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Biomechanics Locomotion and Predation Escape in Cricket Species

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I. Statement of Guiding Hypotheses

Locomotion is a fundamental to everyday life and ultimate survival of almost all living animals through its role in capturing food, escaping predators, defense, finding a mate, and discovering new habitats. Researchers have studied all different components of locomotion, from flying to swimming and from running to jumping. These studies range drastically in numerous organism species, specifically jumping performance in vertebrate and invertebrate animals and insects. In the two semesters I have worked in Dr. Jackson's lab, we have been surprised that researchers have studied very little about the biomechanics behind a crickets jump. The few studies worked with only one species of crickets to analyze the acceleration, power, velocity, and work put out by the jumping performance. We have not found a single comparative study of jumping techniques and mechanics among multiple cricket species which would show how their morphology and physiology differ between jumps. Very few studies have been done on any organism to examine how locomotor performance directly affects important behaviors like escaping from predators.

This semester, Dr. Jackson and I set out a goal to film and track the locomotion of camel crickets (*Rhaphidophoridae Orthoptera*) using the coding software Python and a tracking software DeepLabCut. What we observed is that this cricket species has larger body and leg lengths than other crickets. Cave Crickets (*Rhaphidophoridae Orthoptera*) have longer, more slender legs than most other species (i.e. field crickets, *Gryllinae Orthoptera*). Biomechanical theory says that longer legs should mean more time for force to be applied to the ground, which can lead to higher energy and power exerted in a jump. Perhaps the different leg lengths could aid them when jumping in predatorial escape compared to a shorter body and leg lengths. For this Senior Thesis Research, I aim to investigate how longer body and leg lengths on crickets jumping performance, both within and between two species of crickets, and how that jumping performance affects actual predator escape. Thus, I hypothesis that cave crickets, with their longer legs, will have a better jump performance than other species, and will have a higher likelihood of escaping from predators.

II. Research Significance

There have been numerous prior studies involving crickets and insect jumps where researchers observe different jumping and leg performance between multiple species from humans to locust and jumping froghoppers to stinging jellyfish (e.g., Alexander, R, McN, 1995; Patek, S. N., et al., 2022). Other researchers have specifically looked at ballistic movements of jumping performance and the tasks of specialized appendages (e.g., Hustert, R. and Baldus, M., 2010). Although there’s been little research pertaining jump performance of species between one organism, crickets have specialized morphologies for jumping and are diverse, which would make them an ideal model system for investigating how selected forces on jumping lead to the diversity of extant crickets. Previous studies state that length of hind legs and body weight tend to play a big role in locomotion of millimeter-to-centimeter sized insects, for the inertia force that is depicted in jump performance is dependent on the weight and volume of the body (Li, F. et al., 2012). The hind legs of an invertebrate major importance to jump performance, for when hind legs extend and used as a propulsion for the muscles, generating a constant higher velocity relative to the center of mass while producing low strain-rate that increases energy produced in a jump (Alexander, R, McN, 1995)(Figure 2). In our lab we have already done preliminary data that depicts the way crickets prepare for a jump. The crickets tend to move most of their body when starting a jump performance where they tuck in their head and abdomen and tuck their hind legs in to where the knees point outwards, so that the crickets create that power when extending their hind legs (Figure 1). Studies have been done on female versus male body size of a planthopper, and the females with a larger body size had a longer acceleration time and velocity than males by a significant amount in both tests(Burrows, M., 2009).

When studying a close insect to crickets, researchers have discovered that bred and stress induced grasshoppers have a takeoff velocity 1-2 times faster and 2-6 times longer jump distances than wild grasshoppers due to morphological changes of matured grasshoppers and unmatured grasshoppers (Hawlena, D., 2011). When observing crickets such as bush crickets researchers found that female bush crickets' hind leg femur length equivalates to four times that of male bush crickets which contributed to a higher take-off velocity in females of $2.12 \pm 0.33 ms^{-1}$ while in males resulted in a lower take-off velocity of $1.51 \pm 0.2 ms^{-1}$ (Burrows, M. and Morris, O., 2003). The extension of the hind legs is fascinating to researchers, for how much height it brings to the center of mass to the cricket and how morphological differences in hind leg length aid in jumping performance (Figure 2).

