BIOTIC ASSESSMENT INDEX BASED ON ANURAN SPECIES TO EVALUATE THE BIOTIC INTEGRITY OF THE FLOODED SAVANNAS ECOSYSTEM FROM PAUTO RIVER BASIN (CASANARE-COLOMBIA)

ÍNDICE DE EVALUACIÓN BIÓTICA BASADO EN ESPECIES DE ANUROS PARA EVALUAR LA INTEGRIDAD BIÓTICA DEL ECOSISTEMA SABANAS INUNDADAS DE LA CUENCA DEL RÍO PAUTO (CASANARE-COLOMBIA)

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Resumen.— Actualmente, enormes impactos ambientales como la pérdida de diversidad, la fragmentación del paisaje y la contaminación han modificado la dinámica de los ecosistemas de sabanas inundadas de la cuenca del río Pauto en Colombia. Por tal razón, desarrollé una herramienta práctica para la evaluación del estado de integridad biológica de estos ecosistemas basado en la riqueza y composición de los anuros que allí habitan (IBIA). Esta herramienta busca dar soporte a los tomadores de decisiones y gestores regionales en el monitoreo y manejo de los servicios ecosistémicos de la región. El IBIA mostró ser sensible a la transformación de la vegetación nativa. El índice proporcionó una clara correlación entre la integridad biológica y la calidad ambiental de las áreas en las que se realizó su validación. No obstante, el IBIA requiere implementación y monitoreo a mediano largo plazo dentro de diferentes mosaicos paisajísticos presentes en las sabanas inundadas de la región de la Orinoquia para su calibración.

Palabras clave.— Closed aquatic systems, crocodile conservation, encounter rate, open aquatic systems.

Abstract.— Currently, huge environmental impacts such as diversity loss, landscape fragmentation and pollution have been modifying the dynamics of the flooded savannas ecosystems from Pauto River basin in Colombia. Hereby, I have developed a practical management tool to support decision makers and stakeholders in assessing the state of biotic integrity within an ecosystem based on anuran species composition that inhabit this ecosystem (IBIA). The IBIA shown to be sensitive to native vegetation transformation which is correlated with anuran composition. Also, the index provided a clear indication regarding the biological integrity as well as environmental quality of the areas in which the IBIA was utilized. However, the IBIA requires medium- and long-term application and monitoring within different landscape mosaics present in the flooded savannas from the Orinoquia region for its calibration.

Keywords.— Herpetofauna, environmental conservation and management, biodiversity, Orinoquian ecoregion.

INTRODUCCIÓN

Karr and Dudley (1981) defined biological (or biotic) integrity as:

"*...The ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region...*"

Since then numerous assessments of biological integrity and methodologies have been developed trying to integrate ecological insights about the structure and dynamics of populations, communities and ecosystems (Karr 1981, Karr et al., 1987). Among the vertebrates, anurans have been considered excellent indicators of the biotic integrity and quality of habitats due to their high sensitivity to environmental changes (Welsh & Olliver, 1998; Alford & Richards, 1999; Shulse et al., 2009). In fact, their particular natural history traits such as biphasic life cycle, permeable skin, metamorphosis, and their particular microhabitat preferences allow them focal organisms to study ecosystems' disturbances (Welsh & Olliver, 1998). Due to these biological traits as well as easy field detection, in the past three decades, anurans have been employed in the development of indices of biotic integrity (IBI) or indices of ecosystem health (IEH) at temperate latitudes (Welsh and Olliver, 1998; Shulse et al., 2009; Simons et al., 2000; Micacchion, 2004; Boyer & Grue, 1995; Wilcox et al., 2002; Hopkins, 2007). On the contrary, at Tropical South America ecosystems few species have been studied enough to gather the knowledge necessary to build an Index of Biotic Integrity that can measure the effects of human activities over these ecosystems (França & Araújo, 2006). The dearth of studies in these areas is further complicated by limitations in accessing research sites and a lack of financial support to conduct these.

The Colombia economic development is based on transformation of the ecosystems to use their natural resources into value chains (Viloria de la Hoz, 2009; Ávila-Montealegre, 2010; Abril-Salcedo et al., 2015). As a result, huge environmental impacts such as diversity loss, landscape fragmentation and pollution modify the dynamics of ecosystems. These impacts create risks in the environmental sustainability of goods and services provided to society (Rangel-Ch, 1997; Benavides, 2010; Angarita-Sierra, 2014). Particularly, the flooded savannas ecosystem from Pauto River at the Casanare department have been of impacted by major exploitation of oil reserves, the rapid economic growth of the region, and the radical transformations of the natural landscapes (IGAC 1999, Angarita-Sierra, 2014). As a result, a growing body of research has been developed representing enormous advances in the knowledge of the amphibian fauna of the region (Caro et al., 2006, Acosta-Galvis & Bejarano, 2011, Rangel-Ch, 2014).

Currently, the amphibian diversity of the flooded savannas is represented by 26 species of anurans and one caecilian *Siphonops annulatus* (Mikan, 1820), but the knowledge of their distributions is still limited (Pedroza-Banda et al., 2014, Rangel-Ch, 2014). According with Angarita-Sierra (2014) and Blanco-Torres et al. (2017) about 75% to 96.8% of the anuran assemblage biomass during dry and wet season is allocated at natural savannas and forests, as well as that the anuran assemblage inhabiting savannas are unlike from those that harbors the pastures areas or transformed grasslands for extensive livestock farming (Appendix, Table 8). In fact, during the dry season, the forests are keystone for the establishment and maintenance of anuran assemblages because they work as shelter that safeguards 96.8% of the anuran assemblage biomass (Cortés-Duque & Sánchez-Palomino, 2011, Angarita-Sierra, 2014; Blanco-Torres et al., 2017). Additionally, 70% of the species prefer the natural savanna and forest over any transformed vegetation (Angarita-Sierra, 2014). These studies have provided the necessary elements for researchers, decision makers, and stakeholders to build an index of biotic integrity that monitors and assesses human disturbances to the ecosystem.

The aim of this work is to present a prototype of a Biotic Assessment Index based on anuran species (IBIA) to evaluate the biotic integrity of an ecosystem in the flooded savannas of the Pauto River (Casanare-Colombia). The index is like those developed by Shulse et al. (2009) and Waringer et al. (2005), and is based on the inventory of herpetofauna of Angarita-Sierra (2014) and Pedroza-Banda et al. (2014). This index seeks to provide a practical management tool to help decision makers and stakeholders in assessing biotic integrity and conservation state of the anuran assemblages that inhabit the flooded savannas of the Pauto River basin.

MATERIALS AND METHODS

Study area

The flooded savannas in the Pauto River are located at the municipalities of Trinidad and San Luis de Palenque. Sampling areas were nested into three stations. Station 1 clustered four sampling areas: school Emaus 5.144567°N, 70.972944°W; Altamira farm 5.1860472°N, 70.981639°W; La Bretaña farm 5.144778°N, 70.95775°W; and Matamoriche farm 5.152111°N, 70.968167°W. Station 2 clustered two sampling areas Candalayes farm 5.013111° N, 71.0015°W and Matevaquero 5.338389°N, 71.335861°W. Station 3 clustered three sampling areas: La Palmita farm 5.003167°N, 71.014167°W; El Mirador farm 5.002527°N, 71.013°W; and San Miguel farm 5.013833°N, 71.01067°W (Fig. 1).

