Report: Assessing the church forests of Ethiopia as critical reservoirs of herpetofaunal diversity (NGS-292R-18)

Margaret D. Lowman[1], Dan A. Greenberg[2], Tegistu Adane[3,4], & Alemayehu Wassie[4,5]

[1]TREE Foundation, Sarasota, FL, USA

[2]Dept. of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada

[3]Ethiopian Travel Adventures, Bahir Dar, Ethiopia

[4]Bahir Dar University, Bahir Dar, Amhara, Ethiopia

[5]Organization for Rehabilitation and Development in Amhara (ORDA), Bahir Dar, Ethiopia

Church forest in South Gondar region. Photo credit: Kieran Dodds/ Panos Pictures.

Overview

Landscapes across the globe are increasingly becoming mosaics of both remnant ecosystems and agricultural activities as an expanding human population and per-capita consumption drives land conversion. Whether these now fragmented ecosystems can retain their natal biological diversity in these human-dominated landscapes, particularly over long time-scales, remains an open question. The northern highlands of Ethiopia provides a remarkable case study for this problem, as only 3% of the Afromontane dry forests that covered this region still remain. This remnant ecosystem now exists only as small forest fragments (~3 – 20 hectares) that have been protected by local Ethiopian Orthodox churches for hundreds to thousands of years, providing a window to our understanding of whether biodiversity can persist in fragmented landscapes over long ecological time-scales. Our study set out to document the diversity and abundance of herpetofauna (amphibians, lizards, and snakes) across the church forests of the Amhara region, and to determine whether the installation of stone retaining walls around forest fragments affected herpetofaunal biodiversity in two surveys in 2018 and 2019. Similarly, we also documented the incidental occurrence of numerous other vertebrate species (birds and mammals) that still reside in these remnant forests. We found that the age of stone wall construction was positively related to the number and diversity herpetofaunal encounters, suggesting that over years these projects serve to both attract and potentially bolster local herpetofaunal populations. Similarly, we collected evidence that these church forests are critical habitat for a number of species that are regionally imperilled, underscoring the vital role of church forests as islands of biological diversity in this region. Our results suggest: 1) that many species can persist in small habitat fragments over long time-scales, 2) that stone wall construction appears to have both direct and indirect beneficial effects on vertebrate biodiversity, and 3) that safeguarding the integrity of these church forests is vital if we aim to maintain the biodiversity of this region.

Summary of Key Results

- We recorded 310 encounters of amphibians and reptiles (of 12 species) over three repeated visual encounter surveys at six church forests.
- The abundance and diversity of herpetofauna trends with the length of time since stone walls were constructed at a site, suggesting that these structures act as habitat enhancements that bolster population abundance.
- We recorded the presence of 102 bird species across seven church forest sites, with richness ranging from 18 to 39 species per site.
- We discovered several mammal species that appear to reside exclusively in the church forest ecosystem – including bush duikers and the endemic and data-deficient Abyssinian genet.
- Additional surveys to systematically document the birds and mammals that reside in church forests is a priority to understand the full scope of how these ecosystems retain biodiversity in a human-dominated landscape and prioritize critical habitat for protection and restoration.

Summary of Activities

Our first trip in May 2018 lasted 3 weeks, where we (MDL, DAG, AW) visited 10 church forest sites around Lake Tana and also put together a conservation workshop with 16 priests from the surrounding Amhara region in Debre Tabor to discuss biodiversity conservation and research in their church sites. This initial visit provided valuable baseline data and allowed us to pilot our sampling methodology by comparing pitfall traps vs. visual encounter surveys. Overall, we found that herpetofaunal diversity was low in the forest sites in the dry season. From surveys in adjacent streams, we captured several amphibian species, suggesting that they may seasonally migrate into the forests in the wet season and take refuge in wetlands in the dry season. Follow-up surveys in the wet season will be key to understanding the ecological dynamics of these forests. We recorded numerous incidental occurrences for local bird and mammal species as well and also used this opportunity to distribute literature (https://canopymeg.com/writing/books/beza/) to local schools and churches that highlight the global importance of Ethiopia's church forests. We also organized a workshop that brought together over 20 priests representing over 1400 churches (and forests) in the Amhara region to discuss conservation and research strategies and the importance of stone wall construction.

Church forest conservation workshop – May 2018

Meg Lowman's trip in February 2019 was to foster our relationships with the Orthodox priests and encourage wall construction and biodiversity conservation across the south Gondar region. None of this work can proceed without her memorandum of understanding (MOU) with the church, and they appreciate her visits where she prays, talks, discusses, and inspires conservation of the church forests. This year, she spoke to a group of approximately 75 leadership priests, as well as visiting five church forests with walls. The unique part of this visit was that she and Dr. Alemayehu Wassie rented a bus, and took other priests to see the successful conservation walls around other church forests. The visits and workshops with the priests need to happen in the dry season, since that is the only time when priests can actually leave their own forests and travel easily to a workshop.

Dan Greenberg returned in August 2019 to conduct field surveys during the wet season, where he joined Tegistu Adane to conduct 23 days of field surveys across seven church forest sites in the south Gondar region. The first tasks of our trip were: 1) introductions and permissions to sample in the sacred forests, where we were able to obtain permissions from the regional diocese, local priests, and the Organization for Regional Development of Amhara to conduct our research, and 2) establish some pilot studies of field methodologies, including establishing pitfall traps with drift fences. After establishing our access to these culturally sensitive sites and initial visits, we found that visual encounter surveys – through both the interior forests and surrounding stone walls – were the optimal technique to document the diversity of herpetofaunal species. Our original intention was to compare walled and un-walled sites, which we did – but our encounters in unwalled sites were very low and we decided to modify our strategy to focus instead on sites that varied in time-scale with which they have had a stone wall built. For this end, we surveyed six sites (Fig. 1): Zara (11°47'59.33"N, 37°34'5.00"E), Wonchet (11°45'50.09"N, 37°32'58.09"E), Gibstawit (11°45'41.67"N, 37°35'48.72"E), Woj (11°55'41.74"N, 37°48'55.64"E), Zajor (11°39'15.09"N, 37°36'31.68"E), and Gindatemem (11°44'29.90"N, 37°27'50.84"E). These sites varied in terms of the length of time since a stone wall was first established with Zara, Wonchet, and Woj having had walls for 5+ years, while Gibstawit, Zajor, and Gindatemem had walls that were recently constructed (< 3 years). This provided a contrast between sites with a longer history of stone walls (Zara, Wonchet and Woj) versus those with very recent wall constructions (Gibstawit, Zajor, and Gindatemem). We established a method whereby we recorded our tracks using GPS and conducted time-monitored surveys of the forest sites – recording encounters with amphibians and reptiles (and incidental occurrences of other species) and taking GPS points of where each specimen was encountered so we could evaluate the fine-scale habitat associations of these species. We similarly collected data on canopy cover and habitat within the forests. During this trip, we were able to collect detailed occurrence data through visual encounter surveys for herpetofauna residing in and around the church forests, as well as recording incidental occurrence data for birds and mammals across these sites.

