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Diversity of anurans in forest fragments of southwestern Ethiopia: The case of the Yayu Coffee Forest Biosphere Reserve (YCFBR)

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***Abstract.*—Amphibia is the least studied group of vertebrates in Ethiopia. Besides contributions from a few expeditions in the past, the effort given to amphibian studies among academicians and researchers has been very minimal until recently. This is the cause for the lack of detailed information on amphibians, even in known protected areas. Despite the huge role of forest fragments in southwestern Ethiopia for conserving amphibian diversity, the focus given for amphibian conservation within these forest fragments is almost insignificant. The increasing rate of deforestation and fungal infection are threatening the survival of anurans (tailless amphibians) of the region. The current study focused on determining the anuran (tailless amphibian) diversity in a recently recognized reserve, the Yayu Coffee Forest Biosphere Reserve (YCFBR), in southwestern Ethiopia. A total of 101 individuals, from ten different species (nearly 6.5% of the total number of known species in the country), was collected from four different habitats including forests, stream sides, swamps, and temporary ponds, with a greater number collected or observed in swampy areas. As expected, the wet season collection yielded a greater number of collected individuals than the dry season collection. These results indicated the potential of the reserve for conserving regional amphibian fauna. Future conservation measures should focus on reducing the extent of deforestation, particularly in protected areas, while also estimating the magnitude of fungal infection among diverse anuran species of the region.**

Keywords. Amphibians, biodiversity, conservation, deforestation, fungal infection, survey

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Introduction

Amphibians are the least studied group of vertebrates in Ethiopia (Largen and Spawls 2010). This, according to Mengistu et al. (2013), is due to the fact that amphibians provide no economic value to the society, the society's negative attitude towards them, and the increasing focus among academicians and researchers on large and more visible mammals than on the small and mainly nocturnal amphibians. A significant fraction of the known Ethiopian amphibians is endemic to the country, comprising around 40% of total species (Mengistu et al. 2013). However, the few studies on amphibians that have been conducted in the past were mostly collecting expeditions and did not provide further information on the ecology and systematics of amphibians.

Different scholars from the United Kingdom, Italy, and Germany were involved in these expeditions that took place between 1839 and 1939, resulting in the collection of a large number of amphibians. According to Largen (2001), the collected specimens were placed in different museums in Europe, including: Muséum National d'Histoire Naturelle in Paris, Natural History Museum in London, Museum Koenig in Bonn, and the Liverpool Museum. After 1939, a collaborative work of Yalden, Largen, and Morris identified the collected specimens. The Harenna forest expedition in 1986 was the most successful expedition resulting in the largest number of amphibians ever collected (Largen 2001). This expedition suggests the existence of vast, yet undescribed amphibian fauna in the country that needs further study on distribution, diversity, and abundance in the different regions

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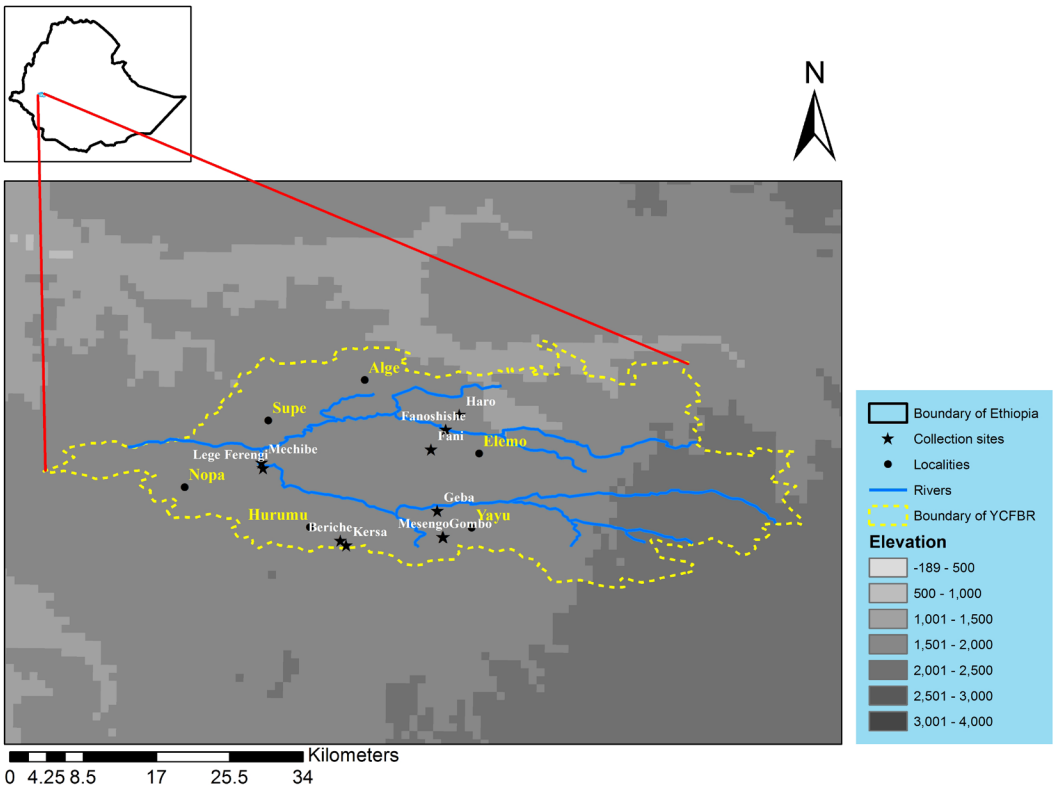

