El Ceibo Stream under the microscope:
Impact of human activity on an aquatic ecosystem

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Contenido

Abstract:

This research arose from a critical analysis of a previous project developed by another educational institution which, in our view, lacked scientifically supported data. This motivated us to deepen the study of El Ceibo Stream, whose source is located in a rural area of the Victoria Department, Entre Ríos Province (Argentina), and which partially borders the urban area of the city of Victoria along its course.

The general objective was to characterize water quality and analyze how it varies along the stream's course. To this end, a bibliographic review was conducted on El Ceibo Stream and similar studies, together with training in several GLOBE Hydrosphere protocols. The limited availability of specific information on El Ceibo Stream gives particular relevance to this study.

Using different GLOBE protocols, field observations, and laboratory analyses, the current condition of the stream was assessed along a section of its course. Macroinvertebrate diversity was analyzed in different habitats, considering their value as bioindicators of water quality through biotic indices.

The results indicate that El Ceibo Stream presents biochemical modifications and variations in macroinvertebrate composition along the studied section, especially in the area where it enters the urban zone, where anthropogenic influence becomes more evident. Although further training is still needed, this research allowed us to gain experience in macroinvertebrate identification and to strengthen our understanding of the impact of human activities on aquatic ecosystems.
Keywords: eutrophication, water quality, BOD, nitrates, GLOBE Protocols.

1. Introduction

On September 27, 2024, during the XIV Environmental Education Conference held in Victoria, Entre Ríos (Argentina), the San Benito Higher Institute of Teacher Education presented a project addressing issues related to a local slaughterhouse and El Ceibo Stream. In our view, the project did not provide conclusive data, which led us to further investigate the topic. This stream separates the urban and rural areas and, along its course, receives runoff from an open-air landfill and effluents from two slaughterhouses.

According to the Instituto del Agua (n.d.), the main uses of water resources include human consumption, food production, energy generation, industrial activity, tourism, and recreation. This study focuses particularly on the latter.

Similar studies conducted in streams in Argentina and Uruguay have applied different protocols to assess water quality, in diverse contexts and study sites. In Uruguay, research projects such as "*Explorando a orillas del río*[1]" (Liceo No. 1 of Mercedes), "*Por un arroyo Sauce sustentable*[2]" (Liceo de Sauce), and "*Water quality in nearby areas to Canelones city through the use of macroinvertebrates as bioindicators*" (School No. 88 Alfredo B. Nobel) analyzed physicochemical and biological water parameters, including pH, dissolved oxygen, and/or macroinvertebrates.

In Argentina, studies carried out in Patagonia—such as those developed by CPEM No. 3 of Junín de los Andes and the Huechulafquen Science Club on the Chimehuín River—assessed water quality using macroinvertebrates and other physicochemical parameters. Likewise, in the province of Entre Ríos, research conducted by the National University of Entre Ríos, the Secretariat of Environment, and the National University of La Pampa applied biotic indices and physicochemical analyses in streams from different departments.

Following a complaint reporting that the slaughterhouse Guillermo Huarte S.A. was discharging effluents into El Ceibo Stream, on July 8, 2021, personnel from the Municipality of Victoria carried out water sampling.

There are several parameters used to evaluate water quality, such as biochemical oxygen demand[3], nitrate, nitrite, and ammonium concentrations[4], chemical oxygen demand[5], and ethyl ether–soluble material[6]. According to GLOBE (2025), nitrate, nitrite, and ammonium concentrations vary depending on surface runoff—mainly of agricultural origin—and groundwater inputs. Urban and industrial effluents also contribute, being rich in nitrogen and phosphorus, which promote excessive growth of algae and aquatic plants. By covering the water surface, these organisms reduce photosynthesis and cause the death of submerged vegetation. The increase in organic matter stimulates bacterial proliferation, which consumes dissolved oxygen, negatively affecting aquatic life and potentially generating toxic algae and pathogenic microorganisms. This process is known as eutrophication (Zarza, n.d.).

Given that only one study on the water quality of El Ceibo Stream was found and that it did not consider the same parameters analyzed by our team, the originality of this research is reinforced, as it aims to provide relevant data on possible biochemical changes caused by human activity. Such changes could impact not only local ecosystems but also human health.

[1] *"Exploring along the riverbanks"*
[2] *"For a sustainable Sauce stream"*
[3] Biochemical oxygen demand (BOD) is the amount of oxygen that would be necessary to degrade the organic matter dissolved in the water through bacterial activity (Personal communication, Turchet, V., 2025).
[4] The concentration of nitrates, nitrites, and ammonium indicates the degradation of nitrogen compounds – Personal communication, Spizzo, S. (2025).
[5] Chemical Oxygen Demand (COD) indicates the amount of oxygen required to oxidize biodegradable and non-biodegradable organic matter (Personal communication, Turchet, V., 2025).
[6] Material soluble in ethyl ether indicates all pollution that is not soluble in water, such as plastic hydrocarbons (Personal communication, Turchet, V., 2025).

Research questions

Do the waters of El Ceibo Stream present biochemical modifications as they pass through the urban area of the city of Victoria, Entre Ríos, Argentina?

How do macroinvertebrates vary along the studied section of the stream?

I. Hypotheses

The students propose that:

- The waters of El Ceibo Stream present biochemical modifications from their entry into the city of Victoria, Entre Ríos, Argentina, to their exit.
- Macroinvertebrate species differ according to habitat type.
- The number of macroinvertebrate taxa varies along the studied section of El Ceibo Stream.

II. General Objective

To characterize the water quality of El Ceibo Stream through the analysis of physicochemical and biological variables.

III. Specific Objectives

i. To compare biochemical characteristics of El Ceibo Stream water in three sections along its course.

ii. To evaluate tree species in the area surrounding the stream.

iii. To determine the percentage of exotic species at each study site.

2. Materials and Methods

I. Description of the study Area

Argentine Republic is located in the Southern Hemisphere relative to the Equator and west of the Greenwich Meridian. It occupies part of the American continent and extends approximately 3,800 km from 22° to 55° south latitude. It borders Uruguay, Brazil, Paraguay, Bolivia, and Chile, and the Atlantic Ocean. The national territory is composed of 23 provinces and the Autonomous City of Buenos Aires, the country's capital.

The province of Entre Ríos is located in the central-eastern region of Argentina. It borders Corrientes Province to the north, Santa Fe to the west, Buenos Aires to the south, and the Oriental Republic of Uruguay to the east. The provincial territory is bounded by the

Paraná and Uruguay rivers, which are part of the La Plata Basin. Each river has several tributaries that run through the province's departments. Entre Ríos forms part of the Argentine plains, where two main landforms can be distinguished: rolling hills and lowlands of the delta. Four ecoregions are recognized: the Pampas, Espinal, wetlands, and the Paraná River Delta.

