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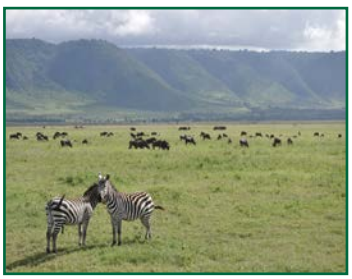

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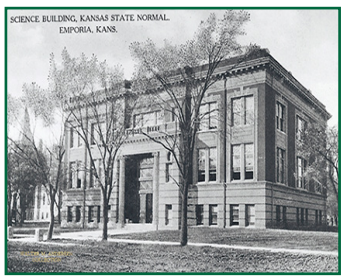

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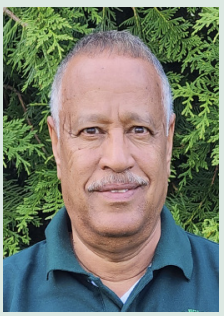
Travels in Tanzania with North American Undergraduates: A Botanical Wildlife Safari

As a botanist and an entomologist, taking a wildlife safari tour was never a high priority for either of us. We've both traveled widely and worked with plants and insects in many parts of the world. Wildlife viewing in Africa sounded interesting, to be sure, but we hardly thought of it as worthy of the effort and expense. As faculty members at SUNY Oswego, our professional lives center on undergraduate teaching and small-scale research experiences, with fieldwork conducted in our local New York fields and woodlands.

New York summers are short, though, and we are always looking for more options for our many students interested in field biology. In 2017, while one of us (K.I.M.) was in Tanzania conducting research on the parasitic genus *Striga*, he was introduced to Dr. Alex Kisingo, at the time a senior lecturer and Head of Research and Consultancy at The College of African Wildlife Management (Mweka), in Moshi. Mweka trains students for careers in wildlife conservation, with most graduates finding work as game wardens, park rangers, safari guides, and climbing guides on Kilimanjaro. The college has been expanding its offerings recently, to include a master's degree program, and—fortuitously for us—it is seeking to grow its international programs, bringing in more students from outside Africa, sending more of its students abroad, and enhancing teaching and research collaborations and exchanges with biologists from around the world. During K.I.M.'s visit, Alex encouraged us to bring over Oswego students for a short training course in wildlife ecology. As one of the few U.S. universities offering a bachelor's degree in zoology, we were pretty sure that there would be interest among our students. His tour of Mweka convinced K.I.M. that the infrastructure and expertise Mweka had in place to lead field research and training for its own students would make it an outstanding destination for ours as well.



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We have now taught the Tanzania Biodiversity and Conservation class three times, in 2018, 2019, and 2022, to an average of 10 students each time. The format of the course is what SUNY Oswego terms "faculty-led travel," in which students do coursework for a portion of the semester, and then are accompanied by the instructors during travel. For half a semester, we met weekly with the students in Oswego to get them up to speed on

Tanzania's history, people, ecosystems, and wildlife, and to get ourselves up to speed as well. We knew embarrassingly little about Tanzania at the start, but (as is often the case for college professors) we did manage to stay just ahead of the students. Besides references that we specifically cite, these are examples of suggested sources students used to prepare talks and a final paper: Kennedy, 2014; Sinclair et al., 2015; Briggs and McIntyre, 2017; Luke and Beentje, 2020; Makunga, 2022.

Some interesting things we learned:

- The name "Tanzania" is a modern invention. The British colony of Tanganyika gained independence in 1961. A few years later, Zanzibar overthrew Arab rule, and the two young countries joined into a single nation, the Republic of Tanzania, blending their names into one as well (Tan-Zan-ia).

- The population of Tanzania is marvelously multicultural, an amalgamation of some 120 tribes with over 100 languages (Swahili being the *lingua franca*, along with English to some extent). Around two thirds of the population is Christian, another one third is Muslim, with small minorities following other practices (Winks, 2009).

- Tanzania takes conservation very seriously. About 40% of the land area of Tanzania is protected (there are marine preserves as well), one of highest percentages in the world. In contrast about 12–13% of the U.S. is protected, which is roughly the world average. Preserves include national parks, which are completely protected and closed to human habitation, and game and forest reserves and conservation areas in which herding, hunting, and human habitation are allowed to varying degrees (United Republic of Tanzania, 2014).