Fig. 1. Location of study area.

of the country. There have been few amphibian studies in the country, such as by Roman Kassahun (2009) in Bale Mountains National Park (BMNP) and Wondwosen Tito (2009) in Abijatta – Shalla Lakes and Awash National Park, Teme (2016) in Wombera district of Awi zone, and NABU (2017) in Kaffa biosphere reserve. The study on the distribution of *Ptychadena* (Mengistu 2012; Freilich et al. 2014), *Leptopelis* spp. (Weinsheimer et al. 2010; Mengistu 2012), *Xenopus* (Evans et al. 2011), *Afrixalus* spp. (Mertens et al. 2016) and *Phrynobatrachus* (Zimkus 2008; Zimkus et al. 2010) were few taxon-based amphibian studies in the country. A new dimension of research on amphibians of Ethiopia i.e., their susceptibility to fungal infection, started in 2008 that surveyed selected parts of Ethiopia for any incidence of fungal infection (Gower et al. 2012). Despite the growing number of research focused on ecology of amphibians, data on status and distribution of amphibians in Ethiopia is still insufficient especially when compared with relatively well-studied bird and mammalian taxa.

Amphibians are strongly associated with wetlands and forest ecosystems, and the forest refuge in southwestern Ethiopia hosts one of the most suitable habitats for amphibians (Mengistu 2012). A continuous study on the status of amphibians and their suitable habitats is necessary to update knowledge of their distribution and to understand their responses to environmental change. The Yayu Coffee Forest Biosphere Reserve (YCFBR) is situated in Ilu Abba Bora Zone of the Oromia Regional State, southwestern Ethiopia (ECFF 2012). It is the center for *Coffea arabica* which is globally a highly popular coffee species. The reserve is an important place not only for the conservation of (wild species of) *Coffea arabica*, but also the vast biodiversity living in the forest reserve. The reserve also includes afro-montane biodiversity hotspots, important bird areas, archaeological sites, ritual sites, caves, and waterfalls (ECFF 2012). The Yayu Coffee Forest obtained its Forest Biosphere Reserve status in 2010, together with 12 other forest fragments throughout the world (UNESCO Press Release 2010). The reserve is divided into core, buffer, and transition zones based on the extent of anthropogenic disturbances in the reserve (Gole 2003). The present study is focused on the anuran (tailless amphibian) diversity and relative abundance in Yayu Woreda, southwestern Ethiopia. This study aimed at providing the first data set of anurans in the reserve and will thus contribute as a basis for future amphibian studies in the reserve.

Methods and Materials

Study area

YCFBR (Fig. 1) is located between 8°42'' to 8°44'23''N and 35°20'31'' to 36°18'20''E, and it covers 167,021 ha (Gole 2003). The forest is characterized by rolling topography and it is dissected by small streams and two major rivers, Geba and Dogi. There is continuous forest cover along the rivers. The land frequently changes from flat surface plateaus to very steep slopes and valley bottoms

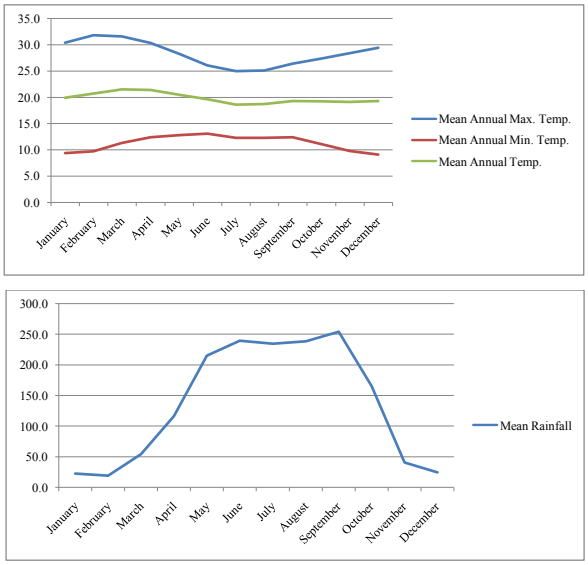

Fig. 2. Climate data of the study area.

within a short distance. The elevation in the whole reserve ranges from 1,100 to 2,337 meters above sea level (Gole 2003). The forest type in the reserve is predominantly afromontane rainforest and considered to be a transition between lowland and montane forest types (Gole et al. 2008). Three plant community types exist within the reserve including *C. Arabica–Cassipourea malosana*, *Argomuellera macrophylla–Celtis africana*, and *Dracaena fragrans–Telclea noblis* communities (Gole et al. 2008). Samples for the recent study were collected from 10 collection sites distributed in four localities in the reserve including Yayu, Elemo, Hurumu, and Nopa (Table 1).

According to the climate data for ten years, obtained from National Meteorology Agency (2012), the mean annual temperature of the study area is 23.76 °C and the mean annual rainfall is 1,625 mm. As it can be seen in Fig. 2, the rainfall pattern is uni-modal and it reaches its highest between May and September (wet season) and its lowest between November and March (dry season) while there is a small amount of rainfall in April and October, although this shows variation year to year.

Anuran sampling

A preliminary survey of the study area was conducted for a week from September 20–26, 2011. Information from local people and an opportunistic night survey were used to locate important amphibian habitats in the study area. A total of 10 sampling sites from among these diverse habitats were selected for collecting species data.