Figure 1. Argentine territory highlighting, within its political division, the province of Entre Ríos. Environmental map of the Province of Entre Ríos, showing its ecoregions, parks, and natural reserves belonging to the National System of Protected Areas (SNAP). Sources: todoargentina.net and Mapoteca Argentina

The Victoria Department is crossed by small streams that flow directly into the Paraná River Delta. According to studies conducted by geologist Juan José Nágera, the province of Entre Ríos has more than seven thousand rivers, streams, and creeks (Nágera, 1938). These watercourses originate from springs and are part of the Minor Tributaries Basin of the Paraná River (Dirección de Hidráulica de Entre Ríos, n.d.). El Ceibo Stream is located in the Victoria Department, Entre Ríos Province; it originates from spring waters and flows into the Victoria River.

The regional relief is characterized by gently rolling hills not exceeding 100 meters in height, known as "cuchillas entrerrianas". This landscape corresponds to an area originally covered by humid grasslands, which have been largely replaced by agroecosystems or urban centers. The numerous watercourses that cross this region, together with their gallery forests, give the landscape distinctive ecological characteristics. The gallery forest is composed of species such as the native willow (*Salix humboldtiana*), ombú (*Phytolacca dioica*), espinillo (*Vachellia caven*), tala (*Celtis tala*), among others.

Figure 2. Location of the study sites (blue icons) in relation to the city of Victoria, the slaughterhouses (red icons), and the municipal landfill (orange icon).
Source: Google Earth

Site 1:

Geolocation

Latitude: -32.623327; Longitude: -60.045777; Altitude: 51.0 m a.s.l.

This site is located farther from the city, near the stream's source, and therefore outside the urban area, within a rural environment. Native gallery forest trees have been completely replaced by invasive exotic species, mainly mulberries (*Morus nigra and Morus alba*), which generate significant canopy cover along the watercourse.

Ground cover consists mainly of herbaceous vegetation, with *Commelina erecta* (Santa Lucía flower) predominating in shaded areas, forming a ground cover that contributes to soil protection. In areas with less canopy cover and near the edges of agricultural fields, other native herbaceous species are present. The soil preserves all its horizons up to the edge of the stream. According to Agronomist Engineer Nicolás Del Valle, soil samples from this site correspond to a clay loam texture.

Site 2:

Geolocation

Latitude: -32.615848; Longitude: -60.110201; Altitude: 31.0 m a.s.l.

This site was selected because it is located downstream from the municipal open-air landfill and the Guillermo Huarte S.A. slaughterhouse.

Native gallery forest trees have been entirely replaced by glossy privet (*Ligustrum lucidum*) and mainly mulberries (*Morus nigra and Morus alba*). In an area close to the study site, some old specimens of white carob (*Prosopis alba*) and espinillo (*Vachellia caven*) are preserved, as the site is part of a tourist complex that has chosen to conserve these native trees.

Significant soil degradation is observed along the riverbank, with large gullies through which rainwater runoff drains into the stream. Surface soil horizons have been eroded, and soil samples show a silty loam texture, according to Del Valle. The soil lacks ground cover and is exposed, although there is substantial canopy cover provided by the aforementioned trees.

Additionally, two different types of rocks were found along a section of the riverbank. For their identification, Omar Peña, Soil Engineer and Director of the Los Altares Mineral Museum (Chubut, Argentina), was consulted. He indicated that the darker rocks correspond to cryptocrystalline quartz pebbles with calcareous material, while the lighter ones may be limestone or dolomitic limestone. This evidence supports the presence of significant carbonate rock deposits (limestone) in much of Entre Ríos Province. Peña also noted that a more precise identification would require diluted HCl, making rock determination more complex than initially assumed.

Furthermore, a brownish sample with a symmetrical ornamented pattern was found and identified as a glyptodont armor plate, along with two premolars that could belong to a glyptodont or a megatherium, animals representative of the megafauna typical of this region during the Tertiary Period.

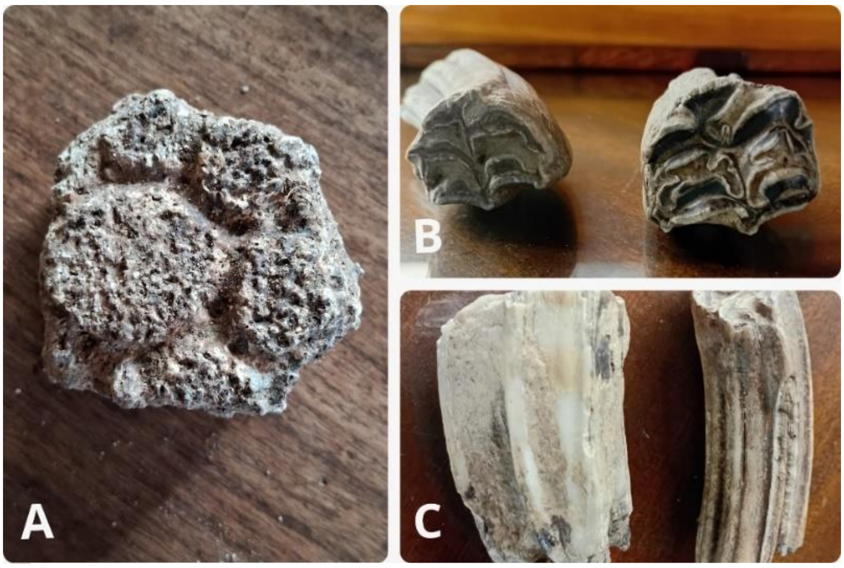

Figure 3. A – Fossilized Glyptodon plate. B and C – Fossilized premolars of Glyptodon or Megatherium.
Source: Authors' own work

Site 3:

Geolocation

Latitude: -32.596233; Longitude: -60.164587; Altitude: 20.0 m a.s.l.

This site is located upstream of its confluence with Corrales Stream, thereby avoiding the incorporation of tributaries from other areas of the Victoria Department. At this point, effluents derived from the drainage of the city's second slaughterhouse are recorded, as well as solid waste deposited in an uncontrolled manner by the local population.

Along the riverbank providing access to the stream, all vegetation has been removed, with only a few glossy privet trees (*Ligustrum lucidum*) present on the opposite bank. The soil is covered by herbaceous vegetation, mainly grasses, as the site is located on a property maintained as landscaped grounds with lawn grass. The area closest to the watercourse shows significant erosion caused by water flow during periods of heavy rainfall, when water levels rise. According to Del Valle, the soil texture is sandy loam. No canopy cover is present at this site.

Land Use Classification:

All three sites are classified according to the MUC System (Modified UNESCO Classification) as Cultivated Land – Parks and Sports Fields (821).