I defined the following landscape units on each station. **Hyperseasonal savannas:** Savannas which exhibit remarkable differences within dry and wet seasons (savannas of alluvial valley overflow, typical flooded savannas, and eolic savannas), that present soils with long periods of hydric stress and unimodal rainfall pattern (Sarmiento 1984). **Forest**: Forests that are located at semi-terrestrial transitional areas regularly influenced by continental waters that extend from the banks of the waterways to the inland limits (gallery forest and isolate woodland forest = "Matas de Monte"). **Rice crops**: Savannas and forests transformed into rice fields of *Oryza sativa* established on moderately flooded lowland "bajos". **Pasture:** Savannas and forests transformed into grass fields of *Urochloa humidicola* and *Urochloa decumbens* established on non-flooded low ridge

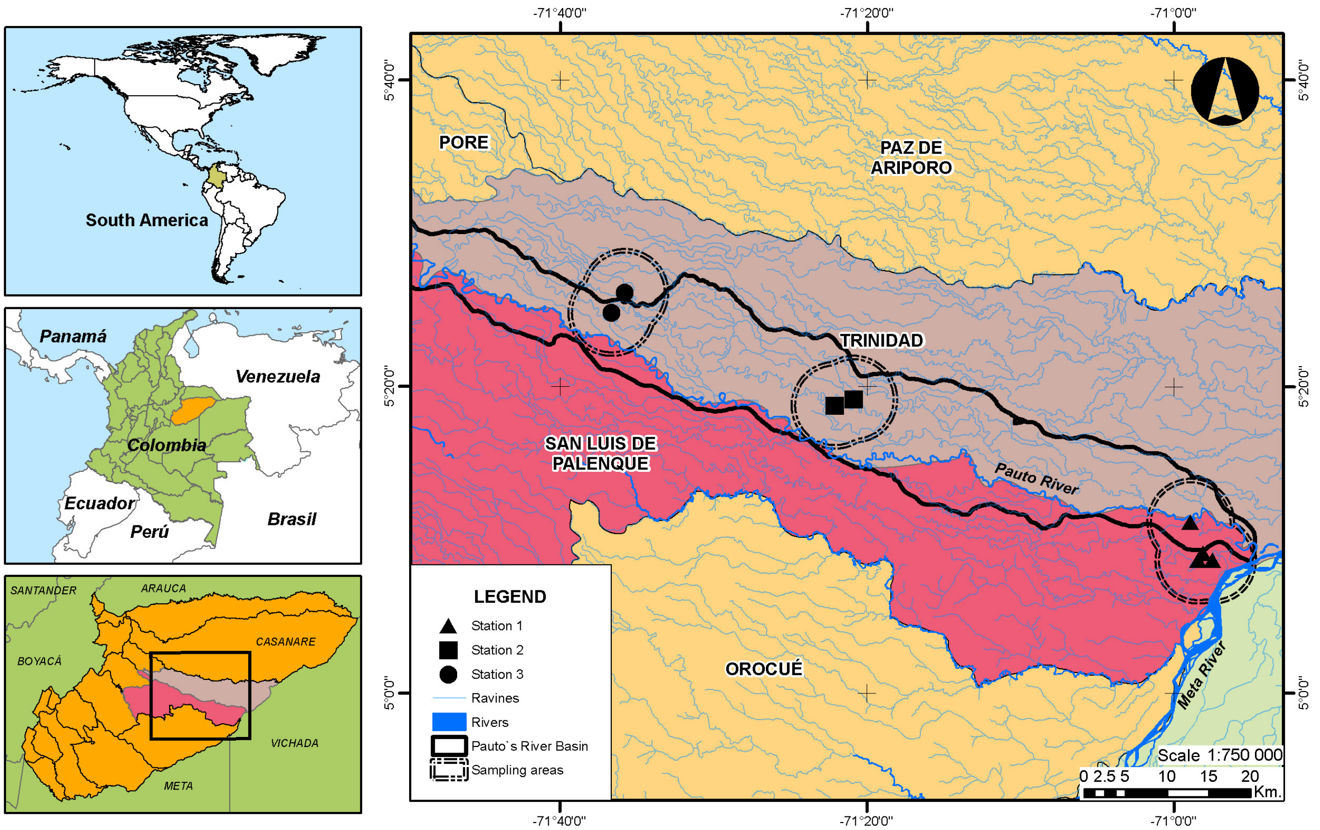

Figura 1. Área de estudio. Los municipios de Trinidad y San Luis de Palenque están divididos por el río Pauto: Lado superior Trinidad y Lado inferior San Luis de Palenque. Triángulos: áreas de muestreo de la estación 1. Cuadrados: áreas de muestreo de la estación 2. Puntos: áreas de muestreo de la estación 3.

Figure 1. Study area. The municipalities of Trinidad and San Luis de Palenque are split by Pauto River: Upper side Trinidad and lower side San Luis de Palenque. Triangles: Sampling areas from station 1. Squares: Sampling areas from station 2. Dots: Sampling areas from station 3.

or "banquetas." To obtain relative abundance of the landscape units as well as to apply the index of cover dominance (O´Neill et al., 1988), 10 spot5 satellite images (2008) from Pauto River basin were analyzed by following the procedures described by Chuvieco (2007) and also by applying the guidelines of CORINE Land Cover methodology adapted to Colombia (IDEAM 2010, Melo & Camacho, 2005; Table 1). All the land cover units obtained based on spot5 satellite images were verified during fieldwork made on 2011 (see Angarita-Sierra, 2014, Cabrera-Amaya et al., 2020).

Sampling protocol proposed for measuring the IBIA in flooded savanna ecosystems.

First, sampling stations along the Pauto River basin must have a minimum buffer of five kilometers radius that attempts to include as many types of landscape units as possible having an analytical scale of 1:25.000 (Table 1). Second, the suggested method is a stratified sampling (McDiarmind, 1994, Angulo et al., 2006) of the habitats. Therefore, microhabitat surveys represent a habitat's sub-sample unit. Each sampling must be done as a visual encounter survey (Crump & Scott, 1994) with a sampling effort of at least eight hours/two researchers/day during a period of 12-15 days.

Sampling should always be done during the wet season, especially during the first weeks because it helps to detect species with explosive reproduction strategies such as *Elachistocleis "ovalis"* (Schneider 1799) (*nomen dubium*) and *Trachycephalus typhonius* (Linnaeus, 1758). Third, during the fieldwork, at least two or three specimens should be collected for accurate taxonomic identification following Cochran and Goin (1970), Dixon and Staton (1976), Lynch (2006a, 2006b), Acosta-Galvis and Alfaro-Bejarano (2011), and Angarita-Sierra et al. (2013). Sampling tadpoles at daytime is essential to maximize species detection (McDiarmind & Altig, 1999). Thus, stratified samplings in ponds, temporary and/or standing bodies of water at the sampling stations are necessary. Following the procedures described by Hutchins et al. (1980) each pond, temporary and/

Tabla 1. Unidades de paisaje y vegetación asociada
Table 1. Landscape unit and associated vegetation.

Landscape Unit	Vegetation cover
Crops	Annual crops Crop mosaic
Pastures	Clean pastures Wooded pastures Weedy pastures
Hyperseasonal Savanna	Non-flooded wooded savannas Flooded savanna Dense shrubland Wetlands or "esteros" Burned areas Sandy areas
Forest	High secondary forest Low secondary forest Fragmented secondary forest Gallery forest Isoled forest "Matas de monte"

or standing bodies must be divided into 9 imaginary quadrants or strata of equal size. One cast should be made at random in each quadrant (stratified random sampling) for each cast series in the pond. Bottom trawls or handheld fishnets must be used to catch tadpoles. All collected tadpoles are fixed in 10% formalin for subsequent taxonomic identification in the laboratory. Taxonomic determination of tadpoles might should followed McDiarmind and Altig (1999), Lynch (2006a) and Lynch and Suarez-Mayorga (2011). Researchers recorded the location in the landscape unit, habitat, and micro-habitat in which the adult or larvae specimen was found. Finally, pitfall traps are recommended to maximize capture success and increase the likelihood of species detection in habitats with fallen leaves. This technique should be used inside the gallery forest and/or on the ecotone between the forest and savanna 24 hours per day during 15 days, using at least 10 pitfall sets.

