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## Journal of Threatened Taxa

Building evidence for conservation globally

[www.threatenedtaxa.org](http://www.threatenedtaxa.org)

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

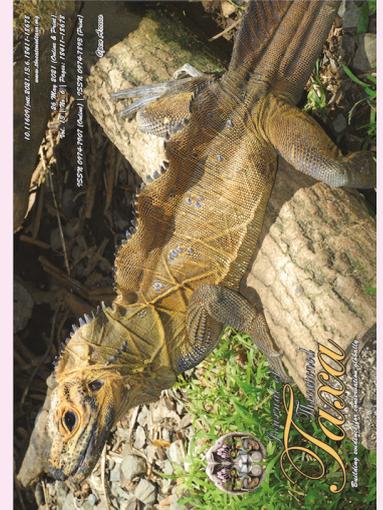
### COMMUNICATION

#### DISCOVERY OF TWO NEW POPULATIONS OF THE RARE ENDEMIC FRESHWATER CRAB *LOUISEA YABASSI* MVOGO NDONGO, VON RINTELEN & CUMBERLIDGE, 2019 (BRACHYURA: POTAMONAUTIDAE) FROM THE EBO FOREST NEAR YABASSI IN CAMEROON, CENTRAL AFRICA, WITH RECOMMENDATIONS FOR CONSERVATION ACTION

Pierre A. Mvogo Ndongo, Thomas von Rintelen, Christoph D. Schubart, Paul F. Clark, Kristina von Rintelen, Alain Didier Missoup, Christian Albrecht, Muriel Rabone, Efole Ewoukem, Joseph L. Tamesse, Minette Tomedi-Tabi Eyango & Neil Cumberlidge

26 May 2021 | Vol. 13 | No. 6 | Pages: 18551–18558

DOI: [10.11609/jott.6724.13.6.18551-18558](https://doi.org/10.11609/jott.6724.13.6.18551-18558)



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## Discovery of two new populations of the rare endemic freshwater crab *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019 (Brachyura: Potamonautidae) from the Ebo Forest near Yabassi in Cameroon, Central Africa, with recommendations for conservation action

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**Abstract:** The endemic freshwater crab, *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, is currently only known from three populations in the biodiversity-rich rainforests of southwestern Cameroon. The first record of *L. yabassi* dates back to 1908 from Yabassi, while the other two populations were discovered in December 2019 and March 2020 from the Ebo Forest near Yabassi. These specimens were initially identified as *L. edeaensis* (Bott, 1969), but were subsequently assigned to *L. yabassi*. The newly-discovered populations of *L. yabassi* provided important data on its habitat, population structure and geographical distribution, all critical knowledge for conservation measures. Reported here are the anthropogenic threats to *L. yabassi* and its rainforest habitat, which include forest destruction, agricultural encroachment, water pollution and firewood collection. This information is inherently useful in the assessment of the extinction risk of *L. yabassi* and highlights the importance of implementing strategies for preserving primary rainforest and its associated aquatic habitats in Central Africa.

**Keywords:** Cameroon, Conservation action plan, diversity, Ebo Forest, freshwater crab, *Louisea edeaensis*, *L. yabassi*, threats, Yabassi.

**Résumé :** Le crabe d'eau douce, *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, est endémique et exclusivement connu par trois populations dans les riches forêts du sud du Cameroun. Il a été collecté pour la première fois en 1908 dans la zone de Yabassi, les deux autres populations ont été échantillonnées en décembre 2019 et mars 2020 dans la forêt d'Ebo près de Yabassi. Les spécimens, initialement identifiés comme *L. edeaensis* (Bott, 1969), ont par la suite été reconnus comme étant des représentants de la nouvelle espèce *L. yabassi*. Les spécimens nouvellement collectés ont fourni des données importantes sur l'habitat, la structure des populations et la répartition géographique de *L. yabassi*, toutes ces connaissances étant préalables pour décider des mesures de conservation de l'espèce. Les menaces anthropiques pesant sur *L. yabassi* sont signalées ici, notamment la destruction des forêts, les activités agricoles, la pollution de l'eau et la collecte du bois de chauffage. Ces informations sont importantes pour l'évaluation du risque d'extinction de *L. yabassi* et soulignent l'importance de la mise en œuvre de stratégies de préservation de la forêt tropicale primaire et de ses habitats aquatiques associés en Afrique Centrale.

**Mots clés:** Plan d'action de conservation, crabe d'eau douce, *Louisea edeaensis*, *L. yabassi*, menaces, diversité, forêt d'Ebo, Yabassi, Cameroun.

