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Research Article

Natural History Observations on a Warty Frog: *Callulina dawida* (Amphibia: Brevicipitidae) in the Taita Hills, Kenya

Patrick K. Malonza

Section of Herpetology, National Museums of Kenya, P.O. Box 40658, Nairobi 00100, Kenya

Correspondence should be addressed to Patrick K. Malonza, kmalonza@museums.or.ke

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Amphibian populations are declining throughout the world, but most of the susceptible species possess particular biological attributes. Understanding these traits plus the environmental factors responsible for declines greatly aids conservation prioritization and planning. This paper examines the natural history observations and ecological characteristics of *Callulina dawida*, a frog endemic to the montane forests of the Taita Hills, Kenya. Sampling was accomplished by use of standardized pitfall trapping, transects, and time-limited searches. Mean monthly temperature and elevation significantly influenced the species distribution and abundance but mean monthly rainfall did not. The species was rare or absent during the cold season and its abundance increased with elevation. Breeding occurred during the long dry season (June to October) with juveniles being abundant between January and March. Available evidence shows that this species deposits a cluster of large yolk-rich eggs on the forest floor with maternal care and direct development. Its occurrence only within highly fragmented indigenous forests makes the species worth listing as critically endangered. To conserve this species, all remaining indigenous forest fragments including those communally or privately owned should be preserved and connected through planting of indigenous trees along stream valleys. In addition, the exotic tree plantations should be replaced with indigenous trees to restore the species habitat.

1. Introduction

Amphibians are more susceptible to changes in the local environment than other vertebrates [1, 2] because of their permeable skin that absorbs water and oxygen, and their lives depend on clean environmental resources.

Almost a third of known amphibian species worldwide are already threatened by a combination of habitat loss, climate change, ultraviolet radiation, diseases, pathogens, global warming, overexploitation, pet trade, environmental pollution, and invasive species [2, 7].

Habitat loss and fragmentation [8, 9] are the major causes of the observed global amphibian population declines [3, 10, 11] and is most prevalent in species-rich tropical regions [12]. Among the highly fragmented and threatened habitats is the east African montane forests of the Eastern Arc Mountains (EAM); with the Taita Hills forests being the most fragmented and threatened [13, 14]. Animal populations within such isolated small fragments are ecologically vulnerable to genetic loss due to inbreeding and genetic drift via "bottlenecks" and "founders' effects" [3, 15, 16].

The rate at which amphibian species are declining as a result of human activities is of significant concern to ecologists and conservation biologists [17]. Amphibian extinction risks and population declines are taxonomically nonrandom [2, 18], indicating that certain species biological attributes influence susceptibility to decline. Such traits include large size, low fecundity, being rainforest endemic specialists, breeding in streams, narrow habitat tolerances, restricted range, living at high altitude and low vagility [3, 18, 19]. Understanding these particular biological traits is important in species conservation management and planning [18, 20].

Despite the exceptionally high amphibian diversity and abundance in many ecosystems, some amphibian species are occasionally misrepresented in biodiversity estimates be cause of their secretive nature, nocturnal habits, and small ranges or because of a general lack of understanding of their life histories [7]. Knowledge on the life history of many amphibians is limited and for some even the most basic biological data are lacking [21]. The brevicipitids (*Breviceps, Balebreviceps, Probreviceps, Callulina,* and *Spelaeophryne*) range from south Africa through east Africa to the Bale Mountains of Ethiopia [22]. They are typically cryptic and spend much of their time in soil or leaf litter [23], a behavior that partly accounts for the paucity of life history information. Many brevicipitids exhibit some form of parental care. There are reports of females found in burrows with a clutch of eggs in *Probreviceps* [23, 24]. *Probreviceps* is the sister genus to *Callulina* [25]. The genus *Callulina* is endemic to the EAM forests of Tanzania and Kenya. The species *Callulina kreffti* Nieden, 1911, was for close to a century assumed to be the only species in the entire EAM. The first to be described as distinct species was *Callulina kisiwamsitu,* De Sá et al. 2004, which is endemic to west Usambara Mountains [26]. Recent taxonomic review has found that *Callulina kreffti* is endemic to the east Usambara Mountains. Following this revelation four more species have recently been formally described: the Taita Hills *Callulina dawida* Loader et al. 2009; North Pare *Callulina laphani* Loader et al. 2010; two species from South Pare Mountains: *Callulina shengena* and *Callulina stanleyi* Loader et al. 2010. This shows that it is likely that many of the remaining mountain forest blocks may have more than one species. For example three forms from the Nguru Mountains are thought to be distinct new species [27]. Together with these all the other forms from the other forest blocks such as Nguru, Kanga, Ukaguru, Rubeho, Uluguru, Mahenge, and Udzungwa most likely represent undescribed species [28].