Researchers have also done many studies involving prey and predator interactions by studying behavioral tactics producing in prey. For this study, we hope to determine how differences in jumping performance is affected with body and length size of different cricket species and predation escape (Figure 4). Previous studies of predation escape have shown that crickets have sensor hairs that will alert them based on wind and a predator is close by, researchers performed this by using airflow stimuli that could aid them in predatory escape (Tauber, E and Camhi, J. M., 1995; Sato, N. et al. 2019). Our research and previous research think that once stimuli happen, depending on morphological benefits such as longer legs would aid the cricket in predatory escape, for longer hind legs result in a longer jump (Burrows, M. and

Picker, M. D., 2010)(Figure 1). For the second part of this research we aim to use lizards as a predatory stimulant for the predatory-prey interactions. Research has been done on Varanid lizards and their consumption rate of different species of prey, researchers elaborated that most invertebrates and especially Orthoptera species are critical for a lizard diet due to habitation and attraction (Cross, S. L. et al., 2020). This is important to our study, for the predation escape of crickets will be more frequent and show differential data in the number of crickets remaining if a predator that consumes invertebrates on a daily is used in this study. This project aims to be the first study that we know of to directly attempt to link comparative cricket morphology, jumping performance, and survival.

As described above, the findings of this project will be one of the first studies reported about cricket species and the effect of body size and leg length have on jump performance and predator escape. While our preliminary work on six camel crickets suggests that there is no effect of leg length on jumping performance within the species, we do expect to find an effect when comparing among species. In addition to other research done in the past on cricket jump performance, we anticipate that other researchers could use this information to help determine other insect or vertebrates jump performance between species – even if they are not studying crickets.

III. Proposed Methodology

Animals and Animal Care

A collection camel crickets (*Rhaphidophoridae Orthoptera*), and field crickets (*Gryllinae Orthoptera*) will be collected outside of the Environmental Education Center using a live insect trap. Crickets will be housed in separate plastic containers depending on species and labeled.

Crickets will be provided access to food (fruits, vegetables, and grass), tap water, cardboard for enrichment, air holes, and a humidity sensor.

A total of six mature unisex Anole lizards (*Anolis carolinensis*) (Carolina Biological Supply Company) will be singly housed in singular 10 gallon (12"x12"x18") glass terrariums with potting soil as bedding. Lizards will be provided with food (Carolina Biological Supply Company), plants and sticks for enrichment, tap water and misting daily, and a low-wattage heating lamp to keep temperature at 24° C to 27° C with a warmer basking area that reaches 29.5° C to 33° C.

Jumping Performance Collection

A built glass arena lined with sandpaper will be used to hold crickets when filming jumping performance. A high-speed camera (Edgertronic, Frame Rate: 500Frames/Second) and LED lights was used to film crickets. Crickets will be individually placed in area and stimulated to jump by air puffs from a disposable pipet to get about 10-20 jumps every week for three hours. Once crickets are filmed with enough jumps they will be euthanized and preserved in 70% ethanol.

Jumping Performance Tracking and Analysis

Each video will be tracked using DeepLabCut (Mathis, A. et al., 2018). The tracking software will be trained using a video of previously filmed cricket videos by hand-labeling points of the body: head, abrear (lower abdomen), hip, knee, and claw. The rest of the videos were tracked using the trained tracking software (DeepLabCut). The preliminary filming and computer model training has already been completed. The videos will then analyzed by the used of calibration to provide femur length, tibia length, body length, jump start frame, jump end frame, jump time, jump velocity, jump angle, jump height, jump power, mass specific jump power, and relative mass. The data will be saved into an Excel file and then Excel was used to convert each trial data from pixels to centimeters. Excel will be used to create acceleration, work, potential energy, and kinetic energy from the data given.