The data collection took place at selected dates during core dry season which is between January 3–19, 2012 and wet season which is between June 28–July 15, 2012. In order to encounter as many anuran species as possible, factors like time of the day were considered. The data collection was conducted in the time interval between 6:00 AM and 9:00 AM for day time and 6:00 PM to 9:00 PM for night time collection. A time-constrained visual and acoustic encounter survey was used for field recording of anuran species.

Table 1. List of species, habitat data, and man-hours spent per collection site. (SWP- Swamp, PND- Pond, FOR- Forest, STS- Streamside, RUN- Rock underneath, Breg- *Amietophrynus regularis*, Hvir- *Hyperolius viridiflavus*, Hnas- *Hyperolius nasutus*, Pobs- *Paracassina obscura*, Lreg- *Leptopelis ragazzii*, Xcli- *Xenopus clivii*, Cbec- *Conraua beccarii*, Panc- *Ptychadena anchiatae*, Pneu- *Ptychadena neumanni*, Pnat- *Phrynobatrachus natalensis*).

Habitat data				Man- Hour spent per habitat			Species list									
Locality	Collection sites	Type of habitats	Elevation	Man-hour/individual collectors	No. individual collectors	Man-hour/ Season	*Breg*	*Hvir*	*Hnas*	*Pobs*	*Lreg*	*Xcli*	*Cbec*	*Panc*	*Pneu*	*Pnat*
Yayo	Gombo	SWP	1490 m	2	3	6	√	--	√	--	√	--	--	√	√	--
		SWP	1490 m	1	3	3	--	--	--	--	√	√	√	--	--	--
	Mesengo	PND	1599 m	1	3	3	--	√	√	--	--	√	--	√	√	--
	Geba	FOR	1267 m	1	3	3	--	--	--	--	--	--	--	--	--	--
Elemo	Fanoshishe	SWP	1952 m	1	3	3	--	√	--	√	--	--	--	--	√	--
	Haro	SWP	1959 m	1	3	3	--	--	--	--	--	√	--	--	√	--
	Fani	SWP	1941 m	1	3	3	--	--	--	--	--	--	--	--	--	--
Hurumu	Kersa	STS	1763 m	1	3	3	--	√	--	--	√	--	--	--	--	--
		SWP	1763 m	2	3	6	--	--	--	--	--	--	--	--	√	√
	Beriche	SWP	1819 m	1	3	3	--	--	--	--	--	--	--	--	--	--
Nopa	Lege Ferengi	FOR	1680 m	1	3	3	--	--	--	--	√	--	--	--	--	--
		SWP	1680 m	1	3	3	√	√	--	--	--	--	--	--	√	√
	Mechibe	STR	1665 m	1	3	3	--	--	--	--	--	--	--	--	--	--
		RUN	1665 m	1	3	3	--	--	--	--	--	--	√	√	--	--

A combination of visual and acoustic encounter surveys was conducted for sampling anurans in terrestrial and semi-aquatic habitats, following Lambert (2002). Ponds, streams, and river banks were sampled using seine netting (Lambert 2002). Randomized walk design within a constrained area was used for sampling swamps and forest habitats (Lambert 2002). Due to the smaller size of swamps, the search was done throughout the entire area. The search for anurans in each habitat was time-constrained, and it was conducted with three people, spending one hour per collection site; a total of three man-hours were spent for each collection site. Collections were done both during the day and night.

Anuran species encountered were identified to the lowest taxonomic level possible. A picture and voucher specimen were taken in those cases where it was not possible to identify the species in the field. The field specimens collected for later identification were kept inside the laboratory for graduate programs in Ecological and Systematic Zoology, Addis Ababa University.

Results and Discussion

Diversity of amphibian habitats

The study area comprises a number of wetlands and rivers (Fig. 3). There are also a number of streams flowing into these rivers. Additionally, the valley bottom which is formed as a result of rugged topography of the study area contributes to the existence of numerous small to large sized swamps and ponds (Gole et al. 2009). Gole et al.