II. Materials

- 150 cm flexible measuring tape
- 250 ml beakers
- 3 ml disposable pipettes
- 50 m measuring tape
- 70% ethanol
- Alcohol thermometer
- Books and guides for macroinvertebrate identification
- Cameras
- Coarse salt
- Compass
- Computers
- Data sheets
- Distilled water

- Garmin eTrex Summit HC GPS
- Glass jars
- Glass stirring rods
- GLOBE Observer application
- Hand lenses
- Infrared thermometer (IRT)
- Latex gloves
- Masking tape
- Net
- NPK Soil Test Kit 3-5880 (LaMotte)
- Nylon bags
- pH meter
- pH meter calibration solutions
- Protective goggles
- Soil auger
- Soil color book
- Water spray bottle
- White plastic trays

III. Methods

Different GLOBE protocols were used in the methodology:

- Atmosphere protocols (air temperature, surface temperature, cloud cover)
- Biosphere protocols (land cover)
- Pedosphere protocols (soil fertility, pH, and soil characterization)
- Hydrosphere protocols (pH, temperature, transparency, and macroinvertebrates)

Fieldwork:

The research design was based on bibliographic review and fieldwork planning. The bibliographic review was used as a source of information, particularly to identify similar environmental issues and to support the identification of macroinvertebrate species, among other aspects. This was the first time the group worked with Hydrosphere GLOBE protocols, especially the macroinvertebrate protocol. Therefore, an initial practice sampling was conducted based solely on GLOBE Hydrosphere reference materials.

Over the course of the year, additional tools were incorporated, including a virtual Hydrosphere workshop organized by GLOBE Uruguay and access to new bibliographic sources. As a result, the research objectives were slightly modified, and it was decided to include a comparison of macroinvertebrate counts at each site within the same habitat type, that is, pool-to-pool and riffle-to-riffle comparisons.

These preliminary samplings, carried out during autumn, allowed the team to practice sampling techniques and macroinvertebrate classification, during which some errors occurred. In spring, once the team was familiar with the macroinvertebrate protocol, all necessary precautions were taken to ensure comparability of samples among the three study sites and their respective habitats.

Biodiversity and water quality indices were calculated based on the total number of macroinvertebrates recorded at each site.

One of the first aspects to be evaluated was the selection of sampling sites. The use of satellite imagery was essential to identify the stream's source and mouth, its course, land use, tributaries, and surface cover, among other features. Most of the stream flows through private properties, so appropriate permits were required to access the sites and to conduct sampling and data collection in areas that ensured physical safety.

Although samples were collected in a different order due to organizational issues and access permissions, they were later arranged following the direction of the stream flow.

Prior to field activities, instruments were calibrated and battery conditions were checked. Materials were also organized into different containers to ensure proper transport and handling during fieldwork.

All available protocols were applied using the instruments at hand. For the transparency protocol, a homemade transparency tube was constructed. Other analyses of interest, aimed at identifying different sources and degrees of contamination, such as nitrates, nitrites, ammonium, and biochemical oxygen demand (BOD), were conducted at the Vivot-Gieco Water Laboratory of the National University of Entre Ríos (UNER), under the supervision of biochemist Silvana Spizzo, who recommended these analyses. Water samples were collected from turbulent sections of the stream to ensure more representative measurements[7].

[7] Hydrosphere notes – Nitrates. GLOBE Uruguay. Version: May 2025. Translation and editing: Lic. Andrea Ventoso. Digitization and adaptation: Lic. María Claudia Mongiardino

At each site, water temperature was measured first, followed by the assessment of cloud cover, air temperature, and surface temperature. A 50-meter transect was then established, with markers placed every two meters. One group of students mapped the site, while others were assigned tasks such as determining cardinal directions using a compass, georeferencing the site with GPS, collecting macroinvertebrate samples, measuring turbidity and water pH, collecting soil samples adjacent to the stream, and taking photographs of the cardinal directions and other relevant features such as the presence of litter, algae, and local vegetation. At the El Ceibo recreational complex, the height of some trees was also measured.

All fieldwork was conducted outside regular school hours, and transportation was coordinated with the students' families.

During autumn sampling, macroinvertebrates were preserved in glass jars containing 70% ethanol diluted in a 70:30 ratio with water, for later analysis at the school. In spring, this methodology was modified, and macroinvertebrate identification and classification were conducted directly at each study site.

For identification, dichotomous keys and extensive bibliographic resources were used. To analyze macroinvertebrate diversity at each study site, families were assigned scores according to the BMWP/Bol index. Based on the scores obtained, water quality was classified as:

Table 1. Score obtained in the water quality index

Biological Condition	BMWP/Bol	Interpretation
Good	>100	Unaltered water body
Acceptable	61-100	With some effect of contamination
Questionable	36-60	Contaminated waters
Critical	16-35	Very contaminated waters
Very Critical	<15	Heavily contaminated waters

Source: Ministry of Environment and Water of Bolivia (n.d.). Guide for the Evaluation of the Biological Conditions of Water Bodies Using Benthic Macroinvertebrates.

To further analyze macroinvertebrate diversity, the software PAST 4.09 was used. With this tool, the Simpson diversity index was calculated, which measures the degree of diversity within a community. This index ranges from 0 to 1: the closer the value is to 1, the greater the diversity and the more even the distribution of species.

Using the same software, beta diversity was also assessed. Beta diversity evaluates differences in species composition between two areas. This index also ranges from 0 to 1: a value of 1 indicates that both sites share exactly the same species (identical communities), whereas a value of 0 indicates that they share no species (completely different communities). For this analysis, the Whittaker index was applied.

The EPT index in aquatic studies refers to a biotic index based on aquatic macroinvertebrates. EPT is an acronym for Ephemeroptera, Plecoptera, and Trichoptera, three insect orders commonly used as indicators of water quality. These organisms are sensitive to pollution, and their presence or absence, as well as the abundance of their populations, provides information about the health of aquatic ecosystems. This index is expressed as the percentage of sensitive orders relative to the total number of taxa recorded. A high EPT index percentage indicates good water quality (Villamarín-Cortez, n.d.).

Formula: Percentage of macroinvertebrates = (Total EPT taxa / Total taxa found) × 100

Table 2. Water quality classification according to the EPT index obtained.

Rating	Excellent	Good	Good-fair	Fair	Poor
EPT	>27	21-27	14-20	7-13	0-6

Source: Villamarín-Cotez

At each site, soil profiles were observed and related to the degree of erosion and riparian ground cover, and the trees present were identified. To assess potential soil alterations, soil samples were collected from the three study sites. Samples were taken from the upper 15 cm of soil using a soil auger provided by the Aranguren Agricultural and Livestock Cooperative. Ten soil cores were collected from the riparian zone of each site, specifically within the floodplain of the stream during periods of high water.

The samples were analyzed in the school setting with fifth-year secondary students specializing in Natural Sciences, following the protocol for pH measurement using a pH meter previously calibrated. In addition, rapid soil fertility analyses were conducted using the NPK Soil Test Kit 3-5880 (LaMotte). Soil characterization included the determination of soil color using a soil color book and texture assessment through tactile evaluation.

Soil cover was assessed using the GLOBE Observer application, and the results were later analyzed and compared with the responses sent by NASA via email, in conjunction with our own field observations.