- Wildlife tourism makes up nearly 20% of the GDP and employs hundreds of thousands of people (United Republic of Tanzania, 2015). Mweka itself is a testament to Tanzania's dedication to protecting these resources. Its founding in 1964, shortly after independence, represented the beginnings of a movement to put Africans in charge of the conservation of their wildlife and other natural resources.

Our two-week visits in Tanzania began with a day of lectures from Mweka faculty on wildlife ecology, local ecosystems (including the vertical vegetation zones of adjacent Mt. Kilimanjaro), and regional conservation practices, followed by a tour of preserves and parks in the northeastern part of the country (Figure 1). Throughout the visit, we kept costs very low by staying in dormitories and camping in tents they provided. We traveled in the back of a repurposed Russian troop carrier (no air-conditioned comforts on this trip), and had communal meals prepared by a team of cooks. Additional lectures and discussions took place in the field, at picnic tables and around campfires.

On our first full day in Tanzania, we explored the Mweka campus and discovered many tree species that our students found to be quite exotic. Some of these are seen in the background of Figure 2: fever acacia (*Vachellia xanthophloea* (*Acacia xanthophloea*)), Senegal date (*Phoenix reclinata*), pencil cedar (*Juniper procera*), Norfolk pine (*Araucaria heterophylla*), and traveler's palm (*Ravenala madagascariensis*). Among others not pictured

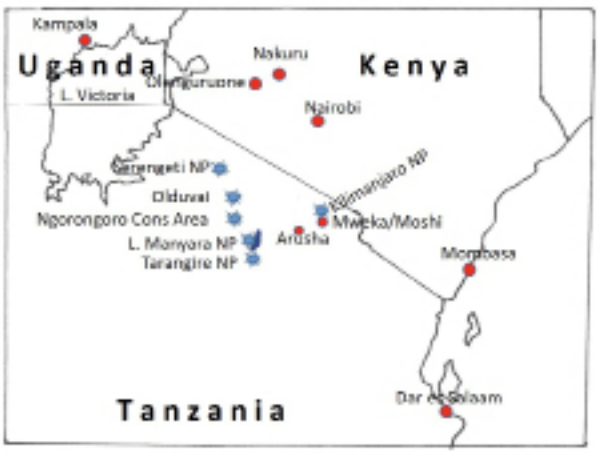

Figure 1. *Star symbols show the National Parks and Olduvai Gorge Museum we visited in Northern Tanzania. The Snake Park, Maasai Museum, and Maasai Boma, just outside Lake Manyara, are other significant sites we visited but are not shown on this map. The College of African Wildlife Management (Mweka) is at the base of Kilimanjaro.*

are strangler fig (*Ficus thonningii*), African tulip (*Spathodea campanulata*), and the giant potato tree (*Solanum macranthum*). Strangler fig is of particular interest to North American students with its unfamiliar appearance and lifestyle. A hemiepiphyte, it starts atop a host tree and sends roots down to the forest floor, squeezing the trunk of the host tree and shading its crown, eventually killing it.

Mweka is located on the lower slopes of Mt. Kilimanjaro at about 1370 m. At slightly lower elevations, the landscape is devoted to coffee plantations. Two wet seasons—a shorter one that runs November to January and a longer one from March to May—supply an annual rainfall of 100–165 cm and support a lush, wooded environment. Hiking up from the college toward one of the entrances to Kilimanjaro National Park at elevation

Figure 2. *Students of the 2018 class on the Mweka campus, along with a Mweka faculty member, Mt. Kilimanjaro in the background. The weather in May was usually overcast, and of the three times we have offered the class, this was the only time we had a sustained clear view of Mt. Kilimanjaro. 1. Fever acacia, 2. Norfolk pine, 3. Senegal date, 4. Traveler's palm, and 5. Pencil cedar.*