Predator-Prey Interaction and Analysis

Crickets that will not be filmed for jumping performance will be used for predator-prey interaction. A total of 24 crickets, four crickets per Anole lizard, will placed into each anole lizard habitat container and left for 30 minutes. Two camel crickets (*Rhaphidophoridae Orthoptera*) and two field crickets (*Gryllinae Orthoptera*) will be placed in each habitat. After 30 minutes, each habitat will be analyzed and recorded by counting how many crickets are still alive to create a percent of crickets remaining (Figure 4). The crickets remaining were then placed back into their normal habitat. This interaction was recorded another 4 times.

IV. Resources and Locations

a. Key Resources
   i. Cricket housing facility, food, and water
   ii. Lizard housing facility, food, and water
   iii. Calibers
   iv. Preservative fluids (70% ethanol)
   v. Data analysis software
   vi. High speed camera (Edgergonics)
   vii. LED lights

b. Locations

    i. All of the camera and recording resources required for this experiment are located in Dr. Jackson's research laboratory Chichester 217
    ii. Software programs such as Python, Excel, DeepLabCut, and specialized computer to run the auto-tracking, are available in Dr. Jackson's Computer Image Analysis lab (Chichester 219)

V. Timeline for Completion

<u>Summer 2022-Spring 2023</u>

- Learn laboratory techniques/skills, including:
    a. Digitizing video
    b. Filming techniques
    c. Programing (Python)
    d. Built filming arena
    e. Trained computer model to track cricket
- Collection of data for crickets
    a. Filming
    b. Statistical data analysis
    c. Tracking via DeepLabCut and Python

<u>Summer 2023</u>

- Literature collection
- Analysis of preliminary data

<u>Fall 2023</u>

- Collection of cricket species at Environmental Education Center

- Build prey-predator filming arena
- Filming
    a. Cricket species
- Tracking via DeepLabCut and Python
- Initial draft of LST paper, including analysis of preliminary data to Dr. Jackson by Spring Break
- Presentation of preliminary data

<u>Spring 2024</u>

- Data Analysis
- Writing of Senior Thesis
- Final Senior Thesis submitted to Dr. Jackson
- Oral Defense Preparation

VI. Anticipated Committee Members

Brandon E. Jackson, Ph.D.	Associate Professor of Biology, Longwood University
Charles D. Ross, Ph.D.	Associate Professor of Physics, Longwood University
Andrew M. Mountcastle Ph.D.	Associate Professor of Biology, Bates College

VII. Approval by the Department Chair (sent via email)

VIII. LITERATURE CITED

1. Alexander, R. McN. (1995). Leg design and jumping technique for humans, other vertebrates and insects. Philosophical Transactions: Biological Sciences 347(1321):235–48.
2. Burrows, M. (2009). Jumping performance of planthoppers (Hemiptera, Issidae). Journal of Experimental Biology 212(17):2844–55.
3. Burrows, M. and Morris, O. (2003). Jumping and kicking in bush crickets. Journal of Experimental Biology 206(6):1035–49.
4. Burrows, M. and Picker, M. (2010). Jumping mechanisms and performance of pygmy mole crickets (Orthoptera, Tridactylidae). The Journal of Experimental Biology 213:2386–98.

5. Cross, S. L., Craig, M. D., Tomlinson, S., & Bateman, P. W. (2020). I don't like crickets, I love them: Invertebrates are an important Prey Source for Varanid lizards. Journal of Zoology 310(4):323–33.
6. Hawlena, D., Kress, H., Dufresne, E.R., & Schmitz, O. J. (2011). Grasshoppers alter jumping biomechanics to enhance escape performance under chronic risk of spider predation. Functional Ecology 25(1):279–88.
7. Hustert, R. and Baldus, M. (2010). Ballistic movements of jumping legs implemented as variable components of cricket behaviour. Journal of Experimental Biology 214(12):18112.
8. Li, F., Lin W., Fu, X., Bonsignori, G., Scarfogliero U., Stefanini C., & Dario P. (2012). Jumping like an insect: design and dynamic optimization of a jumping mini robot based on bio-mimetic inspiration. Mechatronics 22(2):167–76.
9. Mathis, A., Mamidanna, P., Cury, K. M., Abe, T., Murthy V. N., Mathis, M. W., & Bethge, M. (2018). DeepLabCut: markerless pose estimation of user-defined body parts with deep learning. Nature Neuroscience 21(9):1281–89.
10. Patek, S. N., Dudek, D. M., & Rosario, M. V. (2011). From bouncy legs to poisoned arrows: elastic movements in invertebrates. Journal of Experimental Biology 214(12):1973–80.
11. Sato, N., Shidara, H., & Ogawa, H. (2019). Trade-off between motor performance and behavioural flexibility in the action selection of cricket escape behaviour. Scientific Reports 9(1):18112.
12. Tauber, E., and Camhi, J. (1995). The wind-evoked escape behavior of the cricket Gryllus Bimaculatus : integration of behavioral elements. The Journal of Experimental Biology 198:1895–1907.