**Editor:** Anonymity requested.

**Date of publication:** 26 May 2021 (online & print)

**Citation:** Mvogo Ndongo, P.A., T. von Rintelen, C.D. Schubart, P.F. Clark, K. von Rintelen, A.D. Missoup, C. Albrecht, M. Rabone, E. Ewoukem, J.L. Tamesse, M. Tomedi-Tabi Eyango & N. Cumberlidge (2021). Discovery of two new populations of the rare endemic freshwater crab *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019 (Brachyura: Potamonautidae) from the Ebo Forest near Yabassi in Cameroon, Central Africa, with recommendations for conservation action. *Journal of Threatened Taxa* 13(6): 18551–18558. <https://doi.org/10.11609/jott.6724.13.6.18551-18558>

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**Funding:** We thank the Rufford Small Grant Foundation (ID: 28462-D) for funding the field work in southern and southwestern Cameroon.

**Competing interests:** The authors declare no competing interests.

For **Author details**, **Author contributions** and **Acknowledgements** see end of this article.



## INTRODUCTION

The present work arises from the discovery of two new populations of *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, from the Ebo Forest near Yabassi in southwestern Cameroon. This rare endemic species of freshwater crab is currently known from just three small populations found in Yabassi (collected in 1908; Cumberlidge 1994b, 1999), and the Ebo Forest (collected in December 2019 and March 2020; Mvogo Ndongo et al. 2019).

The Ebo Forest, where *L. yabassi* was rediscovered (Figure 1, Image 2), is the largest remaining tract of primary lowland and submontane rainforest in this part of Africa, and is drained by the Wouri and Dibamba rivers that flow into the Atlantic Ocean. This forested area represents a key biodiversity hotspot in southwestern Cameroon for a number of freshwater taxa including crabs. The freshwater catchments of the Ebo Forest are important spawning grounds for fish and invertebrates, and the forest is also a refuge for charismatic wildlife including monkeys, chimpanzees, gorillas, manatees, elephants, birds, turtles, snakes, and amphibians (Cumberlidge 1994b, 1999; Morgan & Abwe 2006; Morgan et al. 2013).

The rediscovery of *L. yabassi* after over 110 years means that living specimens of this species are now available for scientific studies that allow for DNA analysis, a description of its habitat, and ecological and population studies. The difficult taxonomy and the chronic lack of material in the past meant that the original specimens from Yabassi were initially identified as *L. edeaensis* (Bott, 1969) by Cumberlidge (1994a, 1999) and Mvogo Ndongo et al. (2017a).

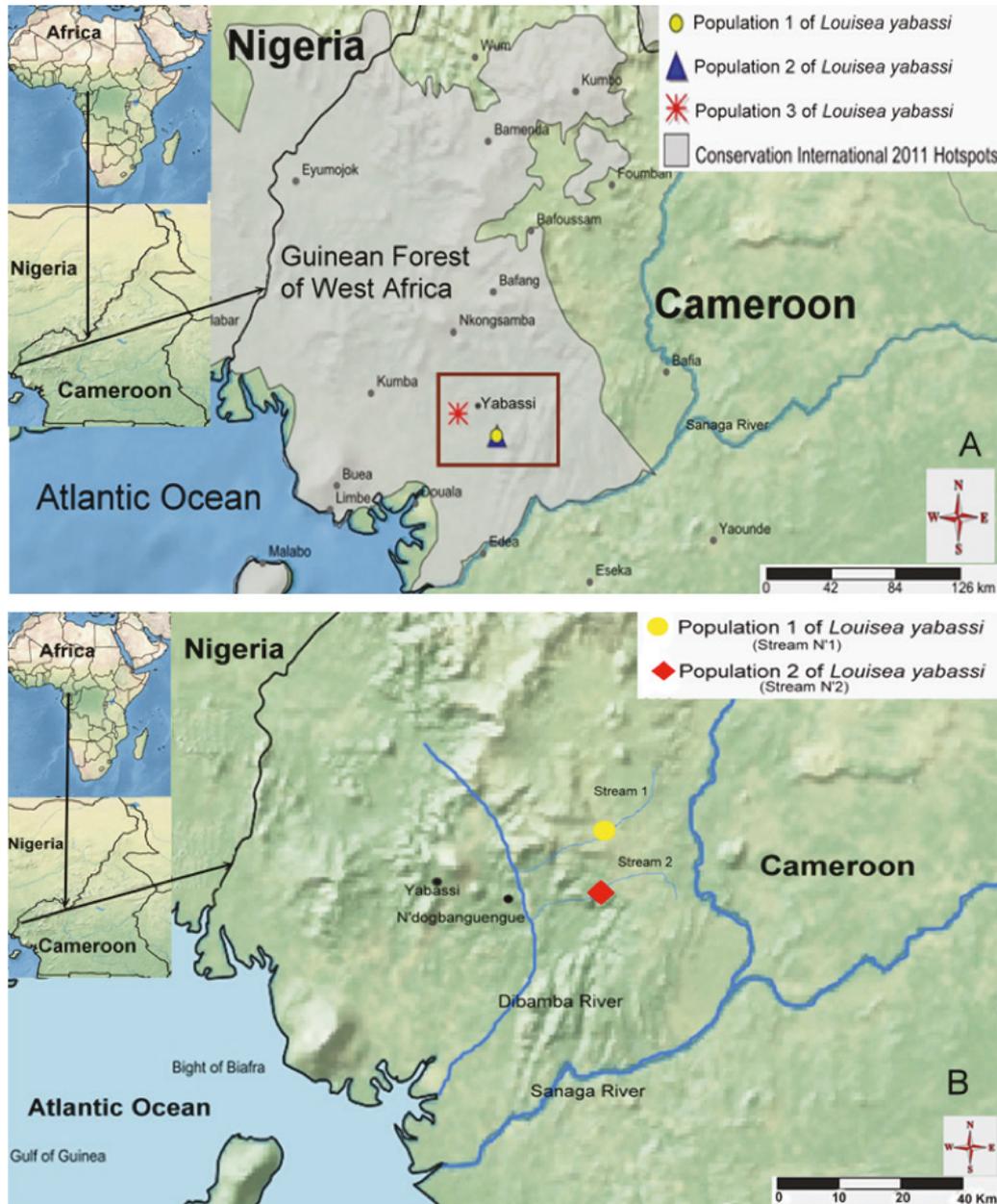
Preliminary surveys indicated that this newly-rediscovered species is facing immediate threats to its freshwater habitat from forest destruction, agricultural encroachment, water pollution, and firewood collection. Presented here is the necessary field data for an IUCN Red List extinction risk assessment of this species including its specific habitat requirements, population trends, distribution, and threats (Mvogo Ndongo et al. 2017a). The importance of assessing the extinction risk of *L. yabassi* is underlined by the status of two other rare endemic species assigned to *Louisea* in southwestern Cameroon, *L. edeaensis* (Cumberlidge, 1994) and *L. balssi* (Bott, 1969) that are both currently listed as Endangered species (EN) on the International Union for Conservation of Nature (IUCN) Red List.

