazilian free-tailed bats (*Tadarida brasiliensis*) use their echolocation calls in an open field compared to calls used during reentry to the roost. We extracted individual echolocation calls from two locations, an open field and the cave edge, during daylight and dark hours. Results demonstrated that calls exhibit decreased duration and increased bandwidth at the cave edge compared to the open field under both light conditions. Additionally, there was no significant difference in parameters of the calls recorded in the open field between hours of daylight and darkness, but all the call parameters were significantly different between daylight and darkness hours at the cave edge. The results of this study provide the first insight into bimodal sensing in bats and how bats adjust echolocation calls based on the environment and levels of ambient light.

## **EVIDENCE THAT CIS-REGULATORY VARIATION IN AN ESTROGEN RECEPTOR CONTRIBUTES TO BEHAVIORAL EVOLUTION IN A POLYMORPHIC SPARROW**

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In the white-throated sparrow, a chromosomal rearrangement has caused changes in social behavior. An identified portion of the genome affecting social behavior in vertebrates is extremely rare, and as such, this species offers an outstanding opportunity to study the mechanisms by which variation in a known set of genes causes variation in social behavior. Birds of the white-striped morph (WS) are heterozygous for the rearrangement (ZAL2<sup>m</sup>/ZAL2) and exhibit greater territorial aggression than do birds of the tan-striped morph (TS), which are ZAL2 homozygotes. Recombination suppression between ZAL2 and ZAL2<sup>m</sup> has led to genetic divergence of genes inside the rearrangement, including ESR1, which encodes estrogen receptor alpha (ER $\alpha$ ). Here, we used complementary *in vitro* and *in vivo* approaches to test a model in which variation in ESR1 causes morph differences in aggression *via* differential ER $\alpha$  expression. We first asked whether genetic variation in ESR1 affects gene expression. We found that SNPs in the promoters lead to allele-specific expression of a reporter gene *in vitro*. We then asked whether this differential expression occurs *in vivo*, and found significant allelic imbalance of the two ESR1 alleles such that the ZAL2<sup>m</sup> allele was overexpressed relative to ZAL2 in nucleus taeniae of the amygdala (TnA). The alleles were also differentially methylated. We then asked whether ER $\alpha$  expression is causal for aggression by knocking down ER $\alpha$  expression in TnA and measuring estradiol-induced aggression. In untreated birds, estradiol rapidly increased aggression in WS, but not TS birds. Knocking down ER $\alpha$  expression in TnA eliminated this morph difference. Taken together, our results suggest that divergence between the alleles of ESR1 drives differential ER $\alpha$  expression, and this differential expression in TnA contributes to differential aggression. In this species, divergence of regulatory elements in ESR1 has contributed to the evolution of social behavior.

## **SHELTER FIDELITY AND SENSORY-HOMING MECHANISMS ON A VERTICAL SURFACE IN THE WHIP SPIDER, *PHRYNUS PSEUDOPARVULUS***

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The ability to navigate is essential for mobile animals and has been widely studied in a variety of different species. Nocturnally active, tropical whip spiders successfully return each pre-dawn to their home shelter after a night's horizontal journey on a forest floor and vertically on a home tree. As such, they are ideal animals to study navigation mechanisms used in both the horizontal and vertical dimensions. The purpose of this study was two-fold. The first was to examine homing fidelity on a vertical surface under laboratory conditions. The second was to investigate candidate sensory mechanisms for the guidance of vertical navigation. Neotropical *Phrynos pseudoparvulus* were placed individually in one of nine possible shelters positioned on a vertical surface and tracked for four nights to determine the extent to which *P. pseudoparvulus* successfully relocate their home shelter on the vertical plane. Particular attention was placed on whether errors were more likely to occur above/below the home shelter vs left/right of the home shelter. Subsequently, for four nights the home shelter was swapped with the location of an alternative shelter to determine whether cues originating from the home shelter, presumably chemical in nature, were more important than the actual location of the shelter, and the sensory cues indicating that location, in guiding homing to the shelter. Preliminary results indicate that whip spiders can successfully return to a home shelter on a vertical surface after a night of hunting. These results suggest that whip spiders probably use multiple sensory cues to relocate shelters when navigating on a vertical surface.