IX. FIGURES

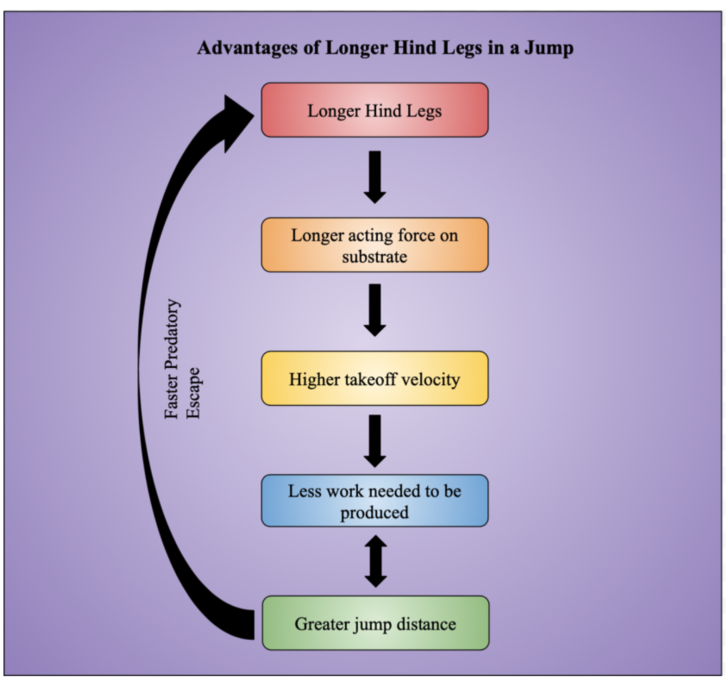

Figure 1. Advantages of having longer hind legs for jumping performance. Long hind legs result in a longer acting force on substrate, which then results in a higher takeoff velocity and a greater jump distance produces more work in a jump that aids a prey for a faster predatory escape.

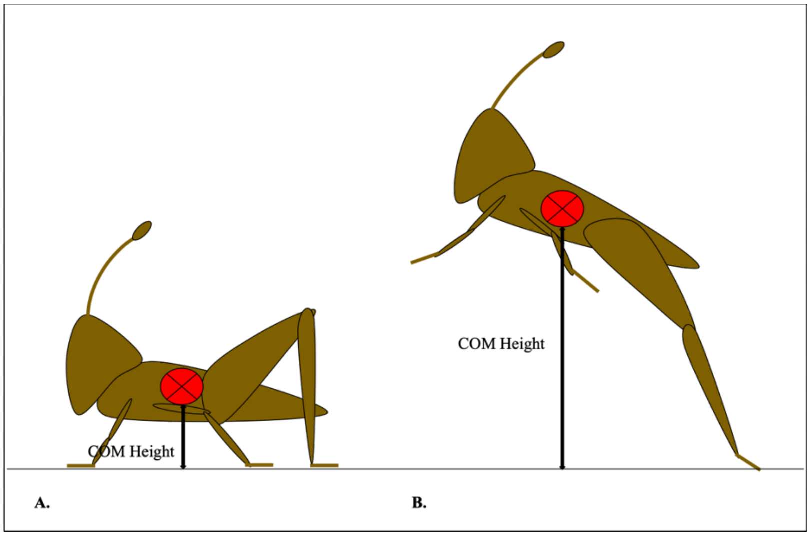

Figure 2. Basic layout of cricket leg extension. (*A*) depicts a cricket's hind leg at resting point a lower COM. (*B*) depicts a cricket's hind leg at full extension a higher COM.