## Freshwater crab diversity in southwestern Cameroon

The rainforests of southwestern Cameroon are emerging as a leading biodiversity hotspot in Sub-Saharan Africa for freshwater crabs (Cumberlidge 1999; Cumberlidge et al. 2019; Mvogo Ndongo et al. 2020). This part of the country currently harbours 22 species of freshwater crabs in five genera all assigned to Potamonautinae (*Buea* Cumberlidge, Mvogo Ndongo, Clark & Daniels, 2019; *Louisea* Cumberlidge, 1994; *Potamonemus* Cumberlidge & Clark, 1992; *Potamonautes* Macleay, 1838; and *Sudanonautes* Bott, 1955 (Cumberlidge 1987, 1989, 1993a–c, 1994a,b, 1995a–d, 1999; Cumberlidge & Clark 1992; Cumberlidge & Boyko 2000; Cumberlidge et al. 2019; Mvogo Ndongo et al. 2017a–c, 2018, 2019, 2020)).

The semi-terrestrial species of freshwater crabs endemic to the rainforests of southwestern Cameroon are of great conservation importance and are also the most threatened by anthropogenic activities in these forests (see Table 1). These species are: *Buea asylos* (Cumberlidge, 1993), *B. bangem* Mvogo Ndongo, von Rintelen, Tomedi-Tabi & Cumberlidge, 2020, *B. mundemba* Mvogo Ndongo, von Rintelen & Cumberlidge, 2020, *B. nlonako* Mvogo Ndongo, von Rintelen & Cumberlidge, 2020, *Louisea balssi* (Bott, 1969), *L. edeaensis* (Bott, 1969), *L. nkongsamba* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, *L. yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, and *Sudanonautes tiko* Mvogo Ndongo, Schubart & Cumberlidge, 2017. Two of these species, *L. balssi* and *L. edeaensis*, are already assessed as EN by the IUCN Red List, and were previously thought to be extinct until their rediscovery in 2017 and 2018 (IUCN 2003; Cumberlidge 2008a,b; Cumberlidge et al. 2009; Mvogo Ndongo et al. 2017a; 2018). These threatened species of freshwater crabs are found in an area of great conservation interest, because their aquatic habitats also serve as key spawning grounds for fish and invertebrates, as well as refugia for other forest wildlife, e.g., monkeys, drills, chimpanzees, and gorillas as well as manatees, elephants, birds, turtles, snakes and amphibians (Cumberlidge et al. 2019; Mvogo Ndongo et al. 2017a–c, 2018, 2019, 2020). Consequently, these areas increasingly attract scientists and tourists.