## RISING TO THE CHALLENGE: MELATONIN MODULATES CIRCULATING ANDROGENS AND AGGRESSION IN A SEASONALLY BREEDING RODENT

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Numerous studies across animal taxa have demonstrated a positive correlation between gonadal steroids and aggression during the breeding season (i.e., challenge hypothesis). However, many seasonally breeding animals exhibit equivalent or increased levels of aggressive behavior during the short-day (SD) photoperiods of the non-breeding season, despite gonadal regression and reduced circulating androgen levels. While the mechanisms underlying SD increases in aggression are not well understood, previous work from our lab suggests that melatonin (MEL) and the adrenal androgen dehydroepiandrosterone (DHEA) are important in facilitating non-breeding aggression in Siberian hamsters (*Phodopus sungorus*). To investigate the role of MEL in modulating seasonal transitions in aggressive behavior, we housed male hamsters in long days (LD) or SD, treated them with either timed MEL or saline injections, and quantified aggression after 3, 6, and 9 weeks of photoperiodic housing. Furthermore, to assess whether MEL mediates seasonal shifts in gonadal and adrenal androgen synthesis, serum testosterone (T) and DHEA concentrations were quantified 36 h before and immediately following an aggressive encounter. LD hamsters administered MEL (LD-M) exhibited SD-like levels of aggression, and aggressive encounters reduced serum DHEA levels, yet increased serum T levels. Interestingly, LD and SD hamsters exhibited distinct relationships between circulating androgen profiles and aggressive behavior, in which changes in serum T following an aggressive encounter ( $\Delta T$ ) were negatively correlated with aggression in LD and LD-M animals, while  $\Delta DHEA$  was positively associated with aggression in SD animals. Collectively, these findings suggest that a SD-like MEL signal mediates a transition from synthesis to metabolism of circulating androgens following an aggressive interaction, a mechanism that may serve to socially prime SD animals for future aggressive encounters.

## THE EVOLUTION OF COLOR VISION ACROSS JUMPING SPIDERS

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In many animals, vision plays a central role in navigation, foraging, and communication. The diversification of visual systems is thus important for exploitation of new visual niches. Jumping spiders are visually guided predators with principal eyes that provide high spatial acuity and color vision. They also exhibit major differences in color signaling across species, particularly in the use of long-wavelength colors. Given that most jumping spiders are thought to have UV-green dichromatic vision, we hypothesized that jumping spider groups that use long-wavelength colors in communication may have evolved improved color vision. Within a comparative framework, we investigated the number and peak sensitivities of photoreceptor types in the principal eyes of jumping spiders using microspectrophotometry. We identify three origins of trichromacy (in Harmochirina, Salticini and Euophryini), and two origins of tetrachromacy (in Euophryini and Aelurillina). This improved color vision is achieved via two different strategies: a) using spectral tuning via an intraretinal long-pass filter; b) adding novel photoreceptors with different spectral sensitivities. Jumping spiders thus represent a promising group for the study of repeated evolution of transitions of color vision from dichromacy to tri- and tetrachromacy in terrestrial habitats. New visual niches may accelerate sexual selection leading to higher rates of diversification in this group of spiders.

