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Environmental pollution

Effect of mining activity on biodiversity in a sector of the Paquisha parish, Province of Zamora Chinchipe-Ecuador

Efecto de la actividad minera sobre la biodiversidad en un sector del cantón Paquisha, Provincia de Zamora Chinchipe-Ecuador

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Abstract

The Ecuadorian Amazon region represents 45% of the national territory and constitutes one of the largest ecological reserves of humanity due to its biological wealth. In recent years, the forest area in the Latin American Amazon has been reduced by 4.5% (240,000 km^2). Ecuador is one of the countries with the highest deforestation in the region (2.4%). The objective of this study was to assess the effect of mining activity on biodiversity, hence possible changes in the ecosystem, fragmentation, abundance, richness, dominance and diversity of species were estimated. The study area was located in a mining area in the Province of Zamora Chinchipe, Cantón Paquisha-Ecuador. Through point estimators, 123 species of vascular plants divided into 43 families were identified, the highest abundance was presented by Asteraceae with 12%, followed by Araceae with 8.5% and Melastomataceae with 7.5%. Likewise, 42 species of birds were identified, 16 of mammals, 12 of amphibians and reptiles, and 36 macroinvertebrate individuals. It could be inferred that there is a marked deterioration of the ecosystem in the area, however an interesting diversity of species remains, mainly flora. In relation to fauna, the loss of certain species is evident, mainly due to agricultural expansion, hunting and mining activity. According to the Shannon index, the aquatic fauna is low, and according to the BMWP / Col index the water in the area is highly polluted.

Keywords: Biodiversity, abundance, ecosystem, dominance.

Resumen

La región amazónica ecuatoriana representa el 45% del territorio nacional y constituye una de las mayores reservas ecológicas de la humanidad debido a su riqueza biológica. En los últimos años el área de bosque en la amazonia latinoamericana se redujo en un 4,5% (240.000 km^2); en este orden, Ecuador es uno de los países con mayor deforestación en la región (2,4%). Por esta razón, el objetivo de este estudio es valorar el efecto de la actividad minera sobre la biodiversidad. Para el efecto se estimaron los posibles cambios en el ecosistema, la fragmentación, abundancia, riqueza, dominancia y diversidad de especies. El área de estudio se ubicó en una zona de explotación minera en la Provincia de Zamora Chinchipe, Cantón Paquisha-Ecuador. Mediante estimadores puntuales se identificaron 123 especies de plantas vasculares divididas en 43 familias. Asteraceae presentó mayor abundancia con el 12%, Araceae con el 8,5% y Melastomataceae el 7,5%. Asimismo, se identificaron 42 especies de aves, 16 de mamíferos, 12 entre anfibios y reptiles y 36 individuos macroinvertebrados. Los resultados permiten inferir que en la zona existe un deterioro marcado del ecosistema, empero se mantiene una diversidad interesante de especies, principalmente de flora. En lo referente a fauna la pérdida de ciertas especies es evidente, debido principalmente a la expansión agrícola, la caza y la actividad minera. La fauna acuática de acuerdo con el índice de Shannon es baja, y de acuerdo al índice BMWP/Col el agua en la zona es muy contaminada.

Palabras clave: Biodiversidad, abundancia, ecosistema, dominancia.

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1 Introduction

Ecuador is home to the highest number of ecosystems, biological species and biodiversity. The Ecuadorian Amazon region represents 45% of the national territory and constitutes one of the largest ecological reserves of humanity (Myers et al., 2000). According to the Amazon Cooperation Treaty Organization (OTCA), the Amazon region contains approximately 80% of the country's biodiversity, with 150 to 312 species of trees per hectare, 600 species of fish, and more than 250 species of amphibians and reptiles (Toro, 2006). The Amazon region has a unique biological importance because it has native microbial load of uncatalogued species of microorganisms. It is important to mention that the topographic and environmental conditions of the region, the sum of these and other interactions directly influence the biodiversity of the area (Alexa, 2010). However, the productive activities cause environmental impacts and the problem in the Amazon region is linked to mining activity and deforestation. According to the report of the Amazonian network of geo-referenced socio-environmental information (RAISG) between the years 2000 and 2010 the forest area of the Latin American Amazon was reduced by 4.5%, about 240 thousand square kilometers approximately, Ecuador is one of the countries in the region with the highest deforestation rate (2.4%); in this sense biodiversity is under increasing pressure and threat (MAE, 2015).

Mining activity particularly related to gold in the republic of Ecuador has been occurring for centuries (Equipo MMSD América del Sur, 2002); therefore, this research suggests that the expansion of mining activity in the area causes losses in biodiversity. The study of the ecosystem had the purpose of identifying possible changes in the ecosystem, fragmentation, abundance, richness, dominance and diversity of species, in short, the aim is to generate data that in the future can be used and compared with other research in order to develop conservation strategies.

2 Materials and methods

This study was carried out in the province of Zamora Chinchipe, Paquisha parish, Congüime community, UTM coordinates: WGS 84.17m 762056.24 m E; 9553263.64 m S; 838 m altitude (Figure 1). The site has elevations with steep slopes that vary between 700 m.a.s.l. and 2800 m.a.s.l. and that make up the Cordillera del Cóndor mountain range to the east and in the lower part the Nangaritza river valley that runs from south to north.

Five sampling points were randomly and strategically located and coded as: *COFA* for fauna and *COF* for flora (Table 1).

Table 1. Flora and fauna sampling points.

POINTS (**CODES**)	COORDINATES UTM (17S Zone) WGS84 X	Y	ALTITUDE (m)	AREA
COF-1/COFA-1	764002	9553233	901.3	Secondary forest and scrub mosaic
COF-2/COFA-2	763548	9552652	857	Scrub and grass mosaic
COF-3/COFA-3	763222	9553334	905.6	Scrub and grass mosaic
COF-4/COFA-4	762188	9552973	844.7	Mosaic scrubland, pasture and crops
COF-5/COFA-5	762042	9553272	842	Scrubland, pasture and anthropogenic actions

Coordinates and location, maximum altitude 905.6 m.a.s.l.