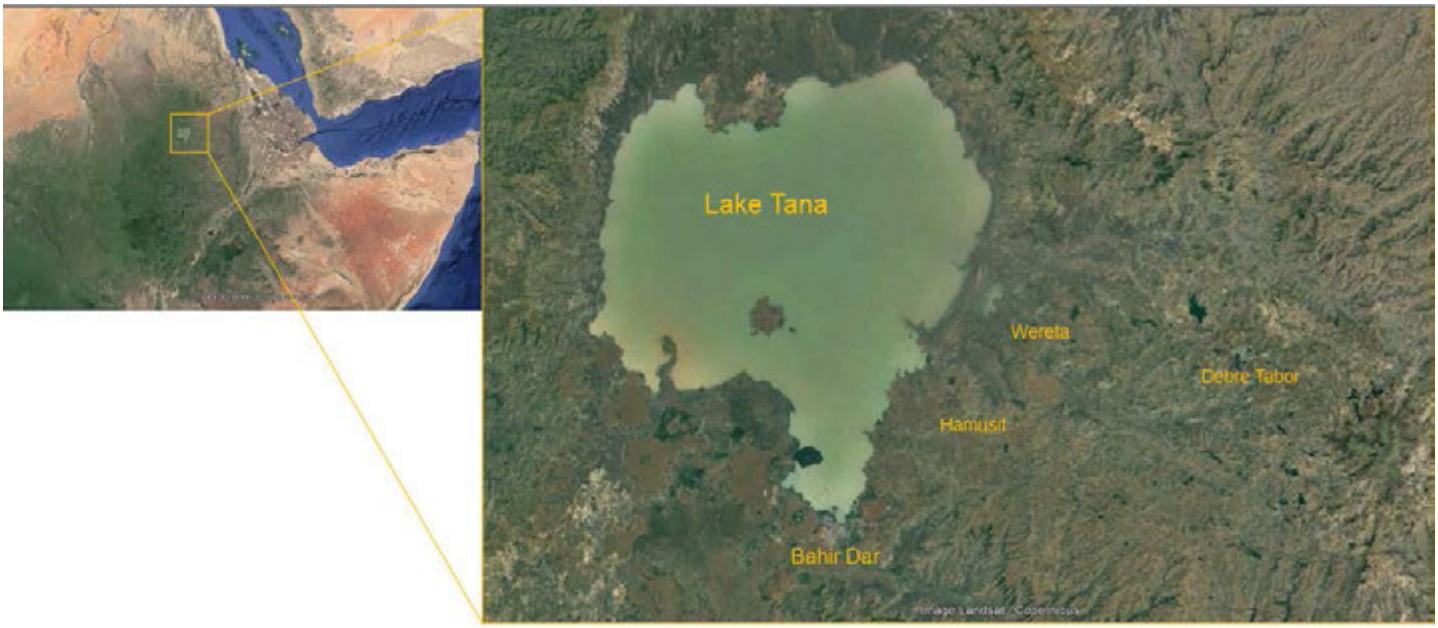


Figure 1. Overview of the study region of South Gondar and Lake Tana, Ethiopia.

Figure 2. The six church forest study sites from our 2019 wet season surveys set against the broader regional landscape of South Gondar: 1. Zara, 2. Wonchet, 3. Gibstawit, 4. Woj, 5. Zajor, and 6. Gindatemem.

Major findings

Herpetofaunal abundance and diversity

Through our visual encounter surveys across six church forests in the South Gondar region, we recorded 310 encounters of amphibians (N = 5), lizards (N = 4), and snakes (N = 3) (Fig. 3; Fig. 6). The distribution of both abundance and diversity of herpetofauna was highly uneven across sites (Fig. 3 and Fig. 4), with particularly high numbers of encounters at Wonchet (n = 82), Woj (n = 47), and Gibstawit (n = 161) relative to the other sites (Zara, n = 18; Zajor, n = 2; Gindatemem, n = 1). Similarly, species richness also varied from 2 – 8 species per site, with the sites having a high abundance of species also typically being taxonomically richer (Fig. 4). The most species rich site was Woj (N = 8), which is situated close to the Fogera wetland that likely harbours a high concentration of herpetofauna. When we rank sites by time since the stone walls were established, there is a general trend hat church forests with a longer history of stone walls currently have a higher abundance and diversity of herpetofauna. This suggests that over time these stone walls may be acting either as an attractant for species from the surrounding landscape or serving to bolster their abundance.