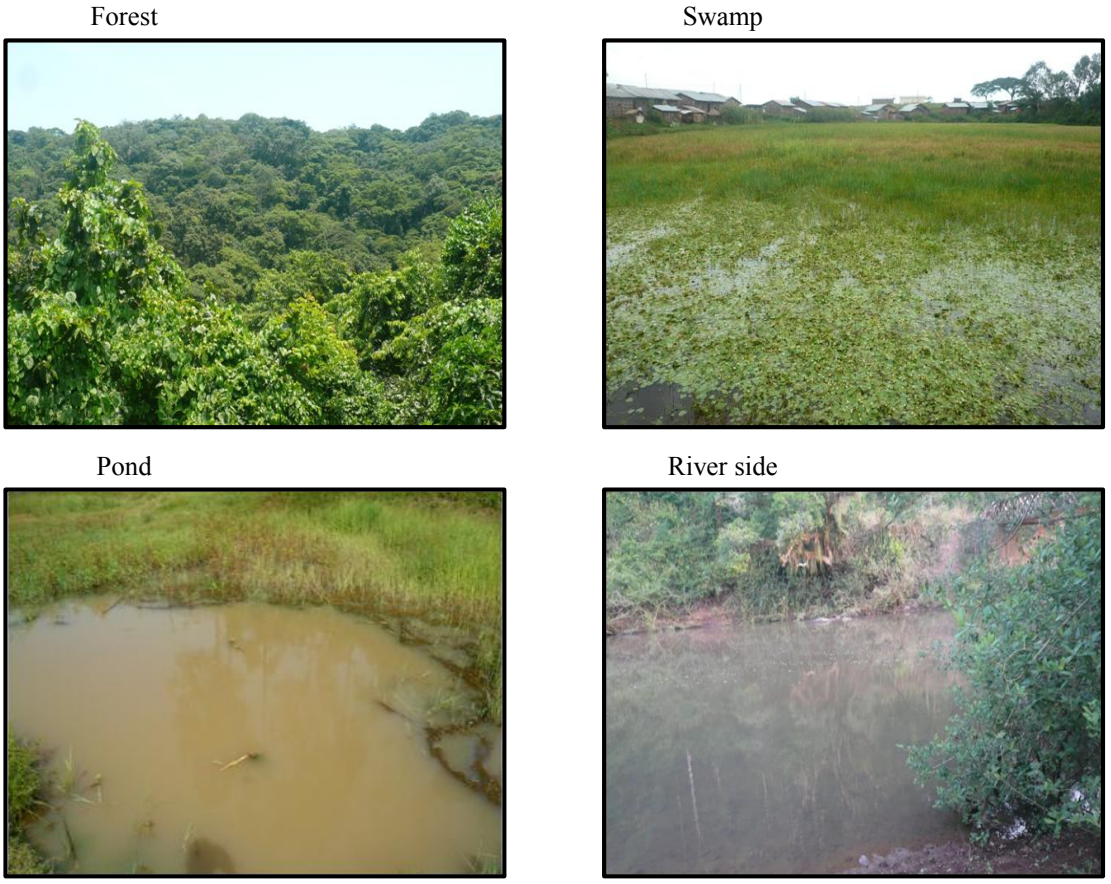

Fig. 3. Types of wetlands in YCFBR.

(2009) indicated that wetlands in the study area consist of at least two physiognomically different vegetation types: riparian forest along the rivers and streams, and the treeless swamp vegetation with stagnant or slowly moving water.

River/stream sides were found in two of the ten collection sites in the study area. The rivers flow year-round, while the streams dry up during the dry season. Different plant vegetations that grow following the river and stream lines potentially serve as a shelter for the adult frogs.

There are a number of swampy areas in the study site. Swamps are the most prevalent kind of wetlands in the study area since they are found in eight of the ten collection sites. The amount of water varies in the various swamps in the study site. The level of water shows great variation between seasons as they get saturated during wet season and dried up during dry season. Few swamps formed close to built-up areas and road sides. The majority of the swamps are dominated by herbs while few of them are dominated by grass. Main disturbances in these habitats include drainage of water for household utilization and removal of vegetation for making thatching.

The majority of the ponds in the study area are temporary ponds which are completely dried up during the dry season. During wet season, it is easier to get temporary ponds since the water level increases during this period. Ponds were found in only one of the ten collection sites in the study area. Human activities near these ponds include using pond water for household utilization and for their cattle, agricultural, and sand mining activities near the ponds, and removal of pond vegetation for making thatching.

The forests of the reserve also serve as suitable habitat for amphibians (Gole et al. 2009). The forest in the study area is divided into core, buffer, and transitional zones. Two of the ten collection sites comprise forest habitats, and these habitats are dominated by wild coffee populations, though other plant species also exist in these forests. Possible anuran microhabitats in these forests include tree leaves, underneath rocks, and rotten logs.

Species accounts

Amietophrynus regularis Reuss, 1833

Amietophrynus regularis, which is the most widespread species of *Amietophrynus* in Ethiopia, is abundant in the central and western plateau of the county between 400–2,500 meters, and its distribution overlaps with the distribution of two other species of *Amietophrynus* (*A. kerinyagae* and *A. asmarae*) in most of its distribution ranges (Tandy et al. 1982; Largen 2001). However, according to Tandy et al. (1982), habitats in southwestern Ethiopia are

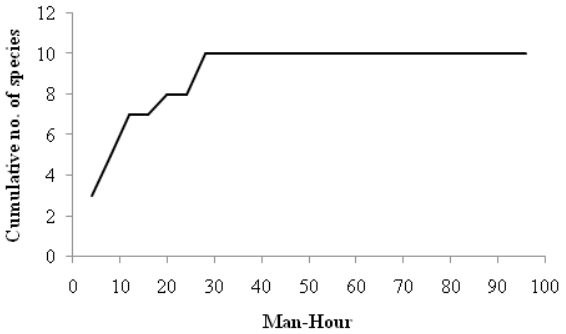

Fig. 4. Species cumulative curve.

exclusively comprised of *A. regularis*. During the current survey, the species was collected from one locality at the elevation of 1,490 meters. Deeply pitted parotid glands, distinct longitudinal ridges on the tarsus, and glands beneath the forearm forming a row of separate tubercles were observed on field-captured individuals. These characteristics are diagnostic for the species (Largen 2001). During the dry season, no individual from the species was collected from any of the possible habitats. However, two individuals were observed calling from a swampy area that was shared by *P. neumanni* and *P. anchiatae*, and one individual was observed in swampy roadsides.