While currently taxonomists are describing new forms from this genus, little information exists on their life history characteristics such as breeding and other habits that can be used to enhance their conservation management plans. What is known is that species in this genus are mainly forest dwellers, good climbers, and lay eggs that are presumed to develop directly into young frogs [23].

Herein I provide additional information on the natural history of one of the warty frogs *Callulina dawida,* by examining its ecological and breeding characteristics. The aim of this study was to get a better understanding of the species' behavioural characteristics that can aid conservation efforts. My specific objectives were to investigate whether: (1) *Callulina dawida* is a forest dwelling species; (2) the distribution and abundance of this frog is independent of mean monthly temperature, rainfall and elevation; (3) the frogs' eggs are terrestrially deposited anywhere in the forest; (4) the frog is a good climber and terrestrially moves widely within the forest

2. Materials and Methods

2.1. Study Site. *Callulina dawida* were studied in fragmented forests of the Taita Hills (Dawida, Mbololo, Sagalla, and Kasigau) mountain blocks. The Taita Hills lie between 38°20′ East and 3°25′ South, in southeastern Kenya. Sampling was done in selected sites of indigenous forests, exotic plantations and farms at varying elevation and disturbance gradients (see the Appendix).

2.2. Sampling. Data collection was conducted over a period of 30 months (December 2004 to March 2008). Sampling was accomplished by use of standardized night transect walks and pitfall trapping for quantitative data. Thirty transects were rectangular in shape totaling 600 m standard similar to that used in previous studies [29, 30]. All *Callulina dawida* individuals observed within 1 m on either side and above the transect path were recorded. Sampling of each transect was repeated every week. The traps consisted of Y-shaped drift fence (30 cm high polythene paper supported with wooden pegs) array with segments of 5 m length in association with four pitfall traps (10 liter plastic buckets) flush with the ground [31]. Three trap sets were set in each site for five days (trapping sessions) after which they were closed and reopened after one week. In total, there were 15 trapping sites. Checking of the traps was done once every morning not later than 7:30 am o'clock morning. Day time one person hour time-limited searches similar to the procedure described by Karns [32] and opportunistic visual encounter surveys generated qualitative data mainly on species habits.

To study movement, capture-mark-recapture was done beginning in September 2006 in Ngangao, Chawia, and Mwachora, and later in Fururu, Ndiwenyi, and Vuria forests. Captured frogs were marked by inserting numbered alphanumeric tags (VIAlpha, northwest Marine, USA) subcutaneously on the ventral surface of the thigh and released for later identity after recapture. A Pesola spring balance (Max. 60 g) was used to take body mass (to the nearest 1 g) while snout-vent length (SVL) was measured using a ruler (to the nearest 1 mm). Age classes were defined using SVL size ranges. Voucher specimens were processed and are deposited at the National Museums of Kenya, Nairobi—NMK Herpetology reference collection (see the Appendix).

To study the species breeding habits, nests were searched and when found they were marked and monitored until all the eggs hatched.

2.3. Statistical Analyses. All quantitative analyses used data from traps as transect data were not sufficiently productive in terms of number of individuals recorded. One sample t-test was used to test the variation in frog abundance among the forest fragments. Nonparametric Spearman Rank Correlation was used to test the influence of temperature and rainfall on abundance. Chi-square was used to test monthly age group variation in abundance and to test whether abundance was associated with altitude. Data were analyzed with STATISTICA 6.0 [33].