### **ACUTE AND REPEATED EXPOSURE TO SOCIAL STRESS REDUCES GUT MICROBIOTA DIVERSITY IN SYRIAN HAMSTERS**

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Recent data indicate that gut microbiota can affect their host's brain and behavior. In humans, social stress is the primary form of stress experienced, and this exposure promotes a variety of gastrointestinal and neuropsychiatric illnesses. It is still not known if alterations in gut microbes are involved in these outcomes. Syrian hamsters are ideal subjects for social stress research because they are territorial and aggressive and rapidly form stable dominant/subordinate relationships. Their agonistic interactions are highly ritualized and thus rarely result in physical injury, making it possible to focus on psychological effects of social stress. The purpose of this study was to determine if brief exposure to social stress in hamsters alters gut microbiota and if gut microbiota composition can predict the outcome of an agonistic encounter. Hamsters were paired for 15 min, leading to rapid formation of a dominance hierarchy. Animals were then paired twice a day over 4 days. Microbiota composition was assessed via 16S mRNA Illumina sequencing on fecal samples collected before and after social interaction. After the first interaction, a decrease in alpha diversity was observed in both dominant and subordinate animals, with this decrease being more pronounced after repeated interactions. Beta diversity analysis revealed distinct clustering, reflecting alterations of microbiota composition, between hamsters undergoing social interaction versus their controls. Linear discriminant analysis (LEfSe) identified specific microbiota members that drove those differences. Importantly, LEfSe analysis on samples collected prior to social interaction revealed that some microbiota were powerful predictors of whether an animal achieved dominant or subordinate status. These data suggest that agonistic social interactions impact gastrointestinal health in both winners and losers, and that the microbial community may predict the outcome of dominant/subordinate relationship.

### **MANIPULATING LEVELS OF ENDOGENOUS SEROTONIN INTERACTS WITH SOCIAL EXPERIENCE TO AFFECT HOW SOCIAL VOCALIZATIONS ARE REPRESENTED IN THE BRAIN'S SOCIAL BEHAVIOR NETWORK**

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Early-life social experience effects the social competence of adults. While much work has focused on aberrant behavior in animals raised in social isolation, fewer studies have addressed potential perceptual abnormalities in these animals. For example, vocalizations are an important aspect of rodent social

behavior and may be differentially processed by animals raised in social isolation. In the auditory system, levels of serotonin increase during social interactions; however, this increase is less coupled to social behaviors in mice without social experience. While animals rely on auditory cues during social interactions, social behaviors are produced in part by coordinated activity within an interconnected suite of nuclei within the basal forebrain, hypothalamus, and midbrain termed the social behavior network (SBN). Each node of the SBN contains markers for serotonin signaling including fiber terminals and receptors and is responsive to social vocalizations. We tested whether social experience interacts with serotonin signaling to affect expression of the immediate early gene product cFos (a marker for neural activation) within the SBN following playback of female vocalization. Male mice were raised in isolated or in social ( $n = 3/\text{cage}$ ) conditions for 30 days. Prior to 60-minute playbacks of female broadband vocalizations, mice were injected with saline, fenfluramine (a serotonin releaser/reuptake inhibitor), or pCPA which blocks serotonin synthesis. Overall, mice raised in social isolation had increased numbers of cFos neurons in most nodes of the SBN regardless of pharmacological treatment. Despite having more activated neurons, we found that socially isolated animals had lower levels of coordinated activity (i.e., functional connectivity) than their socially raised counterparts. Continued analysis at the network level aims to describe how social experience interacts with serotonin signaling to create different patterns of neural activity across the SBN.

## EXPERIMENTAL CROSS-FOSTERING OF EGGS REVEALS EFFECTS OF TERRITORY QUALITY ON REPRODUCTIVE ALLOCATION

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Parental and territory quality are often correlated in birds, and both factors influence the resources allocated to offspring. Surprisingly, the relative contribution of these two components of parental investment remains obscure. We experimentally decoupled the normal covariation between parental quality and territory quality to test the hypothesis that territory quality influences prenatal and postnatal reproductive allocation. Territories were categorized into low-, intermediate-, and high-quality based on fledging success of nesting attempts in nestboxes over a previous 6-year period. To decouple covariation between territory quality and individual quality, nestbox entrance size was increased on high-quality territories and left small on poor-quality sites because house wrens (*Troglodytes aedon*) prefer small over large entrances to their nest sites. We found a significant prenatal effect of territory quality on nestling provisioning: when reared on intermediate-quality territories, nestlings hatching from eggs produced on low-quality territories were provisioned at a higher rate than those hatching from eggs produced on high-quality territories. We propose that the increased provisioning was brought about by increased nestling begging mediated by a maternally derived compound transferred to the eggs of stressed females in poor-quality habitat.