Photographic records were used both to document the study sites and to identify macroinvertebrates. For the latter purpose, magnifying lenses for mobile phones provided by GLOBE Argentina were also used.

During the investigation, interviews were conducted with Verónica Turchet regarding water quality, and with Nicolás Del Valle concerning soil texture and soil horizons. Several members of the GLOBE community were also consulted for support in macroinvertebrate identification and sampling procedures.

Limitations and obstacles:

The first limitation was that macroinvertebrate identification requires more advanced training than other GLOBE protocols with which the group was already familiar. For this reason, the initial data collection was used as a training instance and was not included in the analyses of this study.

Another limitation was related to the lack of instruments to measure dissolved oxygen and alkalinity. In addition, these parameters were not requested from the UNER water analysis laboratory when the samples were submitted, as the importance of obtaining these data was recognized only later during the development of the research.

Furthermore, there is limited specific information available about the El Ceibo Stream. This limitation is compounded by the fact that the stream flows through several privately owned properties, making it necessary to request authorization to access the sampling sites.

3. Data summary

Table 3. Results of the chemical analyses of the water from the three study sites.
CAA: *Argentine Food Code*

Analytical Determinations	Site 1	Site 2	Site 3	Required values for drinking water according to Article 982 (CAA)
Nitrates – ppm NO3-	1,7	1,83	3,75	máx. 45 ppm
Nitrites - ppm NO2-	0,053	0,04	0,546	máx. 0.10 ppm
Ammonium - ppm	0,23	0,3	0,5	máx.: 0,20 ppm
DBO	5	N/D	0,4	

Source: Vivot-Gieco Water Laboratory of the National University of Entre Ríos - Argentine

Table 4. Results of the GLOBE protocols used according to the season of the year

Site Name	Date	Season of the Year	pH	Transparency	Water Temperature (°C)	Air Temperature (°C)	Cloud Cover (%)
Site 1	30/6/2025	Fall	7,9	120	3,3	5	10
	20/10/2025	Spring	7,7	85,83	15,3	24	0
Site 2	2/6/2025	Fall	8.3	99,33	9,67	12	0
	3/11/2025	Spring	8,2	109,17	22	20	50
	10/11/2025		7,9	52,07	18	19	0
Site 3	9/6/2025	Fall	8,4	79,53	6,33	7	0
	27/6/2025		8,5		1	13	0
	15/10/2025	Spring	7,9	42,67	20	26	80

Source: Own authorship

Table 5. Comparison of macroinvertebrate taxa at each study site and at each sampling location (riffle and pool). The total number of individuals recorded is also indicated

ORDER/FAMILY	SITE 1		SITE 2		SITE 3	
	Corredera	Poza	Corredera	Poza	Corredera	Poza
Amphipoda-Hyalellidae	7	66	2	13	16	90
Bivalvia-Sphaeriidae				3		
Coleoptera			1			
Coleoptera-Noteridae		1				
Coleoptera-Scirtidae		22				
Diptera			5			
Diptera-Chironomidae		3	3			5
Diptera-Culicidae	3					
Diptera-Simuliidae						
Ephemeroptera-Baetidae	68	28	26		6	
Ephemeroptera-Caenidae		2				12
Ephemeroptera-Leptophlebiidae				21		
Ephemeroptera-Prosopistomatidae				1		
Gastropoda-Ancylidae		8				
Gastropoda-Physidae					3	1
Hemiptera-Corixidae				1		17
Hirudinea		12	2	1	2	12
Megaloptera-Corydalidae		1				
Odonata		2				
Plecoptera-Diamphinoidae						2
Rombidiformes-Hydracarina				1		
Tricoptera (vida libre)	4	2		2		
Tricoptera-Hydropsychidae			24			
Totales	82	147	63	43	27	139

Source: Own authorship

Table 6. Results of taxon counts, number of individuals, and biodiversity and water quality indices from the chemical analyses of the water at the three study sites.

	SITE 1	SITE 2	SITE 2
TAXA	12	14	8
INDIVIDUALS	229	106	166
SIMPSON INDEX	0.71	0.83	0.57
BMWP INDEX	61	55	38
EPT INDEX	45%	49%	12%

Source: Own authorship

Table 7. Results of pH and soil fertility of the riparian zone of Arroyo El Ceibo

SOIL PROTOCOLS		SITE 1	SITE 2	SITE 3
SOIL pH		7.9	8.6	8.0
SOIL FERTILITY	N	Low/Med	Low	Low
	P	Low/Med	Med	Low/None
	K	Med/High	High	High

Source: Own authorship

4. Analysis of Results

Regarding the determination of nitrates, nitrites, and ammonium, it can be observed that nearly all values increase progressively from Site 1 to Site 3, with the greatest increase occurring between Sites 2 and 3 (see Table 3).

Table 4 shows that water pH increases slightly from Site 1 to Site 3. Additionally, at all three sites, pH values recorded in spring are slightly lower than those measured in autumn. Water transparency exhibits an opposite trend: transparency is highest at Site 1 and decreases progressively along the course of the stream. Furthermore, transparency values are higher in autumn than in spring.

At Site 2, water transparency was measured twice during spring: a few days before a rainfall event and 72 hours afterward. A marked decrease in transparency was observed, dropping from 109.17 cm to 52.07 cm.

Finally, water temperature shows seasonal variations that fluctuate according to changes in air temperature.

When analyzing the distribution of macroinvertebrates between riffles and pools, clear patterns emerge. At Sites 1 and 3, pools concentrated the highest number of individuals (147 and 139, respectively). In contrast, Site 2 shows the opposite pattern, with riffles hosting more individuals (63) than pools (43).

In terms of taxonomic richness, Sites 1 and 2 show similar values (12 and 14 taxa, respectively), whereas Site 3 exhibits markedly lower richness, with only 8 taxa. Regarding abundance, Site 1 records the highest number of individuals (229), followed by Site 3 (166) and Site 2 (106).

Concerning taxonomic composition at the order level, Ephemeroptera is present at all three sites, with the highest abundance at Site 1, while Trichoptera occurs at Sites 1 and 2. These two sites show a higher presence of pollution-sensitive taxa. The Simpson diversity index supports this trend: Sites 1 and 2 show values of 1.71 and 0.83, respectively, indicating more diverse communities compared to Site 3, which presents a lower value (0.57). Site 3 shows lower diversity, consistent with the Simpson and EPT index results.

The BMWP index indicates a progressive decline in water quality from Site 1 to Site 3. Consistently, EPT index values at Sites 1 and 2 show high percentages (45% and 49%), whereas Site 3 presents a considerably lower value (12%) (see Table 6).

A similarity analysis among sites revealed that they are not similar to one another. The Whittaker beta diversity index shows a value of 0.61538 between Sites 1 and 2, 0.54545 between Sites 2 and 3, and 0.5 between Sites 1 and 3.

