Larval feeding habits of Diptera, Coleoptera, and Megaloptera in the Ranchería river, La Guajira, Colombia

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Abstract
Studies on feeding habits of aquatic insects in Colombia are scarce. Previous research on Andean rivers has categorized trophic guilds, finding a predominance of detritivores and omnivory, while studies in the Sierra Nevada de Santa Marta have reported trophic plasticity in macroinvertebrates. This study aimed to characterize the feeding habits of larvae from three insect orders in a section of the Ranchería River. The study was conducted in the middle basin during the dry season using a Surber net. We examined 300 digestive tracts. Gut contents were mounted on slides with polyvinyl alcohol and observed under microscope to identify six food categories: fine particulate organic matter (<1mm), coarse particulate organic matter (>1mm), microalgae, animal material and fungi. Relative proportions of each food item were estimated by examining random fields using ImageJ software. Detritivores mainly consumed fine (FPOM) and coarse particulate organic matter (CPOM). Some taxa specialized in microalgae, hyphae, or animal material. Principal component analysis, heat map, and NPMANOVA segregated trophic groups. FPOM predominated in these insects' diet, similar to findings in other Neotropical rivers. However, some taxa showed trophic plasticity, differing from previous studies in temperate latitudes. Further research on feeding habits across different basins in the region is needed to validate the functional categorization of these communities.

Keywords: Aquatic insects; feeding habits; gut content; Sierra Nevada de Santa Marta

1. Introduction

Rivers are open and heterotrophic ecosystems where a significant portion of energy comes from allochthonous organic matter, primarily leaf litter, contributed from riparian zones (Roldan & Ramirez, 2022). This organic matter is decomposed and processed not only by fungi and bacteria but also by various aquatic insects that fulfill important trophic roles in the ecosystem's food web (Boyero, 2000). Although tropical regions occupy a vast extension globally, most ecological theories about ecosystem functioning have been derived from studies in temperate zones. In contrast, studies focused on analyzing and understanding in depth the food webs, feeding habits, and functional roles of organisms in tropical rivers have been historically scarce (Tomanova et al., 2006; Cheshire et al., 2005; Granados-Martínez et al., 2016; Ramírez & Gutiérrez-Fonseca, 2014). Moreover, many approaches in the tropics have categorized macroinvertebrate trophic groups through simple extrapolation from temperate zone studies, without an empirical basis of gut content analysis in Neotropical species (Cheshire et al., 2005).

Currently, relatively few studies conducted in tropical environments have described in detail the feeding habits of river and stream macroinvertebrates based on quantitative analysis of their gut contents. Among these, the study by Tomanova et al. (2006) represented one of the first to categorize trophic groups based on the examination of digestive tracts of Neotropical species, establishing a pioneering diet composition code for macroinvertebrate taxa in lotic systems of this region.

To date, published works on diets and trophic guilds of aquatic insects in Colombia remain scarce. Notable among these is the work of Chará-Serna et al. (2012), who classified aquatic insects into trophic guilds and functional groups in the coffee-growing region. Guzmán-Soto & Tamarís-Turizo (2014) categorized guilds in Ephemeroptera, Plecoptera, and Trichoptera from the Gaira River, identifying collectors, predators, and shredder-collectors. Granados-

Martínez et al. (2016) determined that detritivores predominate in the Molino River, although consumption of algae and animal tissues occurs. Villada-Bedoya et al. (2017) found no changes in insect feeding habits due to agricultural and mining disturbances in an Andean river, possibly due to resource availability, and finally, Tamaris-Turizo et al. (2020) reported trophic plasticity in arthropods from the Gaira River, with fine particulate organic matter (FPOM) predominating. Collectively, these studies highlight the importance of FPOM in Neotropical insect diets while also evidencing some omnivory and trophic plasticity. The objective of this study was to analyze the feeding habits of larvae from three aquatic insect orders (Diptera, Coleoptera, and Megaloptera) in the middle basin of the Ranchería River, in the El Silencio recreational area. This will expand knowledge about the trophic relationships and functional role of these organisms in rivers of the region