3. Results

3.1. Species Diagnosis. *Callulina dawida* is a medium sized frog in which females can reach 55 mm and males 35 mm (Figure 1). The toes of the hind feet are arranged in two opposable groups, with the fourth and fifth together, pointing backward when walking on the forest floor. The skin is warty and dorsal adult color is variable from light brown, grey, dark brown, orange to yellowish. In terms of coloration there is no well-marked sexual dimorphism. Using SVL, the

Figure 1: A life photograph of *Callulina dawida* in the wild in Ngangao forest P. Malonza.

Table 1: The number of *Callulina dawida* individuals captured and recorded from transects in different study sites. In parentheses are total number of trapping sessions and transect walks. Provided also are some characteristics of the sites; area (ha) and approximate maximum elevation (m).

Site	Size	Elevation	Traps	Transects
Indigenous forests				
Ngangao	192	1952	11 (141)	1 (18)
Chawia	50	1625	4 (146)	0 (17)
Mwachora	3	1650	4 (131)	0 (17)
Macha	3	1700	—	0 (15)
Boma	0.25	1460	—	0 (18)
Mbololo	220	1779	2 (123)	6 (21)
Sagalla	3	1500	0 (132)	0 (15)
Kasigau	20	1645	0 (32)	0 (19)

frog population was grouped into three age groups: juveniles (<20 mm), Subadults (20–30 mm) and adults >30 mm).

3.2. Population and Habitat Characteristics. From December 2004 until March 2008, 101 individuals were recorded. Twenty-one individual frogs were recorded in traps and seven in transects (Table 3). The majority of the rest were from time-limited searches or opportunistic visual encounter surveys and leaf-litter sampling. Thirty three individuals were marked with three recaptures. The SVL of the largest adult and the smallest juvenile recorded in this study were 55 mm and 9 mm, respectively. Characteristically, frogs were found in microhabitats such as on or under leaf litter, or debris and within decomposing logs, tree stems and or bark.

Callulina dawida was only found in indigenous forest fragments above an altitude of 1400 m in the Dawida and Mbololo mountain blocks and not in the Sagalla or Kasigau blocks. No individuals were found in typical farmland or exotic plantation habitats.

3.3. Distribution and Abundance. There was a discernable monthly age group variation in distribution and abundance ($\chi^2 = 20.31$, $d.f. = 2$, $n = 12$, $P = 0.00004$). While adults could be caught in most months of the year; most of the juveniles were trapped in January and February (Table 2).

Table 2: Monthly abundance records of juvenile and adult *Callulina dawida* in traps.

Month	Juveniles	Subadults	Adults
January	5	0	0
February	4	1	1
March	1	0	1
April	0	0	1
May	0	1	1
June	0	0	0
July	0	0	0
August	0	1	0
September	0	1	1
October	0	1	1
November	0	0	0
December	0	0	1

The mean number of individuals trapped in the four forest fragments differed (one sample t-test; $t = 4.17$, $d.f. = 3$, $n = 4$, $P = 0.025$). Consequently, a high number of individuals were recorded in Ngangao as compared to the other three forests (Mwachora, Chawia, Mbololo).

3.4. Influence of Rainfall, Temperature, and Altitude. Spearman Rank Correlation showed that *Callulina dawida* abundance was positively influenced by mean monthly temperature ($t = 2.39$, $P = 0.037$, $R = 0.60$, $n = 12$) and there was no effect of rainfall in the data set ($t = 1.499$, $P = 0.166$, $R = 0.28$, $n = 12$). Therefore individuals are commonly recorded during the warm months of January to March and August to October and less during the cold months of June and July. They are also few to none during the peak rainy seasons in April and November/December (Table 2). The results also demonstrate a clear association between altitude and abundance ($\chi^2 = 8.0$, $d.f. = 2$, $n = 4$, $P < 0.018$). Hence the species is most abundant in the high altitude Ngangao forest fragment (Table 1).

