Ecology & Evolutionary Biology
UNIVERSITY OF TORONTO

Undergraduate Research Fair 2023

Program Guide

Ecology & Evolutionary Biology
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EEB Undergraduate Research Fair

Thank you for joining us for the 2023 EEB Undergraduate Research Fair! We are so excited that you will be joining us for a showcase that highlights the incredible fourth-year research projects students have worked on during the Fall/Winter 2022-23 term. The fair is a great way to experience the diversity of exciting undergraduate research in EEB, to hear about new scientific discoveries made by students, and interact with undergraduates and peers.

The students participating in the fair are competing for the *Corey A. Goldman Prize for Best Research Poster in Ecology and Evolutionary Biology*. The prize is named after former EEB Undergraduate Associate Chair Corey A. Goldman, and recognizes the top students within the department for excellence in their fourth-year independent research projects. Cash prizes will be awarded to the best research poster in each category.

Posters will be available for viewing at https://eebuoft.weebly.com.

Event Details

Date: Friday, March 31, 2023
Time: 2:00PM – 4:00PM EST
Location: Hallway outside ESC3055 and ESC2055

Event Schedule

2pm-3:45pm	The Research Fair is open! Student researchers will be available to answer questions about their research.
3:45pm-4pm	Brief closing remarks by Shelby Riskin and announcement of winners and honourable mentions

Research Categories

Student	Supervisor	Title
Category: Climate Change, Organisms & EEB Education		
LOCATION: 2nd Floor		
Judges: Ben Gilbert & Megan Bontrager		
Jennifer (Jem) Barrett	Shelby Riskin	What Makes Kids Care: Exploring how interactive activities foster engagement with local biodiversity
Lilian Chan	Njal Rollinson	Rapid climate warming drives male painted turtles to mature at a younger age and larger size
Irmak Erdem	Santiago Claramunt	The influence of flight capacity of Neotropical birds in the Ecuadorian Andes on the proportion of Polylepis patches occupied
Jolie Nguyen	Marie-Josee Fortin	Synchrony between spring phenologies of vegetation and bird migration in an urban park
Deniz Raster	Shelby Riskin	Assessing quantitative skills learning at a university level using a newly created manual for the statistical program R
Category: Urban Ecology & Ecotoxicology		
LOCATION: 2nd Floor		
Judges: Celina Baines & Mark Hibbins		
Xingyu (Sam) Chen	Don Jackson	Investigating how characteristics of the surrounding environment of urban stormwater ponds affect benthic invertebrates
Mira Ghosh	Chelsea Rochman	Food availability and microplastic concentration affect Daphnia magna survival
Yi-Chih (Sabrina) Juan	Chelsea Rochman	The microplastic exposure landscape: a mass balance of microplastics in a large in-lake pelagic mesocosm experiment at the IISD Experimental Lakes Area (IISD-ELA)
Gloria Wang	Don Jackson	Environmental variables associated with fish biodiversity in Ontario stormwater ponds
Sabrina Zaidi	Chelsea Rochman	Quantifying the Presence of Trace Element Metals in Yellow Perch (Perca flavescens) Tissue After Microplastic Exposure in In-Lake Mesocosms
Category: Ecological Interactions		
LOCATION: 2nd Floor		
Judges: Nathan Lujan & Benjamin Downer-Bartholomew		
Aidan Godin	Santiago Claramunt	Tail morphologies strengthen the relationship between flight efficiency and natal dispersal distance in birds
Katrina Meihlbradt	Shelby Riskin	The interdependence of plant functional diversity and soil abiotic properties in experimental field plots
Katherine Monat	Luke Mahler	Does climate influence scale morphology among populations of Anolis lizards?
Grace Walker-Mitchell	Ben Gilbert	How does intraspecific trait variation structure functional diversity across a plant community?
Arthur (A.J.) Westerhoff	Nicole Mideo	How Parasite Resource Preferences Influence Malaria Co-Infection Dynamics & Host Outcomes

Category: Evolution, Phylogenetics & Systematics		
LOCATION: 3rd Floor		
Judges: Matt Osmond & Alice Fairnie		
Hou Wai (Colin) Chu	Santiago Claramunt	Unearthing the Miners: Digging Deeper into the Phylogenetics and Diversification of Genus Geositta (Passeriformes: Furnariidae)
Brett Kreinsen	Rowan Sage	Biogeography of C3-C4 evolutionary intermediates: insight into the selection environment for C4 photosynthesis
Brenda Li	Nathan Lujan	Osteological descriptions of six new species of tetras (family Characidae) in the genera Creagrutus, Knodus, and Scopaeocharax
Patrick Ouyang	Tomo Fukuchi	Exploring the Major Axes of Morphological Discordance in Gymnosperms
Thomas Wildeboer	Jacqueline Sztepanacz	Multivariate analysis supports Cheverud's conjecture
Category: Organismal Trait Evolution & Ecology		
LOCATION: 3rd Floor		
Judges: Jacqueline Sztepanacz & Tomo Fukuchi		
Wei Han Lau	Locke Rowe	Do broader heads make for a stronger bite? A biomechanical analysis of a putatively ecologically dimorphic trait in the northeastern pine sawyer beetle (Cerambycidae: Monochamus notatus)
Daniel Mok	Rowan Sage	Does CAM explain C4-like d13C values in Bulnesia retama (Zygophyllaceae), a non-Kranz, non-succulent desert shrub?
Amanda Rokicky	Belinda Chang	The Molecular Evolution of Rhodopsin in the Elasmobranchs and Actinopterygii
Michelle Su	Luke Mahler	Scales, plates, and toepads: investigating evolutionary modularity and rates in Anolis scales
Yihang Zhao	Belinda Chang	Selective pressure shifts on snake visual developmental genes are associated with shifts in their visual ecology

