Bioacoustic assessment of the impact of habitat degradation and partial regeneration on the anuran community in the Mugesera wetland, eastern Rwanda

Mapendo Mindje[1] , Lambert Tumushimire[2] & Ulrich Sinsch[3]

[1.] University of Rwanda, College of Agriculture, Animal Sciences and Veterinary Medicine, Department of Forestry and Nature Conservation, P.O. Box: 117, Huye, Rwanda

[2.] University of Rwanda, College of Sciences and Technology, Biodiversity Conservation and Natural Resources Management, P.O. Box: 117, Huye, Rwanda

[3.] Universität Koblenz-Landau, Institut für Integrierte Naturwissenschaften, Abteilung Biologie, Universitätsstr. 1, 56070 Koblenz, Germany

Afrixalus quadrivittatus

Sclerophrys regularis

African painted frog, *Calliixalus pictus*, last seen in 1956 in Rwanda. Photography Society for the Study of Evolution/Conservation International

Background

- Anurans provide tangible services in the ecosystem (Hocking & Babbitt, 2014) and can be considered useful indicators of wetland health (Saber et al., 2017).
- Anuran population are declining worldwide due to multiple factors (Hof et al., 2011; Stuart et al., 2004).
- Wetlands are crucial for different ecosystem services to human and biodiversity (Barbier, 1997; Rebelo et al., 2010).
- In Rwanda, 53 anuran species and one Gymnophona (*Boulengerula fischeri*) have been identified in Rwanda; *Callixalus pictus* is believed to be extinct.

Rwandan wetlands under human use

- To cope with the issue of food security, the policy for agriculture intensification which includes growing rice in wetlands has been adopted (Nahabanga & Visser, 2013) and may be potential threats to anuran population in Rwanda.
- Rwanda has established programs to manage and restore degraded wetlands and some of these have been recommended as RAMSAR sites such as the Mugesera wetland part of Rweru-Mugesera complex (Karame et al., 2017).

Rice field in wetland-Picture by RWFA

Study problem

Some Rwandan wetlands have been subjected to restoration programs.

Mugesera wetland was heavily exploited by humans before and slightly after 2011 before it was proposed as a RAMSAR site in 2017 (GoR, 2017).

Lack of baseline information to assess effectiveness of the restoration program.

Anurans can be excellent bioindicators of wetland health but are poorly studied in Rwanda (Dehling & Sinsch, 2013).

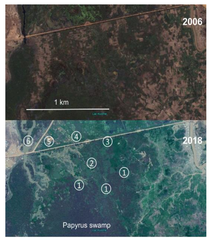
The lack of information on anuran taxonomy, diversity and distribution limits the ability to effectively manage and conserve wetlands in Rwanda.

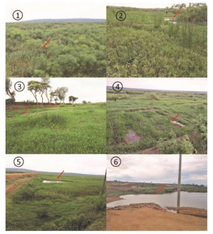
Study objectives

- **The main objective**
  - •Bioacoustically assess the impact of habitat degradation and partial regeneration on the anuran community diversity in the Mugesera wetland, eastern Rwanda.
- **Specific objectives**
  - •Determine the composition of anuran community in Mugesera wetland
  - •Determine the correlation between anuran calling activity (abundance) and time of day and microhabitat types
  - •Estimate diversity and richness of the anuran community in the Mugesera wetland
  - •Assess impact of human disturbance at microhabitat scale on species richness and diversity

Methods - Study area

Mugesera wetland, part of the Rweru-Mugesera wetland complex in Bugesera district; proposed RAMSAR site. Covered by *Papyrus* reed which forms species-poor plant community.