2.1 Flora in the study area

Plots of 50 m $\times$ 50 m were drawn in a total area of 0.25 ha; they were subsequently subdivided into areas of 0.25 $\times$ 0.25 m each (Arias et al., 2012). The study variables were basal area, relative density, relative dominance, importance value index, and Simpson's dominance index. When the range was (0 to 1) values closer to (1) were interpreted as dominance of one species over the other, according to Simpson's dominance index when values were (0 to 5); values close to zero were interpreted as low diversity and vice versa, according to Shannon's di-

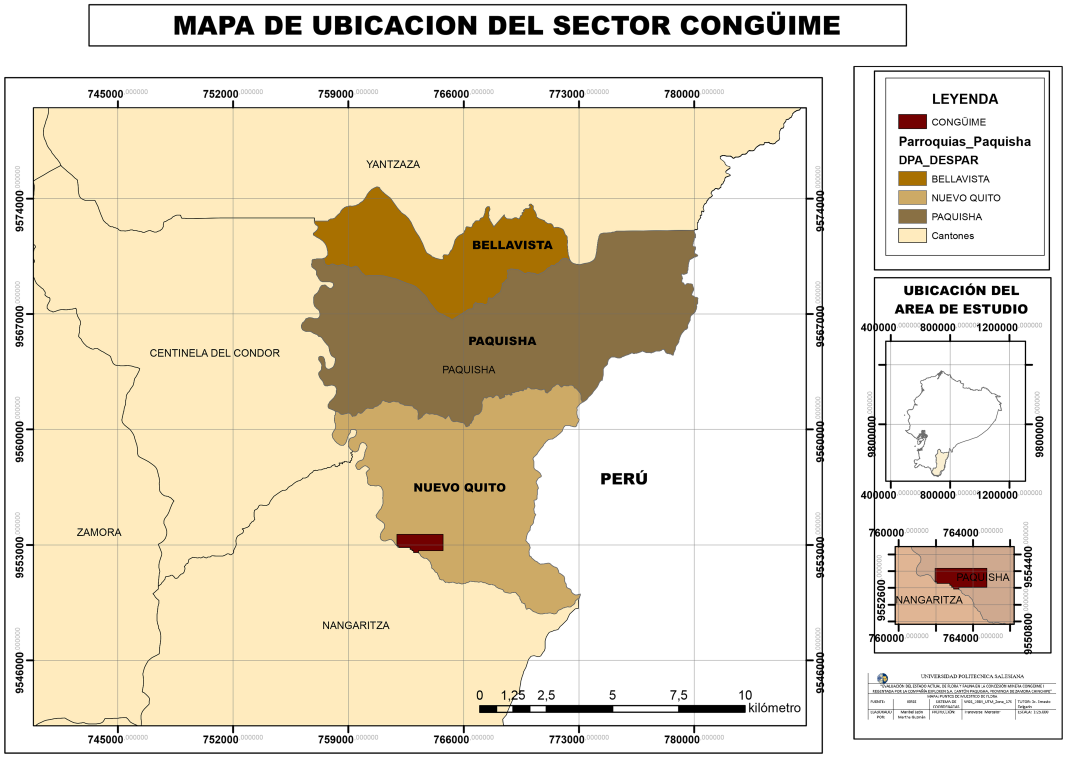

Figure 1. Cartographic map, location of the study area.

versity index (Zamora, 2015).

3 Avifauna

Sampling was done based on 3 criteria: census points, random walks and auditory records (Balderrama et al., 2005); diversity, abundance and geographic location were studied, and the references were taken from the list of birds of continental Ecuador (Ridgely et al., 1998). To estimate the relative abundance and diversity of species, we applied Simpson's dominance index in a range from 0 to 1. We inferred that values close to (1) indicate dominance of one species over the others (Campo and Duval, 2014a). The Shannon-Weaner index was used to estimate diversity (Zamora, 2015); ecological aspects such as trophic guild and sensitive and indicator species were also evaluated.

3.1 Mastofauna y herpetofauna

The study was carried out through transects, sightings, counts, indirect monitoring, trails, presence of excrement, burrows, diameter of holes and surveys of community dwellers (Arévalo, 2001). Three observation walks were made over 200, 500 and 1000 m. In addition, auditory records and visual encounters were used to identify frogs, toads, salamanders, etc (Yánez et al., 2007). The assessment was made using Shannon's index.

3.2 Macroinvertebrates

In the riverbed, sampling was done in the Chinapintza stream, Congüime river and at the junction of the two using a kick net (Carrera and Fierro, 2001). The data sets were compared to determine species richness and abundance. Biological diversity was determined using the indices: Shannon-Weaver (Shannon and Weaver, 1949); Simpson's dominance (Campo and Duval, 2014b); Margalef's richness and evenness index. Water quality was estimated through the EPT (*Ephemeroptera, Plecoptera, Trichoptera*) indexes (Bispo et al., 2006) and the BMWP/Col (Biological Monitoring Working Party/modified by Colombia) index (Zamora and Alba, 1996).

4 Results and Discussion

4.1 Flora of the study area

A total of 123 plant species and 43 families were recorded, showing more abundance *Araceae* and *Asteraceae* species. There was the greatest diversity of species at point (COF-3), while there was a greater number of families at point (COF-1), inferring that points 1 and 3 were areas of less intervention (Figure 2).

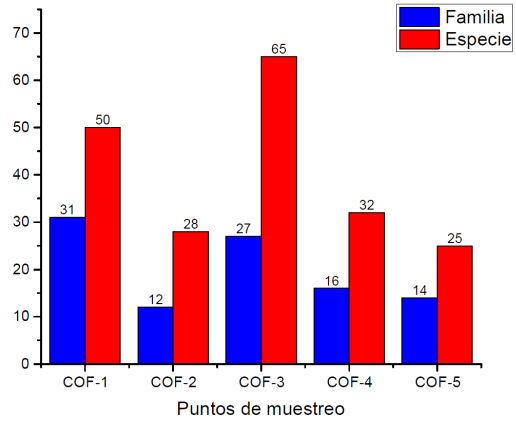

Figure 2. Bar diagram, families and species at sampling points.

4.1.1 Estimation of biological diversity

According to the Shannon-Weaner index, the values (3.708) for (COF-1) and (3.873) for (COF-3), would correspond to a high diversity secondary forest fraction. As for (COF-2) (3.00) (COF-4) (3.01) and (COF-5) (2.87), these are indicators of medium diversity according to Simpson's index (>0.9) (Table 2).