Development of the Index of Biotic Integrity Based on Anurans (IBIA).

The main assumption that supports the IBIA is the closed ecological relationship between the anuran assemblage and the natural vegetation of the flooded savannas (Angarita-Sierra, 2014, Pedroza-Banda et al., 2014, Blanco-Torres et al., 2017). The IBIA has been developed in a similar way as Shulse et al. (2009) and Waringer et al. (2005) as follows.

First, the Ecological Coefficients (EC) were defined following criteria: 1) the availability and habitat use of anuran assemblages; 2) the effect on anuran assemblage of seasonal and flood pulse; and 3) the effect on anuran assemblage after the transformation of savannas and forests into rice fields or pastures. Second, the variables that comprise the ECs for each species were chosen. According with the dataset reported by Angarita-Sierra (2014) and Pedroza-Banda et al. (2014) (Appendix), the habitat preference and relative abundances of each species were included. Likewise, I considered the life history traits of each species as a key factor that defines sensitivity of each species toward environmental changes in the ECs estimation. Consequently, life history traits such as body size reproductive strategies, eggs and larvae development, and oviposition site were variables employed in the ECs estimation because they have been shown to be sensitive to natural vegetation loss (by sowing crops) or landscape transformation (Sinsch et al., 2007; Becker et al., 2009). Life history traits as well as habitat use of the 26 anuran species that inhabit flooded savannas have been summarized in Table 2, and these are based on the biological features reported by Bokerman (1967), Dixon and Staton (1976), Hoogmoed and Gorzula (1979), Hoogmoed (1979), Cochran and Goin (1970), Cei (1980), McDiarmid and Altig (1999), Nieto (1999), Savage (2002), Lynch and Vargas (2000), Duellman (2005), Lynch (2006a), Lynch (2006b), Prado and d´Heursel (2006), Wells (2007), Romero-Martínez et al., (2008), Cáceres-Andrade and Urbina-Cardona (2009), Tárano (2010), Acosta-Galvis and Alfaro-Bejarano (2011), Lynch and Suarez-Mayorga (2011), Angarita-Sierra (2014), Pedroza-Banda et al. (2014).

Finally, the ecological coefficient values were estimated. I employed a mixed-approach in which the EC value come from the average obtained from EC experts-opinion and the assessment done in this study (Rowe & Wright, 2001). Herpetologists from the main universities of Colombia and herpetologist consultants with a long history of fieldwork in the Orinoquian region were asked to participate in a survey. On the survey, each researcher scored each species from 1 to 10, with 10 being the best affinity to the ecological criteria:

1) Sensitivity to disturbance due to forest loss, shrub, or tree cover loss: Those species that used forest cover or high stubble as shelter during the dry season, or those species that live the most part of their life cycle in forest, shrubs, or high stubble which provide vertical stratification necessary for mating and vocalization.

2) Rareness: Those species of difficult detection, explosive reproduction, cryptic habits, and/or a high degree of

Tabla 2. Resumen del uso del hábitat y los rasgos de la historia de vida de las 26 especies de anuros que habitan las sabanas inundadas del río Pauto: Cuerpos de agua permanentes (CP), Estanques temporales (CT), Suelo desnudo (HB), Vegetación sumergida (OV), Pastizales (P), sobre vegetación (SV), sobre el suelo (S), estanques de superficie (SCH), perchada sobre dosel (DB), casas (DOM), tierras bajas moderadamente inundadas = "Bajo" (BA), Humedal = "Estero" (ES), las categorías de tamaño corporal siguen a Savage (2002), donde el tamaño <20 mm es muy pequeño, los tamaños entre 20-30 mm son pequeños, los tamaños entre 30-60 mm son medianos, los tamaños entre 60-200 mm son grandes y tamaño> 200 mm es gigante.

Table 2. Matrix that summarizes the habitat use and life history traits of the 26 anuran species inhabiting the flooded savannas of the Pauto River: Permanent water bodies (CP), Temporary ponds (CT), Soil voids (HB), Hide Vegetation (OV), Pastures (P), on vegetation (SV), above-ground (S), surface ponds (SCH), hanger-on at canopy (DB), Domestic buildings (DOM), moderately flooded lowland = "Bajo" (BA), Wetland="Estero"(ES), Body size categories follow Savage (2002), where sizes < 20mm are very small, sizes between 20-30mm are small, sizes between 30-60mm are medium, sizes between 60-200mm are large, and sizes > 200mm is giant.

Species	Household habitat	Tadpole habitat	Preference vegetation cover (dry season)	Preference vegetation cover (wet season)	Preference micro-habitat (dry season)	Preference micro-habitat (wet season)	Adult size	Repro-ductive strategy	Calling site	Tadpole size	Oviposition site	Eggs	Tadpole type	Tadpole pigmen-tationm
Dendropsophus mathiassoni	Presence	CT, BA, ES	Savanna	Savanna	Under scrubs and high grass (wetland)	Scrubs and high grass	Small	Continuous	SV,P, CP, P	Small	CT, ES	Small floating bodies	Macro-phage	Feeble (yellow and borwn)
Elachistocleis "ovalis" (nomen dubium)	Absent	CT	Forest	Forest	Leaf litter	Leaf litter and under Grass bunch	Small	Explosive	S	Small	CT	Surface sheets	Filter feeder	---
Boana boans	Absent	CT	Forest	Forest	Scrubs	Forest canopy, Scrubs and Shrubbery	Large	Opportunistic	SCH, DB	Large	---	Small bodies	Filter feeder	Faint (cream)
Boana xerophylla (1841)	Presence	CT	Forest	Savanna	Scrubs	Scrubs and Shrubbery	Large	Continuous	SV, DB, CT, P, DOM	Large	CT, DOM, BA	Small bodies	Filter feeder / Benthic	Faint (cream)
Boana lanciformis	Absent	CT, BA	Forest	Forest	Shrubbery	Scrubs and Shrubbery	Large	Opportunistic	SV, DB,	Large	CT	Small bodies	Filter feeder	Faint (cream)
Boana pugnax	Presence	CT, BA	---	Forest	---	Scrubs and Shrubbery	Large	Continuous	SV, DB, CT	Large	CT, DOM, BA	Small bodies	Filter feeder / Benthic	Faint (cream)
Leptodactylus colombiensis	Absent	CT, BA	Forest	Forest	Leaf litter	Leaf litter	Medium	Opportunistic	S,CT	Medium	CT, BA	Foam nest	Benthic	Prominent (black back and white belly)
Leptodactylus fragilis	Presence	CT, BH	Forest	Savanna/ rice crops	Leaf litter at edge of the forest	Under Grass bunch and Soil voids	Medium	Continuous	HB	Medium	CT, BH	Foam nest	Benthic	Prominent (black back and white belly)
Leptodactylus fuscus	Presence	CT, BH	Savanna	Savanna	Soil voids	Under Grass bunch and Soil voids	Medium	Continuous	S	Medium	CT, BH	Foam nest	Benthic	Prominent (black back and white belly)

Tabla 2 (cont.). Resumen del uso del hábitat y los rasgos de la historia de vida de las 26 especies de anuros que habitan las sabanas inundadas del río Pauto: Cuerpos de agua permanentes (CP), Estanques temporales (CT), Suelo desnudo (HB), Vegetación sumergida (OV), Pastizales (P), sobre vegetación (SV), sobre el suelo (S), estanques de superficie (SCH), perchada sobre dosel (DB), casas (DOM), tierras bajas moderadamente inundadas = "Bajo" (BA), Humedal = "Estero" (ES), las categorías de tamaño corporal siguen a Savage (2002), donde el tamaño <20 mm es muy pequeño, los tamaños entre 20-30 mm son pequeños, los tamaños entre 30-60 mm son medianos, los tamaños entre 60-200 mm son grandes y tamaño> 200 mm es gigante.