Student Poster Abstracts

Category: Climate Change, Organisms & EEB Education

Jennifer Barrett (Supervisor: Shelby Riskin)

What Makes Kids Care: Exploring how interactive activities foster engagement with local biodiversity

The purpose of this study was to assess the effectiveness of outreach activities based on ongoing ecological research and local biodiversity and to explore how children's incoming environmental values and time spent in green and blue spaces affect the activities' effectiveness. The outreach project took place at the Royal Ontario Museum within the Earth Rangers Studio over two weekends and utilized established pedagogical approaches including interactive, hands-on activities, place-based learning, and games as learning tools. Participants between the ages of 7 and 14 were surveyed before interacting with the activities to assess their incoming environmental values, as determined using Bogner's modified Two Major Environmental Values model (2-MEV). This model was designed to gauge adolescent attitudes towards the environment and to quantify the effectiveness of educational programs. Participants were also asked about their exposure to green and blue spaces alongside questions designed to assess their pre-existing knowledge about wetland species. After spending time with the various interactive activity tables, participants were surveyed a second time to assess the impact the activities had on participants' knowledge of native wetland species and whether their perspective on the importance of wetlands had shifted. Participants were also asked if there were any activity tables that they particularly enjoyed to provide data for future outreach projects as to what kind of interactive activities promote engagement with children. Analysis of the pre- and post-surveys collected from participants demonstrated a significant increase in the number of native wetland species they could list after spending time at the interactive activities. It was also discovered that high scores in Preservation of Nature (quantified using Bogner's 2-MEV tool) was the strongest predictor of participants strongly agreeing with the statement "Wetlands are important." This highlights the importance of future research into what factors influence the development of an intent to preserve nature in children, because understanding that all types of ecosystems are important is a crucial step in ensuring the protection of Toronto's native wildlife.

Tsz Ying (Lilian) Chan (Supervisor: Njal Rollinson)

Rapid climate warming drives male painted turtles to mature at a younger age and larger size

Since 1880, the average global temperature has risen by 1.1°C. Theory and data suggest that the timing of life history transitions may be affected by this rapid warming. Specifically, theory predicts that age and size at maturity will be affected under a warming climate. If the temperature increase results in physiological constraints, individuals will mature at a younger age and smaller size. However, if the warmer environment leads to higher resource availability, early maturation at a larger size will occur. To date, the majority of studies investigating the effects of warming on age and size at maturity have focused on short-lived organisms. It is unclear if the age and size at maturity of long-lived ectotherms have changed in response to warming and if the effect of warming differs between males and females. Here, we investigate trends in the age and size at maturity of male and female painted turtles (Chrysemys picta) in Algonquin Provincial Park, Ontario, using long-term data from 1978 to 2021. We found that the age at maturity of male turtles has decreased significantly from 8.20 in 1987 to 6.34 in 2011, while the size at maturity has increased from 8.36 cm to 8.64 cm. However, the age and size at maturity have not changed for females. We show that, at least in males, warming in the region has altered the timing of maturation and that this effect is manifested likely through a longer growing

season, which increases food and resource availability, resulting in a higher juvenile growth rate and a larger body size. This study demonstrates that climate change can have differential effects on life history traits between males and females.

Irmak Erdem (Supervisor: Santiago Claramunt)

The influence of flight capacity of Neotropical birds in the Ecuadorian Andes on the proportion of Polylepis patches occupied

Habitat fragmentation and habitat loss are major threats to biodiversity, and can affect the persistence and survival of species. The páramo landscapes of the northern tropical Andes are regions that are facing habitat alterations and are considered to be hotspots for avian biodiversity. These landscapes house Polylepis woodland patches that have also been highly impacted by increased fragmentation and decreased patch quality. Avian species are important indicators of habitat qualities in fragmented landscapes, due to their dispersal abilities. Given the dispersal abilities of birds and morphological predictors of flight capacity, it is predicted that flight capabilities could influence the proportion of patchs the birds in the Ecuadorian Andes would occupy. We tested this prediction by examining the relationship between flight capacity and patch occupancy in the Polylepis patches of Caias National Park, Ecuador. We analyzed patch occupancy in this páramo landscape (Astudillo et al. 2020, Ardeola 67(2), 307-324.). We quantified the flight capacity of 16 Neotropical birds using the aspect ratio, calculated based on measurements of specimens from the Royal Ontario Museum. Upon investigating different models using a phylogenetic binomial multi-predictor regression model, it was found that aspect ratio and total abundance were the two most important predictors for the proportion of patches occupied in the region. These findings indicate that morphological indices that influence flight capacity and the abundance of species should be taken into consideration when analyzing patch movements and the dispersal of species in fragmented landscapes. Other predictors such as, mass, diet, tail length, and stratum could also be investigated to create a more comprehensive model which could help assess species persistence in regions that are threatened by habitat fragmentation.