1640 m, we passed through a landscape of small villages, home to the Chagga tribe, the houses and other buildings interspersed with household gardens planted with banana, coffee, maize, sweet potato, beans, and cassava. These so-called Chagga homegardens, built into the forest over centuries, are a fascinating example of sustainable land use in a mixed-cropping system (Fernandes et al., 1985; Hemp, 2008). The coffee-banana belt occupying the lower flanks of Kilimanjaro is a modified woodland, with the canopy intact and shade-tolerant crops integrated into the forest; over 500 plant species, 400 of which are not cultivated, can be found in this zone (Hemp, 2006, 2008). The typical Chagga homegarden comprises four main layers: larger trees like avocado (*Persea americana*) and albizia (*Albizia schimperiana* var. *amanuensis*), beneath which grow different varieties of bananas (*Musa x sapientum*) 5–7 m high, then coffee (*Coffea arabica*), and at the base a mixture of smaller food crops like cassava (*Manihot esculenta*) and coco yam (*Colocasia esculenta*). These crops make up a large part of the local diet, and the extras (particularly coffee) are sold for cash. Bananas are perhaps the largest single crop, and we were fascinated by the variety of ways in which the Chagga use them. One interesting use is the making of mbege, a strong beer made up of fermented banana mixed with a borage of finger millet and some quinine-bark flour to adjust the sugary taste of banana. Numerous small pubs serving the drink line the roads outside the National Park. Besides sampling the mbege on our hike, we also introduced our students to several plants with medicinal and folk uses, including castor bean (*Ricinus communis*), misty plume bush (*Tetradenia riparia*) (Figure 3), and dragon tree (*Dracaena afromontana*) (Figure 4).

Figure 3. Tetradenia riparia, *a plant found in the Chagga homegardens, which our hosts claimed worked as a COVID-19 treatment either by chewing the leaves or as steam therapy.*

Figure 4. *Among the Chagga, Dracaena marginata is used to build fences and mend relationships—one must forgive when the plant is offered by the offender.*

The Chagga gardens provided the students an education in a type of agricultural system that, while unfamiliar to North Americans, is fairly widespread, particularly in the tropics, among indigenous cultures. For example, K.I.M. witnessed similar homegardens in southern Ethiopia, with an upper layer of ensete (*Ensete ventricosum*); below it, sorghum, millet, or maize; and a bottom layer of smaller crops, such as beans and vegetables (Zemede and Avele, 1995). In parts of Ecuador, inhabitants practice two systems of agriculture: small fields closer to their homes and homegardens. These gardens and fields contain over 50 plant species including cacao, coffee, banana, pineapple, cassava, and a variety of other food and non-food crops (Gari, 2001). Fields are cultivated and managed, and abandoned according to a complex agroecological system (Gari, 2001). Diversified systems such as these ensure the resilience of ecosystems and at the same time maximize the production of food, medicines, and other resources. The study of these systems has much to contribute to improving the effectiveness and efficiency of sustainable agroecosystems worldwide, by integrating indigenous knowledge with scientific methodology (Dewalt, 1994).

After a couple of days at the college, we piled into the troop carrier, accompanied by two Mweka faculty members who would serve as our guides and interpreters, along with the cook and his helpers. We drove several hours to Mto Wa Mbu, staying in a tent campground in the forested hills above the town. Nearby Lake Manyara National Park is the smallest of the parks we visited, with an area of 325 sq km but known for its diverse habitats, which harbor nearly 700 plant species (Greenway et al., 1972); in fact, the density and diversity of wildlife here is extraordinary. Any fears that our zoology students might have been disappointed in their safari were quashed within minutes of entering this park, as we soon had up-close views of baboons, zebras, wildebeest, warthogs, elephants, monkeys, and lions.

This park differs from the others that we visited in that much of it is densely wooded, whereas the others are characterized by open savannah. Most of the park's roads run through the narrow flats bounded by the alkali lake on one side, and the steep sides of the Rift Valley on the other. The woodland is dominated by large, dense *Acacia* and *Commiphora* species, *Albizia anthelmintica*, and *Cassia singueana*, with a variable understory shrub layer. Notable among these is African myrrh (*Commiphora africana*), from the resins of which incense is produced. The slopes, which rise 600–1000 m above lake level, feature baobabs (*Adansonia digitata*), broad-leaved croton (*Croton macrostachyus*), candelabra tree (*Euphorbia candelabrum*), sycamore fig (*Ficus sycomorus*), quinine tree (*Rauvolfia caffra*), Natal mahogany (*Trichilia roka*) (also noted for its medicinal extracts [Sanogo et al., 2001]), and forest toad-tree (*Tabernaemontana ventricosa*) (Greenway et al., 1969, 1972). Closer to the lake are open alkaline flats beds dominated by grasses, mainly *Sporobolus spicatus* in association with *Sporobolus consimilis*, whereas the drier grassy areas are dominated by *Cynodon dactylon*.