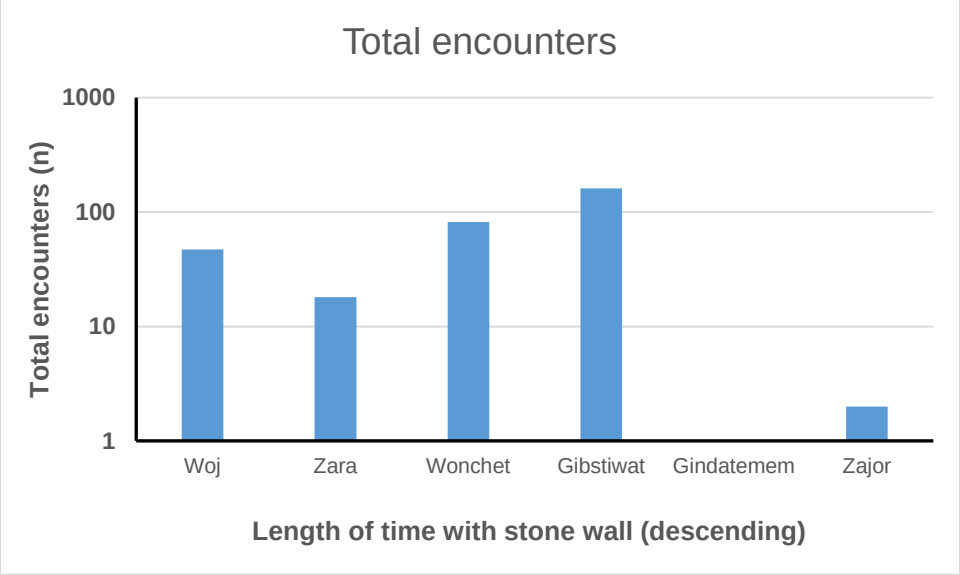
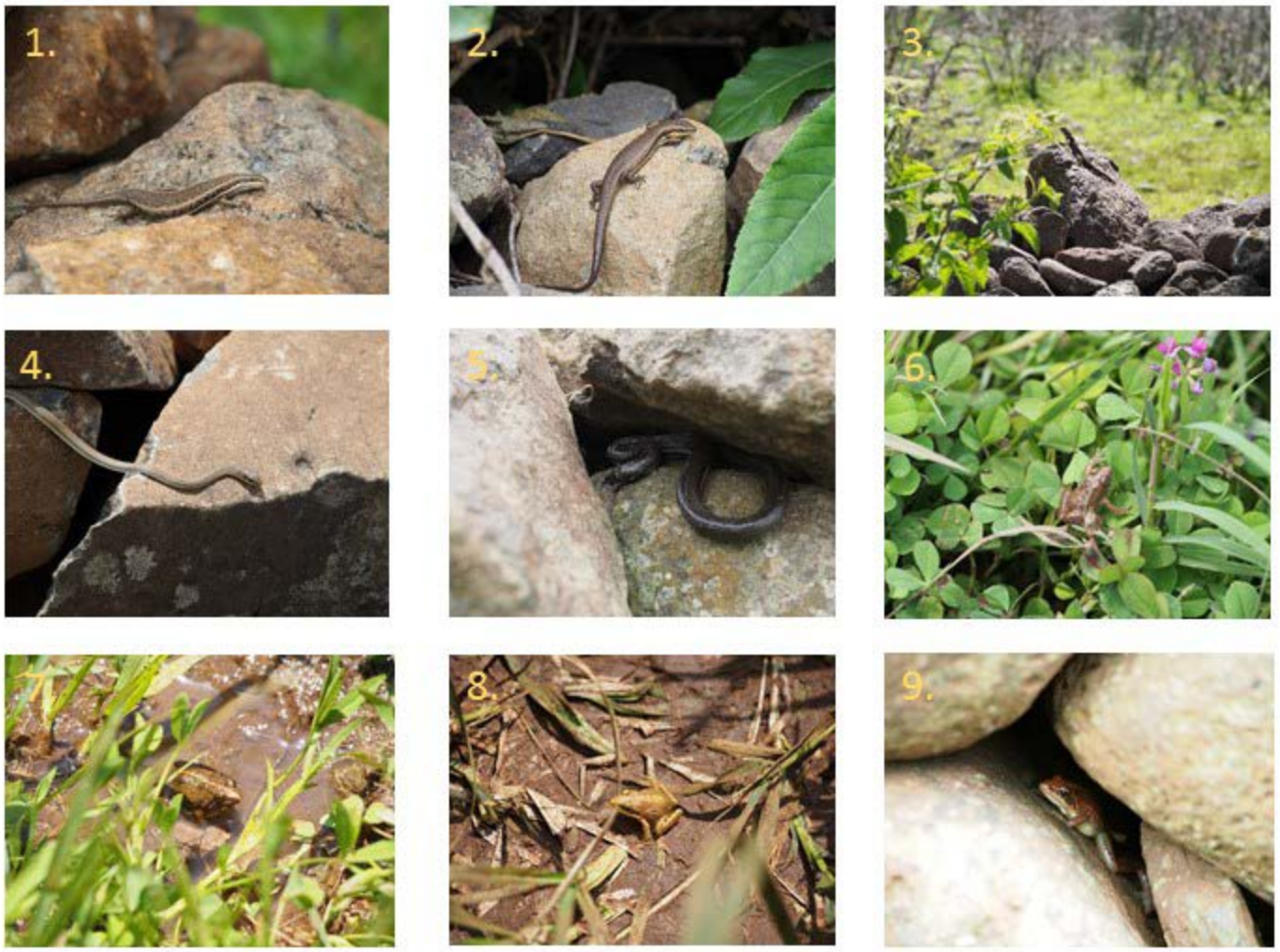


Figure 3. Total encounters over 3 days of visual encounter surveys per site. Sites are ordered by the time since a stone wall was established (in descending order from left to right), and the y-axis on the $\log_{10}$ scale.

Figure 4. Total number of different species (including snakes, lizards, and amphibians) encountered over 3 days of visual encounter surveys per site – which are ordered according to length of time since a stone wall was established.



1. *Trachylepis isselii*
2. *Trachylepis wingati*
3. *Agama doriae*
4. *Psammophis sibilans*
5. *Boaedon fuliginosus*
6. *Phrynobatrachus minutus*
7. *Phrynobatrachus natalensis*
8. *Ptychadena neumanni*
9. *Ptychadena tellinii*
10. *Tomopterna cryptotis*

Figure 5. Examples of 10 of the 12 amphibian and reptile species we encountered during wet season surveys in 2019.

The current landscape in the South Gondar region is dominated by agriculture, consisting of small subsistence farming operations that are tied to a household or family. This system of land use has been maintained in the region for centuries to millennia, and in turn, this has radically transformed the habitat available to native species. The clearing of rocky outcrops, which interfere with tilling, is common practice – but this also denudes the landscape of the natural rock piles that are crucial microhabitats for many lizards and amphibians. As such, the construction of stone walls is essentially a surrogate for these natural rocky landscapes – providing microhabitats that can retain water, buffer against thermal radiation, and protect individuals from predators.

There are several ongoing challenges for herpetofauna in this region. First, human persecution is a persistent issue for some species – for instance, it is common practice for villagers to kill snakes regardless of whether they are venomous or not (Fig. 6). When we encountered snakes, the reaction from onlookers was often one of both fear and amazement when we would let them go. We explained the benefits of these snakes – namely that they will control pest populations that will destroy farmers' crops – and this may have slightly alleviated some of the negative perception in a much-localized manner. Chameleons were also frequently the target for persecution amongst children – interestingly, our work in the site of Woj seemed to inspire change in the attitudes of many of the local kids towards herpetofauna, as they were very keen to help us collect species there. This shows that ongoing education could potential change some of the negative perceptions towards these species in this region (Fig. 7).