Jolie Nguyen (Supervisor: Marie Josee Fortin)

Synchrony between spring phenologies of vegetation and bird migration in an urban park

Migratory bird species depend on stopover sites to rest, replenish energy, avoid adverse weather conditions, and evade predation. During spring it is critical that bird migration happens in synchrony with the timing of their food source's availability, and thus vegetation green-up alongside insect emergence, at these stopover sites. However, as the spring phenology of bird migration and green-up may be changing due to climate change, there is a possibility for phenological mismatches between the two at stopover sites. We used remote sensing green-up data and bird banding data to compare the phenological trends of spring green-up and bird arrival for three warbler (*Setophaga caerulescens*, *Setophaga coronata coronata*, *Setophaga magnolia*) and two kinglet (*Corthylio calendula*, *Regulus satrapa*) species, including differences between males and females of each species, at an urban park stopover site in Toronto from 2004 to 2021. Although there were year-to year fluctuations, neither the average green-up date, at the urban stopover site and two wider regional scales (lake coastal area and part of GTA), nor the median bird arrival date for the five species significantly changed to become earlier or later during the 17-year period. However, the first arrival day for *Setophaga coronata coronata* did become earlier. Males typically arrived earlier than females for each of the five species, generally closer or before green-up. The relationship between the number of days between green-up and median bird arrival decreased for the three warbler species, with the median arrival date of *Setophaga coronata coronata* now becoming earlier than green-up. Our results highlight that the spring phenologies of

vegetation and migratory bird species may be shifting at different rates, which is potentially giving rise to asynchronous phenological responses that could negatively impact the success of bird migrations.

Deniz Raster (Supervisor: Shelby Riskin)

Assessing quantitative skills learning at a university level using a newly created manual for the statistical program R

Scholars have urged for an increase in quantitative skills and literacy among students in the biological sciences, as data management and analysis become more prevalent in scientific research. 'R' is an increasingly popular statistical programming software commonly used for research, and its growing popularity should be reflected in an increase in undergraduate-level courses teaching quantitative literacy using R. The initial steep learning curve of R and the limited availability of resources for beginners result in an incompatibility between resources and students' needs. Through a quantitative survey, we assess if a department-specific resource, in the form of a newly created R manual, is effective at improving student learning of R in an undergraduate course in the Ecology and Evolutionary Biology department at the University of Toronto. We also assess the manual's benefits as a teaching resource for potential users in the department and faculty. We found that exposure to R during the course resulted in a significant increase in quantitative skills knowledge among students with no prior experience with R. Similarly, students who reported that the manual provided improvement to their understanding of R showed a significant increase in their quantitative skills knowledge. Furthermore, the perception of students, graduate student Teaching Assistants and faculty of the R manual as a learning and teaching resource was generally positive. Based on the results of this study, we recommend that undergraduate students are introduced to R at a university-level early, supplemented by a department- or faculty-specific R resource, in an effort to support and improve quantitative literacy in their journey to become independent researchers in ecology and evolutionary biology.

Category: Urban Ecology & Ecotoxicology

Xingyu (Sam) Chen (Supervisor: Don Jackson)

Investigating how characteristics of the surrounding environment of urban stormwater ponds affect benthic invertebrates

As urban areas expand continuously, many natural ponds have disappeared, and the ecosystem services provided by natural ponds must be refilled. We have built many stormwater ponds to control water run-off and flooding in the urban setting. Interestingly, recent research proved that these artificial infrastructures could support a high level of biodiversity compared to natural ponds. Still, we do not fully understand how organisms in these artificial ponds interact with surrounding urban environments and anthropogenic stressors. This project aims to understand how different catchment basin environments affect benthic invertebrate communities in urban stormwater ponds. There are 15 sets of data from 15 different ponds, all located in Brampton, Ontario. All ponds were sampled during the summer of 2022. Each pond was sampled at two locations, and each location was sampled three times. All organisms from one location were put into a jar with ethanol. All organisms were identified based on the OBBN protocol manual. By now, I have obtained data on pond water chemistry, land type land use, distance to the nearest neighbour, pond physical characters, and distance to roads. I will then analyze those data to see how each factor correlates to the species richness and diversity of benthic inverts. And then I'll possibly introduce multivariate models to determine which set of factors has the strongest impact on benthic inverts. I don't have results from those analyses yet, so I can't make any discussions, and everything in this abstract (including the title) is subject to change.

Mira Ghosh (Supervisor: Chelsea Rochman)

Food availability and microplastic concentration affect *Daphnia magna* survival

Microplastics (MPs) are a ubiquitous aquatic contaminant, yet how they affect organisms remains poorly understood. One observed mechanism relevant to adverse effects of MPs is food dilution. These effects may vary with food availability, which has implications for the outcomes of experiments using different food availability, as well as how MPs might affect organisms and food webs under various environmental conditions. In this study, we investigated the relationship between MP effects and food availability through a fully-factorial experiment exposing *Daphnia magna* to two environmentally relevant MP concentrations and three levels of food availability using additive-free PE, PET, and PS microplastic fragments. We exposed 10 *Daphnia magna* individuals per treatment which resulted in 90 total parent individuals including the control treatment. We monitored daily for mortalities and neonates as well as measured growth at the end of the experiment. We found effects of both microplastic concentration and food availability on Daphnia survival, but no interactive effects. Reproduction was affected by food availability but not microplastic concentration. Growth was different depending on food level with no effects of microplastics exposure. Here our results indicated that food availability does not necessarily affect the toxicity of microplastics to *Daphnia magna*. Still, we saw a pattern whereby daphnia exposed to higher microplastics had lower survival with medium food. Thus, we recommend considering food availability in toxicity tests, and we suggest future experiments use finer grain plastic and food treatments to detect an interaction.