Tarangire National Park is about 70 km south of Lake Manyara. Although both parks receive similar amounts of rain (about 70 cm annually), Tarangire seems drier than Lake Manyara National Park, with open water flow largely limited to the Tarangire River, in contrast to the multiple springs and creeks draining through the steep hillsides of Lake Manyara. It is grassier and much more open, with only scattered trees. Nonetheless, many

Figure 5. *(A) Tarangire, the land of baobab. (B) Elephants, a baobab, and an acacia bearing dozens of weaverbird nests. Note the cinder cone in the background. There are dozens of such volcanic features in northern Tanzania (including Kilimanjaro), most of them inactive.*

of the same animals occur at the two parks, and there is significant migration between them.

Tarangire is renowned for its large elephant herds, but we were just as thrilled by the botanical "big game" of its many enormous baobabs (*Adansonia digitata*). We saw more extensive stands of these trees than at any other place we visited in Tanzania (Figure 5A, B). These long-lived, majestic trees reach up to 25 m, with wide spreading branches and stout trunks measuring 10–15 m across. Baobabs are known among the most effective plants that control water loss. Some baobabs in Tarangire

Figure 6. *A termite mound in Tarangire National Park, with a young baboon. The rest of his troop was in a nearby baobab, devouring the fruits and plundering bird nests.*

had been heavily damaged by elephants seeking nutrients and water, bringing to our attention the many uses of baobabs by both people and wildlife. They are important for the livelihood of many people in arid zones for uses in food, beverages, and medicine. The hollow trunk of some specimens can provide shelter, and the tubers, twigs, fruits, seeds, leaves, and flowers are common ingredients in traditional dishes and beverages; they provide a reliable food and water source for birds, baboons, and other animals (Gebauer et al., 2002; Venter and Venter, 2007).

Besides the baobabs, Tarangire's vegetation is a mix of *Acacia* and *Combretum* woodlands and seasonally flooded grasslands. Along the riverbanks, we saw pure Acacia stands and occasional sausage trees (*Kigelia africana*). The drier habitats are highly suited for mound-building termites and feature numerous, often very large mounds (Figure 6), to the delight of the entomologist in the group.

Figure 7. *A typical grassland habitat in Ngorongoro crater with a mixed herd of zebras, Cape buffalo, and wildebeest; in the background, the rim rises some 600 m above the floor of the crater.*

Figure 8. *The walls of Ngorongoro crater, visible in the background with their dense forest, descend into stands of large fever acacia around the base (here with a group of vervet monkeys).*

From the dry lowlands (ca. 900 m elevation) around Manyara and Tarangire, we ascended into the cloud forests at the rim of Ngorongoro Crater, where we camped overnight. Through the mists, we began to see astonishing views of the crater, which is the world's largest intact and unfilled volcanic caldera, some 610 m deep and around 17 km across. At 2300 m elevation, the rim is persistently cool and damp. The steep interior slopes of the crater are occupied by a variety of montane forest trees, including red thorn acacia (*Vachellia gerrardii*) and gum acacia (*Acacia senegal*), sweet olive (*Osmanthus fragrans*), African redwood (*Hagenia abyssinica*), and African pencil cedar (*Juniperus procera*), with fever acacia dominating the lower portions. Enormous candelabra trees also cling to the hillside.

The morning after arriving at the rim, we descended the steep switchback road through these woodlands to the bottom, where we were rewarded by views of the elephants, lions, zebras, wildebeest, hyenas, and other wildlife that congregate in the lush grassy wetlands (Figure 7) and the fever acacia stands at the edges (Figure 8). The highlight of the crater was a close view of the gravely endangered black rhino, made possible when we connected with some of the "rhino rangers" assigned to protect the crater's rhino herd. The rangers were alumni of Mweka College and arranged our viewing with our faculty guides, their former professors. Only a few dozen rhinos live here. The ranger team follows each animal's activities closely, using cameras and tracking devices. Injured or sick rhinos are given aid (which is not done for other species). Although the topography limits poaching in this preserve, it is still a serious concern here as elsewhere.