Regarding riparian soil pH, all three sites exhibit alkaline values. Site 1 presents the lowest value (7.9), followed by Site 3 (8.0) and Site 2 (8.6). Soil fertility analyses show low nitrate concentrations at all sites, although slightly higher at Site 1. Phosphorus content is similar at Sites 1 and 2 but lower at Site 3. Potassium concentrations are comparable across the three sites (see Table 7).

5. Discussion

Although nitrate, nitrite, and ammonium values are acceptable for recreational waters, it can be observed that nitrite and ammonium concentrations increase along the stretch where the watercourse flows through the city. Verónica Turchet indicates that waters with higher BOD values are those that are more polluted; however, the values obtained fall within normal parameters for recreational water use.

If we compare the BOD values obtained from our analyses, ranging from 0 to 5 mg O_2/L, with those recorded on July 8, 2021, following the complaint against Frigorífico Huarte SA, which ranged from 180.5 to 237.5 mg O_2/L, a considerable reduction can be observed. These very high values corresponded to water samples taken near Site 2 of our study, which suggests that the company has improved its settling ponds.

In the interview, Verónica Turchet informed us that the Technical School began holding regular classes, not only practical activities, on the property adjacent to Frigorífico Huarte SA. This situation likely led to modifications in some slaughtering and processing procedures. In addition, the facility is currently operating at a lower processing capacity, resulting in a reduced amount of organic matter being discharged. Previously, due to the lack of adequate settling ponds, effluents were released into the school's experimental field; however, discharge protocols have since been adjusted, and treatment ponds that were previously nonfunctional have now been put into operation.

The BMWP index for Site 1 indicates that the biological condition of the water is acceptable, although it presents some degree of contamination. Sites 2 and 3 indicate doubtful biological conditions and are therefore considered contaminated.

On the other hand, the EPT index for Sites 1 and 2 indicates excellent water quality compared to Site 3, which, according to the classification, corresponds to acceptable quality. This indicates that Sites 1 and 2 contain a higher proportion of species sensitive to pollution.

Among the three sites, it is important to highlight that Site 2 presents the highest species richness, followed by Site 1. This richness contributes to Site 2 being the most diverse site. At this site, it is also important to note that there is greater evenness among the abundances of the species represented in the sample. Site 1 presents the highest number of individuals. In contrast, Site 3 exhibits greater dominance, particularly of the Order Amphipoda.

When analyzing the distribution of macroinvertebrates between riffles and pools, pools concentrated the highest number of individuals at Sites 1 and 3, which is consistent with the typical tendency of slow-flowing waters to accumulate organic matter and provide more stable microhabitats[8]. In contrast, Site 2 presents an inverse pattern, possibly associated with recent disturbances caused by rainfall events, which increased sediment transport into the pool, or with recreational use of the area, which could generate physical disturbances in the streambed and affect organism distribution.

Additionally, overall totals show that Site 1 is the most abundant, followed by Site 3 and finally Site 2. These results are consistent with the previously calculated diversity and water quality indices, reinforcing the idea that Sites 1 and 2 present better ecological conditions than Site 3.

The decrease in water transparency from Site 1 toward Site 3 is consistent with observations made by Agronomist Engineer Del Valle, who explains that in lotic systems the headwater zone of the stream (crenon) presents clearer waters due to a lower sediment load. Toward downstream sections (potamon), the transport and accumulation of suspended material increase, resulting in reduced water transparency.

The alkaline pH observed in both the stream water and the riparian soil is related to the surrounding geology, particularly the presence of carbonate rocks such as limestone. This

[8] Private communication with Caro, C. (2025)

information was corroborated by Turchet, who explains that pH values above 7 in this region are due to the type of rocks present in the soil and the geographical characteristics of the area. She also indicates that the differences observed between autumn and spring pH values may be related to the limestone substrate and reduced rainfall, which results in higher carbonate concentrations and, consequently, a slight increase in pH.

Regarding soil fertility and texture, these characteristics are associated with the degree of degradation of the soil profiles, resulting from water erosion generated by pronounced terrain slopes and intense runoff caused by regional precipitation. Del Valle explains that a loamy structure indicates a balance among sand, silt, and clay, suggesting that Site 1 has a well-preserved soil, unlike Sites 2 and 3, where erosion and sediment transport have reached the C horizon, closer to the parent material.

Although the studies mentioned in the introduction do not specifically include El Ceibo Stream, they employ water quality assessment protocols similar to those used in this study. In the research conducted by Liceo de Sauce (2022), "*Por un arroyo Sauce sustentable: Análisis de la calidad del agua*", BMWP index values are considerably lower than those recorded at our Site 3. In addition, that study reports a lower number of taxa and significantly reduced water transparency values.

Regarding the report by Liceo Nº 1 of Bella Unión, Uruguay (*Explorando a orillas del río*, 2022), the study focused mainly on the analysis of physicochemical water parameters such as temperature, transparency, conductivity, pH, dissolved oxygen, nitrates, phosphates, and potassium. As explained in the introduction of the present study, these parameters may vary depending on surface runoff inputs and urban and industrial effluents. From a biological perspective, the analysis focused on microorganisms present along riverbanks and the performance of bioassays, without including macroinvertebrates as bioindicators, unlike the approach used in this research.

Another study conducted in Uruguay by Escuela Nº 88 Alfredo B. Nobel, entitled "*Water quality in nearby areas to Canelones city through the use of macroinvertebrates as bioindicators*", shows a pattern comparable to that obtained for El Ceibo Stream. In that study, the site corresponding to a rural area with agricultural activity presented the highest level of water quality, as evidenced by the types and quantities of macroinvertebrates recorded, as well as a high abundance of individuals and species diversity.

The case of the Chimehuín River, located in the province of Neuquén and studied by the Huechulafquen Science Club, presents an environmental context different from that of streams in Entre Ríos, as its waters originate from snowmelt in the Andes Mountains. Nevertheless, it shares a relevant aspect: environmental changes linked, among other causes, to anthropogenic influences and the need for sustainable land-use planning to protect water resources. Physicochemical analysis shows that most parameters remain within suitable ranges for aquatic ecosystems, similar to what was observed in El Ceibo Stream. A similar situation is observed in the biological analysis, where Ephemeroptera constitutes the main taxon within the EPT index, coinciding with our study sites. However, values recorded in the Chimehuín River are generally higher than those obtained at our Sites 1 and 2.

In the study conducted in the Gualeguaychú Department, Entre Ríos, "*Aplicación de índices de calidad de agua en un arroyo pampeano utilizando macroinvertebrados bentónicos como bioindicadores*[9]", Cettaz-Minaglia et al. (2014) note that few studies on benthic fauna have been carried out in the province. They also highlight that over the past forty years the region has experienced increasing human intervention, particularly due to land-use changes associated with urbanization and agricultural activities. The authors emphasize that physicochemical analysis and the use of macroinvertebrates as biological indicators are complementary methods for assessing water quality. In their study, application of the BMWP index yielded values classifying water quality as ranging from fair to very poor. However, they note that this index was designed for Pampean environments different from the study area, which is characterized as Mesopotamian Pampa, and therefore suggest the need to adapt biological indices to the specific characteristics of the region.