2. Material And Methods

2.1. Study Area

The Ranchería River basin covers an approximate area of 4,070 km² and is located within the jurisdiction of the municipalities of San Juan del Cesar, Fonseca, Distracción, Barrancas, Hato Nuevo, Albania, Riohacha, Manaure, and Maicao (Corpoguajira, 2011). The Ranchería River originates on the eastern flank of the Sierra Nevada de Santa Marta, in the Chirigua páramo at an altitude of 3,875 m.a.s.l. After flowing approximately 248 km through the region, it discharges into the Caribbean Sea near Riohacha. The basin exhibits a dendritic drainage pattern, and its main channel has an approximate length of 300 km. The study area is characterized by an average annual precipitation of 800 mm, concentrated in a rainy period between April and November. The mean annual temperature is 28°C, with minimums of 18°C and maximums of 40°C. The predominant vegetation corresponds to tropical dry forest (Corpoguajira, 2011). This study was conducted in the middle section of the Ranchería River basin, specifically in the El Silencio recreational area (235 m.a.s.l.) (Figure 1).

2.2. Sampling and Sample Processing

Aquatic insect sampling was conducted during the dry season (January-March 2021), with three replicates for each microhabitat: riffles, woody debris, sand, undercut banks/roots, and leaf packs. Samples were collected using a Surber net (area 0.09 m² and mesh size 250 µm) along a 100-meter linear river stretch. Samples were preserved in 96% ethanol. Specimens were taxonomically identified using specialized keys (Fernández & Domínguez, 2001; Posada-García & Roldán-Pérez, 2003; Domínguez et al., 2006; Domínguez & Fernández, 2009). Gut contents of 25 individuals per taxon were examined following Tomanova et al.'s (2006) methodology. Contents were mounted on semi-permanent slides with polyvinyl alcohol and observed under microscope (100X) to identify six food categories: fine particulate organic matter < 1 mm (FPOM), coarse particulate organic matter > 1 mm (CPOM), microalgae (MCR), animal material (AM), and fungi (FG). Relative proportions of each food item were estimated by examining 20 random fields per slide using ImageJ software (Figures 2).

2.3 Data Analysis

Data were analyzed using Principal Component Analysis (PCA), a heat map, and Non-Parametric Multivariate Analysis of Variance (NPMANOVA) to compare diets among taxa. To visualize relationships between genera and food categories, a heat map was generated using the heatmap() function from the gplots package (Warnes et al., 2015) in R. Distances between genera were calculated using Bray-Curtis distance, which considers the composition of consumed food categories. Clustering was performed using the clustering method. Matrix values were scaled applying square root transformation to improve visualization. The cophenetic correlation between original Bray-Curtis distances and distances represented in the tree was estimated, obtaining a value of 0.91. This indicates a good representation of original distances in the heat map configuration. These analyses were performed using R 4.3.1

3. Results

Gut contents of 300 specimens belonging to three orders, seven families, and twelve genera were examined. Table 1 shows the mean percentage of each food type by taxon. FPOM and CPOM were the main food categories consumed, representing 45% and 16%, respectively. Fine particulate organic matter (FPOM) was the most exploited resource by all three orders, classifying most taxa as detritivores.

Dipterans Chironominae, Tanypodinae, Orthocladiinae, and Simulium, along with coleopterans Cylloepus and Phanocerus, consumed more than 60% FPOM. Conversely, Hemerodromia (Diptera) and Pseudodisersus (Coleoptera; Elmidae) consumed more than 60% MCR. In contrast, the coleopteran Anchytarsus recorded 96% CPOM consumption, while Heterelmis (Coleoptera; Elmidae) showed more than 60% fungi consumption. The megalopteran Corydalus (Megaloptera: Corydalidae) fed exclusively on animal material, and finally, Tipula (Diptera: Tipulidae) split its diet almost 50-50 between FPOM and CPOM (Table 1).