***Hyperolius viridiflavus* Dumeril and Bibron, 1841**

Largen (2001) indicated that a molecular study for the species resulted in three varieties which are the typical *viridiflavus* variety, the *pachydermus* variety and *destefanii* variety. The *viridiflavus* variety is common in southwestern Ethiopia especially in the vicinity of Jimma in the elevational range between 1,200–2,400 m (Largen 1842; Largen 2001). During the current survey, the species was found in elevational range between 1,400–1,900 m. During the dry season, no individuals of the species were observed and advertising calls were not heard for the species during the entire survey. During wet season, a large aggregate of individuals from the species was observed on the vegetation that grows around temporary ponds. The relatively unique advertisement calls of *Hyperolius* spp. (Channing et al. 2002) help to easily determine the presence of the species.

***Hyperolius nasutus* Günther, 1865**

This small sized and slender species of *Hyperolius* was reported to exist in southwestern Ethiopia in elevational range between 500–2,000 m (Largen 2001; Channing et al. 2002) (Fig. 5C). It exhibits a uniform color pattern which is green coloration with silvery white dorso-lateral stripes similar to the findings of Largen (2001). During the current survey, the species was observed in the elevational range between 1,400–1,900 m. The species prefers pond vegetations and it also shares its breeding site with *H. viridiflavous* as Largen (2001) discussed. During the dry season, no individuals were observed for this species and the possible habitats for this species (i.e., pond and stream vegetations) were significantly dried up during this period. During wet season, a good number of this species was observed near pond vegetations. The specific calls of the species were used for their identification during the survey.

***Paracassina obscura* Boulenger, 1895**

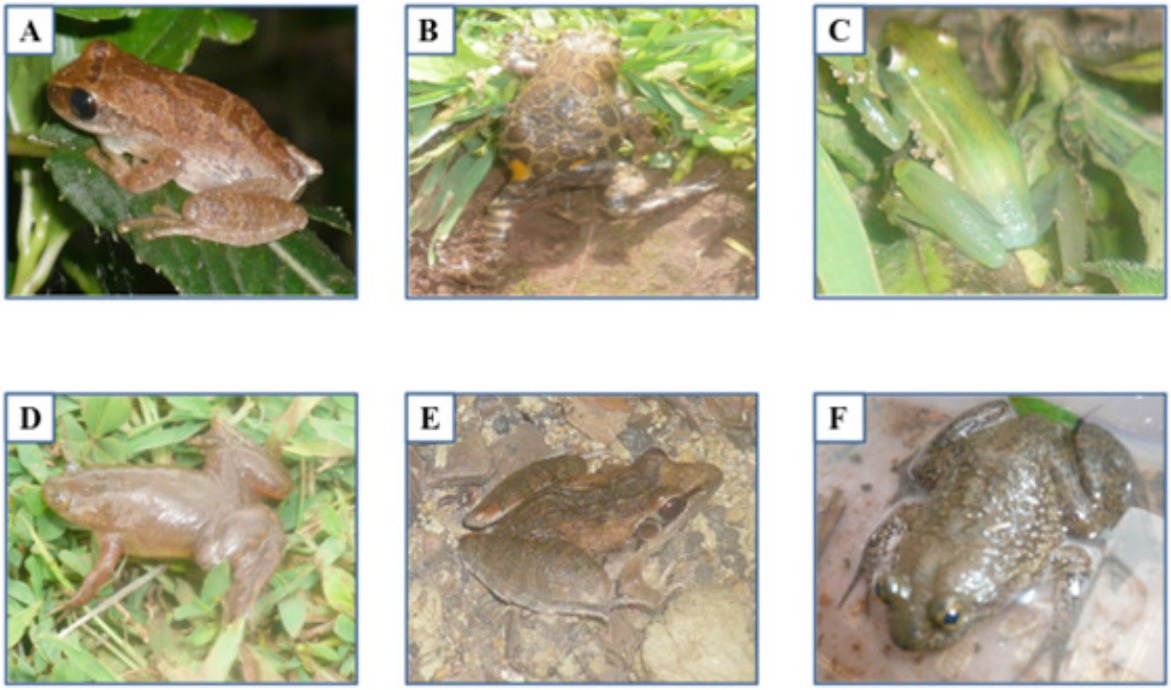

Fig. 5. Selected species encountered in YCFBR. **(A)** *Leptopelis ragazzii*, **(B)** *Paracassina obscura*, **(C)** *Hyperolius nasutus*, **(D)** *Xenopus clivii*, **(E)** *Ptychadena anchiatae*, **(F)** *Conraua beccarii*.

Paracassina obscura (Fig. 5B) is one of the least studied species of anura despite being endemic to Ethiopian highlands. Largen (2001) indicated that the species exists to the west of rift valley, unlike its relative *P. kounhiensis* (distributed to eastern rift valley), in the elevational range between 820–3,000 m. During the current survey, the species was observed in the elevational range between 1,400–1,900 m. The species was observed in home gardens and farm lands. Individuals were heard calling from these habitats during both the day and night time. A bright-yellow patch at the groin which is clearly surrounded by a dark pigment was observed on captured individuals. This character differentiates *P. obscura* from its relative *P. kounhiensis*. During the dry season, no single individual for the species was observed from all sites. During the wet season, the species were abundantly observed in home gardens, forest clearings, swampy areas and abandoned farmlands. It has a species-specific call which is weak and stays for a second. This call is like a sound that comes out from water droppings as Largen (2001) explained.

