How can poaching mediated habitat changes alter community composition and its role in nutrient cycling in the ecosystem?

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November 2024

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Introduction

As human activity drives species' extinctions, it is critical to identify the consequences of species loss and decline on ecosystem functioning. Nutrient cycling and redistribution are key functions that terrestrial mammals provide via defecation and carcass decomposition. Mammal loss or decline can remove critical nutrients thereby hindering nutrient recycling[1]. Furthermore, extinction and local extirpation are typically non-random. Traits, such as large body size, are disproportionately lost[2], with possible implications for carbon sequestration and nutrient cycling[3]. Both feeding interactions and energy flow among species within a community (i.e. energy flux) can be depicted by food webs[4]. However, much of our current understanding of food webs comes from single-site or small-scale studies, making it difficult to generalize patterns at a global scale[5]. Therefore, large-scale, multi-site studies are needed to identify drivers of food web structure and associated ecosystem functioning. ***To fill this knowledge gap, I will quantify (1) the impacts of local variation in community composition on food web structure (2) indirect impacts of poaching on bat species, which are vital to ecosystem health but often understudied mammals and (3) the effects of food web structure on energy flux and nutrient cycling.*** The distribution of animal body sizes within communities affects the ratios of nutrients distributed to plants through animal feces and carcasses due to fixed stoichiometric ratios that vary with herbivore body size[6]. Therefore, spatial variation in the mammal body sizes among locations may affect the redistribution of nutrients. Furthermore, bat species, which are commonly understudied mammals, can further help distribute nutrients through their diet and are a good indicator of ecosystem health. Local-scale gradients in human pressure and plant productivity can enable tests of spatial variation in community composition on food web structure and nutrient cycling. My proposed research will directly test for links between food web structure and critical ecosystem functions that mammals provide by integrating remotely sensed field data on mammals and vegetation, field decomposition data, laboratory analysis of soil samples, acoustic monitoring of bats, and sophisticated quantitative modeling.

Hypotheses. *If poaching has a measurable impact on forest ecosystem functioning, then I predict that areas with higher levels of human pressure will have* ***(1)*** *large differences in food webs compared to sites with lower levels of human pressure* ***(2)*** *less bat species compared to areas without poaching and* ***(3)*** *lower rates of nutrient cycling.*

Justification. This project will help us better understand how illegal poaching impacts ecosystem functioning by examining how species loss changes nutrient cycling. Successful implementation of the protocol for camera trap soil sampling may result in its addition to the long-term camera trap data collection protocol at research sites in the Udzungwa Mountains and Uzungwa Scarp and other tropical forests. If my research finds differences in the nutrients between the National Park and the Scarp, then this information can be used to potentially add nutrients to the environment in the future, to aid in ecosystem recovery.

Methods. *Study system.* The tropical forests of the Eastern Arc Mountains of Tanzania provide an excellent study system given a national park and adjacent heavily poached nature reserve, both with gradients of human pressure from their edges to interior. Landscape level processes support similar biodiversity in the national park and nature reserve, yet mammal species richness and occurrence are lower in areas with high disturbance[7] or lower vegetation surface area[8].

Overview. I will use camera trap data at a subset of **20 sites in the Udzungwa Mountains National Park and 20 sites in the Uzungwa Scarp** with corresponding microhabitat data for soil macronutrients, litter decomposition, and plant productivity at the 20 established sites in each park. I will build camera trap specific food webs based on estimated species occupancies and published predator-prey interactions. I will then use regression models to test how proxies of anthropogenic pressure and plant productivity predict food webs and to what extent food web structure predicts energy and nutrient flows.