Table 2. Species diversity.

sampling areas	N° of species	N° of individuals	Shannon Index	Interpretation	Simpson Index	Interpretation
COF-1	50		3.708	High diversity	0.9713	High diversity
COF-2	28		3.005	Average diversity	0.936	High diversity
COF-3	65	200	3.873	High diversity	0.974	High diversity
COF-4	32		3.01	Average diversity	0.9318	High diversity
COF-5	25		2.877	Average diversity	0.9287	High diversity

4.1.2 Importance Value Index (IVI)

Due to the variety of tree species and the partially open canopy (aerial vegetation layer), was considered to make the assessment in (COF-3). Two *Urticaceae* and *Arecacea* families were observed. The species with the highest IVI were *Mauritia flexuosa L.f.* (27.44), *Pourouma bicolor Mart.* (20.76), *Ficus americana Aubl.* (19.45), *Cecropia ficifolia* (18.56) and *Astrocaryum chambira Burret* (14.91) (Table 3).

Table 3. Importance Value Index (IVI) of the (COF-3).

Species	ABU	AB (m^2)	DR	DM	IVI
Mauritia flexuosa	2	1.865	2.47	24.97	27.44
Pourouma bicolor Mart.	5	1.09	6.17	14.60	20.77
Ficus americano Aubl.	6	0.9	7.41	12.05	19.46
Cecropia ficifolia	12	0.28	14.81	3.75	18.56
Astrocaryum chambira Burret	11	0.1	13.58	1.34	14.92
Batocarpus orinocensis Karsten.	1	0.99	1.23	13.26	14.49
Himatanthus sucuuba Woodson	6	0.48	7.41	6.43	13.83
Pourouma cecropiifolia	9	0.2	11.11	2.68	13.79
Iriartea deltoidea Ruiz & Pav.	8	0.13	9.88	1.74	11.62
Aegiphila sellowiana Cham.	6	0.2663	7.41	3.57	10.97
Myriocarpa stipitata Benth	8	0.025	9.88	0.33	10.21
Perebea guianensis Aubl.	3	0.43	3.70	5.76	9.46
Urera baccifera (L.) Gaudich.	1	0.43	1.23	5.76	6.99
Bactris gasipaes Kunth	2	0.25	2.47	3.35	5.82
Inga thibaudiana DC.	1	0.032	1.23	0.43	1.66
TOTAL	81	74.683	100	100	200

AB= Basal Area, DnR= Relative Density,

DmR= Relative Dominance, IVI= Importance Value Index.

4.1.3 Habit of plant species

Herbaceous species, trees and shrubs were found with 36%, 29% and 22% respectively, the herbaceous species correspond to areas of greater intervention (Jørgensen and León-Yánez, 1999) (Figure 4).

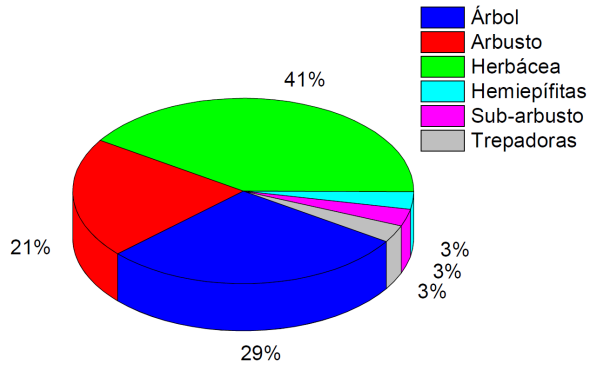

Figure 3. Distribution of plant species according to their development pattern (habit).

4.1.4 Conservation state

Seventy-four plant species were recorded as native (76.2%); 6 introduced species (6.2%); 7 introduced and cultivated (7.2%); 7 native and cultivated (7.2%); and 2 endemic species (2.05%) (Figure 5).

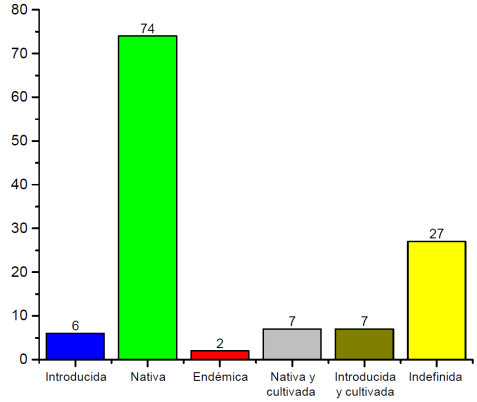

Figure 4. Biotic component (plant species) and their status.

The cultivated species sampled were: *Carica papaya L.* (papaya), *Inga edulis* Mart. (Guabilla), *Ipomoea batatas (L.)* Lam. (wild sweet potato), *Pourouma cecropiifolia* (Uvilla), *Renealmia alpinia* (Achira del monte), *Solanum quitoense* Lam. (Naranjilla) and *Bactris gasipaes* Kunth. (Palmito). In addition, the native species: *Paspalum saccharoides* Ness ex Trin (Yajoch irpa), *Sobralia rosea* Poepp. Endl (Orchid), *Pourouma minor Benoist* (Chumico) and *Piper obliquum* Ruiz Pav (Matico liso). Likewise, 13 introduced and cultivated plant species were observed, 2 endemic species *Anthurium jaramilloi* and *Miconia dodsonii*, species that are in a vulnerable and endangered category (León-Yánez et al., 2011; IUCN, 2017) (Table 5).

Table 4. Habit of species.