The high rate of endemism of freshwater crabs in southwestern Cameroon reflects their low dispersal abilities arising from a lifecycle that includes direct development of eggs into young crabs, without the highly dispersive planktonic larval stages seen in marine crabs (Cumberlidge & Daniels 2007). Most of these endemic species of freshwater crabs (*B. bangem*, *B. mundemba*, *L. balssi*, and *L. edeaensis*) are still only known from



**Figure 1.** Collection localities of the populations of *Louisea yabassi* endemic to southwestern Cameroon. A—Population 1 (circle), population 2 (triangle) both found in the Ebo Forest, population 3 (asterisk) collected between 1900 and 1909 near Yabassi | B—Sampling sites of the newly discovered populations found in the Ebo Forest.

a single population. Other species are better known and are represented by at least two populations, most likely revealing strong phylogeographical structuring. Despite advances in our knowledge of the taxonomy, habitat, and distributional range of each of these species, information on their reproductive biology, ecology, phylogeography, and evolutionary relationships is still extremely limited. This is a problem because of the urgent need to provide vital biological data that are necessary for the management of the freshwater crabs

of southwestern Cameroon and to monitor changes in their populations and habitat as a result of conservation interventions. The present study aims to formulate guidelines towards a more sustainable use of forest and aquatic resources from southwestern Cameroon, and lay the groundwork for a conservation assessment of those species of endemic freshwater crabs most vulnerable to anthropogenic threats.

## MATERIAL AND METHODS

The data presented here for *L. yabassi* were compiled during field surveys of the rivers, streams, wetlands, and nearby land in the Ebo Forest near Yabassi in December 2019 and March 2020. The number of plants destroyed by natural and human activities was assessed at the locality and around the sampling sites. The pH and temperature of water samples where crabs occurred were measured (Table 2), and specimens were identified using the keys provided by Cumberlidge et al. (2019) and Mvogo Ndongo et al. (2019; 2020). Carapace measurements of each specimen were taken using digital callipers, and sex and age were recorded. Photographs of freshly caught specimens and the habitat from where they were collected (Image 1) are also provided. Most specimens were returned to their place of origin, except for one adult male and female, which were preserved in ethanol for subsequent detailed morphological and molecular analyses.

## RESULTS

The updated distributional range of *L. yabassi* is presented in Figure 1A. The two populations recently discovered in the Ebo Forest were collected from two small streams ('stream-1' and 'stream-2') that flow independently into the Dibamba River at the locality N'dogbanguengue (Figure 1B). The first population (15 males and five females) was found ca. 10m from the middle of stream-1 in December 2019 (Figure 1B, Image 2A). At that time of the year, the water levels of the streams and rivers are at their peak and are difficult to sample, so all of our specimens of *L. yabassi* were collected from semi-aquatic habitats on land, adjacent to the streams in damp conditions in puddles, under fallen leaves, and in burrows. The second population of *L. yabassi* (nine males and six females) was found ca. 8m from the middle of stream-2 in March 2020 (Figure 1B, Image 2B). At this time of the year, the water levels of the streams and rivers are much lower, so that sampling in the large streams was now possible under the rocks and boulders that sheltered crabs (Image 2). Most of the natural vegetation at these localities had been destroyed as a result of human activities (by foresters, farmers, and others). The trees had been logged to build huts, camps, and toilets. The remaining vegetation in these locations had been removed for intensive agricultural practices and for firewood. In addition, the farmers encroaching on these habitats use agro-chemicals and pesticides

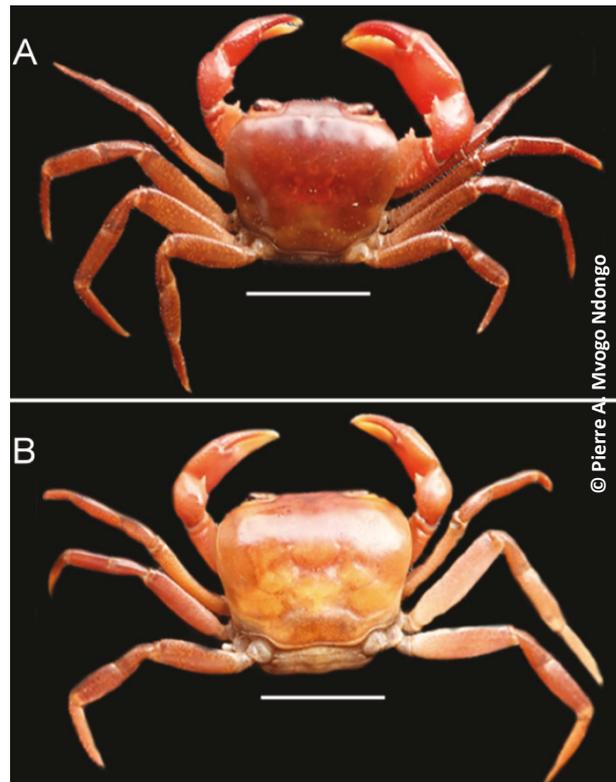


Image 1. *Louisea yabassi* in their natural colour: A—largest adult male | B—largest adult female. Scale bars A, B: 12mm.

on their crops, and these pollutants eventually drain into the aquatic systems and can poison the freshwater communities.