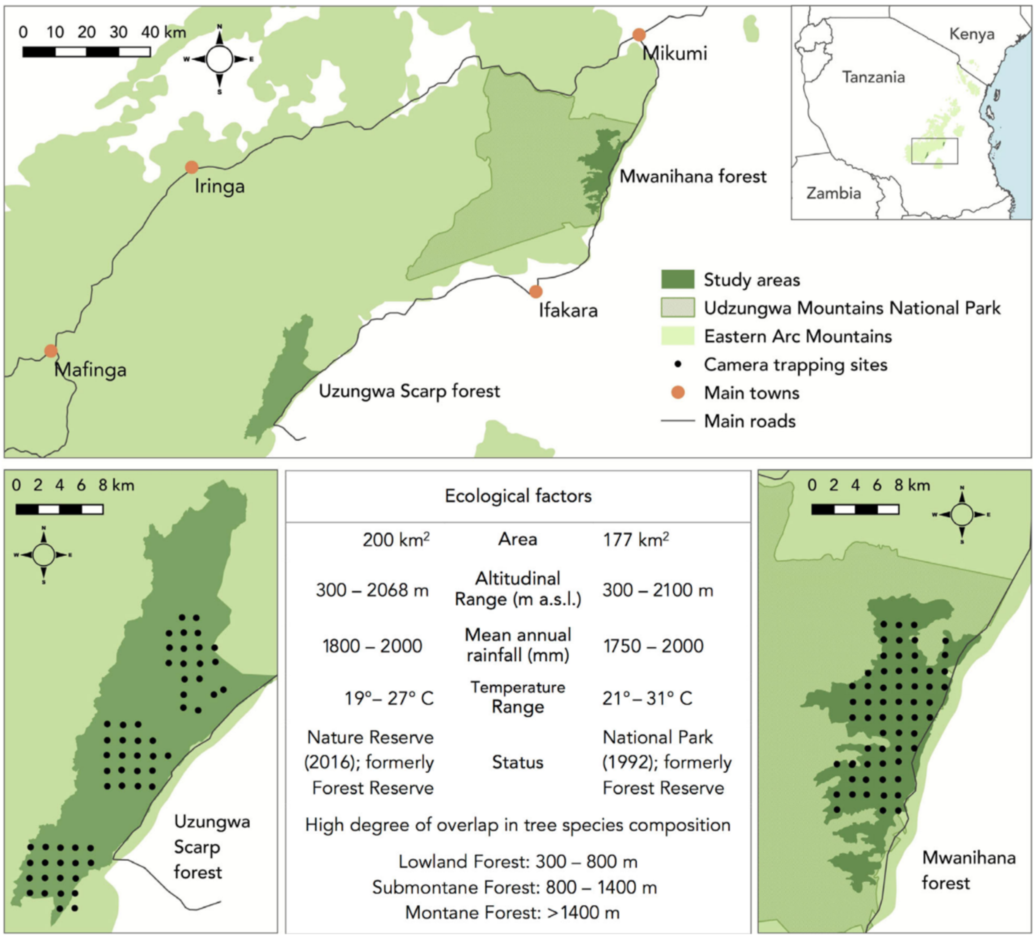

Figure 1. Map of study locations, from Oberosler et al 2020a[7]. Poaching has been eliminated from Udzungwa National Park but remains prevalent in Uzungwa Scarp forest.

<u>Objective 1. Test how food web structure varies locally in response to anthropogenic pressure</u>.
I will utilize 20 data from camera traps deployed by my local collaborators Arafat and Steven through the long-term camera trapping in each forest at a density of 1.5 km^2 for 30 days[8], identify species using an AI-assisted website, Wildlife Insights, and include ground-dwelling mammal species >100g. **I will not be installing the camera traps myself, rather I will use the data from pre-existing camera trap infrastructure after the 2025 camera assays finish.** I will estimate camera-trap and species-specific occupancy (a proxy for abundance[9]), as a function of elevation. To create food webs for each camera site I will use predator-prey interaction data from Kingdon's Mammals of Africa Volumes[10] and I will add species in the web by their occupancy.

Classic approaches for measuring differences in networks rely on Euclidian distances, which fail to explicitly account for network structural information[11]. Instead, I will use a powerful technique from engineering not yet applied to species interaction networks, called Wasserstein distances[12], that captures topological shifts in network structure. Lastly, I will model camera trap specific food webs as a function of distance from nearest road, distance from nearest settlement and forest (i.e., nature reserve or national park), and microhabitat measures of canopy cover and density of large trees as a proxy for plant productivity.

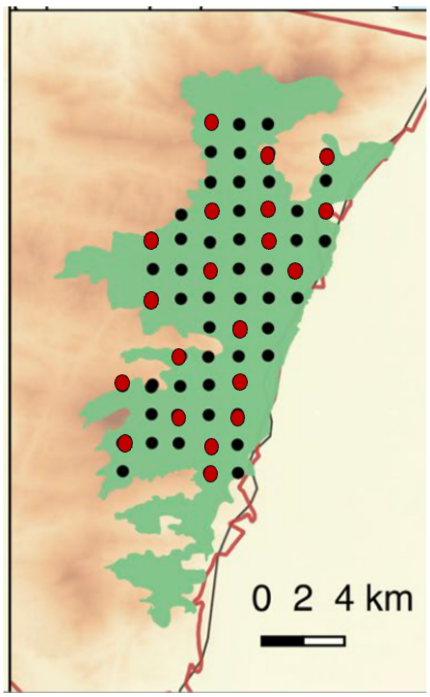

Figure 2. Subset of camera trap sites to be soil sampled in red, edited from Oberosler et al 2020b[13]. Sites will be sampled along an elevational gradient within each area.