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Species	Household habitat	Tadpole habitat	Preference vegetation cover (dry season)	Preference vegetation cover (wet season)	Preference micro-habitat (dry season)	Preference micro-habitat (wet season)	Adult size	Repro-ductive strategy	Calling site	Tadpole size	Ovipo-sition site	Eggs	Tadpole type	Tadpole pigmen-tationm
Leptodactylus insularum	Absent	CT, CP	Forest	Forest	Leaf litter at edge of the streams	On stream edges	Large	Opportunistic	S, CP	Medium	CT, CP	Foam nest	Benthic	Prominent (black back and white belly)
Lithodytes lineatus	Absent	CT, CP	Forest	Forest	Leaf litter	Leaf litter	Medium	Opportunistic	S	Medium	CT, CP	Foam nest	Benthic	Prominent (black back and white belly)
Leptodactylus macrosternum	Absent	CP	Savanna	Savanna	Soil voids	Under Grass bunch	Large	Opportunistic	HB	Medium	CP	Foam nest	Benthic	Prominent (black back and white belly)
Osteocephalus taurinus	Absent	CT	Forest	Forest	Forest canopy	Under Grass bunch	Large	Opportunistic	S, DB	Medium	CT	Over hanging egg mass	Macrophage, oophagy	Prominent (black back and white belly)
Lithobates fisheri	Absent	P,CT, CP	Forest	Forest/ rice crops	Soil voids	Under Grass bunch and Soil voids	Small	Continuous	S	Medium	CT, SCH	Foam nest	Benthic	Prominent (black back and white belly)
Phyllomedusa hypochondrialis	Absent	CT, BA	Forest	Savanna	Canopy layer of forests	On grass bunch and Shrubbery	Medium	Opportunistic	SV, DB, CP	Large	SV, DB	Over hanging egg mass	Scraper feeder	Prominent (black back and white belly)
Pseudopaludicola llanera	Absent	CT	Forest	Savanna/ rice crops	Soil voids	Under Grass bunch and Soil voids	very small	Continuous	S	Small	CT	---	---	Prominent (black back and white belly)
Pseudis paradoxa	Absent	CT, CP, DOM, BA	---	Savanna	---	Under scrubs and high grass (wetland)	Large	Continuous	OV, SCH, CT	Giant	CT, OV	Small bodies	Macrophage, nektonic/ platonic	Prominent (black back and white belly)
Rhinella beebei	Presence	CT	Forest	Savanna	Leaf litter at edge of the forest	Backyars on Grass bunch and road edges	Medium	Opportunistic	S, CT	Small	CH, E	Small bodies	Benthic	Prominent (black back and white belly)

Tabla 2 (cont.). Resumen del uso del hábitat y los rasgos de la historia de vida de las 26 especies de anuros que habitan las sabanas inundadas del río Pauto: Cuerpos de agua permanentes (CP), Estanques temporales (CT), Suelo desnudo (HB), Vegetación sumergida (OV), Pastizales (P), sobre vegetación (SV), sobre el suelo (S), estanques de superficie (SCH), perchada sobre dosel (DB), casas (DOM), tierras bajas moderadamente inundadas = "Bajo" (BA), Humedal = "Estero" (ES), las categorías de tamaño corporal siguen a Savage (2002), donde el tamaño <20 mm es muy pequeño, los tamaños entre 20-30 mm son pequeños, los tamaños entre 30-60 mm son medianos, los tamaños entre 60-200 mm son grandes y tamaño> 200 mm es gigante.

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Species	Household habitat	Tadpole habitat	Preference vegetation cover (dry season)	Preference vegetation cover (wet season)	Preference micro-habitat (dry season)	Preference micro-habitat (wet season)	Adult size	Repro-ductive strategy	Calling site	Tadpole size	Ovipo-sition site	Eggs	Tadpole type	Tadpole pigmen-tationm
Rhinella marina	Presence	CT, BH	–-	Savanna	–-	Backyars on Grass bunch and road edges	Large	Opportunistic	S, CP, CT	Medium	OV, BA	Small bodies	Benthic	Prominent (black back and white belly)
Scinax blairi	Absent	CT	Savanna	Forest	Under scrubs and high grass	Under Grass bunch	Small	–-	SV, DB,	Small	CT	–-	–-	–-
Scinax kennedyi	Absent	CT	–-	–-	–-	–-	Medium	–-	OV	Small	CT, SCH	Small bodies	–-	–-
Scinax rostratus	Presence	CT, BA	Forest	Savanna	–-	Backyars on Grass bunch and road edges	Medium	Continuous	SV, DOM	Small	CT, SCH	Small bodies	–-	–-
Scinax ruber	Presence	CT, BA	Forest	Savanna	Leaf litter at edge of the forest	Backyars on Grass bunch and road edges	Medium	Opportunistic	SV, DOM	Small	CT, SCH	Small bodies	Benthic	Feeble (olive green back and white belly)
Scinax wandae	Absent	CT, BA	Forest	Savanna	Leaf litter at edge of the forest	Between the trunks of trees	Small	Opportunistic	OV, SV, DB	Small	CT, SCH	Small bodies	Benthic	–-
Scinax x-signatus	Absent	CT	–-	Savanna	–-	Between the trunks of trees	Medium	Continuous	SV	Small	CT, SCH	Small bodies	Benthic	Feeble (back olive green and white belly)
Trachycephalus typhonius	Absent	CT	Forest	Forest	–-	Scrubs and Shrubbery	Large	Explosive	S, SV, DB, CT	Medium	CT	Small bodies	–-	Prominent (brown back and white belly)

specialization in habitat use; with low relative abundances and/or few records in major biological collections and literature.

3) Tolerance to disturbance or natural vegetation loss: Those species that prefer open areas, disturbed habitats such as pastures, crops, road edges, etc. In general, they are species that are present during dry and wet seasons. Ecological coefficient values were calculated as the arithmetic average of the sum obtained from the evaluation of the herpetologists that participated in the survey, the assessment of three ecological criteria done in this study (Table 3), and the assessment of the matrix that summarizes habitat use and life history traits for each of the anuran species (Table 4).

Index of Biotic Integrity Based on Anurans (IBIA).

The Index of Biotic Integrity Based on Anurans (IBIA) describes the relation between the species' richness and their sensitivity to landscape transformation or natural vegetation loss. It is calculated using the following equation:

$$\textbf{IBIA} = \left(\frac{\sum_i^n (EC * HV)}{N}\right) \times 100$$

Equation 1. Index of Biotic Integrity Based on Anuran (IBIA).

Where EC is the ecological coefficient (see Table 4), habitat value (HV) which results from equation 2 (which considers the relative abundance of the landscape units in which each species is present), and N is species richness at the sampling area. The index values range from 0% to 100%, in which percentages between 0% to 30% mean low integrity levels, percentages between 31% to 50% mean medium integrity levels, and percentages over 51% mean high levels of integrity. The habitat value (HV) was calculated using the equation:

$$\textbf{HV} = \frac{(1*H_1 + 2*H_2 + 3*H_3 ... + j*H_n)}{10}$$

Equation 2. Habitat value. Where H is the relative abundance of the landscape units in which each species is present; j=1, 2, 3, or 4.