It is striking how some invasive exotic tree species have progressively displaced native species, eventually leading to their disappearance. These changes also affect local fauna, as biotic relationships among species that evolved together are disrupted.

It should be noted that only data from a single season of the year are being compared; therefore, to obtain more reliable results, it would be advisable to repeat the studies in autumn and spring of 2026 and include measurements of dissolved oxygen concentration and water alkalinity. Dissolved oxygen levels are critically important for aquatic life; values below 3 mg/L are critical for most aquatic organisms. Alkalinity data would allow determination of the buffering capacity of the water, that is, its resistance to pH changes when acids are added. In this region, acid inputs generally originate from rainfall, although they may also come from the soil[10].

6. Conclusion

Through our fieldwork and the analyses requested from the UNER Water Laboratory, it was possible to answer the research questions posed and to accept all the hypotheses formulated. El Ceibo Stream shows both biochemical modifications and variations in macroinvertebrate populations, as well as differences in the proportion of species according

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[9] *Application of water quality indices in a Pampean stream using benthic macroinvertebrates as bioindicators*

[10] GLOBE Program Uruguay. (n.d.). Hydrosphere: Introduction. GLOBE.

to habitat type, whether pools or riffles. Compared to studies conducted in other watercourses, the results obtained for El Ceibo Stream are not particularly alarming; however, this does not imply that the situation does not require attention, monitoring, and preventive actions.

Based on the biochemical results obtained at Site 1, it can be inferred that agricultural practices compatible with the so-called Good Agricultural Practices (GAP) are being implemented in the surrounding rural area. According to the Argentine Chamber of Agrochemical and Fertilizer Health (CASAFE), GAP consist of a set of principles, standards, and technical recommendations applicable to the production, processing, and transportation of food. Among the promoted measures is the responsible management of agrochemicals and fertilizers throughout their entire life cycle, from development and use in the field to the final disposal of containers. The implementation of these practices favors environmental protection by contributing to the reduction of greenhouse gas emissions, the decrease in waste generation, and the optimization of resource use such as energy and water.

It is evident that once the watercourse enters the urban area, in addition to the previously mentioned changes, the presence of solid waste of anthropogenic origin can be observed, such as polyvinyl chloride[11] (PVC) plastic bottles and a large quantity of polyethylene bags that are carried by the current, especially during periods when the stream's flow increases due to precipitation. When the stream passes through private properties, it is not possible to assess the level of care provided; however, in public areas, the highest accumulation of waste is observed in the surrounding environment. At Site 1, corresponding to the rural area, the solid waste mentioned above was not observed, unlike Site 2, where only a small amount was found, possibly because it is a private recreational complex where maintenance staff regularly perform cleaning tasks. Site 3 and other freely accessible sectors of El Ceibo Stream, such as the area known as "Puente Verde," show marked visual pollution associated with inadequate waste disposal practices by some citizens. This situation not only affects the landscape but also negatively impacts environmental quality and the organisms inhabiting the watercourse. The problem is exacerbated by the lack of sustained environmental management actions, such as regular cleaning, space-use control, and the development of environmental education and prevention strategies by the municipality, which hinders the conservation of these areas as natural and recreational spaces.

Although the results are not conclusive, as explained previously since they only include macroinvertebrate surveys conducted during the spring of 2025, the indices indicate that there are parameters that need improvement. Actions are required, along with more adequate control over waste management in the city, including waste generated by the general population, its final disposal at the municipal open-air landfill, as well as industrial waste.

[11] Personal communication, Turchet, V. (2025)

It is noteworthy that BOD values have improved since 2021; however, biotic indices remain inadequate. Efforts should be made to improve them in order to align with the provisions of Resolution (SMA) 84/07 dated November 29, 2007, which regulates the use of recreational bathing waters. Among the functions of the Ministry of Environment of the Province of Entre Ríos, the following are mentioned:

> *“to promote and participate, jointly with other agencies, in systems for the control and monitoring of water, air, soil, and subsoil quality, with the purpose of ensuring acceptable quality standards to avoid harm to the population and the environment, determining physical, chemical, and biological parameters that guarantee a healthy environment and ecosystem balance; that water is a scarce natural resource whose quality must be protected, defended, managed, and treated as such; that surface waters, in particular, are renewable resources with limited recovery capacity in the face of negative impacts from human activity, and therefore environmental policy must contribute to environmental preservation while protecting human health; and that it is necessary to control and prevent contamination of recreational waters […]”*

In the Victoria Territorial Strategic Plan, approved in 2011, El Ceibo Stream is explicitly mentioned as a “new axis of public space and environmental lung and as an urban–rural buffer edge,” positioning it as a strategic component for the reconversion of the natural edge of the urban area into spaces for public and environmental use. Therefore, we propose to revisit this idea by incorporating and designing a green corridor that respects and enhances the natural conditions of the stream, ensuring public access, recreational spaces, and environmental conservation, with the aim of achieving more equitable and sustainable urban development.

Likewise, it would be advisable to move forward with the progressive replacement of invasive exotic tree species with native species present along the riverbank. This would help prevent the dispersion of seeds that negatively affect local ecosystems, improve habitat conditions for native fauna, and contribute to the recovery of the gallery forest characteristic of the Entre Ríos region.

Lines of action:

The implementation of this green corridor, together with environmental education and public awareness, combined with joint action among the Municipality, other governmental agencies, and citizens, would contribute to the achievement of several Sustainable Development Goals (SDGs):

SDG 3: Ensure healthy lives and promote well-being for all, by improving air quality and promoting healthier environments.

SDG 11: Make cities inclusive, safe, resilient, and sustainable, by increasing green spaces and strengthening the relationship between nature and the urban community.

SDG 13: Planting more trees along sidewalks would reduce urban temperatures and increase local carbon sequestration, contributing to climate action.

SDG 15: Protect and restore terrestrial ecosystems by promoting biodiversity conservation and local ecosystem balance.

SDG 17: Strengthen partnerships to achieve the goals, promoting collaboration among different stakeholders to design and implement comprehensive and sustainable solutions.

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ANNEX 1. Selected badges

Impact on the Community (I Make an Impact)

We chose this badge because we identified the biochemical condition of El Ceibo Stream, a watercourse that runs through the city of Victoria, Entre Ríos, Argentina, as our main problem. From this concern, we were able to carry out a diagnosis of the current state of the stream. Mitigating this problem would not only help improve the natural environment, but would also generate a positive impact on the community and its quality of life.

Data Scientist (I Am a Data Scientist)

We chose this badge because, as the project progressed, the students collected data that were later uploaded to the GLOBE platform. These data were then downloaded and analyzed using statistical tools, through tables and graphs created with Microsoft Excel, which allowed us to interpret the results and reach well-supported conclusions.