PCA results show that the first two principal components explained 32.3% and 21.8% of the total variance, respectively, accounting for 54.1% of the variability in the original data. The first component strongly separated genera according to their affinity for FPOM microhabitats (positive scores) versus fungi and MCR (negative scores).

Meanwhile, the second component distinguished taxa associated with CPOM and animal material (positive and negative scores, respectively) (Figure 3).

In the space defined by the components, taxa were ordered into four main groups: the first comprising Anchytarsus, Chironominae, Phanocerus, and Tipula, primarily associated with FPOM and CPOM; the second including Cylloepus, Orthocladiinae, and Simulium, strongly associated with FPOM; the third containing Pseudodisersus and Hemerodromia, related to MCR and, to a lesser extent, to fungi; and finally, the fourth group consisting of the genus Corydalus, restricted to animal material. Heterelmis and Tanypodinae showed intermediate positions, reflecting their more equitable distribution among food categories.

These trophic groups identified through PCA were clearly visualized in the heat map generated from diet composition (Figure 4). The genera Anchytarsus, Chironominae, and Corydalus exhibited specialization in a single food category: CPOM, FPOM, and animal material, respectively. Additionally, Cylloepus, Orthocladiinae, Phanocerus, and Simulium showed a dominant preference for FPOM, while Hemerodromia and Pseudodisersus preferred MCR.

NPMANOVA indicates significant differences (ANOVA: $F = 16.8$, $df = 10$, $p < 0.0001$) in diet composition among the analyzed aquatic insect taxa, corroborating that the trophic groups previously identified through PCA and heat map are statistically different based on variations in the proportions of different food categories consumed.

Discussion

Our results align with other studies in rivers and streams where detritivores predominate (Palmer et al., 1993; Reynaga, 2009; Chará et al., 2010; Granados et al., 2016; Villada-Bedoya et al., 2017; Tamaris-Turizo et al., 2020). Many studies provide evidence that detritus is the most common resource in tropical river ecosystems (Tomanova et al., 2006; Chará-Serna et al., 2010; Guzmán-Soto & Tamarís-Turizo, 2014).

Unlike temperate zones, tropical environments have continuous inputs of coarse organic matter (CPOM) that fragments into fine matter (FPOM), making it a ubiquitous resource for aquatic insects (Dudgeon, 2008; Covich, 1988). The presence of FPOM in their digestive tract supports its importance as a food source (Allan et al., 1987; Henriques-Oliveira et al., 2003). Ranchería River insects were classified into detritivores, herbivores, and predators. Some genera showed differences in trophic guild compared to previous studies in other latitudes (Merritt et al., 2008; Guzmán-Soto & Tamarís-Turizo, 2014), evidencing geographical variability.

The specialization observed in genera like Anchytarsus, Chironominae, and Corydalus suggests these taxa have adapted their feeding strategies to efficiently exploit specific resources within their habitat, thus allowing classification of the first two genera as detritivores and the last as a predator. Similarly, the preference for MCR by Hemerodromia and Pseudodisersus suggests these genera specialize in periphyton grazing, classifying them as herbivores.

The identified trophic groups coincide with findings reported in other recent studies on macroinvertebrate feeding habits in rivers (Tamaris-Turizo et al., 2020). Taxa segregation along the first axis reflects the predominance of detritivores feeding on particulate organic resources of allochthonous origin. Fine organic matter (FPOM) primarily originates from leaf litter deposition and microbial processing (Dudgeon & Wu, 1999), while coarse organic matter (CPOM) includes more recalcitrant vascular plant fragments (Lamberti et al., 2017).