3.5. Breeding and Other Behavioral Characteristics. Results from time-limited searches showed that *Callulina dawida* breeds during the long dry season which runs from June to October. In July and August a strong three note trilling call was heard from males in several forests. On 12 September 2007 in Fururu forest a female (45 mm, 7.5 g) was found on leaf litter sitting on a clutch of 30–40 eggs (2-mm diameter egg capsule) bound together (Figure 2). When displaced she returned to sit on the eggs. The female was then visited on 21 November 2007 and found on the same state until 29 November when only 6 eggs remained with the female still sitting on them. It was observed that the eggs hatch directly into froglets which immediately leave the nest. Once all the eggs have hatched the mother leaves the nest. The smallest juvenile (9 mm) recorded was found on 6 December; 2005 perched on grass within a forest site in Fururu infested with army ants *Dorylus molestus* Gerstäcker, 1859. *Callulina dawida* are good climbers and on several occasions in Vuria

Table 3: Distribution of Taita warty frog (*Callulina dawida*) recorded in different forest fragments showing life snout-vent length (SVL) and body weight (Wt), age group, recording date, recording method, and comments. Indigenous forests sizes in parentheses is as follows: Ngangao (92 ha), Chawia (50 ha), Mwachora (4 ha), Ndiwenyi (3 ha), Fururu (12 ha), Boma (0.25 ha), Makandenyi patch (negligible), Kiangungu patch (negligible), Vuria (1 ha), and Mbololo (220 ha). The 18 preserved specimens are shown with NMK catalogue numbers.

Specimen	SVL (mm)	Wt (g)	Age group	Site	Date	Method	Comments
1	45	7.1	Female	Fururu	16/12/2004	Visual encounter survey	Preserved: NMK-A4266
2	36	3.7	Female	Kiangungu	16/12/2004	Visual encounter survey	Preserved: NMK-A4267
3	30	2.5	Male	Ngangao	28/12/2004	Visual encounter survey	Preserved: NMK-A4268/1
4	29	1.8	Subadult	Ngangao	28/12/2004	Visual encounter survey	Preserved: NMK-A4268/2
5	40.68	—	Female	Ngangao	20/04/2005	Pitfall trap	Preserved: NMK-A4343
6	43.11	8.26	Female	Chawia	25/04/2005	Time-limited search	Preserved: NMK-A4344/1
7	30	2.59	Male	Chawia	26/04/2005	Leaf litter search	Preserved: NMK-A4344/2
8	15	—	Juvenile	Mbololo	29/03/2006	Pitfall trap	Preserved: NMK-A4574
9	19	0.6	Juvenile	Mbololo	03/04/2006	Night transect walk	Preserved: NMK-A4582/1
10	20	0.79	Subadult	Mbololo	03/04/2006	Night transect walk	Preserved: NMK-A4582/2
11	19	0.63	Juvenile	Mbololo	03/04/2006	Night transect walk	Preserved: NMK-A4582/3
12	31	—	Male	Ngangao	07/04/2006	Time-limited search	Released
13	35	—	Female	Ngangao	21/12/2005	Pitfall trap	Preserved: NMK-A4492
14	10	—	Juvenile	Ngangao	06/01/2006	Pitfall trap	Released
15	10	—	Juvenile	Ngangao	17/01/2006	Pitfall trap	Released
16	45	—	Female	Ngangao	24/01/2006	Visual encounter survey	Released
17	40	—	Female	Ngangao	10/02/2006	Pitfall trap	Released
18	14	—	Juvenile	Ngangao	21/02/2006	Pitfall trap	Preserved: NMK-A4594
19	11	—	Juvenile	Ngangao	21/02/2006	Pitfall trap	Released
20	15	—	Juvenile	Ngangao	22/02/2006	Pitfall trap	Released
21	12	—	Juvenile	Ngangao	22/02/2006	Pitfall trap	Released
22	34	—	Male	Ngangao	20/03/2006	Pitfall trap	Preserved: NMK-A4590
23	40	—	Female	Ngangao	20/03/2006	Funnel trap against drift fence	Released
24	—	—	Adult	Ngangao	20/03/2006	Visual encounter survey	Disappeared before capture
25	29	2	Subadult	Vuria	16/04/2006	Visual encounter survey	Released
26	12	—	Juvenile	Mwachora	05/01/2006	Pitfall trap	Released
27	14	—	Juvenile	Mwachora	06/01/2006	Pitfall trap	Released
28	15	—	Juvenile	Mwachora	17/01/2006	Pitfall trap	Released
29	21	—	Subadult	Mwachora	14/03/2006	Pitfall trap	Preserved: NMK-A4624
30	9	—	Juvenile	Fururu	06/12/2005	Visual encounter survey	Preserved: NMK-A4416
31	50	—	Female	Chawia	07/02/2006	Leaf litter search	Released
32	38	—	Female	Chawia	22/02/2006	Leaf litter search	Released
33	21	—	Subadult	Chawia	08/03/2006	Leaf litter search	Released
34	46	—	Female	Boma	10/05/2006	Time-limited search	Preserved: NMK-A4645
35	45	—	Female	Mbololo	05/05/2006	Pitfall trap	Preserved: NMK-A4684
36	25	—	Subadult	Mbololo	30/05/2006	Time-limited search	Released
37	33	—	Male	Boma	03/07/2006	Time-limited search	Released
38	51	—	Female	Boma	03/07/2006	Time-limited search	Released
39	—	—	adult	Ngangao	26/06/2006	Time-limited search	Released
40	20	—	Subadult	Ngangao	30/05/2006	Pitfall trap	Released