## DISCUSSION

### Current threats to *Louisea yabassi*

Deforestation, together with intensive and encroaching agricultural practices, are serious issues. These activities present imminent threats to southwestern Cameroon's rich aquatic biodiversity, which is of concern, because this area includes a number of rare endemic species. Large scale habitat disturbance also has a negative impact on the culture of the indigenous people of this region, who depend on the intact forest for their livelihoods. For example, the Pygmy forest people of this part of Cameroon express their problems as follows. "[...] We are in the midst of huge desolation, we no longer recognize the forest, we no longer understand what is happening. Our forests change from one day to the next. What future awaits our children? The settlements destroy the forest, and the felling of trees prevents us from gathering honey to feed our children. The noise



**Table 1. Semi-terrestrial species of primary freshwater crabs endemic to southwestern Cameroon that have been described or redescribed in the last five years, along with the number of populations, locality, habitats, main threats, and IUCN Red List status.**

Genus	Species	Number of known populations	Locality	Habitat	Main threats	IUCN Red List status
<i>Buea</i>	<i>B. asylos</i>	2	Kumba (Southwestern region)	Streams	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Mvogo Ndongo et al. 2020)	VU (Cumberlidge 2008a,b)
	<i>B. bangem</i>	1	Bangem (Southwestern region)	Streams, puddles, and in the damp conditions under stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Ndongo et al. 2020)	NA
	<i>B. mundemba</i>	1	Mundemba (Southwestern region)	Streams, puddles, and in the damp conditions under stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Ndongo et al. 2020)	NA
	<i>B. nlonako</i>	2	Nlonako (Eastern and northern slopes) (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation, agro-chemical release (Mvogo Ndongo et al. 2020)	NA
<i>Louisea</i>	<i>L. balssi</i>	1	Manengouba (Southwestern region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Ndongo et al. 2018, 2019)	EN (Cumberlidge 2008a,b)
	<i>L. edeaensis</i>	1	Bedimet Island of Lake Ossa (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, agro-chemical release, invasive plants, (Mvogo Ndongo et al. 2017a, 2019)	EN (Cumberlidge 2008a,b)
	<i>L. nkongsamba</i>	3	Nlonako (Eastern, southern, northern slopes) (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation, agro-chemical release. (Mvogo Ndongo et al. 2019)	NA
	<i>L. yabassi</i>	2	Ndogbangueue, Yabassi (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation	NA
<i>Sudanonautes</i>	<i>S. tiko</i>	2	Tiko, Edea (Littoral and southwestern regions)	Wetlands, in puddles, and in the damp conditions under small stones	Forest destruction, firewood collection, agricultural encroachment, agro-chemical release. (Mvogo Ndongo et al. 2017b)	NA

NA—not assessed | EN—endangered | VU - Vulnerable.

**Table 2. Field information of two distinct populations of *Louisea yabassi* from the Ebo Forest in southwestern Cameroon, central Africa, showing the geographical coordinates, water pH, water temperature, and the number of specimens at each locality (all collected by P.A. Mvogo Ndongo).**

<i>Louisea yabassi</i>	Geographical coordinates	pH	Water temperature	Number of specimens	Date rediscovered	Plant covering around the locality
Population N°1 in Stream-1	N04.41715°, E010.20021°	6.26	26.9° C	20	10/12/2019	Heavily disturbed
Population N°2 in Stream-2	N04.41646°, E010.20213°	6.70	26.5° C	15	13/12/2019	Heavily disturbed

of their huge machines is causing the animals to flee far away. The trees falling into the rivers and small streams alter the water flow, and the muddy stream beds harm the animals and plants. Some fruits are becoming scarce and we have to walk for a long time to find them. And

the mushrooms we used to gather everywhere are gone. [...] Our children have no future. Where will they find animals to hunt? The bark, the leaves and the fruits for curing and eating? [...]” (See World Rainforest Movement Report, November, 2002, Page 36).



**Image 2.** Streams in Ebo Forest where the newly discovered populations of *Louisea yabassi* were collected: A—Stream-1 | B—Stream-2. © Pierre A. Mvogo Ndongo.

Deforestation has direct effects on the aquatic environment and indirect impacts from changes within the drainage basin, both of which will affect rare endemic forest species, such as *L. yabassi*, that depend on the forest canopy remaining closed and intact (Cumberlidge & Sachs 1991; Dudgeon et al. 2005; Mvogo Ndongo et al. 2018). Not only does deforestation expose aquatic systems and their inhabitants to the heating and drying effects of direct sunlight, but local farming practices also release pollutants such as agro-chemicals potentially affecting the eggs, hatchling-carrying females, and adults of *L. yabassi*. In addition, clearing the tropical rainforest leads to increased agricultural encroachment and firewood collection, which further impacts the habitat of *L. yabassi*.