Each habitat was weighted and ranged between 1 (for habitats without vertical stratification) to 4 (for habitats with high vertical stratification). These weights have been allocated to each habitat in order to identify sensitive habitats, in which four (4) represent the most sensitive habitat. Comparisons between index of cover dominance (D) developed by O´Neill et al. (1988) (Equation 3) versus the IBIA were made to test the sensitiveness of the IBIA to landscape transformation.

The index of cover dominance developed by O´Neill, et al. (1988) is calculated using the equation 3, where D is the index of cover dominance; S is number of cover classes; pi is the ratio of the i-th type of cover.

$$D = \frac{Ln\ (S) + \sum_i pi * Ln(pi)}{Ln\ (S)}$$

Equation 3. Index of cover dominance.

RESULTS

After the application of IBIA on three stations under study, stations 2 and 3 showed a clear difference between wet and dry seasons (Table 5 and 6). While station 2 exhibits low integrity levels during the wet season, station 3 shows low integrity levels during the dry season. However, it must be noted that station 2 suffered a big event of vegetation loss due to the sowing of more than 100 hectares of rice during the time of the study.

In contrast, the assessment of biological integrity for Station

Tabla 3. Ejemplo del cálculo de los Coeficientes Ecológicos (CE). / **Table 3.** Example of the calculation of the Ecological Coefficients (EC).

Species	Survey to Researchers /Consultants						Sensitiveness average	Rareness average	Tolerance average
	Researcher No. 1	Researcher N. 2	Researcher No. 3	Researcher No. 4	Anonymous	Current study			
Dendropsophus mathiassoni	2	1	1	1	1.17	1	1.2	-	-
	1	1	3	2	1.61	1	-	1.60	-
	1	1	1	4	1.57	1	-	-	1.60

Tabla 4. Coeficientes Ecológicos (CE). / **Table 4.** Ecological Coefficients (EC).

Species	Sensitiveness average	Rareness average	Tolerance average	Ecological Coefficient (EC)
Dendropsophus mathiassoni (Cochran and Goin, 1970)	1.20	1.60	1.60	1.47
Elachistocleis "ovalis" (*nomen dubium*) (Schneider, 1799)	3.60	3.40	3.00	3.33
Boana boans (Linnaeus, 1758)	9.00	4.20	9.00	7.40
Boana xerophylla (Duméril & Bibron, 1841)	2.00	1.40	2.20	1.87
Boana lanciformis (Cope, 1871)	7.00	5.80	7.00	6.60
Boana pugnax (Schmidt, 1857)	2.80	6.00	2.20	3.67
Leptodactylus colombiensis (Heyer, 1994)	4.00	3.80	5.00	4.27
Leptodactylus fragilis (Brocchi, 1877)	1.80	1.60	1.60	1.67
Leptodactylus fuscus (Schneider, 1799)	1.80	1.40	1.40	1.53
Leptodactylus insularum (Barbour, 1906)	2.80	3.00	4.20	3.33
Lithodytes lineatus (Schneider, 1799)	8.20	4.20	7.40	6.60
Leptodactylus macrosternum (Miranda-Ribeiro, 1926)	3.40	4.80	4.80	4.33
Osteocephalus taurinus (Steindachner, 1862)	9.20	5.40	8.80	7.80
Lithobates fisheri (Stejneger, 1893)	1.60	2.00	2.60	2.07
Phyllomedusa hypochondrialis (Daudin, 1800)	4.80	3.20	5.60	4.53
Pseudopaludicola llanera (Lynch, 1989)	2.80	3.40	3.00	3.07
Pseudis paradoxa (Linnaeus, 1758)	3.40	3.60	6.60	4.53
Rhinella beebei (Gallardo, 1965)	1.00	1.20	1.00	1.07
Rhinella marina (Linnaeus, 1758)	1.00	3.00	1.00	1.67
Scinax blairi (Fouquette and Pyburn, 1972)	5.60	9.00	7.40	7.33
Scinax kennedyi (Pyburn, 1973)	4.40	5.60	5.80	5.27
Scinax rostratus (Peters, 1863)	2.00	2.40	3.60	2.67
Scinax ruber (Laurenti, 1768)	1.20	1.00	2.40	1.53
Scinax wandae (Pyburn and Fouquette, 1971)	1.40	1.80	2.20	1.80
Scinax x-signatus (Spix, 1824)	1.20	2.40	3.40	2.33
Trachycephalus typhonius (Linnaeus, 1758)	6.60	5.8	7.80	6.73

1 appears to be unaffected by seasonal changes and it showed high integrity levels during both seasons (Table 5). In general, the assessment using the IBIA shows that station 2 has the lowest levels of biological integrity and that stations 1 and 3 have medium levels. This implies that IBIA was sensitive to transformations of natural vegetation, vegetation loss, and landscape fragmentation due to human activity. In this case, human activity consisted mostly of agricultural activities, such as establishing grassland pastures and rice plantations.

The index of cover dominance (D) reported a value of 0.625 for station 1, which means that the landscape is dominated by one or a few types of vegetation coverage (Fig. 2A). This result is consistent with the score obtained by IBIA (Wet season: 46.43%; Dry season: 45.03%) as well as the greater representation of natural vegetation cover (as dense flooded savanna, woodland,

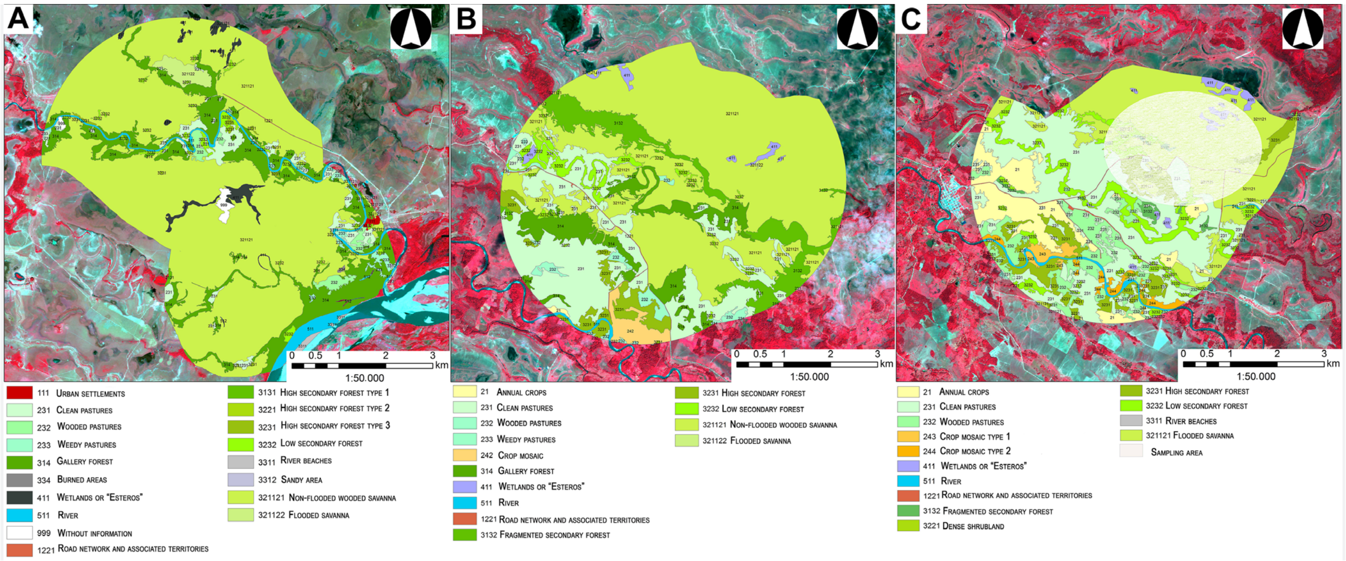

Figura 2. Categorías paisajísticas de las coberturas vegetales. (A) Estación 1: 9 454,7 hectáreas. (B) Estación 2: 9 843,5 hectáreas. Estación 3: 7637,4 hectáreas. Escala de análisis 1: 25000. oeficientes Ecológicos (CE).