Species	Habit	Species	Habit	Species	Habit
Bactris sp.	Tree	*Ficus sp.*	Tree	*Phytolacca rivinoides kunth &CD.Bouché*	Herbaceus
Ipomoea ramosissima (Poir.)Choisy	Herbaceus	*Floscopa sp.*	Herbaceus	*Piper aduncum L.*	Shrubs
Acalypha macrostachya Jacq.	Shrubs	*Gynerium sagittatum (Aubl.) P. Beauv.*	Herbaceus	*Piper obliquum Ruiz & Pav.*	Shrubs
Aciotis indecora	Herbaceus	*Hedychium coronarium J. Koenig*	Herbaceus	*Piper peltatum*	Herbaceus
Aegiphila sellowiana Cham.	Tree	*Hedyosmum racemosum (Ruiz & Pav.) G. Don*	Shrubs	*Piper sp.1*	Shrubs
Aeschynomene americana var. glandulosa (Poir. ex Lam.) Rudd	Sub-Shrubs	*Heliconia orthotricha L. Andersson*	Herbaceus	*Piper sp.2*	Shrubs
Andropogon bicornis L.	Herbaceus	*Heliconia sp.*	Herbaceus	*Piptocoma discolor*	Shrubs
Anthurium jaramilloi	Herbaceus	*Himatanthus sucuuba Woodson*	Tree	*Pourouma bicolor Mart.*	Tree
Aphelandra neillii	Herbaceus	*Hyptis brevipes Poit.*	Herbaceus	*Pourouma cecropiifolia*	Tree
Asteraceae indeterminada	Herbaceus	*Inga edulis Mart.*	Herbaceus	*Pourouma minor Benoist*	Tree
Astrocaryum chambira Burret	Tree	*Inga leiocalycina Benth.*	Tree	*Pourouma sp.*	Tree
Baccharis latifolia (Ruiz & Pav.) Pers.	Shrubs	*Inga thibaudiana DC.*	Tree	*Pteridium arachnoideum (Kaulf.) Maxon*	Herbaceus
Baccharis trinervis Pers.	Shrubs	*Ipomoea batatas (L.) Lam.*	Climber	*Renealmia alpinia*	Herbaceus
Batocarpus orinocensis Karsten.	Tree	*Ipomoea ramosissima (Poir.)Choisy*	Herbaceus	*Renealmia sp.*	Herbaceus
Besleria aff. barbata (Poepp.) Hanst	Sub-Shrubs	*Iriartea deltoidea Ruiz & Pav.*	Tree	*Rhodospatha latifolia Poepp.*	Hemiepiphitic
Caladium steudnerifolium Engl.	Herbaceus	*Leandra cf. Caquetá Spruce*	Shrubs	*Rubus niveus*	Shrubs
Carica papaya L.	Tree	*Macrothelypteris torresiana*	Herbaceus	*Sacharum officinarum L.*	Shrubs
Cecropia andina Cuatrec.	Tree	*Manihot esculenta Crantz*	Shrubs	*Sapium marmieri Huber*	Tree
Cecropia ficifolia	Tree	*Matricaria recutita*	Herbaceus	*Sicydium tamnifolium (Kunth) Cogn.*	Bushes
Chelonanthus acutangulus (Ruiz & Pav.) Gilg	Herbaceus	*Mauritia flexuosa L.f.*	Tree	*Sida poeppigiana (K. Schum.) Fryxell*	Sub-Shrubs
Chelonanthus acutangulus (Ruiz & Pav.) Gilg	Herbaceus	*Merremia quinquefolia*	Herbaceus	*Sobralia rosea Poepp. & Endl.*	Herbaceus
Cissus verticillata (L.) Nicolson & C.E. Jarvis	Climber	*Miconia dodsonii*	Tree	*Socratea exorrhiza (Mart.) H. Wendl.*	Tree
Citrus medica L.	Shrubs	*Miconia sp.*	Shrubs	*Solanum quitoense Lam.*	Shrubs
Clidemia hirta	Shrubs	*Mikania sp.*	Herbaceus	*Solanum sp.*	Shrubs
Colacasia esculenta (L.) Schott.	Herbaceus	*Munnozia hastifolia (Poepp.) H. Rob. & Brettell*	Herbaceus	*Sp.1*	Herbaceus
Columnea inaequilatera Poepp.	Herbaceus	*Musa x paradisiaca L. (pro sp.)*	Herbaceus	*Sp.3*	Tree
Costus lasius Loes.	Herbaceus	*Myriocarpa stipitata Benth*	Tree	*Tessaria integrifolia Ruiz & Pav.*	Shrubs
Costus sp.	Herbaceus	*Niphidium crassifolium*	Herbaceus	*Tibouchina ciliaris (Vent.) Cogn.*	Shrubs
Cyperus aggregatus	Herbaceus	*Opuntia ficus-indica*	Shrubs	*Tibouchina ciliaris (Vent.) Cogn.*	Shrubs
Desmodium aff. purpusii Brandegee	Herbaceus	*Paspalum saccharoides Ness ex Trin.*	Herbaceus	*Urera baccifera (L.) Gaudich. /*	Tree
Drymonia urceolata Wiehler	Herbaceus	*Pennisetum purpureum*	Herbaceus	*Vernonanthura patens (Kunth) H. Rob.*	Tree
Epidendrum bracteatum Barb. Rodr.	Herbaceus	*Perebea guianensis Aubl.*	Tree	*Xanthosoma aff. pubescens Poepp.*	Herbaceus
Epidendrum calanthum	Herbaceus	*Philodendron aff. asplundii Croat & M.L. Soares*	Herbaceus	*Zapoteca sp.*	Shrubs
Epidendrum sp.	Herbaceus	*Philodendron ernestii Engl.*	Hemiepiphitic	*Sp.4*	Tree
Erythrina peruviana Krukoff	Tree	*Philodendron pedatum (Hook.) Kunth*	Hemiepiphitic	*Sp.5*	Tree
Ficus aff. insipida Willd	Tree	*Philodendron sp.*	Herbaceus	*Sp.6*	Tree
Ficus americano Aubl.	Tree	*Physalis pubescens L*	Herbaceus		

5 Fauna of the study area

5.1 Avifauna

Forty-two bird species were observed, which were placed in 13 orders and 22 families (2.31%) of the total birds recorded in Ecuador (MAE-SUIA, 2015). *Tyrannidae* (20%) and *Thraupidae* (15%) were the most abundant (Figure 8).

6 Biogeographic location

Twenty bird species were recorded as common and 13 as uncommon (Ridgely et al., 1998). The dominance of common species over uncommon species is an indicator of the disturbed area (Velásquez et al., 2003).

Tyrannus melancholicus (tropical tyrant), *Sicalis flaveola* (coarse seedeater), *Ramphocelus carbo* (wine-shell tanager), *Oryzoborus angolensis* (lesser seedeater), *Myiozetetes similis* (social flycatcher), *Doliornis remseni* (ventricast cotinga), and *Crotophaga ani* (pied tickcatcher) were the most abundant (Figure 11). The total number of species recorded in the area was 42, and the majority belonged to the Tyrannidae family. A higher percentage of species was recorded in point COFA-3; 49 sp. and in smaller numbers in point COFA-5 19 sp. This is mainly due to the fact that the area is intervened by mining activities.