## MALE MICE ADJUST COURTSHIP BEHAVIOR IN RESPONSE TO FEMALE MULTIMODAL SIGNALS

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Multimodal signaling is nearly ubiquitous across animal taxa. While much research has focused on male signal production contributing to female mate-choice or preferences, females often give their own multimodal cues during intersexual communication events. We investigated the role of two different female vocalizations produced by the female house mouse (*Mus musculus*): the broadband, relatively low frequency squeak (i.e., BBV, broadband vocalization), and the higher frequency, ultrasonic vocalizations (USVs). We presented these vocalizations with and without female urine to examine the influence of combining information across multiple modalities. Multimodal signal components are often classified based on whether they contain the same, or redundant information to the receiver (e.g., the backup hypothesis) or different, non-redundant information to the receiver (e.g., the multiple messages hypothesis). Male mice responded with different investigative behaviors and vocalization rates

depending on the signal presented, suggesting that female urine and vocalizations act as non-redundant multimodal cues. Furthermore, males responded with greater courtship effort to the multimodal combination of female USVs and female urine than any other signal combination, suggesting that urine provides the context by which males can then evaluate female vocalizations.

## **ASSESSING THE RELATIONSHIP BETWEEN TOURISM AND AFRICAN ELEPHANT (*LOXODONTA AFRICANA*) HABITAT USE IN ZAMBEZI NATIONAL PARK, ZIMBABWE**

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As charismatic megafauna and a flagship species, African elephants (*Loxodonta africana*) are vital to the African tourist economy. Conversely, high levels of tourism can induce behavioral shifts that push desired animals into less frequented areas and disrupt natural behaviors. In order to examine this trade-off, African elephant behaviors were studied in Zambezi National Park (ZNP) near Victoria Falls, Zimbabwe. Over the course of 14 weeks during the dry season, in-person observations and camera traps in ZNP were used to collect GPS, behavioral, demographic, habitat type, and environmental data from elephant sightings. As a proxy for human presence throughout the park, GPS data were collected for each vehicle sighted in ZNP. The GPS data of vehicles and elephants were plotted on Google Earth to show a visual representation of their spatial relationship. Analyses found that elephants were more frequently sighted in areas with fewer vehicle sightings and at times corresponding with hours the park was closed. Elephant numbers were also inversely related to vehicles numbers in given locations. These results support prior findings that elephants modulate their movements to avoid areas and times of high human presence. Goals of this work are to inform tourism policy and promote sustainable conservation practices.

## **STRESSFUL PARENTING: OXIDATIVE STRESS AS A POTENTIAL COST OF REPRODUCTION AND PARENTAL CARE WITHIN A MOUTHBROODING CICHLID FISH, *ASTATOTILAPIA BURTONI***

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The investment in reproduction and parental care is an energetically costly, yet fundamental aspect of the life history strategies in many species. Increased reproductive effort could interfere with other life history demands, such as health maintenance and future reproductive success. Recently, oxidative stress has received increased attention as a potential mediator of this trade-off. While some studies find evidence for increased oxidative stress in response to reproduction and offspring care, others find the opposite. However, most studies only consider a single time point during reproduction and offspring care. Here, we tested whether reproduction and offspring care increases oxidative stress in a mouthbrooding cichlid fish, *Astatotilapia burtoni*, at various time points during reproduction. In this species, females mate with dominant, territory defending males and hold the offspring within their mouths until releasing them as independent juveniles. Using mixed-sex cichlid communities, we found that reproductive (mouthbrooding) females tend to have higher levels of oxidative stress than non-reproductive females. Interestingly, females experienced significant changes of oxidative stress following reproduction, with especially high levels of oxidative stress immediately after egg production and again towards the end of mouthbrooding. We also applied a manipulative approach to differentiate the costs associated with mouthbrooding and those associated with reproduction itself by allowing some females to provide care for her offspring and removing the offspring from others. To our surprise, oxidative stress levels were elevated even in females that reproduced but were not mouthbrooding. Our study provides evidence that an increase in oxidative stress is predominantly associated with egg production and egg laying, rather than parental care, and highlights the importance of studying the oxidative cost of reproduction at different time points.