Figure 6. Example of a persecuted snake, *Philothamnus battersbyi*, found near a farmer's field in dry season surveys of 2018.

Figure 7. Tegistu Adane explains our herpetofauna project to the student priests at Wonchet.

Birds

While conducting our surveys across our church forest study sites in South Gondar, we also recorded the identity of bird species that we encountered in and around each forest. Although not a systematic survey, this allowed us to determine roughly the avian community composition and richness in each site and to begin establishing a baseline of the total vertebrate biodiversity present in these understudied ecosystems. We recorded a total of 102 bird species across our sites, with the richness in each forest varying from 18 to 39 species (Fig. 8).

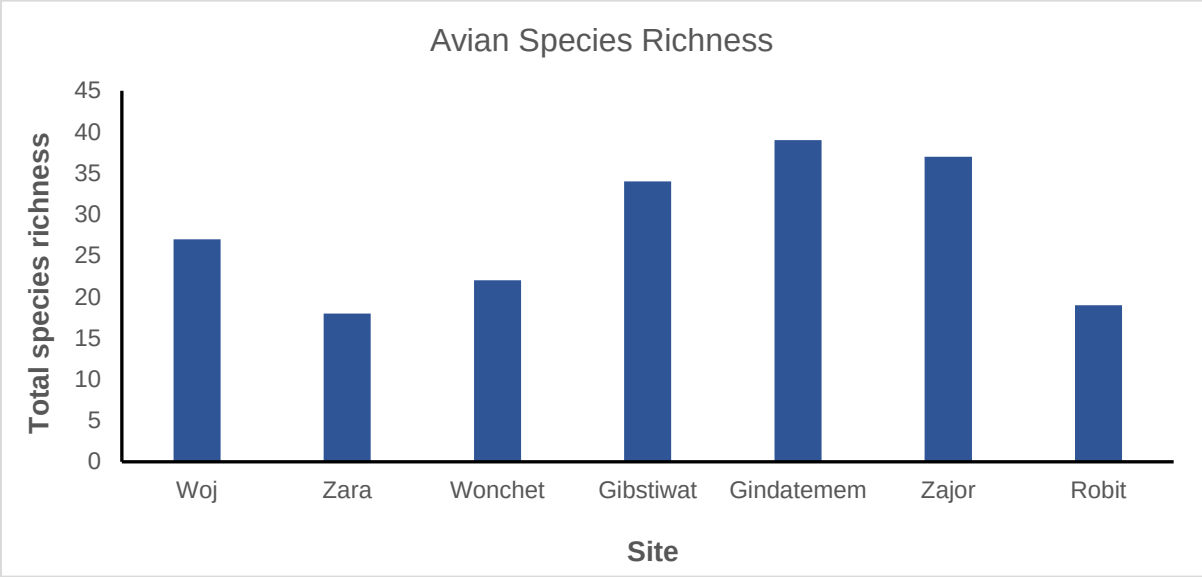


Figure 8. Distribution of bird species richness from incidental encounters at seven church forests.

The church forests appeared to serve functional roles for birds, based on our observations. First, it was not uncommon to find many species nesting in the canopy – particularly the larger-bodied species like Hamerkops (*Scopus umbretta*), Wattled ibis (*Bostrychia carunculata*), White-backed vultures (*Gyps africanus*), and more (Fig. 9). This is likely due to the fact that the large trees required to build a nest for these species are largely absent from the surrounding landscape, and when these large trees are available in the agricultural areas they are almost always highly exposed. The second reason that birds tend to congregate around these church forests is likely due to the availability of food resources. Few patches of native plants exist outside of these forests, and therefore for seed-eating and frugivorous birds these patches of forest likely represent critical foraging habitat. Similarly, for other birds (e.g. predatory and insectivorous birds) the forests also provide resources as the forests act as key habitat for insects and small vertebrates – for instance not only do we find an abundance of amphibians and lizards, but also found many small mammals in the course of our surveys. Interestingly, we note many of the larger predatory birds, such as Abyssinian ground hornbills (*Bucorvus abyssinicus*), foraging in the fields adjacent to the church forests. We also observed kingfishers, actively searching along stone walls for prey – likely the numerous *Phrynobatrachus minutus* (Fig. 10). Finally, during the warmest part of the seasons – the church forests may play another key role: as thermal refugia. The shade given off by the developed upper canopy in church forests can greatly reduce the realized temperature that an individual will experience as the high exposure of the surrounding landscape can be physiologically inhospitable during the warmest times of the year. This is especially true for larger-bodied species that are at-risk of overheating. As such, the church forests may also play a key role as thermal refugia for birds during the dry season.

Systematic surveys on the avian communities in church forests would be useful to understand how these ecosystems support these species across an otherwise hostile landscape – as our preliminary evidence suggests that church forests likely play a crucial role in maintaining avian biodiversity in these human-dominated landscapes.

Figure 9. Verreaux's eagle owl (*Bubeo lacteus*) found nesting in a juniper stand in Woj.

Figure 10. A woodland kingfisher (*Halcyon senegalensis*) looks for prey on the stone wall of Gibstawit.

Mammals

Through the course of our surveys, it became apparent that church forests are also havens for the mammals of this region. Two species were nearly ubiquitous across all church forests sites we visited – the vervet monkey (*Chlorocebus pygerythrus*) and rock hyrax (*Procavia capensis*). From our discussions with priests and villagers, they noted that these species only remain in the forests – in part, because they tend to be persecuted by farmers for raiding crops but also due to a clear lack of habitat in the surrounding landscape. This suggests that these populations are likely quite isolated in these disparate sites. At one site, Wonchet, we witnessed a bush duiker (*Sylvicapra grimmia*) foraging along the margin of the forest (Fig. 11). The people here noted that small herds of up to four individuals were seen in the forest. Interestingly, they also mentioned that these species were traditionally hunted, but that it would be considered taboo to take duikers associated with the church forests, as they were considered to be under the church's protection. This suggests that the religious and social values instilled by the Ethiopian Orthodox church not only protects the forest habitat, but also protect the species from exploitation. The priests at many other sites (Zara, Zajor, and Gibdatemem) similarly confirmed the presence of bush duikers at their forests.

Figure 11. Bush duiker (*Sylvicapra grimmia*) at Wonchet.