Yi-Chih Sabrina Juan (Supervisor: Chelsea Rochman)

The microplastic exposure landscape: a mass balance of microplastics in a large in-lake pelagic mesocosm experiment at the IISD Experimental Lakes Area (IISD-ELA)

Abstract: Microplastics (plastic particles sized <5 mm) are ubiquitous and persistent contaminants of growing concern, plaguing all ecosystems and causing various effects on organisms of all trophic levels. There is increasing attention being paid to microplastic fate in physical matrices, uptake in organisms, and interactions within ecosystem processes, particularly in previously neglected freshwater ecosystems such as lacustrine habitats. Microplastic transport and fate in a lake can affect the exposure landscape (i.e., the amount of plastic each organism may be exposed to relevant to its habitat and life-history strategy). Microplastic uptake in aquatic organisms is not only determined by their feeding behaviour and other life history characteristics, but also particle characteristics such as size, shape, and density. However, distribution of microplastics in pelagic zones of lakes over time are not yet well-understood. Thus, we aimed to elucidate temporal and spatial variations in distributions of microplastics across a lacustrine habitat. This experiment included nine in-lake mesocosms – 10m in diameter and 2m deep. We added 4.4 billion particles to each mesocosm to achieve a nominal concentration of 29,234 particles/L. The experiment ran for 9 weeks, and we sampled water column, surface water, and periphyton wall strips at 24 hours, 72 hours, 1 week, 5 weeks and 9 weeks after addition. We aim to calculate a mass balance of specially manufactured polyethylene (positively buoyant), polystyrene (neutrally buoyant) and polyethylene terephthalate (negatively buoyant), 10 – 750µm in size. Results to date will be presented.

Gloria Wang (Supervisor: Don Jackson)

Environmental variables associated with fish biodiversity in Ontario stormwater ponds

Urbanization is associated with the ecological degradation of streams due to high inflows of stormwater runoff from impervious surfaces. Stormwater ponds (SWPs) are artificial ponds designed to divert runoff

from streams by retaining stormwater before slowly releasing it into streams. In highly urbanized areas where aquatic habitat is otherwise scarce, SWPs can be biodiversity hotspots for many aquatic taxa. However, many SWPs can suffer from salinization, pollution, eutrophication, and hypoxia that affect aquatic species potentially using these ponds. While groups such as benthic invertebrates have been well studied, there is little existing research on fishes in SWPs despite reports of fish being found in them. We sampled fish species composition in 50 SWPs from Brampton, Ontario, along with the associated water quality characteristics, to determine how environmental conditions may impact the fish communities. We determine the relative importance of water quality, pond design, and landscape variables in predicting fish species richness and community composition. As SWPs release into the headwaters of adjacent streams, their contents are likely to impact adjoining streams, rivers, and ultimately Lake Ontario. The findings of this study can help inform SWP management to improve ecological function, as well as identify the potential effects of SWP outflow on downstream waters.

Sabrina Zaidi (Supervisor: Chelsea Rochman)

Quantifying the Presence of Trace Element Metals in Yellow Perch (Perca flavescens) Tissue After Microplastic Exposure in In-Lake Mesocosms

Plastic pollution is becoming an increasingly prominent environmental issue as plastic waste degrades into microplastics and accumulates in ecosystems.

In aquatic ecosystems in particular, they can easily be consumed by zooplankton, fish, or mammals due to their small size, buoyancy, and visual attractiveness. Because plastics are generally treated with additional chemical additives, microplastics are also prone to leaching these additives into the water, which have previously been found to have toxic outcomes for organisms. We aim to quantify the presence of plastic additives in yellow perch (Perca flavescens) tissue using large-scale in-lake mesocosms. Here, we are investigating how metal trace elements (aluminum, titanium, and bismuth) used in pigment additives in common types of plastic might leach and contaminate fish tissue outside the gut. We exposed yellow perch in freshwater pelagic in-lake mesocosms at the International Institute for Sustainable Development's Experimental Lakes Area (IISD-ELA; Northwestern Ontario, Canada). Our experimental design included two plastic treatments with 29,240 microplastics/L of polyethylene, polyethylene terephthalate, and polystyrene microplastics (one with additives and one without) and a negative control (n = 3). The experiment ran for 9 weeks. After 9-weeks of exposure, we sampled the fish (2 – 5 per replicate mesocosm) and removed the gut tissue from each. The remainder of the fish were homogenized, followed by a microwave digestion to extract metals. Once digested, extracts were filtered and diluted, and then analyzed via inductively coupled plasma – optical emission spectrometry (ICP-OES) to determine the concentrations of aluminum, titanium, and bismuth in the tissues. Currently, preliminary results suggest that bioaccumulation of additives might be present in fish tissues, however further analyses need to be completed. These results will help improve our understanding of the fate of additives in organisms, in addition to informing future studies examining additives in freshwater ecosystems.