## **PARTITIONING OF SIGNAL SPACE IN A BREEDING WARBLER COMMUNITY**

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The communication channel of vocalizing animals is called signal space, a multidimensional area defined by temporal and spectral signal features. The availability of signal space depends upon ambient noise, the number of competitors for the space, and the extent of song overlap among species within an acoustic community. To minimize acoustic interference, sympatric species should inhabit a well-defined acoustic niche. Partitioning of signal space results from signal evolution in favor of species-specific song, but also occurs through behavioral adjustments to avoid overlap. Additionally, songs of closely-related species may be less similar than songs of phylogenetically distant species, suggesting divergence of songs to prevent hybrid matings. We hypothesize that warbler species partition signal space, and test whether phylogenetic distance between species predicts overlap within that space. We recorded songs of 10-15 focal males per species from a community of warblers that co-occur at Fort Drum, New York. To generate signal space axes, we ran a principal components analysis of song characteristics, yielding three significant PCs which collectively explained 88% of variation among species and reflected heavy loading of frequency traits (PC1), temporal traits (PC2), and bandwidth (PC3). Most species inhabited clearly partitioned acoustic space, with interspecific variation in area occupied and little overlap among species. Preliminary analysis of distances between acoustic niches suggests that songs of phylogenetically closer species are more similar than those of more distant species. Our study is a critical step in understanding partitioning of signal space in communities, and how signal overlap can drive signal evolution.

## **GEOMETRIC MORPHOMETRIC ANALYSES OF THREESPINE STICKLEBACK IN A NETWORK OF GEOGRAPHICALLY NOVEL LAKES**

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The classic Darwinian view of evolution presents it as a universally slow and ponderous process. However, recent anthropogenic disturbances have caused environments to begin changing rapidly, and many recent studies have shown that in some circumstances the process of evolution can also occur at a rapid pace. Threespine stickleback (*Gasterosteus aculeatus*), a small marine fish species widely distributed across the upper Northern Hemisphere, is a commonly used model organism for such studies of rapid evolution due to its high phenotypic variability. Here, I investigate the phenotypic adaptation of threespine stickleback to recently colonized freshwater lakes formed by the retreat of Icelandic glaciers. Stickleback invasions from marine to freshwater environments are extremely well-documented, especially in terms of morphology, but the invasion of glacial lakes is as of yet unstudied. Using geometric morphometrics, I quantify and analyze body shape differences of threespine stickleback sampled from 14 Icelandic lakes of varying geologic origins and colonization times. I discuss the morphological differences between these populations, distinguishing known environmental drivers of morphologic change and identifying any selective pressures unique to a glacial lake environment. In addition, since the samples include several populations that colonized separate lakes in parallel, these results explore the repeatability of adaptation to new habitats occurring in the presence of similar selective pressures.

## **THE SHY-BOLD SYNDROME: REPEATABILITY IN A WOLF SPIDER**

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Spiders are universally understood as solitary, aggressive and indiscriminate predators. With such a reputation, it is not at all surprising that sociality in this group is exceedingly rare. The behavioral syndrome *aggressiveness* is commonly correlated with the *shy-bold* syndrome, with spiders generally being "risk-prone" as opposed to "risk-averse". This metric was chosen for its high repeatability among individual spiders and how highly-conserved this temperament tends to be evolutionarily. Most importantly, boldness has wide implications in fitness across many taxa as risk-prone individuals exhibit higher reproductive success than those who are risk-averse. As defined in this study, boldness is the

latency to resume movement after an aversive stimulus. With a controlled burst of air, we simulated the approach of an avian predator and obtained repeated latency measurements on several individual wolf spiders (*Schizocosa ocreata*: Lycosidae). We quantified repeatability by calculating the intraclass correlation coefficient (ICC) along with  $R$  and  $R^2$  via generalized linear mixed models (GLMM). Our goal with this preliminary work was to establish a baseline shy-bold spectrum for this species. Thus, we will better understand how the structure and strength of this syndrome may covary under experimental conditions.