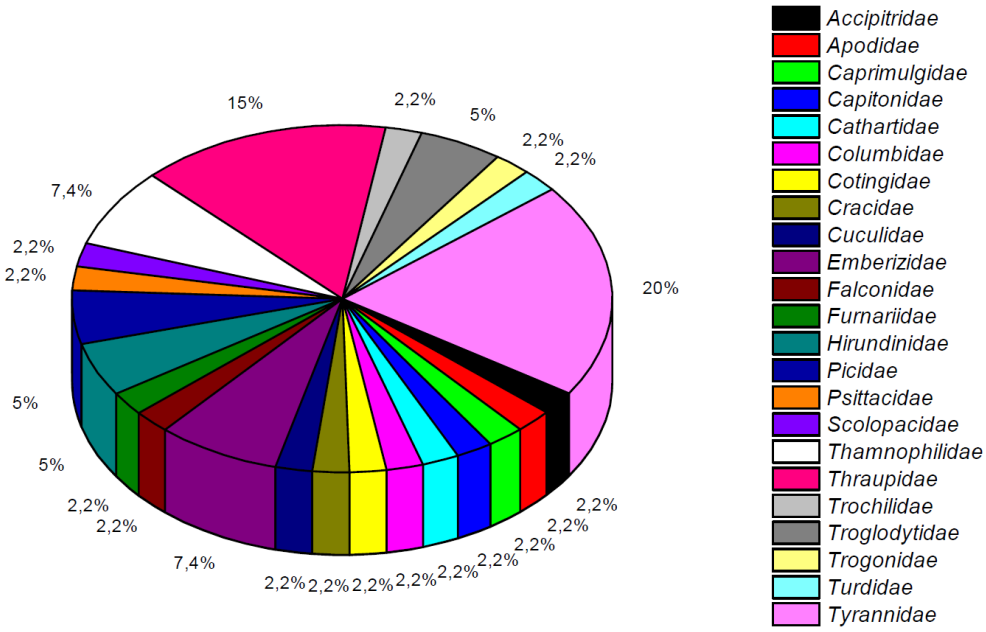

Figure 5. Percentages of birds present in the area.

The species accumulation curve for avifauna is an indicator of the rate at which new species can be found, and each unit of effort consists of sampling points carried out at strategic times and places. The negative exponential model was used to evaluate the quality of sampling and collection, obtaining a determination coefficient (R^2) of 0.9995, a slope of 0.0062 and a sampling effort of 87%, which indicates a good fit of the model and a complete and reliable sampling with a good inventory quality (Figure 6).

6.1 Biodiversity estimation

According to the Shannon-Weaner index, the value (3.1) for COFA-3 is an indicator of high diversity (Zamora, 2015). The biodiversity of the area was assessed by comparing observed and expected values (Pielou-J Index) (Moreno, 2001). The results are close to (1), so we infer that species are abundant in the different points (Table 6).

Table 5. Introduced species and conservation status according to IUCN.

Species	Status (IUCN) (IUCN)	Catalog: Vascular plants of Ecuador
Pennisetum purpureum	LC	Introduced
Citrus medica L.	NE	Introduced and cultivated
Colacasia esculenta (L.) Schott.	LC	Introduced and cultivated
Hedychium coronarium J. Koenig	-	Introduced
Macrothelypteris torresiana	NE	Introduced
Manihot esculenta Crantz	-	Introduced and cultivated
Matricaria recutita	LC	Introduced and cultivated
Musa x paradisiaca L. (pro sp.)	NE	Introduced and cultivated
Musa x paradisiaca L. (pro sp.)	-	Introduced and cultivated
Opuntia ficus-indica	DD	Introduced
Rubus niveus	LC	Introduced
Sacharum officinarum L.	LC	Introduced and cultivated
Urochloa aff. dictyoneura	NE	Introduced

Nomenclature: LC= Least Concern; NE =Not Evaluated; DD= Data Deficient.

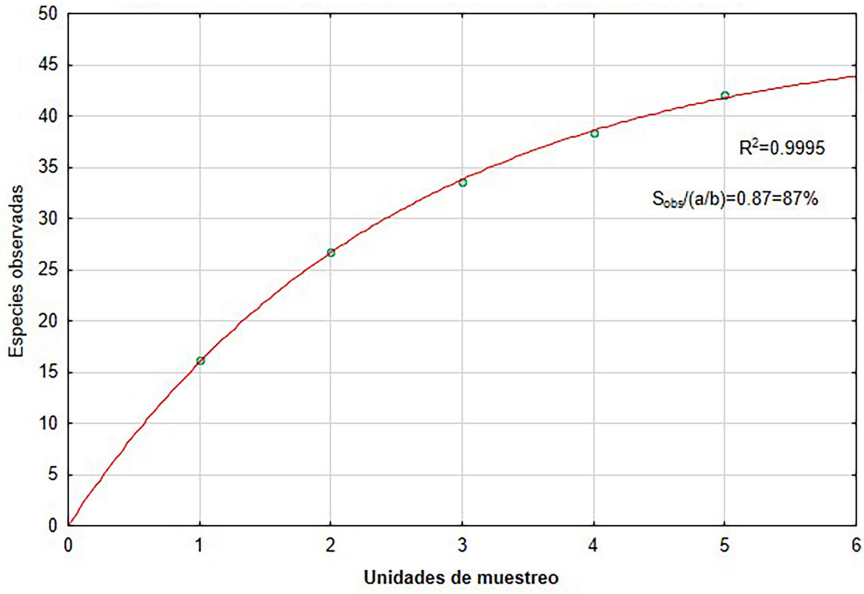

Figure 6. Bird species accumulation curve.

According to Simpson's index, there are no dominant species in the sampling points (Table 7).

6.2 Ecological aspects

The trophic guild was classified under 8 parameters according to the type of feeding or condition (Albuja, 2011). The trophic guild with the highest representation was the insectivore (23), the guild increased its f requency the further it was from the disturbed populations and areas (Canaday and Rivadeneyra, 2001) (Figure 7).

Table 6. Diversity index- avifauna.

Sampling Areas	N° of species	N° of individuals	Shannon Index (H)	Equity (j)	Location
COFA1	20		1,59535	0,8904	Average diversity
COFA2	37		2.36959	0.8979	Average diversity
COFA3	49	173	3.05037	0.9477	High diversity
COFA4	48		2.83833	0.9182	Average diversity
COFA5	19		2.47912	0.9394	Average diversity

Shannon-Weaner indexes and equity data sets.

Table 7. Calculation of Simpson's dominance index - Avifauna.