The data used were our own, since the problem addressed is located within our city. During 2025, data related to the atmosphere, hydrosphere, biosphere, and pedosphere were collected, some of which were specifically used in this research.

The data collection carried out by the students of Colegio de la Mesopotamia at different study sites reflects the strong fieldwork component of the project and supports the choice of this badge.

STEM Professional (I Work with a STEM Professional)

We chose this badge because, throughout the project, we worked with the collaboration of various professionals, including an Agricultural Engineer, a Bachelor's degree holder in Food Science, and a Soil Engineer. All of them provided relevant information, helped resolve questions, and contributed to identifying possible solutions to the problem addressed.

For the implementation of some protocols, we also consulted members of the GLOBE Program, such as Andrea Ventoso, Claudia Caro, and Ana Prieto. Some consultations were carried out in person, while many others were conducted via email or WhatsApp, which allowed us to connect with professionals from different regions of Argentina and even from abroad.

Working with professionals provided access to new knowledge and diverse perspectives, enabling us to analyze, compare, and discuss each situation that arose during the research. This exchange was key to reaching the final conclusions.

ANNEX 2. Members of the research group collecting data.

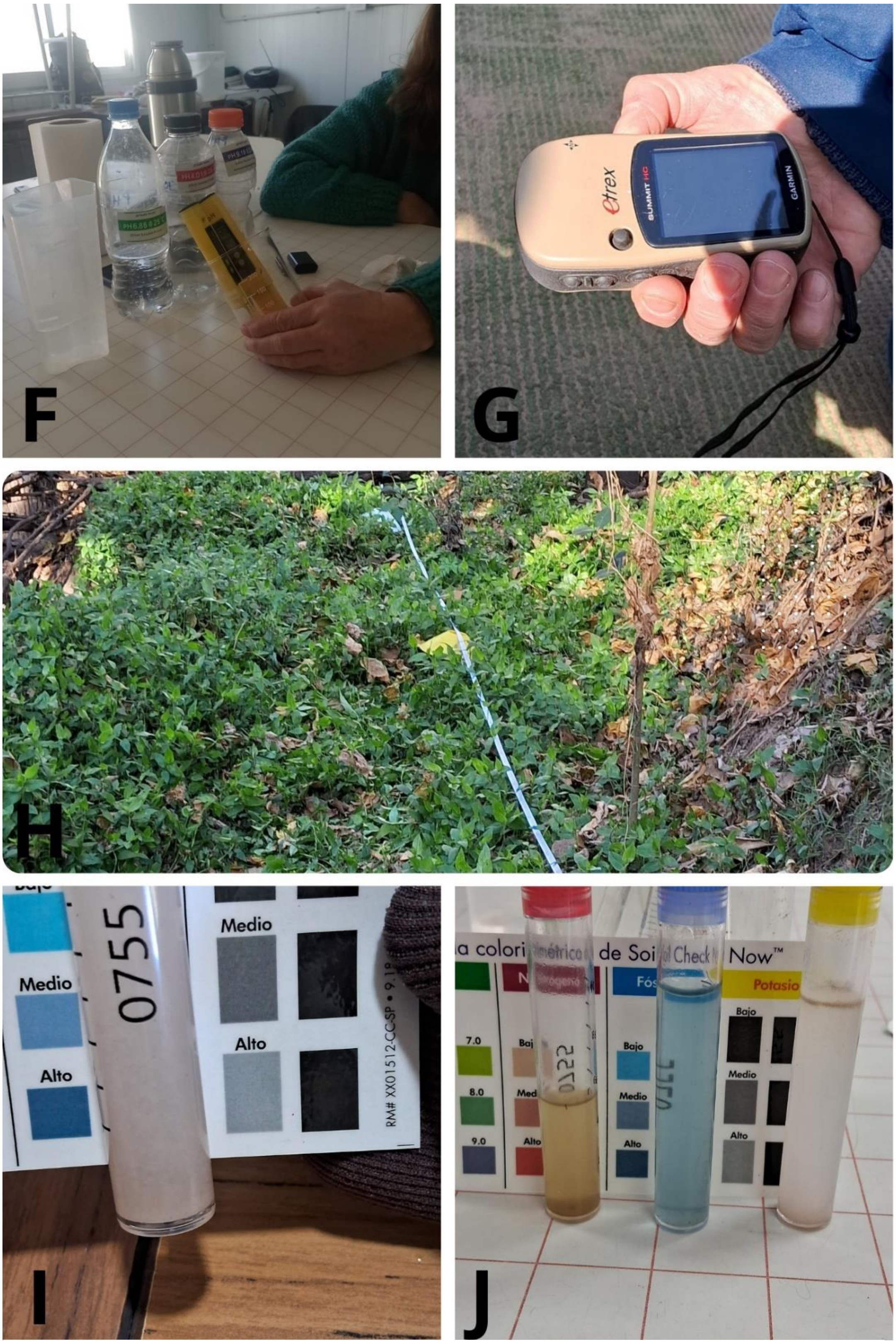

Figure 4. A – Carrying out the water transparency protocol. B, C, D and E – Macroinvertebrate sampling and subsequent identification and classification. F – pH meter calibration protocol. G – GPS usage protocol. H – Mapping of Site 1. I and J – Soil fertility protocol.
Source: Own authorship.