## NEURAL REPRESENTATION OF VALENCE IN THE HONEY BEE BRAIN

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Motivated behavior can be broadly classified as the pursuit of pleasure and the avoidance of pain. Animals must assign valence to a social encounter such that positive, affiliative interactions are pursued, and negative, agonistic interactions are avoided. In vertebrates, mosaic patterns of neural activity underlie the emotional valence of a social experience in numerous brain regions, suggesting that discrete anatomical “modules” specifically encode positive or negative stimuli. Whether or not the modular encoding of valence is a conserved organizational principle of brains across a broad phylogenetic spectrum is an open question, especially as related to miniaturized nervous systems, such as those found in insects. Considering the high metabolic demands of maintaining and activating neural tissue, insects are under increased selective pressure to limit energy investment in the brain. Therefore, the encoding of valenced social information may require alternative strategies to vertebrates, such as overlapping functionality of subpopulations of neurons to represent both positive and negative valence. Alternatively, small brains may employ a modular organizational strategy, like vertebrates, to reduce energy investment by shortening connectivity within similarly functioning neuronal circuits. To explore the architecture of valence encoding in the insect brain, we mapped immediate early gene expression in the brain of the Western honey bee (*Apis mellifera*) following affiliative and agonistic social interactions. We found that the valence of a social signal is represented by distinct anatomical subregions of the mushroom bodies (MBs), a highly conserved invertebrate sensory neuropil associated with social behavior, learning, and memory. Single-cell RNA-Sequencing of ~1,200 individual MB neurons gave similar results. We suggest that the modularization of valenced social information may be a fundamental organizational principle conserved across diverse nervous systems.

## SURVIVAL, HABITAT SELECTION, AND BEHAVIOR OF POST-FLEDGING GOLDEN-CHEEKED WARBLERS

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Understanding associations between habitat and the demography of endangered wildlife is essential for effective management. Understanding this relationship is further complicated by the fact that different habitat features may have different impacts across various life-stages of an individual. Specific habitat features, such as tree composition and canopy cover, may influence survival in that different habitat provides cover and foraging substrate. This study was investigating the endangered golden-cheeked warblers (*Setophaga chrysoparia*) in Texas. To do this, we monitored nests until fledging and deployed a VHF transmitter per nest ( $n=8$  and  $n=15$ , for 2017 and 2018, respectively). We tracked fledglings ~4 weeks after fledging. Fifteen of 23 (65%) fledglings survived at least 32 days (the life of the transmitter’s battery). Using Program MARK and linear mixed models we estimated nest and post-fledgling survival and investigated fledglings’ relationships with differences in habitat, behavior, and an individual’s age. Nest period survival was 0.24 (95% CI 0.10-0.41) and fledgling period survival was 0.75 (95% CI 0.49-0.89). Nest survival decreased over the breeding season, while fledgling survival was influenced by vegetation density. Fledglings also behaved differently as they aged. As fledglings matured, they move to

habitat with more understory density and canopy cover and areas with more oak and less juniper. Fledglings also moved greater distances and foraged more as they aged. This study has identified certain habitat features (i.e., understory density) that managers could use to potentially create high-quality habitat for golden-cheeked warblers.