Sampling points	N° of species	Dominance	Diversity	Location	Location
COFA1	20	0.23	0.77	Low dominance	Average diversity
COFA2	37	0.12	0.88	Low dominance	High diversity
COFA3	49	0.06	0.94	Low dominance	High diversity
COFA4	48	0.07	0.93	Low dominance	High diversity
COFA5	19	0.10	0.90	Low dominance	High diversity

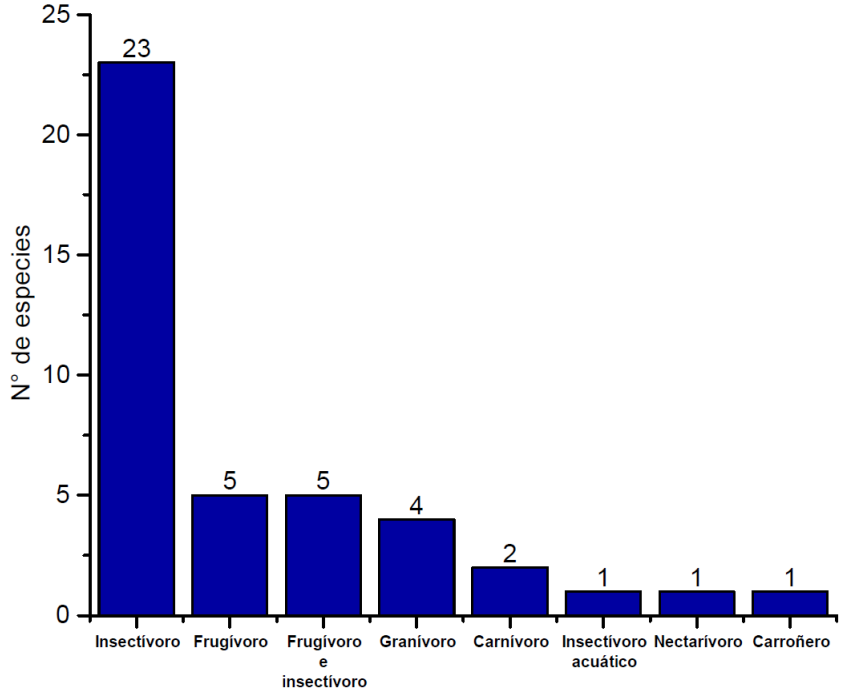

Figure 7. Trophic avifauna guild.

6.3 Sensitive and indicator species

Birds have different degrees of sensitivity to alterations in their environment (Stotz et al., 1996). Species with low sensitivity were recorded in greater numbers (28 sp.); medium sensitivity (13 sp.) and high sensitivity (1 sp.). The dominance of species with low sensitivity is an indicator of ecosystem disturbance.

6.4 Conservation state

Most species were placed in the "Least Concern" (LC) category (40 species); 2 species in the vulnerable category *Patagioenas subvinacea* (Red-breasted Pigeon) and *Doliornis remseni* (Ventricast Cotinga). The species *Buteo magnirostris* (Homing Sparrowhawk), *Thalurania furcata* (Hummingbird scissor-tailed nymph), *Amazona ochrocephala* (Yellow-crowned Amazon Parrot) and *Daptrius ater* (Black Caracara) are not endangered species, but their trade must be controlled (CITES, 2010).

In addition, 3 species of migratory birds, *Buteo magnirostris* (Sparrowhawk), *Coragyps atratusc* (Black Gallinule) and *Actitis macularius* (Sandpiper) (Appendix II), species with an unfavorable conservation status that require international agreements for their conservation (CMS, 2015) (Figure 8).

Figure 8. (A) Common Chickadee (*Crotophaga ani*) (B) Short-toed Sparrowhawk (*Buteo magnirostris*).

7 Presence of mammals

Through surveys, 16 mammal species were recorded (3.7% of the total number of mammals in Ecuador). 100% of those surveyed stated that they knew about it and had had sightings of *Dasypus novemcinctus* (9-banded armadillo), and *Bradypus variegatus* (sloth) and *Leopardus tigrinus* (small tigrillo) to a lesser extent (2.2%).

7.1 Records by indirect methods

The relative abundance index is the result of dividing the number of observations by the length of the route (Zapata et al., 2006). Eight species of mammals were recorded over a distance of 1.250 m (Table 8).

7.2 Estimation of diversity

Indirect sampling recorded 8 species of mammals. The relative abundance was determined through the number of tracks, and the results show a low diversity index (1.50) according to the Shannon-Wiener index.

7.3 Conservation state

Most of the species were found in the category of Least Concern (LC) except for *Cuniculus paca* (lowland guanta); *Tayassu pecari* (Wild Pig); *Mazama americana* (Red Deer) and *Leopardus tigrinus* (Small Tigrillo) which are in the categories: Near Threatened (NT), Endangered (EN), Near Threatened (NT) and Vulnerable (VU), respectively (Cuesta and Tirira, 2011). Most species are in the category of least concern, except *Tayassu pecari* (Wild Pig) and *Leopardus tigrinus* (Small Tigrillo) which are in the vulnerable

Table 8. Monitoring by indirect methods.

Specie	N	Abundance (n/km)	Distance by Specie (km)
Didelphis marsupialis	2	1.6	250
Marmosa murina	3	2.4	200
Dasypus novemcinctus	26	20.8	500
Sylvilagus brasiliensis	3	2.4	250
Cuniculus paca	4	3.2	250
Platyrrhinus brachycephalus	1	0.8	100
Carollia brevicauda	3	2.4	250
Dasyprocta fuliginosa	9	7.2	500
TOTAL	51	40.8	-

Data sets: Relative abundance of mammals in the area.

(VU) category (IUCN, 2017).

Three species were recorded in appendix III. *Nasua nasua* (Cuchucho); *Eira barbara* (Cabeza de mate) and *Cuniculus paca* (Guanta de tierras bajas); 2 species in appendix II, *Tayassu pecari* (Pecari de labio blanco) and *Bradypus variegatus* (Sloth); y *Leopardus tigrinus* (Small Tigrillo) in appendix I (Most threatened species) (CITES, 2017).