The position of certain groups as mycophages and herbivores on the second PCA axis indicates greater dependence on autochthonous resources such as fungal hyphae and periphyton/biofilm. The availability of these primary living resources distinguishes these taxa's diets from those of detritivores. The eigenvector of animal material on the third PCA axis evidences its importance in segregating Corydalus predators, given their high degree of specialization in prey consumption (Merritt et al., 2008; Batzer & Wissinger, 1996). Corydalus adults and larvae are voracious predators feeding on a wide variety of prey, including insects, crustaceans, and annelids (Contreras-Ramos, 1998; Courtney, 2000). Additionally, Tanypodinae larvae showed evidence of active predation, consuming small invertebrates while also feeding on fine organic matter (Merritt et al., 2008). The two PCA axes adequately represent the main sources of particulate organic matter, microalgae/hyphae, and animal material that sustain this assemblage's trophic complexity.

In conclusion, this study reveals the trophic complexity of the assemblage in the three studied orders in the Ranchería River, highlighting the importance of allochthonous and autochthonous resources in structuring trophic guilds. The observed geographical variability in feeding habits emphasizes the need for local studies to better understand trophic interactions and energy flow in Neotropical aquatic ecosystems.

5. Conclusions

This study examined the trophic structure of aquatic insect assemblages in the Ranchería River (Colombia), providing insights into resource partitioning in Neotropical stream ecosystems. Fine particulate organic matter (FPOM) emerged as the predominant food resource across taxa, with detritivory representing the primary feeding strategy within the community.

Distinct trophic guilds were identified through dietary analysis: specialized detritivores (Anchytarsus, Chironominae), FPOM-dependent taxa (Cylloepus, Orthocladiinae, Phanocerus, Simulium), herbivorous scrapers (Hemerodromia, Pseudodisersus), and specialized predators (Corydalus). Statistical analyses revealed significant inter-taxa dietary differences, supporting the existence of distinct trophic niches within the community.

Geographic comparisons highlighted divergent feeding patterns between Neotropical and temperate stream communities, emphasizing the necessity for region-specific trophic studies. These findings enhance our understanding of energy flow and resource utilization in tropical river ecosystems, contributing to the growing body of knowledge on Neotropical stream ecology. Future research incorporating stable isotope analysis could further elucidate seasonal variations in trophic relationships and quantify resource contribution patterns.