Similarly, we also found evidence of a number of other large mammal species that occur in these church forests. Across several sites, we discovered the distinctive quills of the African crested porcupine (*Hystrix cristata*) suggesting they are fairly widespread across the landscape. There was also evidence that several species include the church forests as core components of their home range. We discovered a hyena (*Hyaena hyaene* or *Crocuta crocuta*) den in the church forest of Woj. Similarly, we found several burrows that seemed could be associated with Aardvarks (*Orycteropus afer*), given their size and shape (Fig 12). The locals called this animal a *faro*, and we were unable to link it definitively to a specific species.

Figure 12. Example of a burrow found in Zajor church forest – which is referred to locally as *faro*.

During our introductions with priests at each forest, we often heard anecdotal evidence about other species that currently reside in the forest. Priests referred to a number of other mammal species which we did not observe including multiple large species of antelopes (that we clarified were not bush duikers), wild pigs, and even large cats that were in the forest. At one site, Wonchet, the priests insisted that there were leopards in the forest – this seemed unlikely given that the entire forest is ~6 hectares. However, a much smaller endemic species, the Abyssinian genet (*Genetta abyssinica*), has a similar coat colouration pattern. This species is highly data-deficient (according to the International Union for the Conservation of Nature) and rare in its range; little is known about where it still currently resides. After many conversations with the priests here, we were alerted one day (Sept. 18, 2019 – after our surveys) that one of the cats had emerged and one of us (Tegistu Adane) was able to visit the site and capture photos of this elusive predator (Fig. 13). This confirmed that the church forest was acting a vital refuge for this rare, endemic species and suggests that these sacred forests may be integral for protecting this species from extinction within its native range, which is heavily threatened by habitat loss and degradation.

Figure 13. The Abyssinian genet (*Genetta abyssinica*) in Wonchet church forest.

Clearly, the church forests also appear to be supporting a remarkable diversity of mammal species and future surveys that could document the full extent of this would be very useful for a region that is both so understudied and at-risk from human impacts such as ongoing habitat loss and climate change.

Conclusions

Based on our studies, funded through the National Geographic Explorers Grant, we have demonstrated the crucial role of church forests in maintaining biodiversity in the landscapes of the Amhara region of Ethiopia. The surveys we were able to undertake have provided some very valuable baselines and inventories on the amphibians, reptiles, birds, and mammals that persist within these sites. Our focus on stone wall construction, and its benefits to herpetofaunal communities, has shown that building walls appears to bolster amphibian and reptile populations over the long term, once established and given time to build up. Our incidental observations and records suggest that the forests are beacons for the birds in this area – and provide critical habitat for many species. Finally, our interactions with the people that live in and around these forests suggest that a considerable diversity of mammals also call these forest home – and church forests may be the final refuge for many of these species in this region.

Collectively, this sets the stage for both future research and conservation action for this region. The ongoing effort to protect and restore church forests appears to be very beneficial to the biodiversity of this region – and our efforts to communicate and work with the priests and diocese indicate that the Church is committed to protecting and maintaining their forests. The challenge will be to act now to protect these forests in the face of ongoing population growth, demand for land for agriculture, and the looming spectre of climate change. This baseline data, however, helps establish the vital role of these forests as arks of the relictual biodiversity in this region and demonstrates the effectiveness of one management strategy, stone wall construction, for bolstering the abundance and biodiversity of herpetofauna, in addition to the prevention of overgrazing from livestock. With continued efforts to protect and expand this forest network, there is the potential to protect these critical reservoirs of biodiversity for both the people of Ethiopia and the world.

Appendix

Trip Report: May 2018

The world is changing at an incredibly rapid pace, but unfortunately, our ability to understand how the Earth's biological diversity is responding to these shifting conditions still lags far behind. The Amhara region of Ethiopia represents a fascinating region to study human effects on biodiversity, as it has one of the longest continuous histories of human settlement and agrarian civilization in the world. This long history of human habitation has left its scars and marks on the landscape, and today the vast majority of the ancestral Afromontane dry forest has since been cleared for agriculture. Yet, remarkably, small fragments of this ancient ecosystem persist to this day due to protection granted by the Ethiopian Orthodox Church (Fig. 1). The Church and their followers consider these forests sacred, and this in turn preserves these Church forests against clearing for firewood, building materials, and agriculture. Many of these Church forests have existed in this state for hundreds to thousands of years, providing a unique opportunity to study how species can persist in small, isolated fragments over numerous generations. The long history of Ethiopia's church forests give us a unique view into the potential future for many landscapes around the world: will species be able to survive in fragmented agricultural landscapes in the long-term?

Figure 1. A lone Church forest near Debre Tabor, surrounded by land cleared for agriculture.

This is the basis of our interest in these remarkable forest ecosystems. As part of our National Geographic Society Explorer Grant (NGS-292R-18), we aimed to survey the abundance and diversity of

herpetofauna (Amphibians and reptiles, that is: frogs, lizards, snakes, etc.) in the Church forests of the south Gondar region. Herpetofauna can be important constituents of forest ecosystems, achieving high biomass and in turn influencing nutrient flows, controlling insect populations, and bolstering the populations of their predators (Valencia-Aguilar *et al.*, 2013; Hocking & Babbitt, 2014). Though several species have been found incidentally in the Church forests, and in other ecosystems throughout the region, there have been no systematic surveys for herpetofauna in these ecosystems. Although the Church forests are also protected from broad-scale tree felling, there are persistent threats to these ecosystems through agricultural encroachment and overgrazing by (very abundant) livestock (Fig. 2). The TREE foundation has been raising funds to provide stone and masons that enable the local communities to build stone walls (Fig. 3) to protect these forests from clearing and grazers (Fig. 4). Luckily, these stone walls also provide ideal refugia for herpetofauna (Fig. 5) and make ideal linear features to survey populations.

Figure 2. Meg Lowman and Alemayehu Wassie outside the forest of Gibstawit.

Figure 3. Local farmers working to finish the stone wall for Zajor as our group and the head priest inspect the progress of the wall for this forest.

Figure 4. A domestic donkey (top) and sheep (bottom) grazing on seedlings in a Church forest with an unfinished stone wall.

Figure 5. An Issel's skink (*Trachylepis isselii*) taking refuge in a stone wall.