Category: Ecological Interactions

Aidan Godin (Supervisor: Santiago Claramunt)

Tail morphologies strengthen the relationship between flight efficiency and natal dispersal distance in birds

Natal dispersal is the process of organisms moving from where they are born to where they first breed, and this distance has many important ecological implications. Previous studies have found a positive

relationship between flight efficiency as an estimate of the energetic cost of movement, and natal dispersal distance in birds. These papers have mostly estimated flight efficiency by focusing solely on wing characteristics. Tails have their own implications for flight efficiency, including both the generation of lift and drag. In this paper, we hypothesize that supplementing the flight efficiency proxy of wing aspect ratio with tail morphologies will strengthen the positive correlation between flight efficiency and natal dispersal distances in birds. This hypothesis was evaluated by measuring the tail sizes of 36 species of North American birds and contributing this data to wing aspect ratio calculations. Phylogenetic generalized least squares (PGLS) models were then used to analyze the relationships between natal dispersal distance and wing aspect ratio + tail size (Method 1) and wing aspect ratio including tail area (Method 2). Finally, these models were compared to a PGLS model of wing aspect ratio excluding tail data, and natal dispersal distances. We found that adding relative tail size or including tail area in the wing aspect ratio calculations of birds better predicts their natal dispersal distances. This suggests that flight efficiency and dispersal ability may be better estimated by models that include tail morphologies.

Katrina Miehlbradt (Supervisor: Shelby Riskin)

The interdependence of plant functional diversity and soil abiotic properties in experimental field plots

The rapid, global loss of biodiversity due to human activities necessitates understanding how diversity affects ecosystem functioning to maintain the provision of vital ecosystem services. Functional diversity, a measure of the range of traits in an ecosystem affecting how organisms interact with their environment, is increasingly being used as a relevant measure of ecosystem functioning because it is consistently associated with the rates and magnitudes of ecosystem processes. We wanted to investigate the interactions between abiotic soil conditions and functional diversity. To do this, this study investigates how soil nutrient pools correlate with plant functional diversity in temperate, experimental field plots at the Koffler Scientific Reserve in King, Ontario. Plots are separated equally into 14 sections referred to as blocks. Soil samples were taken at 0-10cm deep from 84 plots, six plots within each block, of varying levels of plant functional diversity, measured as the mean functional diversity index from 2016-2019. We find that total nitrogen, organic matter, and available phosphorus are significant predictors of plant functional diversity. However, experimental block, meaning the abiotic soil conditions specific to each section of plots, is a more important predictor of total nitrogen, total carbon, organic matter, and cation exchange capacity than plant functional diversity. Variation in these soil properties among different blocks is closely correlated with the variation in plant functional diversity, suggesting underlying heterogeneity in soil nutrient levels in part controls the level of plant functional diversity that can be supported in each plot. Plant functional diversity is a significant predictor of available phosphorus, indicating that high functional diversity may initiate a positive feedback loop whereby phosphorus is further amplified. Thus, environmental protection efforts to sustain ecosystem functioning and services should consider the importance of abiotic conditions in regulating functional diversity, and that establishment of high plant functional diversity can help maintain and increase concentrations of certain soil nutrients.

Katherine Monat (Supervisor: Luke Mahler)

Does climate influence scale morphology among populations of Anolis lizards?

The scales of reptiles have been hypothesized to play roles in protection, thermoregulation, and hydroregulation. Scale shape and size can vary between species, within species, and even across different body regions within a single individual. Though scales have been proposed to be important for thermo- and hydroregulation, the physiological role that scales play in those processes is still unclear. Two primary mechanisms have been proposed to explain variation in scale morphology: (1) scale size

changes in response to temperature, with populations in warmer environments exhibiting larger scales which increase heat loss to maintain homeostasis; and (2) scale size reflects humidity, where populations in wetter environments have smaller scales because individuals are less vulnerable to desiccation. To explore these hypotheses, we measured scale size in populations of four widespread species of Anolis lizards (A. cristatellus, A. cybotes., A. semilineatus., and A. stratulus) and tested for correlations between the environmental variables and scale size. Populations of these species inhabit a wide range of environmental conditions, enabling us to examine the effect of climatic variables on intraspecific variation in scale morphology. Our results indicate that precipitation may be affecting scale morphology, as regions of high precipitation were consistently correlated with populations with small dorsal scales. However, these results differ across body regions and species. Populations of our four study species appear to experience different selection on scale size, which has led to local evolutionary changes in morphology.

Grace Walker Mitchell (Supervisor: Ben Gilbert)

How does intraspecific trait variation structure functional diversity across a plant community?
Recent research has recognized the important contribution of variation among individuals to functional variation within a species. Questions around the role of variation among individuals within a species (intraspecific trait variation - ITV) in structuring community diversity, particularly across populations, have yet to be robustly tested, however. Here, we sample four functional traits (specific leaf area, leaf dry matter content, height, and vegetative to reproductive biomass ratio) from over 1800 individuals across 33 plant species occurring in artificial fragments to test how ITV alters trait distributions within communities. We find that population-level ITV acts to increase differences in average trait values among co-occurring species, resulting in greater functional diversity across a community than we would estimate if ITV were ignored. Our results thus suggest that ITV is an important source of trait diversity in ecological communities, and that measuring trait variation among individuals is important for our understanding of how functional diversity is partitioned and maintained in ecological communities.