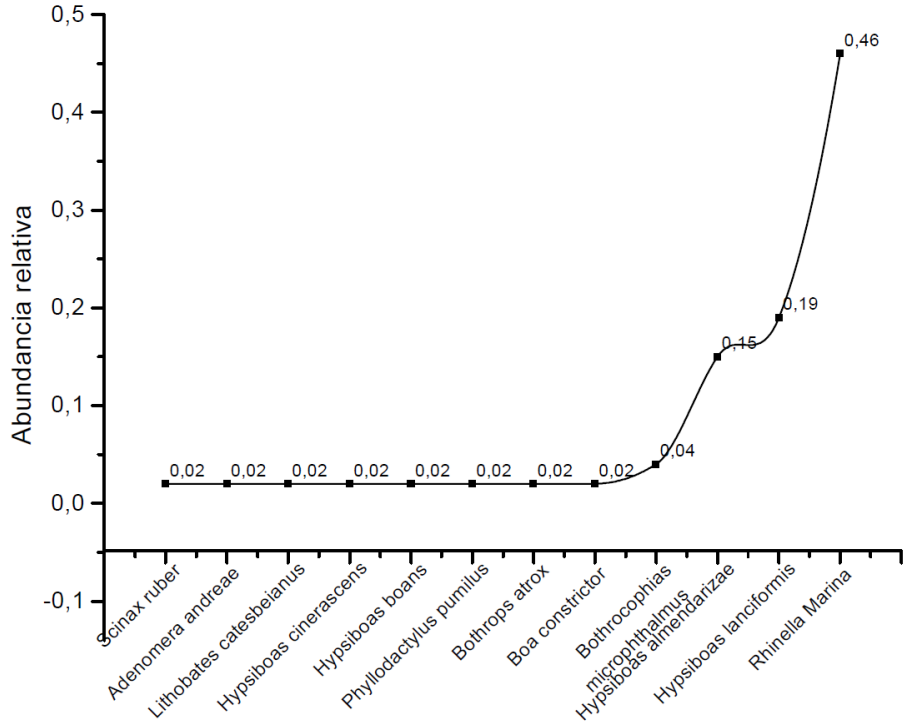

Figure 9. Abundance-diversity herpetofauna.

7.4 Trophic guild analysis of mammals

Changes in habitat and ecosystem were assessed, as well as the way in which species use their resources over time (Pérez-Irineo and Santos-Moreno, 2013). Six trophic groups were recorded at the site: carnivores (1); omnivores (5); insectivores (1); frugivores (6); folivores (1) and herbivores (2). (second trophic level) (secondary consumers).

8 Herpetofauna

There were 52 individuals (47 amphibians and 5 reptiles) 0.96% reptiles and 1.62% amphibians that were located in 7 families. The most abundant was Bufonidae with 46%, while Hylidae had 40%, and Leptodactylidae and Ranidae with 2%. Most reptiles belong to the Squamata family, with the highest abundance of Viperidae with 6%; while Gekkonidae and Boidae had 2%. As for amphibians, *Rhinella marina* (Giant Toad) was the most abundant (Figure 14) (0.46%), followed by *Hypsiboas lanciformis* (Tree Frog) (0.19%), *Hypsiboas almendarizae* (Tree Frog) (0.15%), *Bothrocophias microphthalmus* (Hoja podrida) (0.04%); the remaining species represent 0.02%. According to Shannon's index (1.70), the diversity in the study site is medium (Figure 13).

8.1 Conservation state

Hypsiboas almendarizae (tree frog) is in the Near Threatened (NT) category. *Bothrocophias microphthalmus* (Hoja podrida) and *Boa constrictor* (Boa Mata caballo) are in the vulnerable category (VU) (Carrillo et al., 2005; CITES, 2017) (Table 10). According to the IUCN most species are in the category "Least Concern" (LC). *Hypsiboas almendarizae* is an endemic species according to the red list of amphibians of Ecuador (Coloma, 2005).

Table 9. Mammalian guild analysis.

Specie	Trophic guild	Activity
Didelphis marsupialis	Om	Nocturnal terrestrial arboreal
Marmosa murina	Om	Arboreal nocturnal
Carollia brevicauda	Fr	Night forage
Platyrrhinus brachycephalus	Fr	Nocturnal
Dasypus novemcinctus	In	Terrestrial night
Sylvilagus brasiliensis	H	Terrestrial night
Sciurus granatensis	Fr	Diurnal arboreal
Cuniculus paca	Fr	Night foraging
Dasyprocta fuliginosa	Fr	Daytime
Nasua nasua	Om	Daytime
Eira barbara	Om	Diurnal-crepuscular arboreals
Mazama americana	H	Diurnal with more frequency at night
Ateles sp.	Om	Daytime
Tayassu pecari	Fr	Terrestrial and diurnal gregarious
Bradypus variegatus	Fo	Diurnal and nocturnal arboreals
Leopardus tigrinus	Cr	Nocturnal-crepuscular

Nomenclature: Carnivore (Cr), Frugivore (Fr), Insectivore (In), Omnivore (Om), Folivore (Fo), Herbivore (H).
Compiled from: Vallejo & Boada, (2014); Brito, Astua de Moraes, & Lew, (2015); Emmons y Feer, (1999); Tirira, (2007).

Table 10. Conservation status of Herpetofauna species.

Specie	UICN (2017)	CITES (2017)	Red lis of amphibians of Ecuador	Red list of reptiles of Ecuador
Rhinella Marina	LC	NA		
Scinax ruber	LC	NA		
Adenomera andreae	LC	NA		
Lithobates catesbeianus	LC	NA		
Hypsiboas almendarizae	NE	NA	NT	
Hypsiboas lanciformis	LC	NA		
Hypsiboas cinerascens	LC	NA	LC	
Hypsiboas boans	LC	NA	LC	
Phyllodactylus pumilus	DD			DD
Bothrops atrox	NE	NA		LC
Bothrocophias microphthalmus	NE	NA		VU
Boa constrictor	NE	Apendix I		VU

Nomenclature: DD =Data Deficient; LC = Least Concern; NT = Near Threatened; NE = Not Evaluated; VU = Vulnerable

Figure 10. (A) *Rhinella Marina* (Giant frog), (B) *Hypsiboas boans* (Tree frog).

8.2 Sensitive and indicator species

The "low sensitivity" condition is the most representative (8 species); medium sensitivity (3) and high sensitivity (1). The indicator species of disturbed environments are: *Rhinella marina* (Giant Toad), *Scinax ruber* (S/n), *Hypsiboas lanciformis* (Tree Frog), *Lithobates catesbeianus* (Bullfrog); *Bothrops atrox* (Equis); *Hypsiboas cinerascens* (Tree Frog) and *Hypsiboas boans* (Tree Frog) (IUCN, 2017).