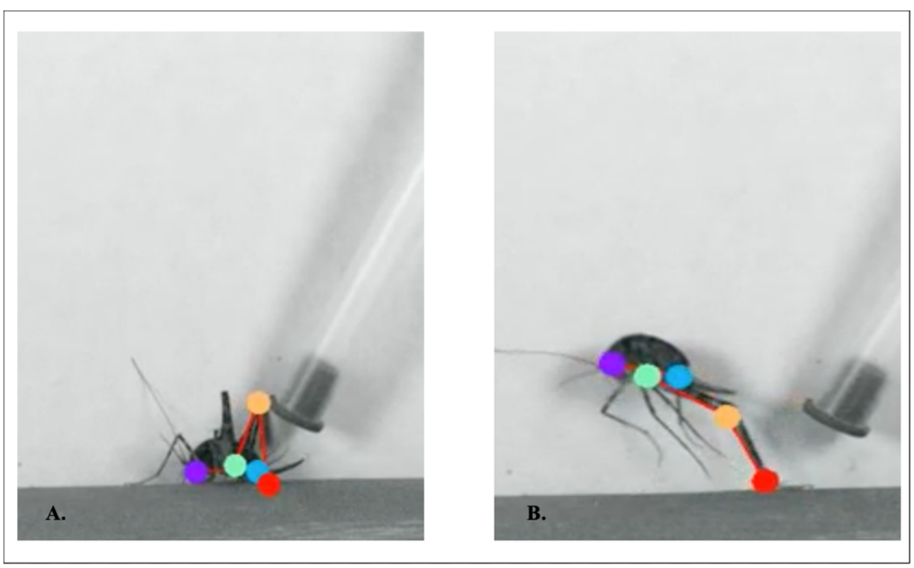

Figure 3. Preliminary tracked data from DeepLabCut of camel cricket jump performance in lab. Colored dots include: purple (Head), green (Hip), blue (Abrear or lower abdomen),

orange (Knee), and red (Claw). (*A*) depicting the stance in which the cricket is preparing for a jump by bring the head and abdomen inwards and pointing hind legs outwards. (*B*) depicting the extension of the hind legs at the jump end frame.

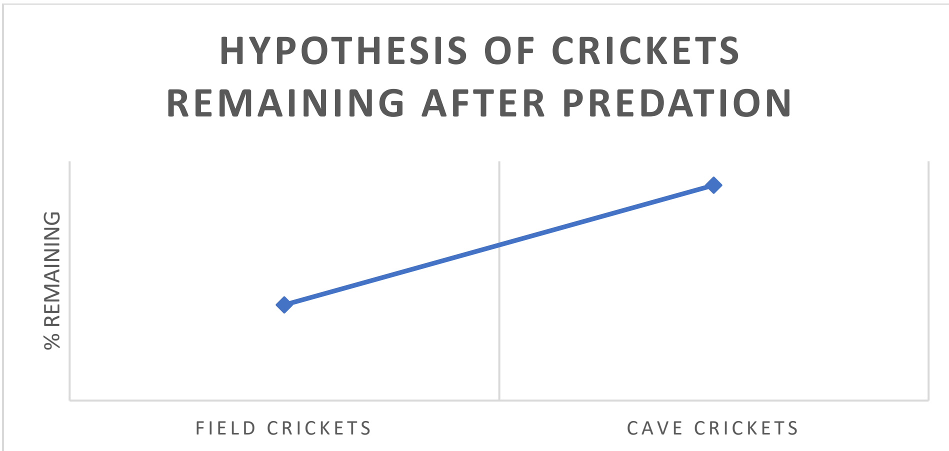

Figure 4. Hypothesis of what is predicted that might happen with the percentages of remaining crickets after predator-prey interaction trials. This is based on the leg lengths of cave crickets and advantages of higher take off velocity and greater distances to escape predators.