Table 3: Continued.

Specimen	SVL (mm)	Wt (g)	Age group	Site	Date	Method	Comments
41	—	—	Adult	Makandenyi	March 2006	Visual encounter survey	Released
42	30	—	Male	Chawia	08/08/2006	Pitfall trap	Released
43	33	—	Male	Ngangao	14/08/2006	Time-limited search	Released
44	34	—	Male	Chawia	20/09/2006	Pitfall trap	Released
45	30	—	Male	Chawia	20/09/2006	Pitfall trap	Released
46	20	—	Subadult	Ngangao	25/09/2006	Patch sampling	Recaptured on 01/04/2007; SVL 42 mm
47	44	7	Female	Ngangao	27/09/2006	Patch sampling	Released
48	22	1.25	Subadult	Ngangao	October 2006	Patch sampling	Released
49	21	1.25	Subadult	Ngangao	October 2006	Patch sampling	Released
50	35	—	Female	Chawia	11/10/2006	Patch sampling	Released
51	27	—	Subadult	Chawia	28/10/2006	Pitfall trap	Released
52	32	—	Male	Chawia	29/10/2006	Pitfall trap	Released
53	43	6.5	Female	Ngangao	02/11/2006	Time-limited search	Released
54	35	3	Female	Ngangao	2/11/2006	Time-limited search	Recaptured on 02/05/2007; SVL 48 mm, wt 9 g
55	30	2	Male	Ngangao	02/11/2006	Night transect walk	Released
56	45	6	Female	Ngangao	03/11/2006	Time-limited search	Released
57	30	—	Male	Mbololo	05/12/2006	Night transect walk	Released
58	35	—	Female	Mbololo	05/12/2006	Night transect walk	Released
59	46	—	Female	Mbololo	06/12/2006	Time-limited search	Released
60	55	—	Female	Mbololo	08/12/2006	Time-limited search	Released
61	43	—	Female	Ndiwenyi	03/04/2007	Time-limited search	Released
62	40	—	Female	Fururu	05/04/2007	Time-limited search	Released
63	29	—	Subadult	Ndiwenyi	05/04/2007	Time-limited search	Released
64	46	—	Female	Vuria	11/05/2007	Time-limited search	Released
65	45	—	Female	Ndiwenyi	28/05/2007	Time-limited search	Released
66	48	—	Female	Ngangao	02/05/2007	Time-limited search	Released
67	43	12	Female	Mwachora	04/05/2007	Time-limited search	Released
68	48	9.5	Female	Mbololo	17/05/2007	Time-limited search	Recaptured on 09/12/2007, SVL 48 mm
69	48	11	Female	Ngangao	09/06/2007	Time-limited search	Released
70	40	6.5	Female	Ngangao	09/06/2008	Time-limited search	Released
71	26	2	Subadult	Ngangao	09/06/2009	Time-limited search	Released
72	47	—	Female	Vuria	23/06/2007	Time-limited search	Released
73	50	—	Female	Vuria	24/06/2007	Time-limited search	Released
74	30	—	Male	Vuria	24/06/2007	Time-limited search	Released
75	47	—	Female	Vuria	25/06/2007	Time-limited search	Released
76	55	—	Female	Vuria	25/06/2007	Time-limited search	Released
77	52	—	Female	Vuria	25/06/2007	Time-limited search	Released
78	33	—	Male	Vuria	25/06/2007	Time-limited search	Released
79	50	—	Female	Vuria	26/06/2007	Time-limited search	Released
80	30	—	Male	Vuria	26/06/2007	Time-limited search	Released
81	12	—	Juvenile	Vuria	26/06/2007	Time-limited search	Released
82	30	—	Male	Mwachora	14/08/2007	Time-limited search	Released
83	45	7.5	Female	Fururu	12/11/2007	Time-limited search	Released: female sitting on 30–40 egg clutch
84	48	9	Female	Ngangao	08/10/2007	Time-limited search	Released
85	45	8	Female	Ngangao	28/10/2008	Time-limited search	Released
86	45	6	Female	Chawia	30/10/2007	Time-limited search	Released
87	47	8.5	Female	Chawia	03/12/2007	Time-limited search	Released