Most of the crater floor is grassland, with some small sections of standing water surrounded by swampy areas (Anderson and Herlocker, 1973). In late May, at the end of the rainy season, we found many roads still muddy or inundated. Few trees exist at the floor, mainly near the swamps and the edges of the crater, including species of *Acacia, Vangueria, Commiphora, Albizzia,* and *Rauvolfia.* Common herbaceous plants include species of *Chloris, Cynodon, Digitaria, Andropogon,*

Sporobolus, and *Leucas*. We also encountered several invasive species: yellow flower bidens (*Bidens schimperi*), wild cannabis or khaki weed (*Tagetes minuta*), and purple flower gutenbergia (*Gutenbergia cordiflora*)—the latter two species in particular implicated in dramatic alterations to the native flora of the crater in recent years (Ngondya and Munishi, 2021). *Bidens schimperi* has edible leaves, and Tanzanians claim that the roots cure coughs and colds.

Ngorongoro Crater is situated between the Serengeti plains on the northwest and the Rift Valley to the east, and together with surrounding lands comprises the larger Ngorongoro Conservation Area (NCA), a UNESCO World Heritage Site that is home to many Maasai, albeit with restrictions on their use of the land. The NCA has been celebrated as a model for cooperative conservation, the semi-nomadic, pastoralist Maasai coexisting with protected game (we saw many mixed herds of cattle, goats, zebras, giraffes, and gazelles), but for the Maasai the story has been fraught with tensions (Buzinde et al., 2014; Melubo and Lovelock, 2019). Many moved to the NCA after being evicted from the adjacent lands that were designated as Serengeti National Park in 1959. The crater itself was made off-limits to the Maasai for pastoral use and habitation in 2009. One of the Mweka faculty members accompanying us was a Maasai who grew up in a village near the crater rim and recalled bringing his herds into the crater as a boy. More recently, the Tanzanian government has moved to further restrict Maasai use of the NCA, leading to the possibility of another round of displacement.

From the crater, we descended into the Serengeti plains, traveling toward Serengeti National Park. This stretch is in the rain shadow of the crater rim and adjacent uplands, an ecosystem dominated by dry grasslands and thickets of stunted acacia species, including whistling acacia (*Acacia drepanolobium* syn *Vachellia drepanolobium*). Before entering the park, we stopped at Olduvai Gorge and its visitor center (Figure 9), with its excellent museum chronicling the paleoanthropological discoveries made in the adjacent ravine by Louis and Mary Leakey and their colleagues. It was here that the Leakeys found the key fossils that consolidated the evidence for an African origin for the human species. Excavations in the area are ongoing. We didn't see much wildlife here—a few troops of baboons—but as evolutionary biologists we were thrilled to explore the Leakeys' field sites. Incidentally, the name "Olduvai" comes from (a mispronunciation of) *oldupai,* the Maasai word for sisal (*Agave sisalana*) (Figure 9), which is abundant in this area. Although native to Central America, sisal has been cultivated for commercial purposes in Tanzania since the 1880s, and grows wild near the gorge (Carr et al., 2006).

Figure 9. *Entrance to Olduvai Museum with sisal plants lining the road on either side.*

We spent four nights in Serengeti National Park. The park is large, extending some 150 km south from the Kenya-Tanzania border and 150 km southeast from points near the shores of Lake Victoria, with elevations ranging from 900 to 1800 m. Much of it is rolling plains, with as many as 200 species of grasses (Williams et al., 2016), characterized by short and tall grasslands and small stretches of woody savannah dominated by *Acacia, Vachellia, Commiphora*, palms, and sausage trees. The short grasslands in the eastern parts of the park are dominated by *Sporobolus* and *Kyllinga* species, while the tall grasslands in the west are dominated by *Pennisetum, Andropogon*, and *Themeda* species (Lind and Morrison, 1974). Intermediate grasslands of *Cynodon* and *Sporobolus* are found between them. McNaughton (1983) divided the Serengeti grasslands into 17 different communities including 6 short grassland communities, 3 tall, and 8 intermediate. Anderson and Talbot (1965) and Lind and Morrison (1974) attributed the distribution and growth of grass species in the plains to a number of factors, including soil depth and texture, salinity, wind erodability, rainfall, and grazing pressure.