In May 2018, we set out to do some initial opportunistic surveys of the forests to document and photograph as many amphibians and reptiles (and any other interesting species we encountered) that we could find. The climate and geography of the Amhara region (and indeed, Ethiopia generally) makes this area of the world very unique in terms of both landscape and biodiversity. There are two climatic seasons in this area: a dry season running from October to June, and a short wet season from June to September. Since so little is known about the herpetofauna in the Church forests, we aimed to visit in both the wet and dry seasons as they may have very distinct biological communities. Amphibians and reptiles usually (although not exclusively) prefer wetter conditions, and many species will retreat to wet habitats or go dormant over pronounced dry seasons. We reasoned that it was plausible that the forests themselves, due to the water retention and moisture given off by the ample vegetation, may offer herpetofauna more abundant and preferred microhabitats.

In this region, most of the land is used for subsistence agriculture as many villagers tend small land-holdings to grow crops and livestock to feed their family and sell at market. During the dry season, the fields are hot and dusty, with scant vegetation – providing a very hostile environment for wildlife, particularly ectotherms. There is a stark contrast when you enter the forests however (Fig. 6), and the cooling effect of a developed upper canopy is immediately noticeable when entering the Church forests (Fig. 7). It is no wonder that these forests also serve as social focal points for people as well (Fig. 8). The forests are rich with vegetation and animal life, despite still being relatively dry this time of year. Beyond the herpetofauna we were looking for, we found numerous other species such as the white-cheeked turaco (*Tauraco leucotis*), a rare canopy-dwelling frugivore (Fig. 9). We also found many populations of mammals in these forests: including many populations of rock hyrax (*Procavia capensis*; Fig. 10) and vervet monkeys (*Chlorocebus pygerythrus*; Fig. 11).

Figure 6. Edge of the Gibstawit Church forest against the surrounding agricultural landscape.

Figure 7. Interior of the Wonchet Church forest, which is in stark contrast to the surrounding landscape.

Fig. 8 The priests and villagers taking lunch in Zajor Church forest.

Figure 9. The white-cheeked turaco (*Tauraco leucotis*) visits a well in the Zajor Church forest.

Figure 10. A surprised tree hyrax (*Procavia capensis*) looks on from the safety of a tall tree.

Figure 11. A vervet monkey (*Chlorocebus pygerythrus*) forages in the bushes adjacent to the forest.

During our trip, we visited 10 Church forests around Lake Tana, where we conducted visual encounter surveys along the outer stone walls and in the interior of the forests. This also gave us a chance to engage with local villagers, asking them about what they have seen and when the best times are to observe frogs and lizards. Some of the locals were even very eager to join us in our surveys. We similarly experimented with several different methods to capture and observe animals including setting up pitfall traps around the forest (Fig. 12). Along the way, we also couldn't resist distributing some literature on the Church forests both to priests and some very keen schoolchildren (Fig. 13).

Figure 12. Setting up a basic pitfall trap in the forest to capture wandering frogs and lizards.

Fig. 13. Meg Lowman hands out copies of *Beza* to a local teacher while eager students look on.

Overall, we found that the abundance and diversity of herpetofauna during this hot and dry period was quite low. The most widespread and common species we encountered was Issel's skink (N = 5 sites; Fig. 14), *Trachylepis isseli*, a small-bodied lizard that was common within the stone walls and rock piles in the forests.

Though we expected that perhaps the forest would be an important refuge during the dry season, it seemed that instead it was quite possible that during the harsh dry season amphibian and reptile species may actually migrate to nearby freshwater habitats. To that end, we also surveyed nearby streams to determine whether potential Church forest species may find refuge in these habitats during the dry season. Interestingly, we found many amphibians, both tadpoles (Fig. 15) and adults Fig. 16 - 18), along the stream banks despite the human pressures of agriculture, cattle grazing, and lots of people doing laundry in and around these streams. We captured 6 individuals, and were able to identify at least 2 species of frogs: *Amietia angolensis* and *Ptychadena erlangerii*. The latter group, *Ptychadena*, is a speciose genus of puddle frogs where different species often have very subtle distinguishing characteristics and a recent study on these frogs in other regions of Ethiopia revealed 5 cryptic, undescribed species in southern Ethiopia (Smith *et al.*, 2017). This suggests that we may be underestimating the amphibian diversity, and potentially overlooking unique endemic species, in the Amhara and other regions of Ethiopia. We plan to collect tissue samples for our next trip.

Figure 14. Issel's skinks (*Trachylepis isseli*) captured in Wonchet church forest.

Figure 16. Small tadpoles found in the streams, indicating that populations are breeding in these fragile habitats.

Figure 17. *Amietia angolensis* found along a nearby riverbank.

Figure 18. A species of *Ptychadena* found in a shallow stream pool.

Figure 19. Another species of Ptychadena captured nearby a farmer's irrigated sugarcane field.

Overall, this first trip helped establish some very important baselines about the ecology of herpetofauna in these ecosystems. We now know that during the dry season, herpetofaunal diversity and abundance appears to be quite low. This, combined with our stream surveys, suggests that movement along riparian corridors to and from the Church forests may be very important if species retreat to these wet microhabitats during the dry season. Systematic surveys during the wet season of 2019 will likely reveal an increased abundance and diversity of herpetofauna, which will in turn suggest that these habitats are particularly important during this critical period of species' life cycles.

Trip Report: August 2019 – 1

Arriving back in Bahir Dar, Ethiopia, I was struck by the transformation of the landscape since my last visit in the dry season. The barren red soil that once dominated this place has been replaced with lush green carpets of grass, wildflowers, and burgeoning croplands. I have come here to survey the amphibian and reptile biodiversity in the church forests around the South Gondar region. Working with colleagues Dr. Alemayehu Wassie, Dr. Meg Lowman, and Tegistu Adane, we are assessing how stone wall construction to protect the church forests from livestock grazing and agricultural encroachment may also serve as valuable habitat for many species.

Fig 1. Views from the plane to Bahir Dar in the wet season (left) vs. dry season of 2018 (right)

Fig 2. The stone wall separating forest and agriculture in Gibstawit church forest.

To that end, Tegistu and I (Dan Greenberg) have been conducting herpetological surveys along the stone walls and in the forests, and trialing some pitfall traps and drift fences in four church forests sites: Zhara, Wonchet, Gibstawit and Robit. We have documented a plethora of biological diversity in and around the forests, recording birds, mammals, and of course our targets: lizards, snakes, and frogs. Naturally, our activities draw a lot of attention (mostly good though!), so a big part of each day is science communication with priests, farmers, and villagers who are curious about what we are doing. It has been amazing to see how captivated many people become once we explain why we are here, and show them some photographs of species in our field guides; and then I like to show them photographs of some of the species we have found in their church forests.