### **SPECIES DISCRIMINATION IN BLUE-WINGED AND GOLDEN-WINGED WARBLERS**

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In most temperate passerine species, bird-song functions for males to attract conspecific mates and defend territories on their breeding grounds. Bird-song has been extensively studied for its role in pre-mating reproductive isolation between species. Sometimes song fails to effectively isolate a species and hybrids are produced, giving an opportunity to investigate the mechanisms of how song might act as a reproductive barrier. The ways in which two hybridizing species respond to and recognize each other's songs can influence the dynamics of the hybrid zone, both via female mate choice and male-male competition. Blue-winged Warblers *Vermivora cyanoptera* and Golden-winged Warblers *Vermivora chrysoptera* are closely related species that hybridize frequently and produce fertile offspring, yet tend to mate assortatively and hold overlapping territories. Our first objective was to assess the structural differences between each species' secondary songs (specialized songs thought to function primarily in male-male territorial disputes) in both allopatric and sympatric populations. Our second objective was to determine if males of each species can discriminate against heterospecific secondary song and whether responses differ in allopatric and sympatric populations. We conducted a simulated territorial intrusion experiment in allopatric and sympatric populations, and measured how aggressively each species responded to heterospecific song. We also collected song recordings from both allopatric and sympatric populations. Preliminary results show species-specific differences between secondary songs in sympatric populations. We also saw a strong response to heterospecific song in allopatry and a weak response in sympatry, suggesting that males in sympatry may learn to discriminate between the two species where they come into contact and that secondary song may serve as a reproductive barrier between them.

### **THE EFFECTS OF ANTHROPOGENIC ENVIRONMENTAL CHANGE ON PERCEPTION, PROCESSING, AND RESPONSE IN A LARVAL FISH**

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Anthropogenic environmental change can modify the expression of simple and complex behaviors within individuals, and the outcomes of interactions between individuals. One way that this can happen is through changes that compromise an organism's ability to correctly perceive, process and respond to abiotic and biotic stimuli. Many common aquatic chemical pollutants have the potential to affect stimulus-response pathways through their effects on brain function; however, our understanding of the ecological and evolutionary outcomes of these changes is limited. This deficit of knowledge is important because sensorimotor integration is critical to successful survival and reproduction. In this study, we examined the effects of a neurodegenerative cyanotoxin (2,4-diaminobutyric acid; DABA) produced by harmful algal bloom (HAB) species on the ability of a larval fish (*Promelas pimephales*) to visually perceive and recognize salient stimuli, respond appropriately, and reevaluate and recalibrate appropriate motor responses under changing conditions. We exposed larvae to environmentally relevant concentrations of the metabolite for 21 days. We then tested larvae in hunting and prey-capture assays and quantified changes in visually guided behavior. Exposure to DABA significantly modulated the responses of larvae to sensory inputs; exposed fish were less likely to successfully capture prey, potentially because of a reduced perceptual field and an impaired ability to detect prey. By contrast, we did not find an effect of exposure on motor performance. These data suggest that aquatic organisms living in HAB-affected waters may experience perceptual or cognitive deficits that can have marked effects on fitness.

## WHEN MOM TAKES A SICK DAY: SEX-SPECIFIC TELOMERE DYNAMICS IN RESPONSE TO EARLY POSTNATAL STRESS

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Early life stress can have long-term effects on many phenotypic qualities, including telomere dynamics. Telomeres are the guanine-rich, protective ends of chromosomes that shorten with accelerated growth and exposure to stressors, and prior work suggests that telomeres in male and female animals may differ in sensitivity to stress. Here, we tested how a mild maternal stressor influences offspring telomere dynamics during postnatal development in tree swallows (*Tachycineta bicolor*) and asked whether sex predicts the effects of stress on a suite of traits. Specifically, when chicks were 5 days old, we injected mothers with either saline or lipopolysaccharide (LPS), which elicits a 24h sickness response. In the week following treatment, we measured chick growth, telomere length, and restraint-induced corticosterone (CORT). We found that within 24h post-injection, LPS females decreased nest visitation rate, resulting in a short-term reduction in chick growth relative to controls. Consequently, telomere dynamics differed between treatments, and stronger effects were observed in males. Males from LPS nests also exhibited dampened stress reactivity (i.e. CORT elevation), which was positively correlated with telomere length, suggesting that changes in telomere length may be mediated by CORT. However, chicks from experimental and control nests did not differ in morphology at 12 days old, suggesting that stress-exposed chicks may carry cryptic physiological variation that could manifest later in life. While additional research is necessary to identify the mechanisms underlying these sex-specific patterns, our results provide novel insights into sex-specific vulnerability to early-life stress.