### Conservation recommendations

The extinction risk status of *L. yabassi* has not yet been assessed, but the data now available allow us to present a preliminary pre-assessment. Unfortunately, the two additional localities for this species are so close together that IUCN Red List protocols treat them as a single location. This is because the calculation of the extent of occurrence (EOO, the area contained within the minimum convex polygon around all sites of present

occurrence) and the area of occupancy (AOO, the area within the EOO that is actually occupied by the taxon) requires at least three locations. Despite this, if an IUCN Red List extinction risk assessment were to be made, then we anticipate that *L. yabassi* would be assessed as Critically Endangered (CR) under criterion B alone using the small number of locations, the low population levels, the disruption of the habitat, and the severity of the immediate known threats.

The obvious nature and the large scale of the threats to the habitat of *L. yabassi* in the Ebo Forest mean that a conservation action plan needs to be formulated if this threatened species is to be protected from the anthropogenic threats it is facing. Conservation actions include the monitoring of populations, studies of population genetics, and protection against threats. These actions would also include a strategy for communication and education of the stakeholders in the local community about the consequences of engaging in forest destruction, firewood collection, and agricultural encroachment. Local knowledge from indigenous people should also form part of the conservation messaging. Conservation action on a local scale is feasible because of its 'low-tech' approach that is necessary (and successful) in the context of rural Africa. The content of the educational messaging needs to be structured to highlight the need for protection and to emphasise the potential advantages brought to the area by increased numbers of visitors (eco-tourists and scientists). The targeted stakeholders in the local communities should be brought to understand that *L. yabassi* is found only in the remaining rainforest tracts around Yabassi, and that this habitat is globally unique. The semi-terrestrial lifestyle of *L. yabassi* means that its habitat ranges from permanent streams to seasonal shallow waters and wetlands, all of which are impacted by intensive destructive agricultural practices that degrade and pollute the natural vegetation. The release of pesticides into the environment containing substances that either harm or kill most species of invertebrates and vertebrates (most certainly including *L. yabassi*) needs to be mitigated. In addition, these pesticides have been linked to a wide range of human health hazards ranging from headaches and nausea to cancer, reproductive harm, and endocrine disruption. Pesticides have also been linked to nerve, skin, and eye irritation, dizziness, fatigue, and even sometimes fatal systemic poisoning (Roberts & Reigart 2013).

In addition to highlighting the problems facing the rainforest around Yabassi and the Ebo Forest, the education of the local people and the Government includes the need for awareness building about the



broader lasting benefits of conservation action. These include hosting and guiding tourists and scientists from Cameroon and all around the world attracted by Africa's intact tropical rainforest ecosystems and associated unique wildlife. Further, the local markets and hospitality industry in the area will benefit from the increased flow of visitors, and this will contribute to the development of the local community. The problem of firewood collection requires the promotion of the legal harvesting of forest resources found in the forested habitat of *L. yabassi*. This distinction is important because there are no alternative sources of firewood other than the natural rainforest itself. Legal exploitation of forest resources involves avoiding cutting young trees and bushes, and only cutting off dead branches or using parts of the trees that fall naturally. It also means that the vegetation that falls around streams should be left untouched, because this constitutes good habitat for aquatic invertebrates, including *L. yabassi*. As for agricultural encroachment, it is necessary to recommend to farmers to focus their attention on land that has already been used for cultivation and direct them away from the natural vegetation around the streams that form the habitat of *L. yabassi*. What this study suggests is that farmers should curtail their activities, avoid disturbing the natural vegetation near aquatic habitats and keep these watersheds free from pesticides.

The success of this conservation action also requires public training/education sessions (workshops) aimed at involving a wider section of the local community beyond those individuals encountered during field work. Monitoring strategies for *L. yabassi* mean that local young people, students, and engineers need to be trained in how to communicate the above educational messages, and how to undertake routine monitoring to collect data on the organisms present in a habitat and general ecosystem health. The local authorities (e.g., the chiefs of the villages, sub-prefets, and prefets) need to be directly involved, because educational messaging in the community is an ongoing process, and the involvement of community leaders is key to engaging the wider community in these conservation efforts. The targets of the educational messages (local people, fishermen, farmers, foresters, hunters, and other scientists) should also be made aware of the need to constantly monitor the health of the habitat, such as monitoring changes in forest cover, agricultural practices, and the expansion of farms. As conservationists it is of great importance to inform people on the broader role of biodiversity (vertebrates and invertebrates) in the rainforest ecosystem and why illegal poaching of wildlife (e.g.,

gorillas, chimpanzees, and numerous bird species) and unsustainable fishing practices (such as small mesh size of nets, unenforced fishing seasons, and fishing with poison) requires controlling.