***Leptopelis ragazzii* Boulenger, 1896**

Identification of the various species of the genus *Leptopelis* (especially *L. susanae*, *L. ragazzii*, and *L. vannutellii*) using only morphological characters is almost impossible (Mengistu et al. 2012). Consulting former distribution of the species is more reliable for identifying the species (Weinsheimer et al. 2010). *L. ragazzii* (Fig. 5A), which is a small sized species, is known to exist in southwestern Ethiopia in the elevational range between 1,900–3,100 m (Largen 2001). During the current survey, the species was collected in the elevation range between 1,490-1,680 m. During wet season, a greater number of individuals was caught than during dry season collection.

***Xenopus clivii* Peracca, 1898**

Largen (2001) discussed the existence of two species of *Xenopus* in Ethiopia, *X. clivii* and *X. largeni*. *X. clivii* (Fig. 5D), which is the widespread species of *Xenopus*, is the one that was reported to exist in southwestern Ethiopia (Evans et al. 2011). Largen (2001) indicated that the species exists in the elevational range between 1,900–2,750 m. During the current survey, the species was observed in the elevational range between 1,400–1,900 m. Dorsoventrally flattened body with dorsal eyes and the digits that are extensively webbed were observed in collected individuals. This is an adaptation for entirely aquatic existence. The species has a very narrow habitat requirement since it only exists in permanent and temporary ponds. Tentacles that surround their eyes and the black claw on their metatarsal tubercle, that differentiate this species from its relative (*X. largeni*), were observed in the current collection. The adult individuals for the species were collected only from one collection site while the tadpoles were observed in temporary ponds in other collection sites. During the dry season, a good number of individuals were collected, while the number decreased during the wet season.

***Conraua beccarii* Boulenger, 1911**

Conraua beccarii (Fig. 5F), the largest anuran species in eastern Africa, was reported to exist in southwestern Ethiopia in the elevational range between 300–2,500 m (Largen 2001). During the current survey, the species was collected from one collection site at elevation of 1,665 m taking refuge under rock crevices over which fast moving stream water flows. The hidden nature of the habitat and the fast-flowing stream water were barriers for catching individuals. Dorsal eyes, a dorso-ventrally flattened body especially near the head region, and digits that are significantly webbed like *Xenopus* were observed in caught individuals. During the dry season, three adult individuals and many tadpoles and froglets were observed under rock crevices. However, during the wet season no individual tadpole or froglet was observed while the number of adult individuals does not show significant variation from the dry season.

***Ptychadena anchiatae* Bocage, 1868**

Largen (2001) discussed that *P. anchiatae* (Fig. 5E) is a widespread species of *Ptychadena* like its relative *P. neumanni*, and he also indicated that the species exists in southwestern Ethiopia below 1,800 m. During the current survey, the species was only recorded from one locality at the elevation of 1,400 m. The species shares it breeding site with its relative (*P. neumanni*) and it was difficult to differentiate them by their calls when they coexist. The species has extended webbing on the digits and a pale triangle on the anterior region of the head to differentiate it morphologically from *P. neumanni*. The female is significantly larger than the male and like other species of *Ptychadena* the male is characterize by the vocal sac. During the dry season, no individuals from the species were caught while few individuals were caught during the wet season.

***Ptychadena neumanni* Ahl, 1924**

Ptychadena neumanni, which is the most widespread species of anura throughout the country, is also reported to exist in southwestern Ethiopia (Largen 2001). Recently, Freilich et al. (2014) and Smith et al. (2017) indicated that climatic variabilities and geologic events in Ethiopia contributed for adaptive speciation within the species. Largen (2001) indicated that the species exists in the elevational range between 1,800–3,800 m though some specimens were collected in lowland with the elevation of 820 m in southwest Ethiopia. During the current survey, the species was recorded in the elevational range between 1,400–1,900 m. The species was cosmopolitan,

existing in almost all types of habitats (i.e., swamps, pond edges, stream sides, and forest clearings), and it was also collected from all collection sites. The species has restricted webbing on its digits that differentiate it from its relative (*P. anchiatae*) (Largen 2001). However, it shares many characteristics with *P. erlargeri*, which make it difficult to differentiate the two species using morphology (Mengistu et al. 2012). Wet season collection yields more individuals from the species than dry season collection.

Phrynobatrachus natalensis Smith, 1849

Phrynobatrachus natalensis, which is a small sized species, was reported to be as equally well-distributed as *Ptychadena neumanni* throughout Ethiopia in the elevational range between 300–2,200 m (Largen 2001; Schick et al. 2010; Zimkus and Schick, 2010; Zimkus et al. 2010). During the current survey, the species was observed only in a single locality at the elevation of 1,680 m. The species possesses large oval marks on the anterior region of its dorsum that are arranged in an X-shaped configuration and dark pigmentation on the gular region as Largen (2001) discussed. This feature differentiates it from its relative (*P. minutus*) which was not collected in the current study though it has a possible existence in southwestern Ethiopia (Largen 2001; Schick et al. 2010). This could arise due to the higher probability of the species to exist above 2,000 m than *P. natalensis*. During the dry season, many individuals for the species were collected from a swamp near to a slow-moving stream. During wet season, no individuals were observed from any of the collection sites. The species produces an abrupt species-specific call that has high strength and spans very short. It shares its habitat with *P. neumanni*.