Six microhabitats were selected

1. Edge of uncultivated Papyrus
2. Swamp intermediate
3. Swamp near road
4. Semi cultivated swamp
5. Fish pond
6. Dammed lake

Table 1. Microhabitats and their disturbance history

Microhabitat	Level of disturbance (%)	Structure
Edge of the papyrus swamp (three replicate sites	10%	Regenerated natural-like habitat with little open water surface
Intermediate swamp	40-50%	Obvious signs of human use especially agriculture
Swamp near road	70-80%	Short grasses and small open water bodies
Semi-cultivated swamp	80-90%	Mixed short and tall grasses with small water bodies and agriculture activities
Fishpond	80-90%	Shore vegetation and open water bodies
Dammed Lake	100%	Open large water body and little to no vegetation at the steep shores

Sampling

Bioacoustic and visual surveys done in **six microhabitat** types for **eight nights** in three months (Oct, Nov and Dec., three replicate surveys in each) during the rainy period of 2018.

In each night, advertisement calls were recorded using a **PCM** sony recorder in a motionless position for 2 minutes at 7, 8, and 9 pm inclusive,

Data set: 192 recordings taken (24 records at each microhabitats)

➢**Anuran identification:**

Call structure (Adobe audition)

Morphological corroborations

Homing in approach

Expert consultation

➢**Statistical analysis:**

Alpha- and Beta-diversity measures using EstimateS version 9.1.0 .

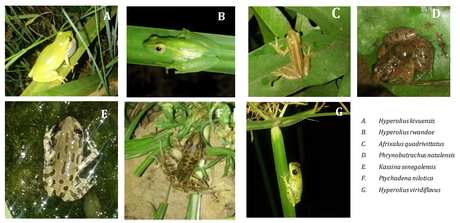
ANCOVA (impact of human disturbance and species diversity and estimate influence of time of day and type of microhabitat on calling activity (abundance))

Statistical procedures made using Statgraphics Centurion version 18.1.01 (64-bit).

Results

Objective 1. Composition of anuran community in Mugesera wetland

- **12 anuran species were detected**
- •**Visual & acoustic detection: seven species**



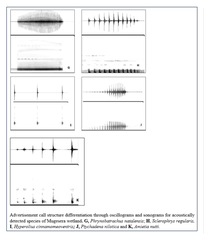
A. *Hyperolius kivuensis*
B. *Hyperolius rwandae*
C. *Afrixalus quadrivittatus*
D. *Phrynobatrachus natalensis*
E. *Kassina senegalensis*
F. *Pychadena nilotica*
G. *Hyperolius viridiflavus*

•**Acoustic only (four species):** *Sclerophrys regularis, Amietia nutti, Phrynobatrachus kakamikro* and *Hyperolius cinnamomeoventris*

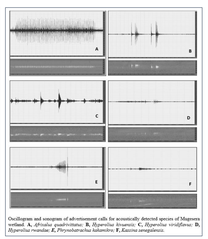
Anuran species detected by acoustic recording in Mugesera wetland: A, *Sclerophrys regularis*; B, *Amietia nutti*; C, *Phrynobatrachus kakamikro* and D, *Hyperolius cinnamomeoventris*. Picture sources: for A, B and C (Tyrcher et al., 2011) and D (Sinsch et al., 2012).

•**Visual only:** *Xenopus victorianus* **(E)**

Obj.1. Call structure identification: Oscillograms and Sonagrams of advertisement calls



Advertisement call structure differentiation through oscillograms and sonograms for acoustically detected species of Mugesera wetland. **G,** *Phrynobatrachus natalensis*; **H**, *Sclerophrys regularis*; **I**, *Hyperolius cinnamomeoventris*; **J,** *Pychadena nilotica* and **K**, *Amietia nutti*.



Oscillograms and sonograms of advertisement calls for acoustically detected species of Mugesera wetland. **A**, *Afrixalus*; **B**, *Hyperolius*; **C**, *Hyperolius viridiflavus*; **D**, *Hyperolius rwandae*; **E**, *Phrynobatrachus kakamikro*; **F**, *Kassina senegalensis*.

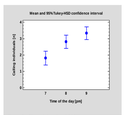
List of anuran species detected in the Mugesera wetland in 2011 and in this study (2018).