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- Author contributions:** Pierre A. Mvogo Ndongo collected the data, Pierre A. Mvogo Ndongo, Neil Cumberlidge, Thomas von Rintelen, Christoph Schubart, Paul Clark, Christian Albrecht, and Muriel Rabone analysed the data and wrote the manuscript. Kristina von Rintelen, Alain Didier Missoup, Thomas Efole Ewoukem, Joseph L. Tamesse, and Minette Tomedi Tabi-Eyango gave valuable inputs in data processing and made constructive improvements to the manuscript.
- Acknowledgements:** We thank the Rufford Small Grant Foundation for funding the field work in southern and southwestern Cameroon. We are also grateful to Dr. Ekwoje Awe and Mr. Daniel Fossa for their support during the first fieldtrip to a rainforest of Yabassi (Ebo Forest Zone). Dr. Charles Fransen (Naturalis Biodiversity Centre, Leiden, The Netherlands), Dr. Tomoyuki Komai (Natural History Museum and Institute, Chiba, Japan) provided the first author with constructive advice during the course of the project.





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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

May 2021 | Vol. 13 | No. 6 | Pages: 18411–18678

Date of Publication: 26 May 2021 (Online & Print)

DOI: 10.11609/jott.2021.13.6.18411-18678

#### Conservation Application

##### First attempt at rehabilitation of Asiatic Black Bear cubs to the wild in Thailand

– Robert Steinmetz, Worrapan Phumane, Rungnapa Phoonjampa & Suthon Weingdow, Pp. 18411–18418

#### Communications

##### Status of Sumatran Tiger in the Berbak-Sembilang landscape (2020)

– Tomi Ariyanto, Yon Dinata, Dwiyanto, Erwan Turyanto, Waluyo Sugito, Sophie Kirkin & Rajan Amin, Pp. 18419–18426

##### The diversity of small mammals in Pulau Perhentian Kecil, Terengganu, Malaysia

– Aminuddin Baqi, Isham Azhar, Ean Wee Chen, Faisal Ali Anwarali Khan, Chong Ju Lian, Bryan Raveen Nelson & Jayaraj Vijaya Kumaran, Pp. 18427–18440

##### Patterns, perceptions, and spatial distribution of human-elephant (*Elephas maximus*) incidents in Nepal

– Raj Kumar Koirala, Weihong Ji, Yajna Prasad Timilsina & David Raubenheimer, Pp. 18441–18452

##### Assessing spatio-temporal patterns of human-leopard interactions based on media reports in northwestern India

– Kaushal Chauhan, Arjun Srivathsa & Vidya Athreya, Pp. 18453–18478

##### Bat diversity in the Banpale forest, Pokhara, Nepal during spring season

– Prabhat Kiran Bhattarai, Basant Sharma, Anisha Neupane, Sunita Kunwar & Pratyush Dhungana, Pp. 18479–18489

##### A patho-microbiological study of tissue samples of the Greater Adjutant *Leptoptilos dubius* (Aves: Ciconiiformes: Ciconiidae) that died in Deeporbeel Wildlife Sanctuary, Assam, India

– Derhasar Brahma, Parikshit Kakati, Sophia M. Gogoi, Sharmita Doley, Arpita Bharali, Biswajit Dutta, Taibur Rahman, Saidul Islam, Arfan Ali, Siraj A. Khan, Sailendra Kumar Das & Nagendra Nath Barman, Pp. 18490–18496

##### Vaduvur and Sitheri lakes, Tamil Nadu, India: conservation and management perspective

– V. Gokula & P. Ananth Raj, Pp. 18497–18507

##### A new species of shieldtail snake (Squamata: Uropeltidae: Uropeltis) from the Bengaluru uplands, India

– S.R. Ganesh, K.G. Punith, Omkar D. Adhikari & N.S. Achyuthan, Pp. 18508–18517

##### A looming exotic reptile pet trade in India: patterns and knowledge gaps

– A. Pragatheesh, V. Deepak, H.V. Girisha & Monesh Singh Tomar, Pp. 18518–18531

##### Legal or unenforceable? Violations of trade regulations and the case of the Philippine Sailfin Lizard *Hydrosaurus pustulatus* (Reptilia: Squamata: Agamidae)

– Sarah Heinrich, Adam Toomes & Jordi Janssen, Pp. 18532–18543

##### Conservation breeding of Northern River Terrapin *Batagur baska* (Gray, 1830) in Sundarban Tiger Reserve, India

– Nilanjan Mallick, Shailendra Singh, Dibyadeep Chatterjee & Souritra Sharma, Pp. 18544–18550

##### Discovery of two new populations of the rare endemic freshwater crab *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019 (Brachyura: Potamonautidae) from the Ebo Forest near Yabassi in Cameroon, Central Africa, with recommendations for conservation action

– Pierre A. Mvogo Ndongo, Thomas von Rintelen, Christoph D. Schubart, Paul F. Clark, Kristina von Rintelen, Alain Didier Missoup, Christian Albrecht, Muriel Rabone, Efole Ewoukem, Joseph L. Tamesse, Minette Tomedi-Tabi Eyango & Neil Cumberlidge, Pp. 18551–18558