***Objective 2.* Examine indirect impacts of poaching on bat species, which are vital to ecosystem health.** I will deploy acoustic recorders at 20 sites within each park, to record 5 minutes of every hour, from sunset until sunrise (all night, for 12 hours). The recorders will be tied to trees and placed in waterproof cases. The recorders will record for 3 nights total and then will be recollected. I will use the free software Arbimon to identify bat calls and compare the number of bat species found in the National Park compared to the Nature Reserve using a t.test looking at difference in means. I will also use sticky insect traps to see which insects are at sites for bat species to consume.

Objective 3. Quantify how food web structure affects nutrient and energy cycling.
I will model energy and nutrient fluxes through the food webs as a proxy for ecosystem functioning using the R package fluxweb[14], using a subset of 20 sites per location. Specifically, I will model camera trap specific energy flux as well as carbon and nitrogen mineralization rates[15] based on (i) biomass estimates calculated from average species body mass and camera trap specific occupancy estimates, (ii) metabolic rates from the literature, (iii) C:N ratios, soil pH and moisture obtained from five soil cores collected randomly within in a 10 x 10 m plot at each camera trap (samples sent to Texas A&M's Soil Testing Lab), and (iv) nutrient cycling estimated via decomposition rates from litter bags filled with local nutritious litter, (v) plant leaf samples (exported to the USA) and (vi) arthropod extractions and identification. Soil will be collected and refrigerated at the field station and then shipped back to the USA using a USDA permit. I will apply for a Tanzanian export permit once I finish collecting my samples and I will pay the export fees. I will have approximately 200 samples to send back to the United States of America. Each site will have litter bags left for 1 year. I will fill and weigh the litter bags while I am in Tanzania and I will hire a field assistant to collect and weigh the litter bags 12 months after leaving them. My local collaborators will work with this field assistant to collect the bags during the camera trapping season in 2026. I will write a contingency plan for the field assistant about what to do if a litter bag cannot be found. I will then use regression to test how energy flux and C:N mineralization rates vary among camera traps as a function of food web structure.

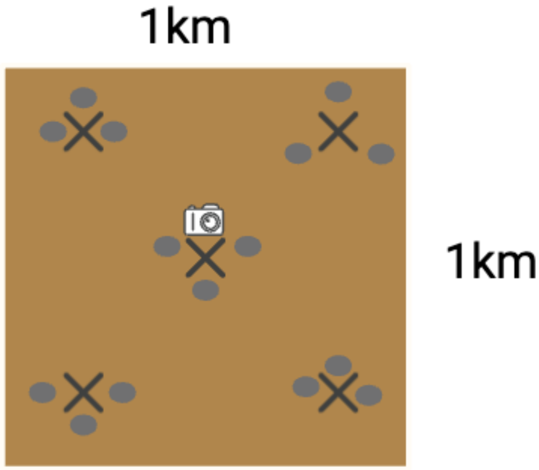

Figure 3. Schematic of sampling protocol at a site, with camera trap in the middle. X marks 1 of 5 soil cores and circles represent triplicates mixed to create soil core sample. Microhabitat and canopy cover will be taken at each X.

Personnel Logistics. I will collect data in both the Udzungwa Mountains National Park and the Uzungwa Scarp Nature Reserve. I will be bringing one undergraduate student from the USA with me as a field assistant. We will work together in the National Park. We will hire two more Tanzanian field assistants through the field station, Udzungwa Ecological Monitoring Centre, one with a bachelor's degree and one with a master's degree, to assist us in the National Park. Arafat and Steven will work with us to find other field assistants We will also hire 3 more Tanzanian field assistants through the same field station, two with multiple years of field experience and 1 with less field experience (in order to help them build their skill set) to work in the Uzungwa Scarp area in the project. All field assistants will be paid by the number of days worked, which will be approximately 25 days. Please see timeline below for an approximate schedule for the project. We will sample a subset (6-8 sites) of each existing camera trap array (3 arrays, 20 sites each in the National Park and the Nature Reserve). We will hire cooks for each camping trip in both locations, and an armed ranger for the National Park. We will pay all required fees. We will also buy equipment to camp once we arrive in Tanzania. I will train all field assistants and provide instructions written in English and Swahili.