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7. References

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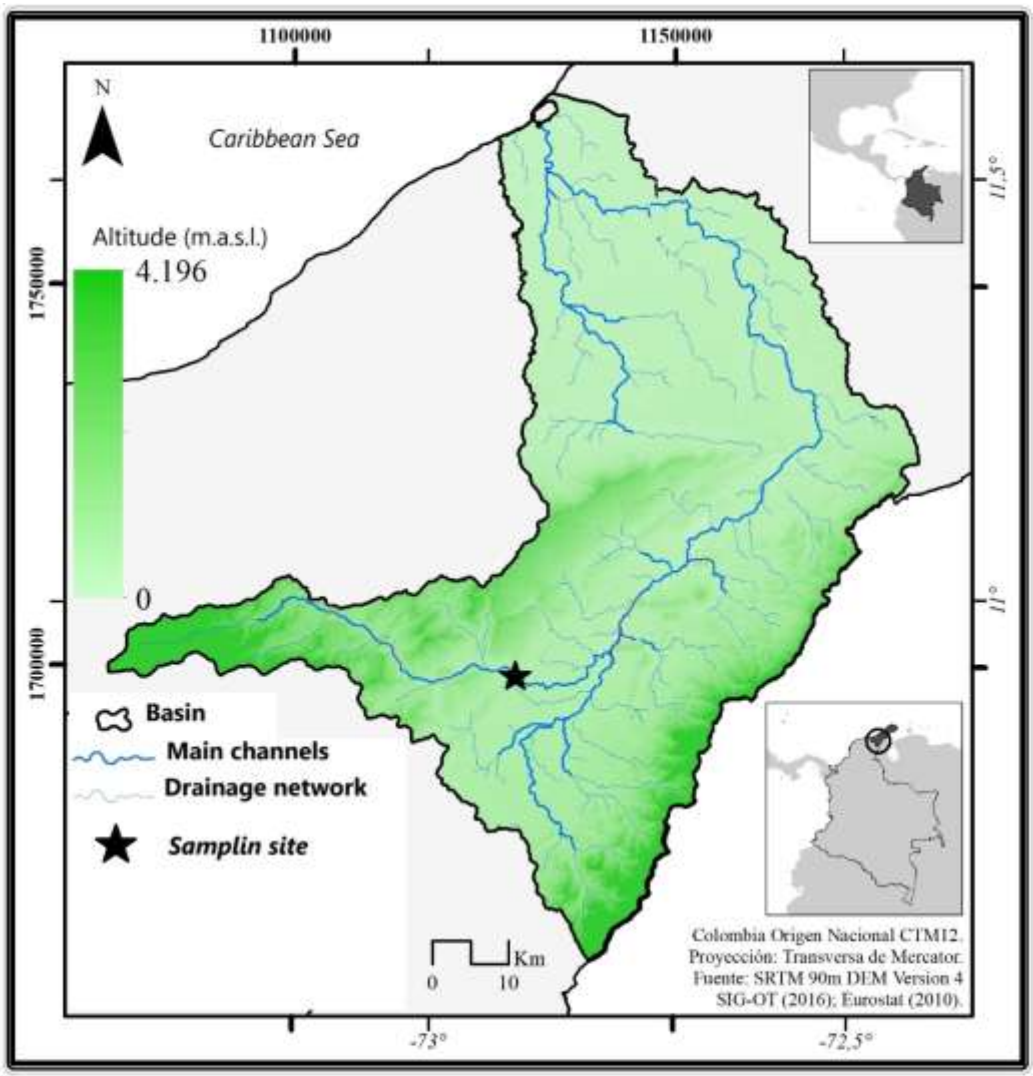

Figure 1. Map of the Ranchería River basin showing sampling site location (star), drainage network, main channels, and altitude (m.a.s.l.).