Arthur (A.J.) Randolph-Westerhof (Supervisor: Nicole Mideo)

How Parasite Resource Preferences Influence Malaria Co-Infection Dynamics & Host Outcomes
Infectious diseases can often pose a serious threat to human health, but this threat can compound when we consider incidences of co-infections by two parasite species simultaneously. As novel interactions between competing species occur, we can see a multitude of unexpected outcomes arise which can significantly increase the threat pathogens pose. Previous research has demonstrated a prior infection by the malaria parasite *P. falciparum*, a generalist that infects all ages of host red blood cells (RBCs), can change the host environment throughout an infection. As it destroys RBCs it infects, in conjunction with the host increasing production of new RBCs in response to maintain their health, reduces the average age of RBCs. This can facilitate future infections by *P. vivax*, a malaria parasite specializing in infecting young RBCs. Due to the dynamic nature of pathogen lifecycles and RBC production, the strength of the facilitation may vary depending on the timing of infection by the second parasite species. Furthermore, these within-host interactions between parasites may influence the success of any subsequent drug treatment. Here, I develop an agent-based model of malaria parasite co-infections within a host to investigate how the fitness of co-infecting parasite species with differential resource preferences changes with the timing of co-infection. I also consider the role that both drug treatment and competition with co-infection pathogen species play in parasite fitness.

Category: Evolution, Phylogenetics & Systematics

Hou Wai Colin Chiu (Supervisor: Santiago Claramunt)

Unearthing the Miners: Digging Deeper into the Phylogenetics and Diversification of Genus Geositta (Passeriformes: Furnariidae)

Accurate time calibrations are essential to the study of biogeography. Previous phylogenetic studies of Geositta sp. (miners) have relied on gene trees or sequence divergence, which can be inaccurate or may overestimate divergence times. This leads to the mismatch between speciation events and orogenic or climatic changes. Bayesian methods and relaxed clocks provides tools to address these issues. Species tree constructed with multispecies coalescent methods suggests that the diversification of Geositta occurred much later than previous estimates. The divergence times suggest that most of the diversification occurs in the Miocene-Pliocene. This holds true regardless of the nodes used for fossil calibration. The ancestral geographic ranges are also reconstructed using BioGeoBEARS. The increased sampling of G. cunicularia confirm the status of G. cunicularia as a valid species, but the validity of its subspecies are brought into question.

Brett Kreinsen (Supervisor: Rowan Sage)

Biogeography of C3-C4 evolutionary intermediates: insight into the selection environment for C4 photosynthesis

Over 65 lineages of flowering plants have independently evolved the C_4 photosynthetic pathway as a CO_2-concentrating mechanism. Among these clades, there exists a gradient of intermediate character states between the ancestral, C_3, and the derived, C_4, pathways. These 'C_3-C_4 intermediates' represent transitional species and offer unique insights into the evolution of C_4 photosynthesis. Current understandings of the physiology of C_3-C_4 plants suggest that they are found in areas that promote high levels of photorespiration and stomatal closure. These environments have been broadly described as low-CO_2/high-O_2, hot, dry, bright and/or saline; however, other factors, such as seasonal variations in temperature and precipitation, must be considered to fully describe the geographic range of each species. Using occurrence records obtained from the Global Biodiversity Information Facility (GBIF), this study aims to better define the ecological niches of C_3-C_4 species. Centers of high C_3-C_4 intermediate diversity are delineated with Geographic Information Systems (GIS) using an ecoregions-based approach. The climates of these centers are summarized with an average monthly time series for several atmospheric variables using historical raster files sourced from WorldClim. Here we find support that hot climates with seasonal precipitation favor C_3-C_4 species, though other contributing factors are usually involved. The centers of diversity, and their climates, contribute to the knowledge of the environments that are associated with a complex, primary metabolic trait.

Brenda Li (Supervisor: Nathan Lujan)

Osteological descriptions of six new species of tetras (family Characidae) in the genera Creagrutus, Knodus, and Scopaeocharax

With over 1250 currently valid species, the tetra family Characidae is the fourth most species-rich fish family on Earth. Within Characidae, 363 valid species (~29%) and 45 genera are in the subfamily Stevardiinae, which is common mostly in higher elevation stream habitats from Costa Rica to northern Argentina. Stevardiinae is distinguished from other Characidae subfamilies by the prevalence of strong sexually dimorphism, internally insemination, and caudal modifications associated with pheromone

glands or pumps, and the subfamily is cladistically diagnosed by modifications of the skull. In this study we describe and illustrate the cranial osteology of six new species of Stevardiinae in the genera Creagrutus, Knodus and Scopaeocharax: C. sp. 'mancha humeral', C. sp. ‘Chinchipe’, K. n.sp. ‘Tencua’, K. n.sp. ‘pseudogephyrocharax’, S. sp. ‘Caqueta’ and S. sp. ‘Due’. For species of Scopaeocharax, the strikingly sexually dimorphic caudal skeleton was also illustrated and compared. Anatomical data were collected from direct observation and through segmentation of high-resolution X-ray micro-computed tomography (HRXµCT) scans of type and non-type specimens. We found that the new species can be diagnosed by characteristics of their premaxillary teeth arrangement, modifications in the infraorbital series, features in the neurocranium, number of teeth in the mandible and maxilla and principal caudal-fin ray modifications. Our preliminary morphological results support the hypotheses that these species differ from each other and all currently valid congeners. Future research will further test these hypotheses using genetic data.