ANNEX 3. Some identified macroinvertebrates

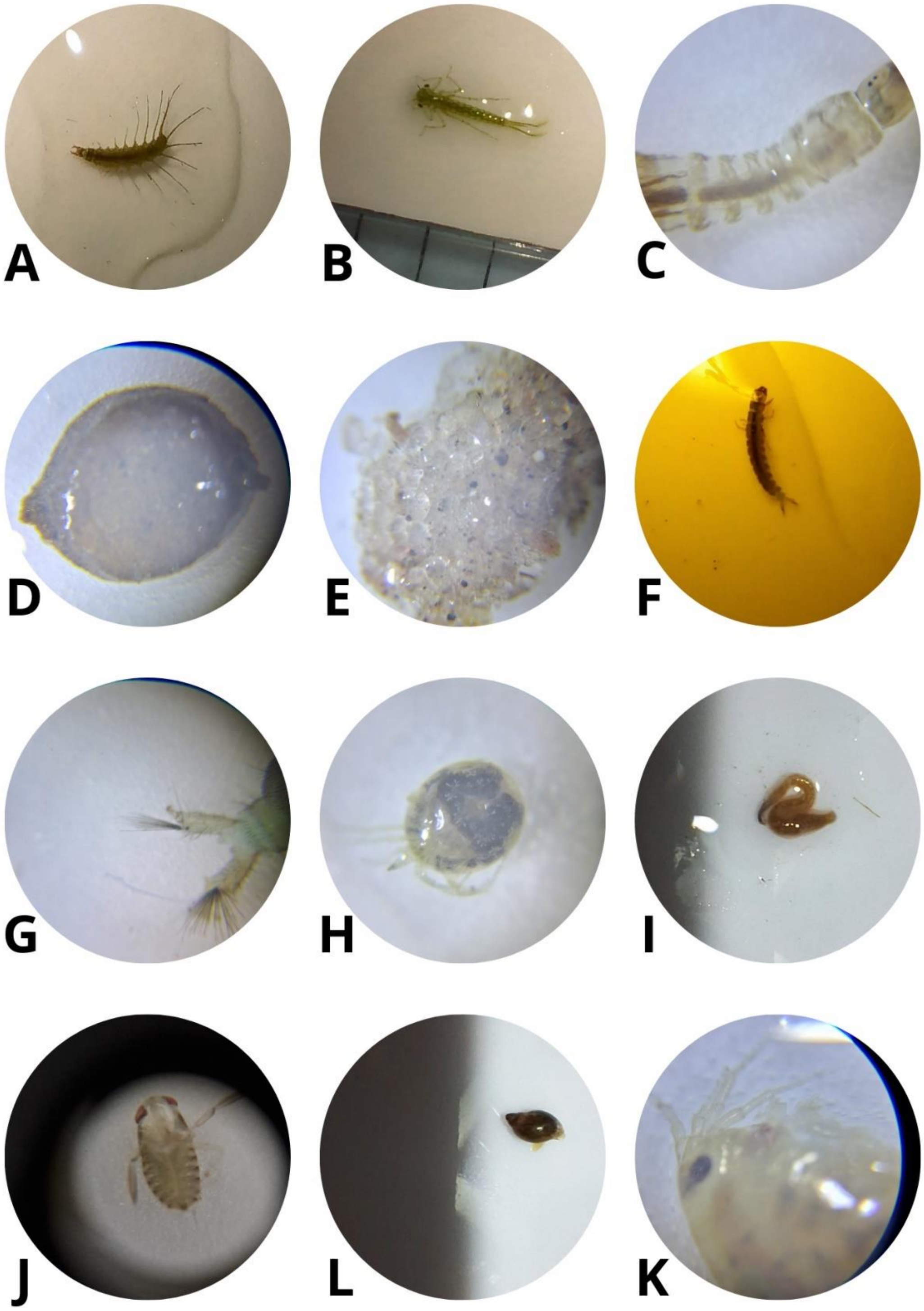

Figure 5. A – Order Megaloptera, Family Corydalidae. B – Order Odonata. C – Order Diptera, Family Simuliidae. D – Order Ephemeroptera, Family Prosopistomatidae. E – Order Trichoptera. F and G – Free-living Trichoptera. H – Suborder Hydracarina. I – Family Hirudinea. J – Order Hemiptera. K – Class Amphipoda. L – Order Gastropoda. Source: Own authorship.

ANNEX 4. Anthropogenic impact and opportunities for environmental restoration in the surroundings of Arroyo El Ceibo.

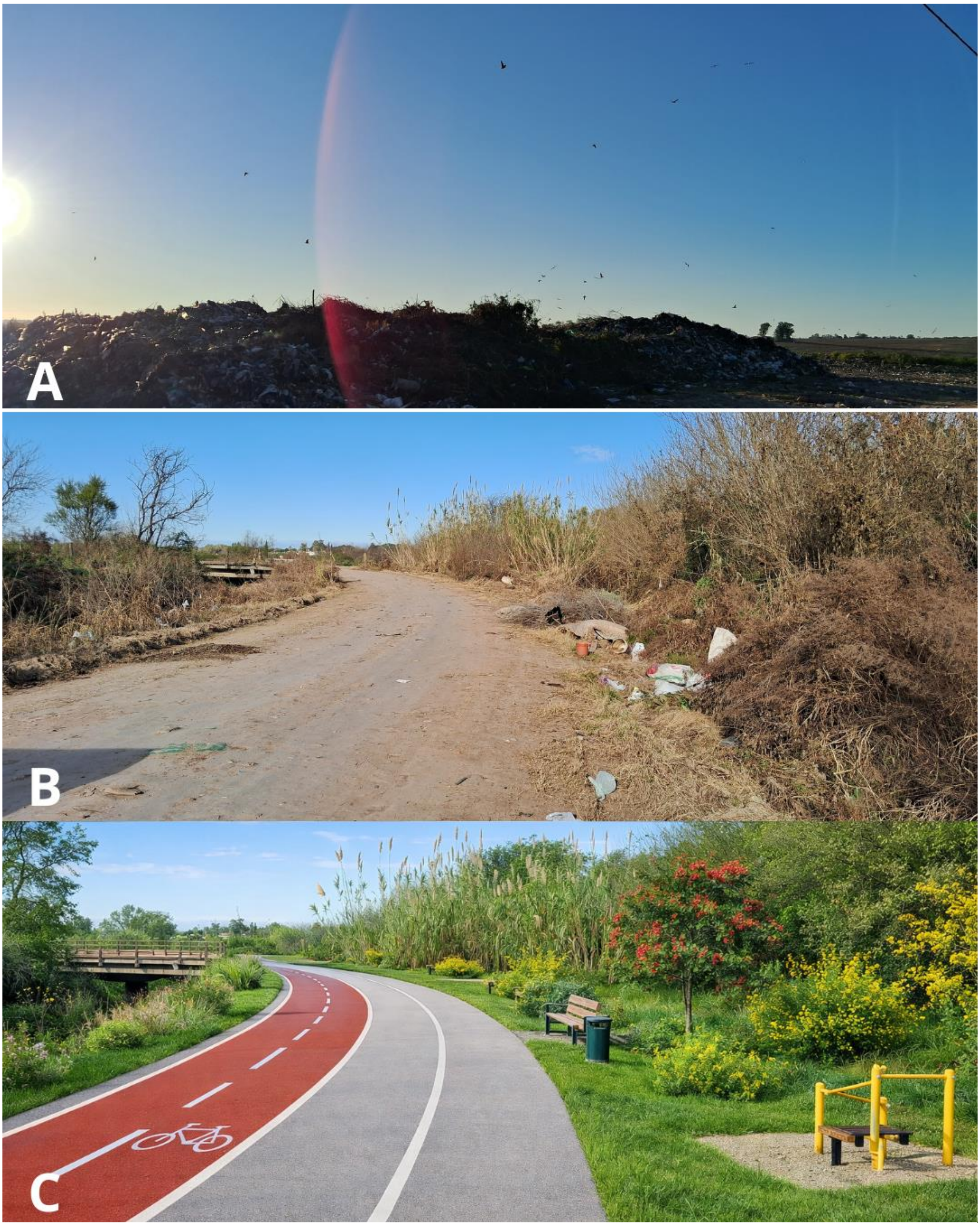

Figure 6. A – Open-air landfill of the city of Victoria, Entre Ríos, Argentina. B – Degraded landscape along Camino del Puente Verde. Visual evidence of environmental deterioration. C – Potential landscape of Camino del Puente Verde: Arroyo El Ceibo as an environmental corridor. Source: Own elaboration based on field photographic records, with assistance from generative artificial intelligence.