Species Diversity and Relative Abundance

A total of 101 individuals that belong to four families and ten species were collected, both during the wet and dry season, investing a search effort of 96 man-hours in total for all the collection sites (Table 2, Fig. 4). The majority of the collected individuals belong to one species (*P. neumanni*) that comprises around 31% of all collected individuals, while *B. regularis* is the least represented in this collection (3%). As expected wet season collection resulted in significantly larger number of anurans than dry season collection (t = -2.6, df = 18, $P < 0.05$) and the species collected in both seasons were distributed between an elevational gradient of 1,400 and 1,900 m. However, a species-wise comparison between the two seasons shows a different result for *Phrynobatrachus natalensis* and *Conraua beccarii*. In the case of *P. natalensis*, no individual was collected in the wet season and for *C. beccarii* the same number of individuals was collected between the two seasons (Table 2).

Largen (2001) reported the existence of around 31 anuran species taking refuge inside forests of southwestern Ethiopia, however in the current research we were able to observe 10 anuran species. A potential reason for a reduced number of species in the current study is that some of the species reported by Largen (2001) including *Bufo steindachneri*, *Hemisus marmoratus*, *Hyperolius balfouri*, *Hyperolius kivuensis*, *Kassina senegalensis*, *Leptopelis bocagii*, *Haplobatrachus occipitalis*, and *Ptychadena mascareniensis* are essentially lowland savanna species (Largen and Spawls 2010) with reduced potential of occurrence in transitional afromontane rainforest forest of YCFBR. The behavior of some species as being highly secretive (*Hemisus microscaphus* and *Leptopelis gramineus*) and species with extremely rare distribution in southwestern Ethiopia (*Ptychadena pumilio*, *Bufo petoni*, and *B. maculatus*) could be the reason for not observing these species with the 96 man-hours invested in the field. The unresolved and overlapping taxonomic identification key of the two species of *Leptopelsis* (*L. ragazzii* and *L. vannutellii*) and *Ptychadena* (*P. neumanni* and *P. erlargeri*) (Weinsheimer et al. 2010; Mengistu 2012; Freilich et al. 2014) seems to be the reason for no representation of *L. vannutellii* and *P. erlargeri* in the current observation indicating the absence of these to be non-genuine. Despite the fact that *Afrixalus* spp. (*A. clarkeorum*, *A. enseticola*, and *A. quadrivittatus*) have significant portions of their distributions in southwestern Ethiopia (Largen 1974; Mertens et al. 2016), we were not able to observe a single individual that we are certain of identifying as *Afrixalus* spp. However, a number of immature individuals we observed have close resemblance with *Afrixalus* spp. giving us a clue that the *Afrixalus* spp. potentially shares habitats with *Hyperolius* spp. in our study site.

Most surprisingly two other species (*Afrana angolensis* and *Phrynobatrachus minutus*) are not observed in the current study despite, as indicated by Largen (2001), their habitat requirement and geographic distribution matches our study area. Hence, it seems our results do not confirm a genuine absence of *P. minutus* from our study area. The more infrequent occurrence of *P. minutus* in comparison with *P. natalensis* (Largen 2001) could be the reason for no observation of the species. However, lack of observation of *A. angolensis*, which is abundant

Table 2. Wet and dry season diversity and abundance of anuran species in YCFBR.

Family	Species	Abundance		Total
		Dry	Wet	
Bufonidae	*Bufo regularis*	0	3	3
Hyperoliidae	*Hyperolius viridiflavous*	1	8	9
	Hyperolius nasutus	0	4	4
	Parakassina obscura	0	7	7
	Leptopelis ragazzii	3	10	13
Pipidae	*Xenopus clivii*	3	12	15
Ranidae	*Conraua beccarii*	3	3	6
	Ptychadena anchiatae	0	5	5
	Ptychadena neumanni	12	19	31
	Phrynobatrachus natalensis	8	0	8
	Total	30	71	101

and frequently observed in its natural habitat (Largen and Spawls 2010), is in contrast to the findings of previous studies including Largen (2001) and Largen and Spawls (2010). The fact that a recent inventory of anurans in other coffee forests in southern Ethiopia (NABU 2017) and southwestern Ethiopia (Mertens et al. 2016), with similar physiognomy and climatic features with YCFBR, also lacking observation of the same species could indicate that the known distribution range of the species needs to be revised with additional field observations.

In general, the Yayu Coffee Forest Biosphere Reserve (YCFBR) comprises diverse wetlands including swamp, stream side and temporary ponds comprised within and around the vast forested areas. Such abundant and diversified wetlands are the result of the rugged topography of the study area (Gole et al. 2009). Considering the fact that the reserve is the only internationally recognized biosphere reserve in southwestern Ethiopia and still comprises 10 species and 101 individuals of amphibians which is comparable to what is found in other biodiversity hotspots and protected areas in the country (Kassun 2009; Tito 2009; Teme et al. 2016), it can be concluded that the reserve contributes immensely to the conservation of amphibians in the country. According to EWNHS (1996), there are natural forest priority areas in southwestern Ethiopia, namely Syllem-Wangas, Sheko, Yeki, and Godere that have similar climate and floral composition with YCFBR. However, there is scant information on herpetofauna of these naturally forested priority areas and hence the findings of our research can also be an indicator for the possible existence of even greater diversity and abundance of anurans in these forest priority areas.