The diversity of grasses may have failed to capture the interest of our zoology students, but they could not help but notice the scattered trees, which were focal points for wildlife observation. Predators frequently climb them, to scan for prey and possibly also to avoid biting flies. We often spotted lions and leopards on sausage trees (Figure 10) and acacias; once, we counted 11 lions (females and several cubs) lounging in a large acacia (Figure 11). The sausage trees, which we had first spotted in Tarangire National Park, are particularly interesting. These semi-deciduous trees are common and widespread in African savannah, and they're large, reaching up to 25 m. They are easily identified by the sausage-like dangling fruits, which can be a meter long (Figure 10). The fruits are poisonous if consumed raw, but if prepared correctly have significant food and medicinal value (Jackson et al., 1996; Picerno et al., 2005). Indigenous people make them into a beer and have used them in wound healing and to treat rheumatism, psoriasis, diarrhea, and stomach ailments.

Figure 10. *Serengeti lions resting on a sausage tree after a big meal. Notice the typical open grassland with scattered trees, typical of this park. The insert on the left shows the sausage fruits.*

Figure 11. *There were 11 lions in this umbrella acacia (females and cubs), plus a few more on the ground, obscured by the tall grass (Serengeti National Park).*

Up to our arrival in the Serengeti we had been astonished at the bounty of wildlife sightings; and here we were astonished again, at the sheer abundance and magnitude of the herds in the park. Pools packed with hundreds of hippos; gazelle, zebra, and elephant herds so vast as to disappear into the horizon. We witnessed thousands of migrating wildebeest accompanied by zebras and trailed by cheetahs, lions, and hyenas. Even our guides, who had spent much time in the park, expressed joy, wonder, and excitement at the scene.

While the animal highlights of a Tanzanian safari would be well known to any fan of BBC and PBS nature specials, the many plant highlights are most fascinating as well, and not only within the preserves. Driving between parks, we saw numerous additional species of interest, whether for their uses by locals or for their familiarity as garden and house plants in North America, and we had opportunities to relate their stories to our students. These included desert date (*Balanites aegyptiaca*), with its edible fruits often serving as fodder for goats and camels; sandpaper bush (*Ehretia obtusifolia*), whose distinctive tough leaves are infused into teas to treat pain; frankincense (*Boswellia papyrifera*), African chewing gum (*Azanza garckeana*); toothbrush bush (*Salvadora persica*), which is used as such and has added antiseptic and analgesic effects (Niazi et al., 2016); and plants commonly cultivated in North America such as maidenhair fern (*Adiantum venustum*), lantana (*Lantana camara*), and jimsonweed (*Datura stramonium*). Jimsonweed is a large herbaceous plant with well-known poisonous and hallucinogenic effects (Trancă et al., 2017). It occurs in North America but is seldom seen in our part of New York.

Why would a botanist teach a "safari class"? In a sense, it was under the guise of a wildlife safari that we were able to expose our students to a great many botanical wonders: unfamiliar plants, plant communities, and agroecosystems, as well as new insights into familiar plants and products. They were excited to taste the sweet pulp of the coffee

fruit and dig out the green beans within, to sample mbege made from bananas growing just outside the pub, to see the plants from which frankincense and myrrh originate, and to learn the names of plants that provide habitat, food, and water for animals. They gained a new appreciation of indigenous and folk uses of plants, most of them unfamiliar; they learned about agroecosystems entirely different from, and more sustainable than, the typical North American farm; and they learned about kinds of plants, such as strangler fig, that behave very differently from any they know in the U.S. The opportunity to view animals in their native settings was the bait, perhaps, and the wildlife viewing was wonderful indeed—but we also aimed to stimulate these young zoologists to learn more about the plants with which their objects of study interact. Zoology students, in our experience, are often reluctant to study plants, but in Tanzania, through hands-on study, they discovered that plants and animals are inseparable when studied in the field, and gained a new appreciation for botanical knowledge.

By collaborating with faculty members at Mweka, we were able to provide our students with a rich learning experience focused on wildlife conservation and ecology, subjects outside our own areas of expertise. We learned a great deal as well—about wildlife, about Tanzanian ecosystems, about the effects of climate change in this region, and about political, economic, and cultural aspects of species and habitat conservation in this part of the world. In turn, we were able to share with our Mweka colleagues some of our knowledge of plants and insects, making the trip more rewarding for everyone.

Field work in Africa can be expensive and logistically difficult for scientists based far away and with limited knowledge of local resources. Organizing a class for undergraduates made available to us with support from both our own university and from Mweka, providing a convenient and low-cost way to travel. Both for us and for our students, the class was an opportunity to work in a part of the world that would otherwise have been very difficult for us to visit.

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