9 Aquatic Fauna

Thirty-six aquatic macroinvertebrates were collected in 4 orders, 8 families and 10 genera (Figure 15). In the Chinapintza stream, 12 individuals were collected from 4 orders, 4 families and 6 genera. In the Congüime river, 13 individuals were collected from 3 orders, 5 families and 5 genera, and in the junction between these two rivers, 11 individuals were collected from 3 orders, 4 families and 4 genera (Figure 15).

Forty-two percent belonged to the order *Ephemeroptera* and 33% to the order *Diptera*, which in turn represents the largest number of genera at the sampling points (Figure 16). In the richness and abundance variables, there is no significant difference in the sampling points; the low abundance and richness is due to the evident contamination of the water due to mining activity in the area (Table 11).

Figure 11. Stereomicroscope photos: Macroinvertebrates (A) *Diptera* Order- Chironomidae family, the most abundant in the sampling points and tolerant to high levels of contamination; (B) *Coleoptera* Order- Elmidae family- *Cylloepus* genus; (C) *Diptera* Order- Empididae family; (D) *Coleoptera* Order- Hydrophilidae family; (E) *Coleoptera* Order- Elmidae family- *Neoelmis* genus, (F) *Ephemeroptera* Order- Baetidae family- *Paracloeodes* genus are tolerant to certain levels of pollution; (G) *Diptera* Order- Psychodidae family; (H) *Trichoptera* Order- Hydropsichydae family- *Smicridea genus*; (I) *Ephemeroptera* Order- Leptohyphidae family- *Trichorytodes* genus, considered as bioindicators of water quality like the *Trichoptera* order.

Table 11. Richness and abundance at each macroinvertebrate sampling point.

	Chinapintza Creek	Congüime River	Chinapintza and Congüime confluence
Wealth	4	5	4
Abundance	12	13	11

Wealth = Families; Abundance = Individuals

9.1 Diversity and abundance by family

Baetidae and Chironomidae, considered tolerant to certain levels of contamination (Mosquera, 2008), were dominant. The highest number was recorded in the Congüime river. It is important to mention that Chironomidae are associated with environments with low oxygen levels and high pollution levels (Hahn et al., 2009).

9.2 Estimation of diversity

According to the Shannon-Weaver index, the site is in a low diversity range, mainly due to water pollution. Simpson's dominance index shows medium values, with the presence of a certain number of dominant individuals in the community. According to the Margalef index, diversity in the area is low, as well as the evenness index, the values were medium and low (Table 12).

9.3 Water quality indices

The values of the BMWP/Col index in the 3 sampling points are 20%, 26% and 18%, respectively, and are located in class IV (very polluted waters with critical quality) (Zamora and Alba, 1996). In the ASPT calculation, values of 5, 5.2 and 4.5 were obtained, respectively, when compared with the BMWP/Col. indexes (Pérez, 1999) (Table 13).

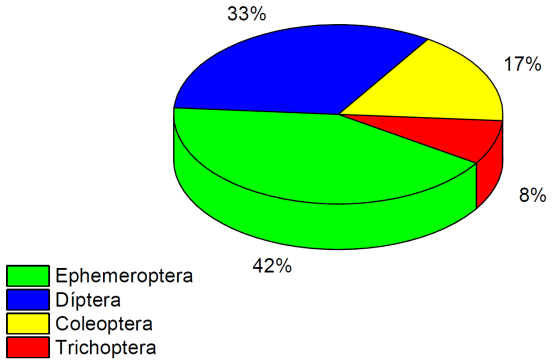

Figure 12. Total percentage of macro benthos orders present in the sampling points.

The calculation of the Andean Biotic Index (ABI) shows values of 16, 20 and 15, respectively, and according to these parameters we infer that the water quality is poor with a range between 11 and 26 (Loayza, 2016) (Table 13).

Table 12. Diversity indices- Macroinvertebrates.

Index	P1	P2	P3
Shannon-Weaver index	1.27	0.90	1.04
Simpson dominance	0.31	0.52	0.37
Margalef diversity	3.22	3.90	4.02
Uniformity index	0.35	0.24	0.30

Table 13. BMWP/Col., ASPT and ABI indices for each sampling point.

CHINAPINTZA RIVER				
Index	**Value**	**Range**	**Quality**	**Meaning**
BMWP/Col	20	16 - 35	Critical	Highly polluted waters
ASPT	5	0-10		
ABI	16	01/11/26	Bad	–
CONGÜIME RIVER				
BMWP/Col	26	16 - 35	Critical	Highly polluted waters
ASPT	5,2	0-10		
ABI	20	01/11/26	Bad	–
INTERSECTION OF THE RIVERS				
BMWP/Col	18	16 - 35	Critical	Highly polluted waters
ASPT	4,5	0-10		
ABI	15	01/11/26	Bad	–

BMWP/Col (Biological Monitoring Working Party/ modified by Colombia); ASPT (Average Score per Taxon); ABI (Andean Biotic Indexes).

10 Conclusions

The objective of this research was to evaluate the effect of mining activity on the biodiversity of the study area, estimating possible changes in the ecosystem in relation to fragmentation, abundance, richness, dominance and diversity of species. According to the results, we can conclude that the flora of the site has a medium level, although the level of species dominance is low in all sampling points. As for fauna, the level is medium for avifauna, except in point COFA-3 where diversity is high. A total of 42 species of birds were recorded in 22 families, with the highest abundance presented by *Tyrannidae* and *Thraupidae*, species considered with low sensitivity (28 sp.). Sixteen species of mammals were recorded; *Cuniculus paca*, *Tayassu pecari*, *Mazama americana* and *Leopardus tigrinus* are species considered highly threatened; the relative abundance of these species is low (1.50). In terms of herpetofauna *Bufonidae* (46%) and *Hylidae* (40%) were the most abundant. Most of the reptiles belong to the *Viperidae* family (6%). *Rhinella marina* (giant neotropical toad or marine toad) was the most common

amphibian species. In the riverbed, 36 macroinvertebrates were identified in 4 orders and 8 families, predominantly Baetidae and Chironomidae, species considered tolerant to water pollution.

Therefore, the study area showed a medium diversity and dominance of species with low sensitivity, most of them generalists, with more abundance of frugivorous and omnivorous guild and indicators of disturbed environments due to mining activity, agricultural and livestock expansion and deforestation.

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