Table 3: Continued.

Specimen	SVL (mm)	Wt (g)	Age group	Site	Date	Method	Comments
88	47	12	Female	Ngangao	05/12/2007	Time-limited search	Released
89	40	7.5	Female	Ngangao	05/12/2007	Time-limited search	Released
90	50	7	Female	Mwachora	17/12/2007	Time-limited search	Released
91	20	2	Subadult	Ngangao	6/01/2008	Time-limited search	Released
92	46	—	Female	Mbololo	18/02/2008	Time-limited search	Released
93	45	—	Female	Mbololo	22/02/2008	Time-limited search	Released
94	40	—	Female	Mbololo	25/02/2008	Time-limited search	Released
95	49	8.5	Female	Mwachora	26/02/2008	Time-limited search	Released
96	50	8	Female	Mwachora	14/03/2008	Time-limited search	Released
97	42	—	Female	Vuria	20/03/2008	Time-limited search	Released
98	45	—	Female	Vuria	20/03/2008	Time-limited search	Released
99	22	—	Subadult	Vuria	20/03/2008	Time-limited search	Released
100	40	—	Female	Vuria	21/03/2008	Time-limited search	Released
101	55	—	Female	Vuria	23/03/2008	Time-limited search	Released

Figure 2: A *Callulina dawida* egg mass (clutch) in a ground nest and a displaced female walking away (Oliver Mwakio).

forest individuals were found perched higher than 1 m on tree stems. *Callulina dawida* is normally solitary although on two occasions in Mbololo forest during night transect walks two individuals were found within a meter of one another. One of the adults which had been found perched on a sloping dry thin branch about 30 cm off the ground, was subsequently found on the same site and position the following night. On the forest floor the frog mainly walks but can also make short hops. When disturbed; while walking it tends to become immobile, inflating itself or freezing before proceeding. Information gathered from three marked and recaptured individuals indicates that the species movement is limited: (a) An individual of 20 mm had moved about 25 m after 8 months with a new SVL of 42 mm. (b) An adult of 35 mm was recaptured about 7 m away having increased in SVL to 48 mm after 7 months. (c) An adult of 48 mm was recaptured about 30 m away after 7 months with no change in body length.

4. Discussion

Callulina dawida is a high-elevation species occurring in indigenous forest fragments above 1400 m within Dawida and Mbololo blocks of the Taita Hills [28]. These fragments range from <1 ha to 220 ha [34]. It is absent in typical farmland and plantation habitats as well as the isolated indigenous forest fragments on Kasigau Mountain and Sagalla Hill. Results on monthly distribution showed age group variation in abundance, which for juveniles reflects the time of their recruitment. This means after hatching around November it is in January and February when they are grown-up enough to move around and become easily detected.