Figure 2. Landscape classes of the vegetation covers. (A) Station 1:9 454.7 hectares. (B) Station 2: 9 843.5 hectares. Station 3: 7 637.4 hectares. Analytical scale 1:25000.

and gallery forest) versus lesser representation of savannas and forests transformed into pastures.

In contrast, the (D) values reported for station 2 and 3 were 0.447 and 0.424 respectively. These values indicate that the landscape is composed of numerous types of vegetation coverage in which the natural cover has low dominance (Fig. 2B and 2C). Under this scenario, the IBIA score reported at station 2 is consistent (Wet season: 20.48%; Dry season: 47.46%) with natural vegetation loss and landscape fragmentation as well as with the decrease in species richness in the wet season. It also indicates that a greater proportion of tolerant (or very tolerant) species are capable of inhabiting pastures, crops, road edges, or vegetation cover that is fragmented. On the other hand, the IBIA score reported from station 3 is not consistent with the (D) values reported and with the marked transformation of natural cover by human activities.

DISCUSSION

The stability over time of the ecological dynamics of the anuran assemblage from the flooded savannas is being compromised by the accelerated and intense transformation of the natural vegetation into rice crops and pasture for extensive livestock farming (Cáceres-Andrade & Urbina-Cardona 2009; Angarita-Sierra, 2014). As a consequence, the whole ecosystem has been suffering a decrease of its biological integrity which was clearly detected by the IBIA score (20.48%) for station 2. This phenomenon is derived from the habitat homogeneity and the weak load capacity of the rice crops and pastures to support the diverse anuran assemblages which normally require heterogeneous habitats that must be stratified and permanent over time (Wells, 2007; Peñuela & Fernández, 2010; Peñuela et al., 2011; Zúñiga-Palma & Zúñiga-Vargas, 2012).

In general, anuran assemblages are excellent indicators of the biotic integrity of the flooded savannas. The IBIA scores of the three stations evaluated never reached a high integrity level (> 51%) which is consistent with the vegetation loss and landscape fragmentation reported by the index of cover dominance, as well as huge environmental transformation due human activity over the last decade (Viloria de la Hoz, 2009; Benavides, 2010; Angarita-Sierra, 2014;. Pedroza-Banda et al., 2014; Rangel-Ch. 2014). However, station 1 which is located at the mouth of Pauto River, showed the area with the highest level of biological integrity (IBIA score = 49.60%), as well as the highest proportion of natural vegetation covers (D = 0.625) that provide great stratification and habitat availability for anuran assemblages.

This pattern of vegetation disturbance has been observed as the typical result of human colonization that employed rivers as colonization pathways (Stanford et al., 1996; IGAC 1999, Townsend & Riley, 1999; CORPORINOQUÍA, 2013) and it fits with the historical human colonization pattern of the Orinoquian savannas (Viloria de la Hoz, 2009; Benavides, 2010). The colonization began from piedmont to savannas using river basins

Tabla 5. Índice integridad biótica basado en anuros (IBIA) aplicado en la estación 1. / **Table 5.** Index of biotic integrity base on anuran assemblage (IBIA) applied at station 1.

Total area station 1 (ha)			**9 454.69**
Landscape Unit	**Relative dominance (ha)**	**weighing**	**HV**
Crops	0	1	0.00
Pastures	0.05	2	0.11
Savannas	0.74	3	2.21
Forest	0.17	4	0.68
WET SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Dendropsophus mathiassoni	1.47	0.29	0.43
Boana xerophylla	1.87	0.23	0.43
Leptodactylus colombiensis	4.27	0.07	0.29
Leptodactylus fragilis	1.67	0.30	0.50
Leptodactylus fuscus	1.53	0.30	0.46
Leptodactylus insularum	3.33	0.07	0.23
Leptodactylus macroternum	4.33	0.22	0.96
Phyllomedusa hypochondrialis	4.53	0.08	0.36
Lithobates fisheri	2.07	0.07	0.14
Pseudis paradoxa	4.53	0.22	1.00
Rhinella beebei	1.07	0.23	0.25
Rhinella marina	1.67	0.23	0.39
Pseudis paradoxa	4.53	0.22	1.00
Scinax rostratus	2.67	0.29	0.77
Scinax ruber	1.53	0.23	0.36
Scinax wandae	1.80	0.23	0.42
Trachycephalus typhonius	6.73	0.07	0.46
∑ (EC*HV)			**8.45**
Species Richness			**17**
IBIA			**49.70%**
DRY SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Dendropsophus mathiassoni	1.47	0.29	0.32
Boana xerophylla	1.87	0.23	0.45
Leptodactylus colombiensis	4.27	0.07	0.29
Leptodactylus fuscus	1.53	0.30	0.48
Leptodactylus macroternum	4.33	0.22	0.71
Lithobates fisheri	2.07	0.07	0.11
Scinax rostratus	2.67	0.29	0.54
Scinax ruber	1.53	0.23	0.29
Scinax wandae	1.80	0.23	0.34
Sinax blairi	7.33	0.17	1.24
∑ (EC*HV)			**4.95**
Species Richness			**11**
IBIA			**45.03%**

Tabla 6. Índice integridad biótica basado en anuros (IBIA) aplicado en la estación 2. / **Table 6.** Index of biotic integrity base on anuran assemblage (IBIA) applied at station 2.

Total area station 1 (ha)			**9 454.69**
Landscape Unit	**Relative dominance (ha)**	**weighing**	**HV**
Crops	0.02	1	0.02
Pastures	0.21	2	0.42
Savannas	0.55	3	1.64
Forest	0.22	4	0.88
WET SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Dendropsophus mathiassoni	1.47	0.002	0.003
Boana crepitans	1.87	0.02	0.043
Leptodactylus fragilis	1.67	0.04	0.074
Leptodactylus fuscus	1.53	0.13	0.202
Lithodytes lineatus	6.60	0.09	0.580
Leptodactylus macrosternum	4.33	0.04	0.192
Pseudopaludicula llanera	3.07	0.04	0.136
∑ (EC*HV)			**1.229**
Species Richness			**6**
IBIA			**20.48%**
DRY SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Dendropsophus mathiassoni	1.47	0.088	0.129
Elachistocleis "ovalis" (nomen dubium)	3.33	0.13	0.43
Boana xerophylla	1.87	0.166	0.310
Leptodactylus colombiensis	4.27	0.16	0.70
Leptodactylus fragilis	1.67	0.294	0.491
Leptodactylus fuscus	1.57	0.16	0.26
Leptodactylus insularum	3.33	0.251	0.837
Leptodactylus macrosternum	4.33	0.16	0.71
Pseudopaludicula llanera	3.70	0.251	0.930
Rhinella beebei	1.07	0.16	0.18
Scinax ruber	1.53	0.164	0.250
∑ (EC*HV)			**5.22**
Species Richness			**11**
IBIA			**47.46%**

as pathways in which urban settlements gradually took place (Instituto Geográfico Agustin Codazzi 1999, Mora-Fernández et al., 2011). As a consequence, human colonization and settlements have been creating a gradient of disturbance that begins from piedmont to the river mouth, and where the greatest disturbance is located near the piedmont and their urban settlements. Thus, the lesser disturbance is located around the river mouth and its gallery forest and savannas (Mora-Fernández et al., 2011; Peñuela and Fernández, 2010). The index of cover dominance (D) agreed with this pattern (Fig. 2). It reported greatest homogeneity on the river mouth (Station 1) where rural population is low, and forest and savannas are the dominant covers. On the contrary, the (D) values toward the piedmont (Station 2 and 3) reported a gradual increase on the landscape heterogeneity, higher density of crops, native vegetation transformation and dense rural settlements. This gradient of disturbance has been typified as

Tabla 7. Índice integridad biótica basado en anuros (IBIA) aplicado en la estación 3. / **Table 7.** Index of biotic integrity base on anuran assemblage (IBIA) applied at station 3.