Taxon	Detection in 2018		Detected in 2011 by Fischer et al.
	acoustic	visual	acoustic+visual
Bufonidae			
Sclerophrys regularis (Reuss, 1833)	+	-	+
Hyperoliidae			
Hyperolius cinnamomeoventris (Bocage, 1866)	+	-	-
Hyperoliust kivuensis (Ahl, 1931)	+	+	+
Hyperolius lateralis Laurent, 1940	-	-	+
Hyperolius rwandae (Dehling et al., 2003)	+	+	+
Hyperolius viridiflavus (Duméril and Bibron, 1841)	+	+	+
Kassina senegalensis (Duméril and Bibron, 1841)	+	+	+
Afrixalus quadrivittatus (Werner, 1908)	+	+	+
Phrynobatrachidae			
Phrynobatrachus natalensis (Smith, 1849)	+	+	+
Phrynobatrachus kakamikro (Zimkus et al., 2010)	+	-	+
Pipidae			
Xenopus victorianus (Ahl, 1924)	-	+	+
Pychadenidae			
Psychadena anchietae (Bocage, 1868)	-	-	+
Psychadena nilotica (Seetzen, 1855)	+	+	+
Psychadena porosissima (Steindachner, 1867)	-	-	+
Pyxicephalidae			
Amietia nutti (Boulenger, 1896)	+	-	+

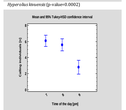
+: Present -: Absent

Obj. 2.1. Relationship between calling activity and time of day and types of microhabitats

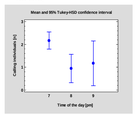
Calling activity influence by time of the day



Hyperolius kivuensis (p-value=0.0002)

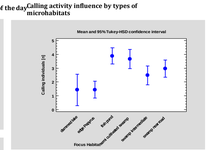


Hyperolius rwandae (p-value=0.0001)

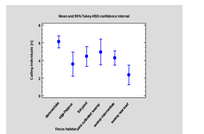


Kassina senegalensis (p-value=0.01)

Calling activity influence by types of microhabitats

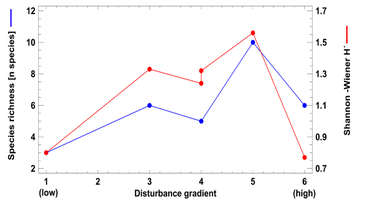


Hyperolius kivuensis (p-value<0.00001)



Hyperolius viridiflavus (p-value<0.00001)

Obj. 4. Impact of human disturbance at microhabitats on species richness and diversity



Microhabitats = (1) Edge of uncultivated Papyrus, (2) Intermediate swamp), (3) Swamp near road), (4) Semi-cultivated swamp, (5) Fishpond and (6) Dammed Lake.

Relationship between anthropogenic habitat disturbance and local amphibian diversity and richness.

Local alpha-diversity differed systematically along the present-day disturbance gradient

Objective 3. Diversity and richness of the anuran community in the Mugesera wetland

Alpha diversity (Shannon (H') and Simpson indices (D)) and richness of anuran species (n)

Microhabitat type / Species	Edge of papyrus	Intermediate swamp	Swamp near the dam	Semi-cultivated swamp	Fishpond	Dammed lake
Species richness	3	6	5	5	10	6
Shannon -Wiener Index H'	0.8	1.33	1.24	1.32	1.56	0.77
Simpson Index	2.05	3.05	2.73	3.37	3.82	1.61
Hyperolius kivuensis	X	X	X	X	X	X
Hyperolius viridiflavus	X	X	X	X	X	X
Phrynobatrachus kakamikro		X	X		X	X
Amietia nutti	X	X	X		X	X
Hyperolius rwandae				X	X	X
Afrixalus quadrivittatus		X	X		X	
Kassina senegalensis		X		X	X	
Psychadena nilotica				X	X	X
Phrynobatrachus natalensis					X	
Hyperolius cinnamomeoventris					X	
Xenopus victorianus					X	
Sclerophrys regularis						