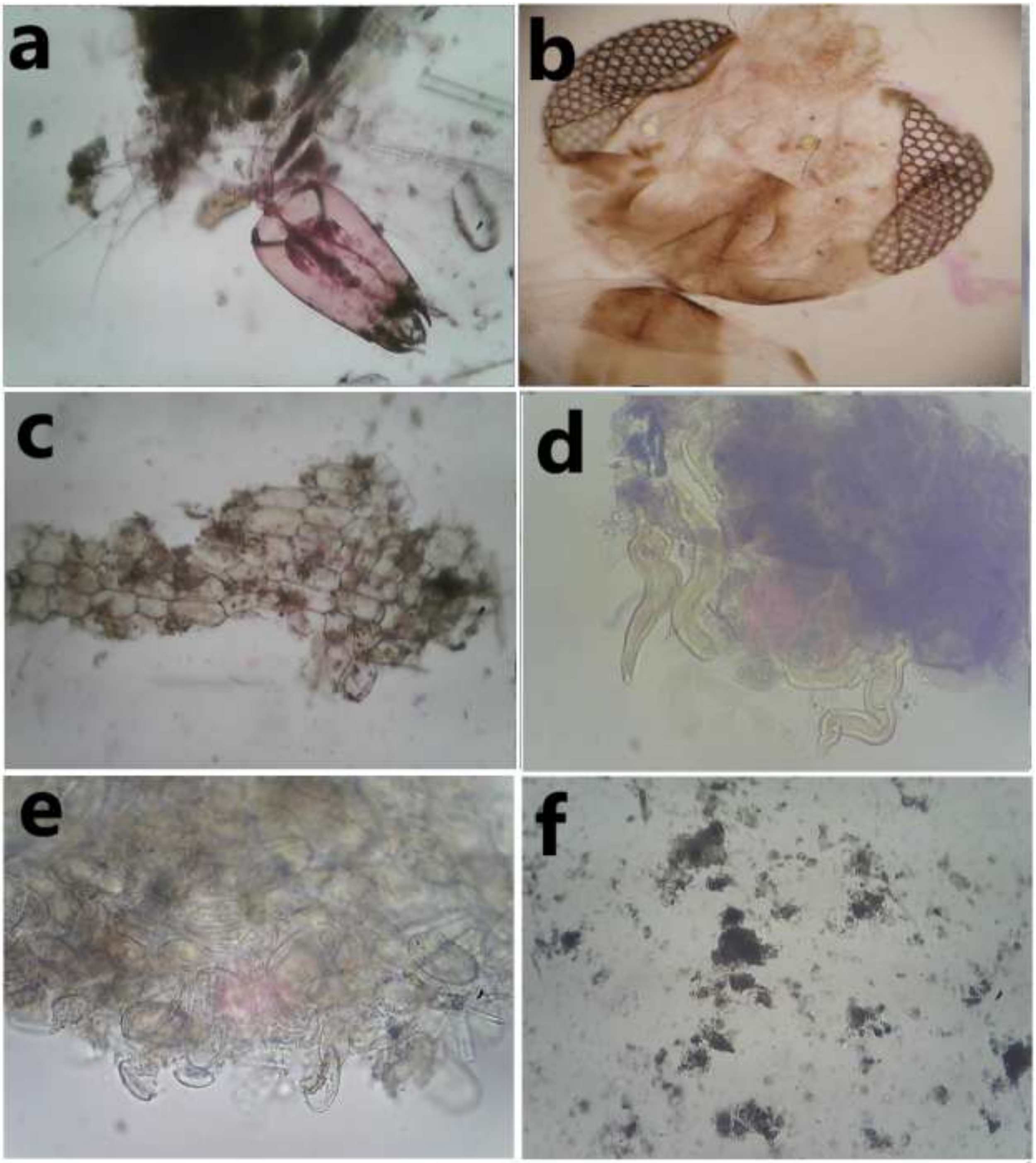

Figure 2. a, b) Animal tissue (AT), (Chironomidae and Simuliidae larvae) in the gut Corydalus (10x). c) Coarse particulate organic matter (CPOM) in the gut of Anchitarsus (10x). d) Fungi (FUNG) in the gut of Heterelmis (40x). e) Microalgae (ALG) in the gut of Pseudodisersus (40x). f) Fine particulate organic matter (FPOM) in the gut of Simulium (10x).