Patrick Ouyang (Supervisor: Tomo Fukuchi)

Exploring the Major Axes of Morphological Discordance in Gymnosperms

Morphological homoplasy has long held the interest of evolutionary biologists, as convergence points to evidence of common, deterministic selective pressures. Much work has been put into elucidating the degree to which ecological niche space, developmental constraint, and genetic mechanisms for variation contribute to homoplasy, along with developing tools to increase the accuracy with which we can infer its presence among confounds like incomplete lineage sorting’s hemiplasy. Broadly speaking, homoplasy is often invoked when trait states are discordant (incongruent) with the species phylogeny. In this exploratory project, we took advantage of the high morphological variation present among Gymnosperms to ask whether certain types of traits are more variable in their distributions than others, and if their discordant state patterns among particular taxa can reveal potential convergence. We partitioned a dataset of 148 Gymnosperm traits into clusters of similar patterns of homoplasy based on mutual compatibility and Louvain community detection, before comparing parsimony trees from each cluster to a reference species tree to gauge phenotypic discordance. We found that: 1) vegetative traits tend to cluster together, while reproductive traits are broadly distributed, indicating that the latter are more variable in their distribution across the clade (and potentially more prone to homoplasy), and 2) that despite possessing many unique synapomorphies, the positioning of members of the order Gnetales in two clusters is highly discordant with the species tree, in line with the clade’s varied natural histories leading to convergence with disparate taxa. These results facilitate more defined questions regarding the degree to which relatively recent selective pressures on extant lineages are responsible for the patterns seen in Gnetales, as opposed to a diverse and more speciose evolutionary past.

Thomas Wildeboer (Supervisor: Jacqueline Sztepanacz)

Multivariate analysis supports Cheverud’s conjecture

Genetic correlations and covariances are fundamental to predicting the evolution of traits in populations, finding use in economically important fields such as agricultural breeding and wildlife conservation. However, obtaining accurate estimates of these parameters is often challenging, requiring large sample sizes and information on relatedness between individuals. In many cases, it is simply infeasible, as in paleontological studies. A widely used solution to this problem is to use phenotypic correlations as an approximation of genetic correlations. James Cheverud posited that developmental and environmental effects often act through similar pathways as genetic effects in 1988, following that this approximation is therefore valid. Many studies have since tested this conjecture, often finding high levels of similarity between genetic and phenotypic correlations. These studies typically used simple pairwise comparisons of these correlations, however, ignoring their multivariate nature. Our study built

on this research by employing modern statistical techniques from a multivariate perspective to rigorously investigate this conjecture. We performed computer simulations of trait values and genetic effects under various combinations of heritability, effective sample size, and genetic integration. We then compared the accuracy of phenotypic and estimated genetic correlations to the true population values, finding general support for Cheverud's conjecture in cases of small sample sizes.

Category: Organismal Trait Evolution & Ecology

Wei Han Lau (Supervisor: Locke Rowe)

Do broader heads make for a stronger bite? A biomechanical analysis of a putatively ecologically dimorphic trait in the northeastern pine sawyer beetle (Cerambycidae: Monochamus notatus)

The diverse array of sexually dimorphic traits in nature can be driven by different forces of selection. Although many sexual dimorphisms result from sexual selection, some instead arise as a result of divergent patterns of natural selection on homologous traits in ecologically differentiated males and females. Biomechanical studies of such ecological dimorphisms can clarify how differences in performance between the sexes can be shaped by variation in ecologically relevant modes of behaviour and their associated patterns of morphological divergence. Here, I quantitatively link morphology to performance to study the function of a putative ecological dimorphism. In this study, I examine the trait of bite force in Monochamus notatus, a species of longhorn beetles in which the capacity to chew oviposition slits is a distinctive aspect of female reproductive behaviour. Female M. notatus have wider heads than males, and I hypothesize that this represents an ecological dimorphism resulting from the different ways in which the different sexes utilize their mandibles. Through an analysis of external morphology and microtomographic scans of specimen heads, I test whether morphological differences are associated with bite force divergence between males and females. I measure the mechanical advantage of the mandibular system, muscle fibre length, and muscle volume to approximate the trait of bite force from ethanol-preserved specimens. Linear measurements of the size and shape of the morphology of M. notatus were also taken to examine the scaler relationship of various traits between the sexes.

Daniel Mok (Supervisor: Rowan Sage)

Does CAM explain C_4-like $\delta^{13}C$ values in *Bulnesia retama* (Zygophyllaceae), a non-Kranz, non-succulent desert shrub?