##### Checklists of subfamilies Dryptinae and Panagaeinae (Insecta: Coleoptera: Carabidae) from the Indian subcontinent

– V.A. Jithmon & Thomas K. Sabu, Pp. 18559–18577

##### Mantids (Insecta: Mantodea) of Uttar Pradesh, India

– Ramesh Singh Yadav & G.P. Painkra, Pp. 18578–18587

##### An assessment of genetic variation in vulnerable Borneo Ironwood *Eusideroxylon zwageri* Teijsm. & Binn. in Sarawak using SSR markers

– Siti Fatimah Md.-Isa, Christina Seok Yien Yong, Mohd Nazre Saleh & Rusea Go, Pp. 18588–18597

#### Review

##### Termites (Blattodea: Isoptera) of southern India: current knowledge on distribution and systematic checklist

– M. Ranjith & C.M. Kalleshwaraswamy, Pp. 18598–18613

#### Short Communications

##### Population status and distribution of Ibisbill *Ibidorhyncha struthersii* (Vigors, 1832) (Aves: Charadriiformes: Ibidorhynchidae) in Kashmir Valley, India

– Iqram Ul Haq, Bilal A. Bhat, Khurshid Ahmad & Asad R. Rahmani, Pp. 18614–18617

##### A new fish species of genus *Garra* (Teleostei: Cyprinidae) from Nagaland, India

– Sophiya Ezung, Bungdon Shangningam & Pranay Punj Pankaj, Pp. 18618–18623

##### Occurrence of Tamdil Leaf-litter Frog *Leptobrachella tamdil* (Sengupta et al., 2010) (Amphibia: Megophryidae) from Manipur, India and its phylogenetic position

– Ht. Decemson, Vanlalsiammawii, Lal Biakzuala, Mathipi Vabeiryureilai, Fanai Malsawmdawngliana & H.T. Lalremsanga, Pp. 18624–18630

##### Further additions to the Odonata (Insecta) fauna of Asansol-Durgapur Industrial Area, Paschim Bardhaman, India

– Amar Kumar Nayak & Subhajit Roy, Pp. 18631–18641

##### A note on the ecology and distribution of Little Bloodtail *Lyriothemis acigastra* Brauer, 1868 (Insecta: Odonata: Libellulidae) in Kerala, India

– Jeevan Jose, Muhamed Sherif & A. Vivek Chandran, Pp. 18642–18646

#### Viewpoint

##### A unique archetype of conservation in Himachal Pradesh, western Himalaya, India

– Rupali Sharma, Monika Sharma, Manisha Mathela, Himanshu Bargali & Amit Kumar, Pp. 18647–18650

#### Notes

##### A camera trap record of Asiatic Golden Cat *Catopuma temminckii* (Vigors & Horsfield, 1827) (Mammalia: Carnivora: Felidae) in State Land Forest, Merapoh, Pahang, Malaysia

– Muhamad Hamirul Shah Ab Razak, Kamarul Hambali, Aainaa Amir, Norashikin Fauzi, Nor Hizami Hassin, Muhamad Azahar Abas, Muhammad Firdaus Abdul Karim, Ai Yin Sow, Lukman Ismail, Nur Azmin Huda Mahamad Shubli, Nurul Izzati Adanan, Ainur Izzati Bakar, Nabihah Mohamad, Nur Izyan Fathiah Saimhe, Muhammad Syafiq Mohamad Nor, Muhammad Izzat Hakimi Mat Nafi & Syafiq Sulaiman, Pp. 18651–18654

##### Reappearance of Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) in Gujarat after 70 years

– A.A. Kazi, D.N. Rabari, M.I. Dahya & S. Lyngdoh, Pp. 18655–18659

##### Mating behavior of Eastern Spotted Skunk *Spilogale putorius* Linnaeus, 1758 (Mammalia: Carnivora: Mephitidae) revealed by camera trap in Texas, USA

– Alexandra C. Avrin, Charles E. Pekins & Maximillian L. Allen, Pp. 18660–18662

##### Record of Indian Roofed Turtle *Pangshura tecta* (Reptilia: Testudines: Geoemydidae) from Koshi Tappu Wildlife Reserve, Nepal

– Ashmita Shrestha, Ramesh Prasad Sapkota & Kumar Paudel, Pp. 18663–18666

##### Additional distribution records of *Zimiris doriae* Simon, 1882 (Araneae: Gnaphosidae) from India

– Dhruv A. Prajapati, Pp. 18667–18670

##### Notes on new distribution records of *Euspa motokii* Koivaya, 2002 (Lepidoptera: Lycaenidae: Theclinae) from Bhutan

– Jigme Wangchuk, Dhan Bahadur Subba & Karma Wangdi, Pp. 18671–18674

##### New distribution records of two little known plant species, *Hedychium longipedunculatum* A.R.K. Sastry & D.M. Verma (Zingiberaceae) and *Mazus dentatus* Wall. ex Benth. (Scrophulariaceae), from Meghalaya, India

– M. Murugesan, Pp. 18675–18678

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