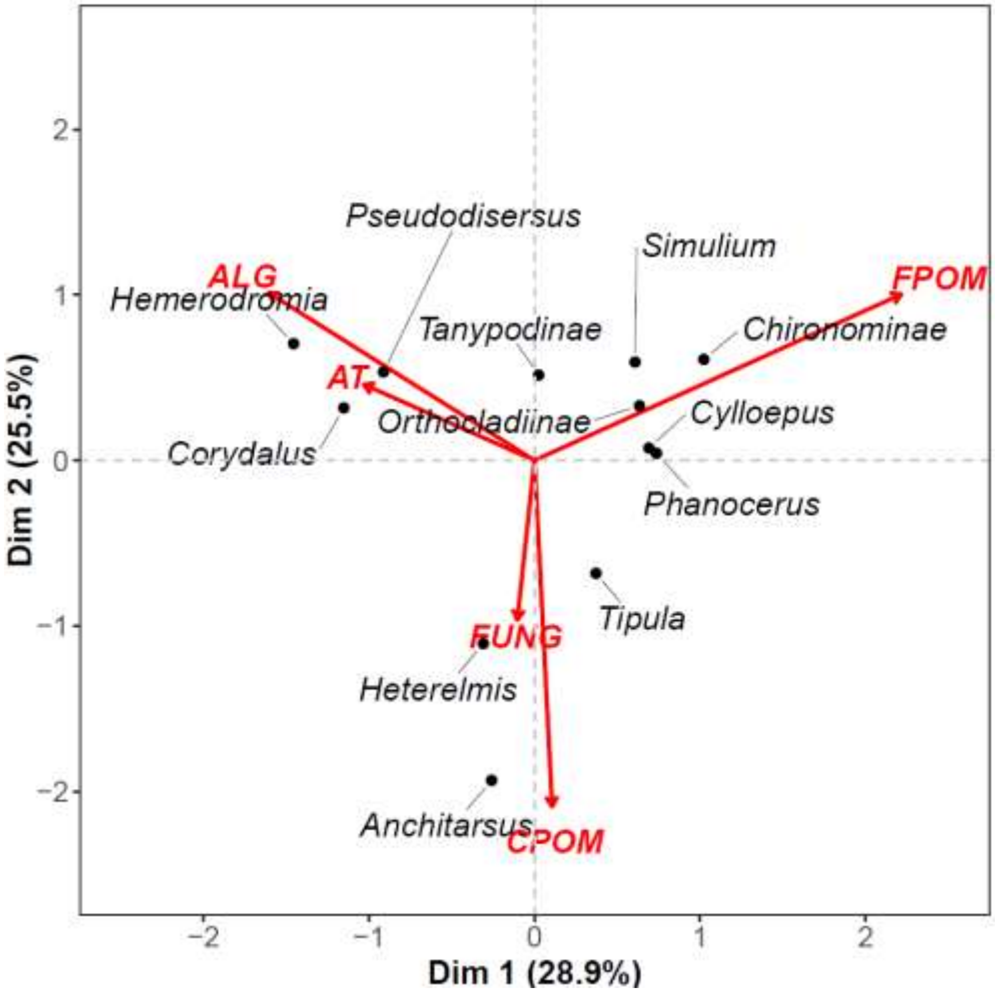

Figure 3. Principal component analysis (PCA) of taxa found in the gut contents of three orders of insects (Diptera, Coleoptera, and Megaloptera) in the Ranchería River, El Silencio sector.