Fig 3. Tegistu Adane talks to priests at Zhara about their resident lizards and frogs.

Fig. 4 Priests and students look on as we show them some of the species we've found.

Fig 5. A small group forms as we (Dan Greenberg and Tegistu Adane) sample and measure *Trachylepis wingatii* at Zhara

Sometimes people want to get involved too, and it is not unusual to have a small crowd and sometimes some additional field assistants. While piloting our trap arrays, we recruited four priest students (Berza, Tegistu, Tseghe, and Tseghuy) who have been dedicated field hands ever since -- in addition to helping us set up the traps, they dutifully monitor them and make sure they are well guarded. We often get tips from the people who live in these forests about what animals they've found there. For instance, we stumbled upon a Bush Duiker (*Sylvicapra grimmia*) one afternoon during our surveys at Wonchet and subsequently were informed by the priests that sometimes they see groups of up to 4 duikers at a time there and that duikers are present in many other forests (Zhara, Wonchet, and Gibstawit). This adds another mammal to our list, including the rock hyrax and vervet monkeys, which find refuge in these sacred forests.

Fig 6. Young priests in training help us dig in our pitfall traps in the forest

Fig 7. Priests and students help us catch and process lizards at Wonchet

Fig 8. A bush duiker (*Sylvicapra grimmia*) forages on the outskirts of Wonchet church forest

Our surveys of the stone walls have been finding many amphibian and reptile species that we are now first recording in the church forests. Our protocol is to walk slowly along the outer walls, looking in the cracks and crevices for any signs of life. When we encounter any individual, we record its GPS location and identify it to species – when it's something new we make sure we take many photographs. So far, we have found a lot of herpetofauna taking refuge in the church walls – recording up to 37 lizards in a single visit! Each survey seems to come up with some new observation too; over the past 5 field days we've recorded over 100 counts and discovered various frog (n = 1), lizard (n = 2), and snake (n = 2) species using the wall as habitat. The walls are dominated typically by two species of *Trachylepis* skinks: *Trachylepis isseli* and *Trachylepis wingatii*. Interestingly, both species are endemic to Ethiopia and they appear to achieve very high densities on the walls, likely due to the abundance of insects it attracts and the natural cover it creates for these species. We believe, in turn, this high density of lizard likely attracts both predatory birds (we find many skinks with dropped tails, which we also record) and lizard-eating snakes including the Brown House Snake (*Lamprophis fuliginosus*) and the Hissing Sand Snake (*Psammophis sibilans*). In this way, it seems that the positive effect the stone walls have on the lizard populations likely cascades up into the rest of the ecosystem by supporting a robust diversity of predators.

Fig 9. Issel's skink, *Trachylepis isselii*, our most abundant resident of the church walls

Fig 10. Wingate's skink, *Trachylepis wingatii*

Fig 11. Brown House Snake (*Lamprophis fuliginosus*) rests in the wall at Zhara

Fig 12. The Hissing Sand Snake (*Psammophis sibilans*) in the stone wall at Wonchet

In the past two days of field surveys, we've also been finding very tiny frogs associated with the stone walls: the aptly named Ethiopian Dwarf Puddle Frog, *Phrynobatrachus minutus*. This tiny frog is also endemic to Ethiopia, and it is truly minute and easily mistaken for a small cricket. Interestingly, they seem to benefit from the stone walls that similarly serve as natural habitat and a refuge from the surrounding desiccating conditions of the cleared agricultural fields.

Fig 13. The Ethiopian Dwarf Puddle Frog, *Phrynobatrachus minutus*, Gibstawit.

Fig 14. To give a sense of scale, *P. minutus* relative to a 1x1cm grid.

During our surveys, we also take time to catch some of the species we find in order to sample their DNA – which we hope to ultimately sequence, to provide vital molecular sequence data for these species that are often endemic or may represent uniquely isolated populations from their broader ranges across Africa.

We hope this multi-pronged approach will pay dividends for understanding the unique herpetofaunal communities of Ethiopia, and how the church forests contribute to their continued protection. Not only that, the species occurrences and photographs we're collecting will be both useful and motivating for the people that are both spiritually and instrumentally invested in these forests. The reaction we get when explaining our purpose is typically very positive and we hope to use our photos to publish a guide to the species we've found in Amharic and then distribute the guide to each church. Given the excitement we have already experienced in our forays into these communities, we think that highlighting the amazing diversity of species protected by their church forests will be appreciated by both priests and parishioners.

Trip Report: August 2019 – 2

We have now been in the field for about 2 weeks, and have visited 6 different church forests in the South Gondar region. Every day brings new discoveries, underscoring how much there is still to learn about the ecology of these ecosystems. As of this day, we've recorded over 150 observations of 9 species of herpetofauna across our 6 forest sites! We are also collecting a lot of valuable information as we engage each community and learn more about their unique forests – and indeed, each forest seems to be quite distinct in both habitat structure and the species that inhabit them.

Fig 1. We (TA and DAG) discuss our project with the priests at the Diocese office in Hamusit, as they prepare us a letter of introduction for when we visit new church forest sites.

We started our surveys with two sites near the village of Hamusit: Wonchet and Zhara. These sites are relatively easy to access (if you don't mind jumping over a river for Wonchet), and have a history of being sites for research on a number of taxa including insects and plants. Despite that history though, we are still making many discoveries in these sites – for both herpetofauna and other species. We trialed pitfall traps at Wonchet, to see how effective they would be for capturing ground-based reptiles and amphibians. After five trapping nights and daily checks (including the occasional stop to join the forest feasts) we ended up with zero herpetofauna, however, we did find several small mammals in our traps including a shrew and vole. We let these little creatures go, and decided to dismantle the traps to prevent any stress or deaths to any of the animals in the forest. We had been having a lot of success running simple visual encounter surveys around the forests, so we decided to focus our energy there instead and expand the number of sites for our surveys.

Fig 2. The forests become alive with people every other Sunday for communal feasts that are a center of village life. After checking our trap-line, we partook in some dried chickpeas and *tella* in Wonchet.

Fig 3. Photographing the birds of Wonchet with our field assistants.

Fig 4. A shrew and vole from our pitfall traps in Wonchet. Both were released unharmed.