Total area station 1 (ha)			**9 454.69**
Landscape Unit	**Relative dominance (ha)**	**weighing**	**HV**
Crops	0.10	1	0.10
Pastures	0.38	2	0.75
Savannas	0.33	3	0.99
Forest	0.17	4	0.69
WET SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Dendropsophus mathiassoni	1.47	0.17	0.26
Elaclistocleis "ovalis" (nomen dubium)	3.33	0.60	2.00
Boana xerophylla	1.87	0.17	0.33
Leptodactylus fragilis	1.67	0.09	0.14
Leptodactylus fuscus	1.53	0.09	0.13
Lithodytes lineatus	6.60	0.07	0.46
Leptodactylus macrosternum	4.33	0.08	0.33
Phyllomedusa hipochondrialis	4.53	0.14	0.66
Lithobates fisheri	2.07	0.08	0.16
Pseudis paradoxa	4.53	0.24	1.11
Pseudopaludicula llanera	3.07	0.09	0.26
Rhinella beebei	1.07	0.08	0.08
Scinax blairi	7.33	0.07	0.51
Scinax rostratus	2.67	0.07	0.18
Scinax wandae	1.80	0.10	0.18
Boana lanciformis	6.60	0.07	0.46
Scinax x-signatus	2.33	0.10	0.23
∑ (EC*HV)			**7.47**
Species Richness			**17**
IBIA			**43.94%**
DRY SEASON			
Species	**EC**	**HV**	**(EC*HV)**
Elachistocleis "ovalis" (nomen dubium)	3.33	0.07	0.23
Boana xerophylla	1.87	0.07	0.13
Leptodactylus colombiensis	4.27	0.07	0.30
Leptodactylus fragilis	1.67	0.17	0.28
Leptodactylus fuscus	1.53	0.17	0.26
Leptodactylus linneatus	6.6	0.07	0.46
Leptodactylus macrosternum	4.33	0.17	0.73
Lithobates fisheri	2.07	0.17	0.35
Pseudopaludicula llanera	3.07	0.07	0.21
Rhinella beebei	1.07	0.14	0.15
Scinax rostratus	2.67	0.10	0.27
Scinax ruber	1.53	0.07	0.11
∑ (EC*HV)			**4.95**
Species Richness			**11**
IBIA			**45.03%**

a characteristic trend of human activity that simplifies patch complexity, increases fragmentation of native vegetation as well as crops and livestock pasture (Gordon & Forman, 1983; Boren et al., 1997). Also, this link between spatial patterns and ecological processes at a landscape scale has been reported for many taxonomic groups (Rosenzwieig, 1995; Krauss et al., 2003) in which negative effects for species richness were found with increasing habitat isolation and/or landscape fragmentation (Ricketts et al., 2001, Krauss et al., 2003).

The inconsistency between the IBIA score and the (D) value in station 3 reflects that IBIA measurement depends on two factors: 1) the landscape context, which implies an appropriate sampling effort that includes at least one representative cover of each landscape unit of the flooded savannas, and 2) a careful sampling to detect the greatest number of species in each landscape unit. Consequently, station 3 showed a sampling that was incomplete due to access limitations in some locations, which reduced 19% (1 817.28 ha) of the sampled area. As a consequence, the real heterogeneity of the vegetation included on the geographic analysis was not assessed in the IBIA measurement. In fact, the fieldwork encountered more natural vegetation covers than transformed vegetation covers (Fig. 2C). Hence, the IBIA score showed station 3 as a medium integrity level zone when in reality it has the highest heterogeneity due to landscape fragmentation.

Because anurans are ectoderms with permeable skin, they are more susceptible to the vicissitudes of the environment, especially in conditions of low moisture (Duellman & Trueb 1994). However, by combinations of many unique morphological structures, physiological mechanisms, and behavioral responses, they have adapted to life in adverse environments such as the Orinoquian flooded savannas in which the dry season extends more than four months (Dixon & Staton, 1976; Montoya et al., 2011). This climatic condition has acted as a strong selective pressure to the anuran ensembles that inhabit the flooded savannas. It has caused great changes of its richness, composition, and abundance between dry and wet seasons (Montoya et al., 2011; Angarita-Sierra, 2014; Blanco-Torres, 2017). For example, three out of five frog families present in this ecosystem (Leptodactylidae, Bufonidae and Microhylidae) contain the highest species abundance and are composed by species with opportunistic life traits, semi-fossorial habits, low water dependence, and wide habitat preference such as *Leptodactylus fuscus* (Schneider, 1799), *Leptodactylus fragilis* (Brocchi, 1877), *Rhinella beebei* (Gallardo, 1965; Dixon & Staton, 1976; Duellman & Trueb, 1994; Tárano, 2010). There are a few species, like *Pseudopaludicula llanera* (Lynch, 1989), *Boana xerophila* (Wied-Neuwied, 1824), *Dendropsophus mathiassoni* (Cochran & Goin, 1970) that have adapted to use specific habitats during the dry season, such as the forest leaf litter, backyards, and under the dry vegetation of the wetlands. On the other hand, the highest species abundance of the remaining families (Hylidae, Leuperidae) are present only during the wet season and are composed by species with explosive reproduction like *Osteocephalus taurinus* (Steindachner, 1862) and *Trachycephalus typhonius* (Linnaeus, 1758), who ovoposite on temporary puddles thus have a high water dependence and high specificity in habitat preference (Höld, 1990; Lynch. 2006b; Cáceres-Andrade & Urbina-Cardona, 2009; Tárano, 2010). As a consequence, the IBA is sensitive to spatial-temporal variation in richness and composition of the anuran assemblage. This is mainly due to the anuran's richness variation which fluctuate 30% between the dry and wet seasons (Angarita-Sierra 2014; Pedroza-Banda et al., 2014).

Therefore, the IBIA score changes according to the richness observed as well as the species' composition and its ecological coefficient (EC). For instance, the IBIA scores from stations 1 and 3 during the dry season are always lower than the wet season because the species richness is lower during dry season and their composition has species with low EC values. The low values of EC correspond to life history traits of the tolerant species that prefer open areas and disturbed habitats such as pastures, crops, road edges and backyard. In general, those are species that are present during dry season and have lower water dependence. Hence, low EC values are expected when there are increases of fragmentation of native vegetation as well as increases of the landscape heterogeneity. Additionally, it is also expected that species composition for such areas contains mostly frogs with continuous or opportunistic reproductive life traits, foam nests, preferences to open areas for the display of advertisement calls, and presence in people's yards.

Rareness, as a measure to assess biotic integrity, has had detractors when used to build ecological coefficients or indices. Detractors argue that rare species may add noise to assessment and provide little additional information beyond more common species (Gauch, 1982; McCune et al., 2002; Poos & Donald, 2012). On the other hand, supporters often retain rare species in assessments because they may be better indicators of ecosystem stress than common species (Faith & Norris, 1989; Cao & Williams, 1999; Poos & Donald, 2012). In both cases, the underlying question over the rareness concept is, how species richness affects ecosystem functionality? The effect of species on an ecosystem function appears to vary depending on their commonness and rarity (Flather & Hull, 2007).