Tentative Timeline for Project

May 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
25 Leave USA	26	27 Arrive in Tanzania	28 Immigration logistics	29 Immigration logistics	30 Immigration logistics	31 Immigration logistics

June 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1 Immigration logistics	2 Immigration logistics	3 Immigration logistics	4 Immigration logistics	5 Immigration logistics	6 Immigration logistics	7 Immigration logistics
8 Immigration logistics	9 Arrive to field station	10 Prep for sampling and train field assistants	11 Prep for sampling and train field assistants	12 Prep for sampling and train field assistants	13 Prep for sampling and train field assistants	14 Camp + Sample Array 1
15 Camp + Sample Array 1	16 Camp + Sample Array 1	17 Camp + Sample Array 1	18 Camp + Sample Array 1	19 Camp + Sample Array 1	20 Camp + Sample Array 1	21 Return to field station and store samples
22 Rest	23 Visit Uzungwa	24 Visit Uzungwa	25 Prep for sampling	26 Prep for sampling	27 Prep for sampling	28 Camp + Sample Array 2
29 Camp + Sample Array 2	30 Camp + Sample Array 2					

July 2025

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4	5

		Camp + Sample Array 2	Camp + Sample Array 2	Camp + Sample Array 2	Camp + Sample Array 2	Return to field station and store samples
6 Rest	7 Rest	8 Prep for sampling	9 Prep for sampling	10 Prep for sampling	11 Prep for sampling	12 Camp + Sample Array 3
13 Camp + Sample Array 3	14 Camp + Sample Array 3	15 Camp + Sample Array 3	16 Camp + Sample Array 3	17 Camp + Sample Array 3	18 Camp + Sample Array 3	19 Return to field station and store samples
20 Apply for export permit	21 Organize samples	22 Prepare for shipment	23 Logistics buffer day	24 Logistics buffer day	25 Logistics buffer day	26 Logistics buffer day
27 Logistics buffer day	28 Logistics buffer day	29 Travel to Dar es Saleem to ship samples	30 Last minutes logistics	31 Leave for USA		

August 2025-June 2026:
Begin analyzing the data in the USA.

June 2026:
After 1 year, my field assistants will go weigh the litter bags during the camera trap season with my collaborators Arafat and Steven. I will not return to Tanzania to weigh the litter bags. The litter bags will not be exported, just the weight will be recorded and emailed to me in an excel data sheet.

BUDGET

Full Project Budget

$26,738

Item	Quantity	Price	Total (Quantity*Price)
(A) Berlese Funnel, no electricity	20	$75.25	$1505
(B) Soil moisture probe	2	$884.00	$1768
(C) In Country Travel to Field Station and Back to Airport, as well as travel to site– Private Car hire	Several trips	~$1500	$1500
(D) Two round trip flights from IAH-DAR and DAR-IAH, luggage fees included for equipment Approx. May 25th-July 31st	2	$2900.00	$5800.00
(E) Field station room fees at Udzungwa Ecological Monitoring Centre	2 months	$340/month x 2 people	$1360
(F) Field assistant salary	25 days, 5 assistants	$18.38/day (Tanzania set wage)	$2285
(G) Food Costs	70 days	$20 per day	$1400
(H) Camping equipment	3 tents, sleeping bag, sleeping pad	$200/per camping set	$600
(I) Cook and guard salary	25 days	2 Cooks: $11/day Guard: $23.60/day (Tanzanian set wage)	$1140
(J) Permit Costs -TAWIRI is $50 for application fee (per person) + $20 of application fees for local + $1200 research fee = $1270 -COSTECH $50 application fee for foreigner + $20 for local field assistant + $300 research fee = $370 total	2 persons	$2190	$4380

-Immigration $50 application fee to resident permit application + $500 for resident permit card = $550 total to immigration			
(K) Audio Recorders	15	$100/each	$1500
(L) Shipping Samples Tanzania Fees + Shipping Cost with DHL or Baggage Cost on Airline	~ 200 samples	$10 per sample $1500 to ship	$3500

Total: $26,738

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