We've shifted our attention to 3 other sites: Gibstawit, Zajor, and Woje, and interestingly they are all unique in both forest structure and the biodiversity.

Fig 5. Gibstawit church forest emerges like an island in a landscape of finger millet and maize.

We've spent 3 days surveying Gibsayit, cataloguing species encounters and measuring canopy structure, and this site is absolutely rife with frogs! So far we've logged dozens of occurrences for one particularly abundant species: the Ethiopian dwarf puddle frog (*Phrynobatrachus minutus*), which is found on the edge of agricultural fields and, more often, nearby the stone walls constructed by the TREE foundation. Indeed, walking along the walls the grass buzzes with activity as frogs scramble towards the safety of the stone walls. This is quite interesting, as it suggests the walls are indeed a key micro-refuge for this species. I suspect that the walls also retain a lot of water (it rains very reliably each night, but the days are typically hot and dry), creating an ideal microclimate for these small frogs to escape into. We've also found potentially two other frog species in this site: both members of the *Ptychadena* (*P. anchietae* and *P. telinii*), which are hard to differentiate and known for having many cryptic (*i.*e. hidden) species – so our DNA samples may come in very handy here. It is also quite interesting to see the other species that may be foraging for these frogs including Woodland kingfishers and a group of the very large (and impressive) Abyssinian ground hornbills. Therefore, it seems quite plausible that these frogs are a key part of the food web in these ecosystems, and the stone walls may be greatly benefitting their overall abundance and biomass.

Fig 6. *Ptychadena anchietae* captured outside the stone walls of Gibstawit.

Fig 7. A woodland kingfisher (Halcyon senegalensis) perches along the stone wall at Gibstawit.

Fig 8. Abyssinian ground hornbills (*Bucorvus abyssinicus*) forage in the millet.

To get to Zajor, we have to travel along many kilometers of bumpy and muddy road and then hike in about 1 hour through some truly beautiful scenery. Accessing this site is like stepping back into time, as we get a glimpse of deep rural Ethiopia and a way of life that's probably existed for thousands of years here as we pass through farmer's fields and small villages. We were welcomed with open arms in these sites, as priests and villagers were very hospitable and eager to join us on our surveys and regale us with tales of the animals in the Zajor forest. Interestingly, several people told us that a species of gazelle lives in the forest (these have been driven to extinction across most of the Amhara region due to hunting and habitat loss), in addition to bush duikers (which we also observed at Wonchet). If true, this would be a significant finding for the region. Indeed, we hear a lot from people in each forest about curious sightings – including a mysterious *leopard* at Wonchet (which I suspect may be the secretive, endemic, and somewhat leopard-esque, Abyssinian genet). While I believe the sightings we hear about from the people who spend so much time in these forests, it would be great to have hard evidence of these species – which may make for an intriguing future project for a mammal specialist.

Fig 9. A priest leads us to the church forest of Zajor.

Fig 10. The den of a mysterious mammal the locals call “Faro”, possibly an aardvark (they describe it as a termite eater) – but from pictures they claim it is not this.

The wall at Zajor is very new, having been completed in the past year – and interestingly, we haven’t found nearly the same abundance of reptiles and amphibians at this site as we have in the others. It may be that colonization of the stone walls takes some time. We did find one Issel’s skink, and spotted a *Ptychadena* that quickly escaped into the forest brush, but there are not nearly as many individuals (so far) as at the older walls in Zhara and Wonchet. This adds another intriguing bit of evidence about how the ecology of these systems progresses. We are continuing our surveys in this forest, so we may discover a greater diversity of species as we keep returning.

Fig 11. The rolling landscapes of rural Amhara, not a bad way to start your day of work.

Finally, the church forest at Woje is very interesting and we've focused our surveys on this site in the past two days. First, this site is quite a bit farther away than our other sites, but it is situated near the vast Fogera wetland and rice agricultural area. This seems to mean that a very different fauna exists at Woje. Indeed, we have found 8 amphibian and reptile species at this site alone! I am still working through the exact species identities of several of them (many of the species here are highly variable, so it can take some sleuthing to nail down the identity), but, regardless, this site is really exciting to work in. We have already gained a reputation amongst the villagers of Woje – particularly as the children have lapsed in their cattle tending duties in order to join us instead looking for lizards, snakes, and frogs! We've taken this opportunity to pass on knowledge about the local species, and how and why we do science. One interesting experience was when I captured a (harmless) Hissing Sand Snake (*Psammophis sibilans*), which of course solidified my reputation as a crazy *farenji* (foreigner), but was also a good opportunity to teach these children about snakes. The cultural norm in Ethiopia is to kill any snake on sight, which of course is unfortunate, as most snakes here are not venomous and are important players in the ecosystem (not to mention any intrinsic moral value, which is a concept that's going to be even more difficult to communicate). So capturing a live snake by hand, observing it, and releasing it, shows a very different way of interacting with these animals for these kids (indeed, they were quite wide-eyed). We tell them that they should just leave snakes alone and let them live their life, and we hope these sort of encounters may slowly change the cultural attitude towards snakes here.

It’s a tricky situation of course, as people do encounter and are killed by venomous snakes. Nevertheless, if you just leave snakes alone, then it won’t be a problem.

Fig 12. The view from atop Woje.

Fig 13. A very exciting find (for me), Doria's agama (*Agama doriae*) sits atop the stone walls at Woje.

Fig 14. If you want everyone to question your sanity in Ethiopia, just catch a snake (and then release it). Here the harmless Hissing Sand Snake, *Psammophis sibilans*.

Fig 15. After the “snake incident” the kids started finding frogs for us (like this Natal Puddle Frog, *Phrynobatrachus natalensis*), so perhaps appreciation of nature’s oddities is infectious.

We have about nine more days in the field left for my trip here, and we will be shifting towards nocturnal surveys and some follow-up surveys for our remaining sites. Night surveys are something we have been trying to arrange since I arrived here, but, unfortunately, there is a lot of suspicion about entering the church forests at night. This is largely because of some rather unfortunate occurrences here where foreigners have actually been looting artifacts from churches and, in turn, the diocese has advised all the churches not to allow strangers to enter the forests. This has caused us some difficulty when approaching new church forests, but after we explain our purpose and show some supporting letters from Dr. Alemayehu and the diocese in Hamusit, we usually get our foot in the door relatively easily.

Fig 16. The resident Verraux's eagle owl of Woje. We found her twice in the same thicket of Juniper.