Contradictory evidence of this effect has been seen in several studies, where reductions in the abundance of common or "dominant" species resulted in immediate negative impacts on productivity (Smith & Knapp, 2003), as well as where rare species were removed. These effects reduced overall richness, and were more prone to generate exotic species' establishments than other plots where an equivalent biomass of common species was removed (Lyons & Schwartz, 2001). According to Rabinowitz (1981), rareness is a concept defined by three dimensions: geographic range, habitat specificity and local abundance. The IBIA considers these dimensions in its definition of rareness, in which the geographic range of the species assessed is restricted to flooded savannas of the Pauto River. In addition, habitat specificity is related by preference of the landscape unit and associated vegetation (Table 3), and local abundance was based on data reported by Angarita-Sierra 2014 and Pedroza-Banda et al., 2014, as well as by the knowledge of the researchers surveyed.

Therefore, the IBIA considered *Boana boans*, *Boana lanciformis*, *Osteocephalus taurinus*, *Scinax blairi* and *Trachycephalus typhonius* as rare species based on the agreement that resulted from surveys and previous studies. Comparing between the outcomes of Acosta-Galvis and Alfonso-Bejarano (2011), Angarita-Sierra (2014), Pedroza-Banda et al. (2014) and Blanco-Torres et al. (2017), rare species are not a bias from sampling protocols. On the contrary, they are frogs that have a common denominator: low relative abundance, a narrow habitat use, and high degree of specialization in the use of forests as their main habitat (Lynch, 2006b; Lynch & Arroyo, 2009; Camacho-Rozo & Camacho-Reyes, 2010). Hence, if they are removed according to detractors, we could be limiting the number of species assessed in the anuran assemblage (Preston, 1948; Arscott et al., 2006; Poos & Donald 2012), as well as missing the relationship between specialist frogs and loss of the native vegetation.

The biological integrity loss of the flood savanna ecosystem has deep repercussions on the benefits and services that anuran assemblages provide to the people that inhabit the flooded savannas in the Pauto River basin. Among the services of direct use, the main loss is the aesthetic scenery as well as the recreational, scientific and educational information. The "Llanera" culture is defined by their landscape and how the people use the fauna that inhabit their territory. The anuran decline due to habitat loss represents to rural communities from River Pauto basin the loss of the "gibberish that gives life to the savanna" (Manuel Barragan *pers. comm.* July 2012). In other words, the soundscape provided by the anurans has been lost due to deep transformation of the forest and savannas.

On the other hand, the IBIA was sensitive to deterioration and the transformation process of the natural vegetation covers, which is reflected in the decrease of biological integrity and detriment of the ecosystem services provided by the anuran assemblage. These outputs have been considered the symptoms of an unhealthy ecosystem (Godron & Forman, 1983; Odum, 1985; Steedman & Regier, 1987). Thus, decision makers and stakeholders could use the IBA into a monitoring program as environmental barometer of the pressures on the Pauto River ecosystem. Additionally, the IBIA can help to build conservation actions towards amphibian conservation communities, exploring if anuran assemblages of the flood savannas of the Pauto River are following the worldwide pattern of species decline, or by contrast, they are exhibiting wide degree of variation in the current trends (Campbell-Grant et al., 2020).

Although the IBIA was tested at some areas of the flooded savannas of the Pauto River, the index still needs to be further refined, evaluated and tested especially in response to unknown environmental disturbances. For example, none have estimated the degradation and natural vegetation loss due to the hypothesized increase of oil palm plantations or cane crops on the flooded savannas of Pauto River. These are some of the crops that will be cultivated within the next decade. (CORPORINOQUÍA, 2013). Likewise, the metric and criteria presented should be tested in order to provide insights about the types of considerations necessary for regional applications. Finally, it is recommended to further scrutinize the IBIA in order to achieve its refinement by applying it on other flooded savannas ecosystems with the involvement of resource managers.

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APPENDIX 1

Tabla S1. Abundancia relativa de anuros durante la estación seca y húmeda (Angarita-Sierra 2014)

Table S1. Relative abundance of anurans during dry and wet season (Angarita-Sierra 2014). .

Species	Dry season %				Wet season %			
	Pastures	Forest	Savanna	Rice crop	Pastures	Forest	Savanna	Rice crop
Dendropsophus mathiassoni	0	2	0	0	3	6	14	7
Elachistocleis "ovalis" (*nomen dubium*)	0	2	0	0	3	6	1	0
Boana xerophylla	0	5	3	0	12	3	12	0
Leptodactylus colombiensis	0	4	2	0	0	19	0	0
Leptodactylus fragilis	83	18	20	0	6	6	30	53
Leptodactylus fuscus	0	7	17	0	12	6	8	13
Leptodactylus insularum	0	1	3	0	0	13	0	0
Leptodactylus linneatus	0	1	0	0	0	6	0	0
Leptodactylus macrosternum	0	11	29	0	35	0	3	17
Leptodactylus sp.	— —	— —	— —	— —	3	0	0	0
Lithobates fisheri	0	3	5	0	0	3	0	3
Phyllomedusa hypochondrialis	— —	— —	— —	— —	6	6	4	0
Pseudopaludicula llanera	0	33	10	0	6	0	0	7
Pseudis paradoxa	— —	— —	— —	— —	6	3	12	0
Rhinella marina	— —	— —	— —	— —	0	0	2	0
Rhinella beebei	0	6	7	0	9	0	4	0
Scinax blairi	0	0	2	0	0	3	0	0
Scinax rostratus	17	2	0	0	0	9	2	0
Scinax ruber	0	7	2	0	0	0	2	0
Scinax wandae	0	1	0	0	0	0	3	0
Scinax sp.	— —	— —	— —	— —	0	0	1	0
Trachycephalus typhonius	— —	— —	— —	— —	0	9	1	0

Tabla S2. Cobertura vegetal preferida por los anuros durante las épocas seca y húmeda (Angarita-Sierra 2014).

Table S2. Vegetation preference of anurans during dry and wet seasons (Angarita-Sierra 2014).

Species	Dry season %				Wet season %			
	Pastures	Forest	Savanna	Rice crop	Pastures	Forest	Savanna	Rice crop
Dendropsophus mathiassoni	0	100	0	0	6	11	72	11
Elachistocleis "ovalis" (*nomen dubium*)	0	100	0	0	25	50	25	0
Boana xerophylla	0	75	25	0	25	6	69	0
Leptodactylus colombiensis	0	83	17	0	0	100	0	0
Leptodactylus fragilis	13	56	31	0	4	4	58	33
Leptodactylus fuscus	0	44	56	0	24	12	41	24
Leptodactylus insularum	0	67	33	0	0	100	0	0
Leptodactylus linneatus	0	100	0	0	0	100	0	0
Leptodactylus macrosternum	0	43	57	0	60	0	15	25
Leptodactylus sp.	— —	— —	— —	— —	100	0	0	0
Lithobates fisheri	0	57	43	0	0	50	0	50
Phyllomedusa hypochondrialis					25	25	50	0
Pseudopaludicula llanera	0	87	13	0	50	0	0	50
Pseudis paradoxa	— —	— —	— —	— —	14	7	79	0
Rhinella marina	— —	— —	— —	— —	0	0	100	0
Rhinella beebei	0	64	36	0	43	0	57	0
Scinax blairi	0	0	100	0	0	100	0	0
Scinax rostratus	20	40	0	0	0	60	40	0
Scinax ruber	0	89	11	0	0	0	100	0
Scinax wandae	0	100	0	0	0	0	100	0
Scinax sp.	— —	— —	— —	— —	0	0	100	0
Trachycephalus typhonius	— —	— —	— —	— —	0	75	25	0