Bulnesia retama (Zygophyllaceae) is a South American xerophytic shrub or small tree with green stems and drought-deciduous leaves. *B. retama* is distinguished from others in the genus by its high carbon isotope ($\delta^{13}C$) in field sampled specimens ranging -17.2‰ to -17.4‰. This is indicative of CAM or C_4-like photosynthesis which are both highly convergent evolutionary traits. However, greenhouse grown specimens have a C_3 $\delta^{13}C$ ranging -30.9‰ to - 33.2‰; all other *Bulnesia* species are also C_3-like. Gas exchange measurements rule out C_4 in both the leaves and stems (including single cell), and both lack distinct C_4 Kranz anatomy. The leaves and stems appear fully C_3 when well-watered. Here, we report that *B. retama* stems exhibit low levels of nocturnal CO_2 uptake and tissue acidification when well-watered or droughted. This indicates an obligate C_3 + weak CAM system which cannot explain the -17‰ $\delta^{13}C$ values in field specimens. Ongoing work is examining the possibility of another carbon concentrating mechanism.

Amanda Rokicky (Supervisor: Belinda Chang)

The Molecular Evolution of Rhodopsin in the Elasmobranchs and Actinopterygii

Rhodopsin is a visual pigment found in rod photoreceptors, which mediates dim light vision. It has a complex evolutionary history across vertebrate lineages. Notably, a retroduplication is thought to have occurred in the ancestor of the Actinopterygii, resulting in an intronless form unlike the intron-containing form of other vertebrates. However, most studies on the rhodopsin gene focus only on actinopterygians, specifically teleosts. Of species with the ancestral form, elasmobranchs are particularly noteworthy as they are a diverse but understudied group in this regard. To examine the molecular evolution of the ancestral form of rhodopsin, we generated a maximum likelihood phylogeny, with an emphasis on elasmobranchs and actinopterygians, and performed tests of selection to estimate different selective pressures specifically acting upon elasmobranch rhodopsin. Moreover, we performed tests of selection on all the intronless rhodopsin sequences to examine the variation in selective pressures from intronless forms. In the elasmobranchs clade, we found evidence of strong positive selection in a low proportion of sites with the majority of other sites being under negative selection. The positively selected sites are associated with aspects of rhodopsin function that may be important in this group, such as transducin activation. We also found evidence of slightly higher nonsynonymous to synonymous substitution ratios in both the elasmobranch and intronless partition when compared to their respective backgrounds. Ultimately, this study allows us to understand the different selective pressures acting upon intron-containing and intronless rhodopsin, which provides new insight into their evolutionary history.

Michelle Su (Supervisor: Luke Mahler)

Scales, plates, and toepads: investigating evolutionary modularity and rates in Anolis scales

Biologists have long sought to understand what processes shape morphological diversity. The evolution of modularity, wherein sets of traits are more evolutionarily integrated with each other than with other traits, has been proposed to influence morphological diversification. Modularity can allow subsets of traits to evolve in semi-independent directions and at different rates. Here, I examine whether functional and/or developmental modularity have shaped the patterns of scale variation in Anolis lizards. Anoles are an adaptive radiation exhibiting repeated convergent evolution of morphologically distinct microhabitat specialists (ecomorphs), making them an interesting system for studying evolution. In squamate reptiles such as anoles, scales have many functions, including mechanical protection, crypsis, hydrophobicity, and photoprotection, and are very morphologically diverse. Systematists have recognized the incredible diversity of scale appearance among species, and frequently use scale traits to distinguish between species. However, the evolutionary mechanisms underpinning this diversity are not well-understood. To investigate whether modularity plays a role in shaping scale evolution in anoles, I tested several hypotheses of modularity based on regional differences in scale function and development, and compared evolutionary rates between modules. Using high-resolution photographs of ethanol-preserved specimens, I counted scales from several key body regions, including toepads (modified scales). My analyses found that all modularity hypotheses described the data better than the null hypothesis of no modular structure, though they could not be distinguished from each other. This suggests that developmental and/or functional modularity could indeed be influencing scale evolution, though more inquiry is needed. I also found that modules containing dorsal scales evolved at the highest rate while modules containing toepads evolved at the slowest rate. This is consistent with microhabitat specialization and concomitant toepad evolution occurring early in the anole radiation, and further divergence occurring later within ecomorph categories, involving traits related to macrohabitat differences, such as scales.

Yihang Zhao (Supervisor: Belinda Chang)

Selective pressure shifts on snake visual developmental genes are associated with shifts in their visual ecology

Due to their potential fossorial origin, snakes possess visual system that have experienced a series of degenerations that put evolutionary constraints on its further evolution. However, the presence of diverse retina types in snakes suggests constraints are successfully overcome, which is likely achieved through photoreceptor transmutation-a process that converts one photoreceptor type to the other type. For phototransduction genes, previous research demonstrated selective pressure shifts in the largest clade of snakes, known to have experienced photoreceptor transmutations. This suggests a potential association between selective pressure shifts in visual genes and photoreceptor transmutation. However, the relationship between visual developmental genes and photoreceptor transmutation remains unknown. In this research, by using evolutionary analyses based on codon models to infer selection pressures experienced by visual developmental genes, patterns of selection are found to be highly inconsistent among snake species with photoreceptor transmutation. This indicates the selection shift is likely not associated with photoreceptor transmutation. Alternatively, snake species that experienced changes in visual ecology exhibit obvious shifts in selection patterns, therefore suggesting the association between shifts in visual ecology and selection pressure shifts.