Beta diversity: Sörensen similarity index (bolded) and Bray-Curtis dissimilarity index (unbolded) among anuran species

Microhabitats	Dammed lake	Semi-cultivated swamp	Fishpond	Edge of papyrus	Swamp near road	Intermediate swamp
Dammed lake		**0.727**	**0.667**	**0.667**	**0.727**	**0.667**
Semi-cultivated swamp	0.36		**0.714**	**0.5**	**0.4**	**0.545**
Fishpond	0.39	0.83		**0.333**	**0.571**	**0.667**
Edge of papyrus	0.274	0.531	0.427		**0.75**	**0.667**
Swamp near road	0.24	0.625	0.606	0.667		**0.909**
Intermediate swamp	0.478	0.574	0.618	0.577	0.722	

Dissimilarity ↔ Similarity

Discussion

- Anuran diversity in Mugesera wetland comprises 12 species, two less than encountered during a previous assessment by Fischer et al. (2011).
- Eleven species are represented in both inventories, **all of them generalist species and common in heavily disturbed wetlands** (Sinsch et al. 2012).
- Fischer et al. (2011) may have overlooked the local record of ***H. cinnamomeoventris*** due to the short seasonal activity period of these frogs in the Mugesera wetland.
- ***H. lateralis*** not detected in this study. It often co-occurs with *H. cinnamomeoventris*, but usually is restricted to near-natural reed habitats with shrubs or trees.
- ***P. anchietae*** and ***P. porosissima*** not recorded; both typically abundant in heavily disturbed habitats and absent from natural wetlands of Rwanda (Sinsch et al. 2012, Dehling & Sinsch, 2013).
- The anuran community of Mugesera wetland comprises mainly generalist species, indicating persistent effects of heavy human disturbance.
- The presence of *H. cinnamomeoventris* and absence of *Psychadena spp* may indicate on-going changes in species composition in response to the partial regeneration of the natural papyrus cover.
- Time of day and microhabitat types correlated with calling activity.
- Local alpha-diversity corresponded to present level of human disturbance in sampled microhabitats; consistent with predictions of Intermediate Disturbance Hypothesis (Weithoff et al. 2001, Roxburgh et al. 2004, Bongers et al. 2009, Liu et al. 2019).
- Fish ponds had highest Shannon index; dammed lake and Papyrus had lowest Shannon index. Tropical fishpond microhabitats are amongst the most heterogeneous sites, offering physical and acoustic niches for many species (Bertoluci & Rodrigues 2002, Vasconcelos & Rossa-Feres 2008).
- Near-natural habitat (papyrus swamp) provides few physical niches for anurans, probably leading to strong competition and resulting reduction of diversity.

Conclusion

Anuran species composition did not change parallel to partial regeneration of the natural papyrus vegetation following massive human disturbance in the Mugesera wetland.

Generalist species that are common in cultivated wetlands continue to dominate all available microhabitat types independent of former or present degrees of disturbance.

Mugesera wetland, once regarded as one of the key wetlands of Rwanda, is currently a secondary papyrus swamp habitat with an amphibian community indistinguishable from that of cultivated swamps.

Recommendations

Need adequate management strategies to minimize or halt human pressure exerted on the Mugesera wetland to allow its full regeneration.

Increase awareness about wetland conservation in Rwanda among communities at large and farmers in particular.

Need wetland biodiversity assessment so that these act as baseline data to enable effective monitoring of restoration or changes in wetland health after the efforts being invested in restoring degraded wetlands.

Need of a continuous monitoring of wetland health after restoration program.

Acknowledgement

University of Rwanda for the tuition fee waiver and collaboration with the University of Koblenz-Landau.

My supervisors for inputs, encouragement and motivation

Rwanda Defense Force for security

Tumushimire Lambert, my anuran research partner

My classmates

My family.