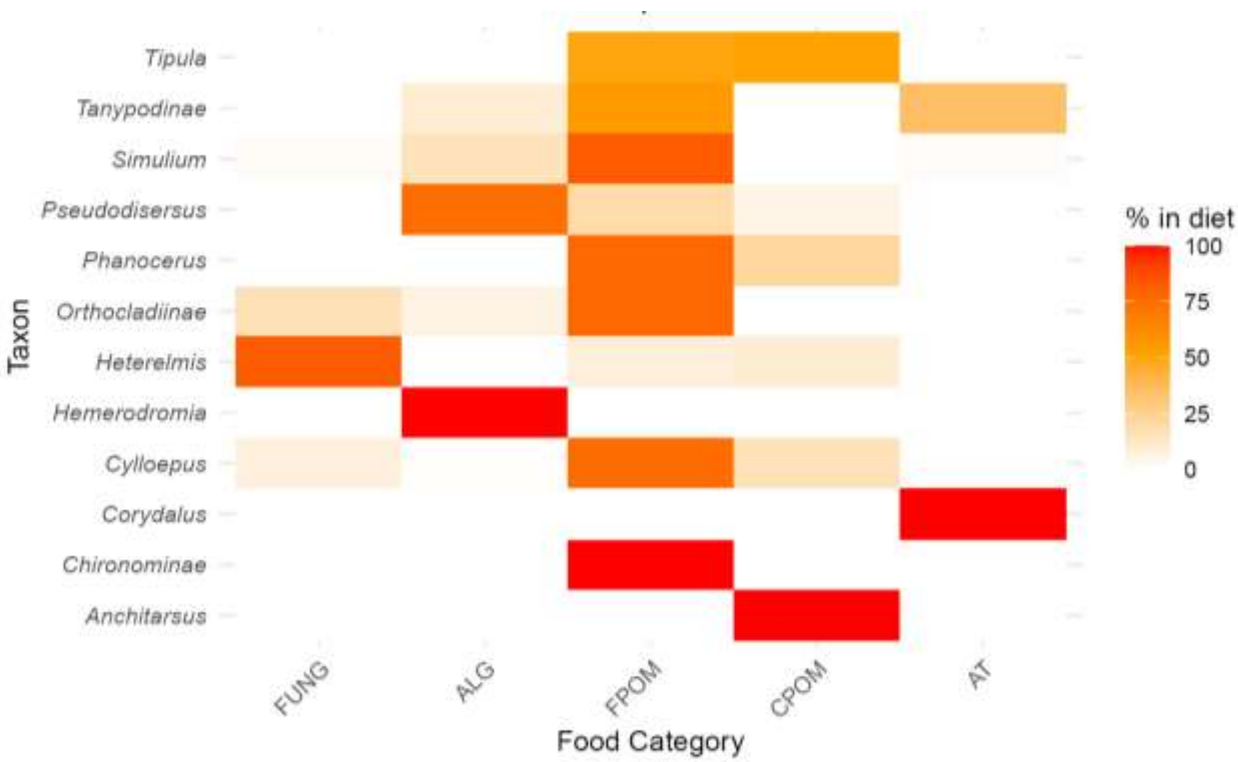

Figure 4. Heat map of dietary relationships between found genera and analyzed food categories, using complete linkage clustering with Bray-Curtis distance. Cophenetic correlation: 91%. Light yellow values indicate lower relationship, while red values indicate stronger relationship.

Table 1. Mean percentage of food categories found in the gut contents of three orders (Diptera, Coleoptera, and Megaloptera) of insects in the Ranchería River, El Silencio sector, and mean size of taxa used in the content analysis

Orden	Taxa	L(mm)	FUNG	ALG	FPOM	CPOM	AT
Diptera	Chironominae	1,40±0,10	0,00±0,00	0,00±0,00	100,00±0,00	0,00±0,00	0,00±0,00
	Orthocladiinae	1,30±0,10	16,00±1,80	6,20±6,10	77,80±23,80	0,00±0,00	0,00±0,00
	Tanypodinae	1,60±0,20	0,00±0,00	9,40±1,60	55,50±9,80	0,00±0,00	35,10±8,00
	Simulium	5,20±0,70	1,50±1,30	14,90±12,20	82,50±15,20	0,00±0,00	1,10±1,90
	Tipula	12,10±8,70	0,00±0,00	0,00±0,00	49,20±38,00	50,80±39,10	0,00±0,00
	Hemerodromia	3,10±0,20	0,00±0,00	100,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
Coleoptera	Phanocerus	4,30±0,70	0,00±0,00	0,00±0,00	77,70±2,10	22,30±7,10	0,00±0,00
	Cylloepus	5,60±0,80	7,50±5,30	0,50±0,30	75,90±24,90	15,80±20,20	0,30±0,40
	Pseudodisersus	4,20±0,20	0,00±0,00	75,10±19,40	19,10±0,60	5,80±0,30	0,00±0,00
	Heterelmis	3,90±0,30	82,20±12,30	0,00±0,00	8,00±5,10	9,80±6,50	0,00±0,00
	Anchitarsus	13,90±3,70	0,00±0,00	0,00±0,00	0,00±0,00	100,00±0,00	0,00±0,00
Megaloptera	Corydalus	20,30±1,40	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	100,00±0,00

L, length, FUNG, fungi; ALG, microalgae; FPOM, fine particulate organic matter; CPOM, coarse particulate organic matter; AT, animal tissue. Values are mean ±SD.