Movement is limited in this species justifying its survival in tiny forest patches though continued population viability within such small isolated patches is questionable due to the associated ecological and genetic problems [3, 15, 16]. Ngangao forest had the highest number of individuals captured in traps. This suggests that it has a combination of ideal habitat characteristics suitable for the occurrence of this species. Also there is less human disturbance than in Mwachora and Chawia. The high density of individuals in small fragments such as Vuria forest which is at the highest altitude could be because of a combination of factors. It could be due to the fact that the habitat is ideal and the dispersal area is small and there is low disturbance because of inaccessibility of the forest to humans as well as less predation and competition from other species.

The abundance of the *Callulina dawida* is influenced by temperature with more individuals being recorded during the warm months of the year in the Taita Hills [35]. This coincides with the periods of moderate to high temperatures and humidity. No individuals were recorded in July which is the coldest month in the Taita Hills [36, 37]. These observations concur with other studies that have shown that temperature affects amphibian populations through its effects on growth and development [38]. It was also found that more individuals were recorded in high altitude forests of Ngangao in traps and Vuria in time-limited searches than those on lower elevations. Extrinsic factors such as temperature, rainfall, and altitude are interrelated [38–41] and affect the biology of amphibians and hence their abundance [42]. In particular, studies have found that altitude and its relation with temperature has negative effects on amphibian population [40]. A study on Mount Kupe in Cameroon found that species that do not depend on water for breeding (direct developers like *Callulina dawida*) were more abundant on high altitudes than the open water breeders [43]. Previous studies have generally found that rainfall and temperature directly affect food availability which in turn affects amphibian populations through growth and development and these factors relate to elevation [38–41]. Other studies have found rainfall to be the most important abiotic factor influencing tropical anuran reproduction by affecting and regulating the timing and length of breeding season in open (water) site breeders [21].

Callulina dawida start breeding with calls mainly during the long dry season from around July. The call is a fast repeated "brrr brr brr..." [44]. Then egg clutch is deposited on leaf litter nests in September and the mother broods them for three months until November, a relatively long developmental period as expected at high elevations [38]. While a clutch of 30–40 capsulated eggs was found, it was only 6 that were found towards the end of the incubation. This means that eggs hatch at different times and the young ones immediately leave the nest site. Elsewhere in another brevicipitid (*Probreviceps macrodactylus macrodactylus*), Müller et al. [45] found a clutch of 32 eggs including 21 infertile jelly-filled capsulated eggs laid during the dry season. They suggested that infertile jelly-filled egg capsules prevent the fertile eggs from desiccation during the dry period. This form of parental care is not new as it has been recorded in other brevicipitids, for example, *Probreviceps uluguruensis, Probreviceps macrodactylus loveridgei* [23] and *Probreviceps rhodesianus* [24]. These results also show that *Callulina dawida*, like other brevicipitids, deposit relatively small clutches of large yolk-rich eggs that are buffered by infertile jelly-filled egg capsules. My findings concurs with others that have shown that direct developing montane species produce relatively small clutches of large yolk-rich eggs and exhibit increased parental care [41].

Growth and development in *Callulina dawida* is fast attaining sexual maturity within eight months. This rapid attainment of a reproductive size is expected in tropical areas where temperatures are high, allowing anurans to grow throughout the year [38, 42].

4.1. Conservation and Management Strategy. The species is restricted to severely fragmented indigenous forests and I conclude that its extent of occurrence, area of occupancy, and habitat quality will continue to decline. A combination of these factors makes the species eligible for listing in the critically endangered (CR) category B 1a&b (i, ii, iii, iv) [46]. To ensure a comprehensive protection of *Callulina dawida* maintenance or step-up efforts for all currently known indigenous forest fragments is paramount. I strongly recommend promotion of local initiatives that encourage planting indigenous plant species over exotics and preservation of private or community sacred forest groves including maintenance of potential habitat corridors (e.g., riverine forests) that connect existing forest fragments. I also support habitat restoration programmes that involve careful replacement of exotic tree plantations with native trees.

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