Potential threats for the survival of anuran species

Amphibian population decline was first recognized as a global phenomenon in the early 1990s (Hayes et al. 2010). Nowadays, amphibians have been repeatedly reported to decline at an alarming rate by many authors (Pechmann and Wilbur 1994; GAA 2004; Stuart et al. 2004; Blaustein and Bancroft 2007; Gallant et al. 2007; Hayes et al. 2010), and these same authors also discussed this global decline of amphibians together with appropriate measures which could be taken to minimize the problem. In Ethiopia, the main factor triggering the loss of amphibians from different ecosystems is habitat degradation and deforestation (Mengistu 2012), though other unstudied factors like climate change and pollution from agrochemicals and disease (Gower et al. 2012) could also play their own role for the declining number of amphibians in the country.

The chain of forests in southwestern Ethiopia, the largest tract of forest next to the one found in the Harena forest of Bale Mountains (Williams et al. 2004), is known for remarkably unique species that are not shared by similar habitats in East and Central Africa (Yalden et al. 1996). Williams et al. (2004) indicated that the arid and semi-arid belts stretching from southern Sudan to northern Kenya is insulating the forest fragments, serving as an effective barrier to the forest-dwelling species of the Guineo-Congolian forest block. This elevates the relevance of YCFBR for conserving the typical herpetofauna of southwestern Ethiopia. However, a significant decline of forested areas in southwestern Ethiopia due to the ever-increasing deforestation (Reusing 2000; Dessie and Kleman 2007) can pose serious problems threatening the survival of not yet well-studied anuran species of the region. Studies indicate recent expansion of coffee farms, plantations, and agricultural fields into former natural forest areas in response to the ever-increasing population of the region (Reid et al. 2000; Denboba 2005; Tadesse et al. 2014) and coal mining (Suleman 2016) to be the main reasons for deforestation.

Weinsheim et al. (2010) stressed that deforestation is higher in the highlands of Ethiopia where greater amphibian endemism is recorded. As also indicated by Loader et al. (2014), it is the long-term persistence of highland forested habitats in Ethiopia which contributes to increasing the diversity of anuran species. Besides, the discovery of pathogenic chytrid fungus (*Batrachochytridium dendrobatidis*) on anuran samples from the highlands of Ethiopia particularly in Bale Mountains (Gower et al. 2011) could indicate the potential existence of the same pathogen in highland afromontane forests in southwestern Ethiopia as the pathogen is highly epidemic in moist highland (Pounds et al. 2006). This potentially risks the survival of the anuran species taking refuge inside forests of southwestern Ethiopia. However, the study by Gower et al. (2011) asserts no lethal impacts of the fungus on selected anuran species in Bale Mountains, different anuran species have variable levels of susceptibility to the fungus (Savage and Zamudio 2011) and hence further study on its impacts on all anuran species in highlands afromontane forest including YCFBR is recommended to estimate the real impact of the fungus.

The combined effects of deforestation and sporadic pathogenic fungus are the main threats for anuran species of southwestern Ethiopia, asserting that future conservation efforts should be targeting minimizing agricultural expansion and halting the spread of fungal infection. Avoiding the expansion of agriculture is often very challenging as it demands local farm holders to entirely depend on coffee plantation, which is harvested at only one time of the year and is not always reliable to support the livelihood of the small farm holder. Fortunately, the livelihood of local people in and around YCFBR is not dependent on crop cultivation, offering a good opportunity to augment forest biodiversity conservation (Nischalke et al. 2017). Besides, the implemented nature conservation approaches in the reserve are reconciled with social development strategies and hence they demand the active participation of local community in the management and protection of their natural resources for their own benefit (Gole et al. 2003; Senbeta et al. 2007). YCFBR has

huge potential for supporting local communities through provision of non-forest tree products (Asfaw and Etefa 2017). Hence, the recognition of the forest in 2012 as a biosphere reserve through UNESCO's Man and the Biosphere Program was the right move to reconcile local development and nature conservation. A recent study, Beyene (2014), also showed that the recognition of the forest as a biosphere reserve contributes to reducing the extent of deforestation and hence strengthens biodiversity conservation efforts in the region.

Conclusion

Forest fragments in southwestern Ethiopia are the remnants of three-decade long deforestation that took place throughout Ethiopia. However, the same history of deforestation seems to reappear on these forest fragments as we have witnessed a recent expansion of agricultural areas and coal mining sites into formerly forested areas. Such trends will deteriorate the yet unstudied biodiversity comprised within these forest fragments. Called by addressing this issue, the Yayu Coffee Forest Biosphere Reserve (YCFBR) was established in 2010 as part of UNESCO's Man and the Biosphere Program.

While YCFBR has huge potential for conserving biodiversity, only few researchers were focused on uncovering the rich biodiversity of the reserve. Particularly, when it comes to amphibians or anurans, the focus is very limited due to the negative attitude of the general public toward amphibians and the economic worthlessness of amphibians. Considering the anuran species diversity in the reserve, YCFBR can contribute to conserving the amphibian diversity of southwestern Ethiopia. The afromontane forests in the reserve, which has no equivalent in the rest of Africa, serve as refugia for typical anuran diversity of southwestern Ethiopia.

Future conservation efforts should focus on understanding the status and distribution of anurans or amphibians in forest fragments of southwestern Ethiopia. This includes detailed study on the responses of anuran species to deforestation and their susceptibility for the sporadic *Bd* (*Batrachochytridium dendrobatidis*) infection. Altogether, this will contribute to reducing the declining number of anuran species in the country.

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