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Water boatmen (Heteroptera: Corixidae) in wetlands of patagonia central, Argentina: study of environmental variables associated with their presence and abundance

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ABSTRACT

In Sarmiento (Chubut province, Argentina) populations of species of corixids were studied. The different aquatics habitat types (100 water bodies totals) were categorized, according to morphometric characteristics and permanence of water in: temporary and semi-permanent bodies of water, irrigation and drainage canals. The following variables were recorded in each aquatic habitat: surface area of water, maxim depth, percentage of vegetation, sunshine degree, turbidity, pH, conductivity, dissolved oxygen, salinity, and water temperature. Besides, the habitat type and the location ("urbanized areas" and "non urbanized areas") were considered as categoric variables. Four species of Corixidae were found: *Ectemnostega (Ectemnostega) quadrata, Sigara (Tropocorixa) rubyae, S. (T.) santiagiensis*, and *S. (T.) vuriloche. Sigara santiagiensis* and *E. quadrata* were recorded from Chubut province but not from Sarmiento city, being these the first records of the species. Only *S. rubyae* and *S. vuriloche* were recorded before from Sarmiento city. *Sigara santiagiensis* was the most frequent and dominant species in abundance. *S. santiagiensis* was negatively associated with semipermanent habitats and non-urbanized areas, and, it was also associated with higher sunshine degree, and higher values of dissolved oxygen. *S. rubyae* was associated with high insolation, a greater amount of dissolved oxygen in the water, pH., conductivity, salinity and turbidity of water. For the different species of corixids found in this study, the records of the characteristics of the environment and physical-chemical variables of the water constitute contributions that can be antecedents to face what has been proposed for this taxonomic group, that is, to be indicators of changes in aquatic habitats.

Key words: Patagonia, system irrigation, environmental variables, Corixidae

Barqueros de agua (Heteroptera: Corixidae) en humedales de la patagonia central, Argentina: estudio de variables ambientales asociadas a su presencia y abundancia

Author contributions:

NB: Sampling, conservation of samples, taking of environmental records, data analysis, main writing of the text, preparation of graphs and maps.

SK: Taxonomic identification, main wording of the text.

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DConflict of interest:

There is no conflict of interest.

RESUMEN

En Sarmiento (provincia de Chubut, Argentina) se estudió la comunidad de corixidos. Se categorizaron los diferentes tipos de hábitat acuáticos (100 cuerpos de agua totales), según aspectos morfométricos y permanencia del agua: en cuerpos de agua temporarios y semipermanentes, canales de riego y drenaje. En cada hábitat acuático se registraron las siguientes variables: superficie de agua, profundidad máxima, porcentaje de vegetación, grado de insolación, turbidez, pH, conductividad, oxígeno disuelto, salinidad y temperatura del agua. Además, se consideraron como variables categóricas el tipo de hábitat y la ubicación ("áreas urbanizadas" y "áreas no urbanizadas"). Se encontraron cuatro especies de Corixidae: *Ectemnostega (Ectemnostega) quadrata*, *Sigara (Tropocorixa) rubyae*, *Sigara (Tropocorixa) santiagiensis* y *Sigara (Tropocorixa) vuriloche*. *S. santiagiensis* y *E. quadrata* fueron registradas para la provincia de Chubut pero no para la ciudad de Sarmiento, siendo estos los primeros registros de la especie. Solo *S. rubyae* y *S. vuriloche* fueron registrados anteriormente en la ciudad de Sarmiento. *S. santiagiensis* fue la especie más frecuente y dominante en abundancia. *S. santiagiensis* se asoció negativamente con hábitats semipermanentes y áreas no urbanizadas, y también se vinculó con un mayor grado de insolación y valores más altos de oxígeno disuelto. *S. rubyae* se asoció con alta insolación, mayor cantidad de oxígeno disuelto en el agua, pH., conductividad, salinidad y turbidez del agua. Para las diferentes especies de coríxidos encontradas en este estudio, los registros de las características del ambiente y variables físico-químicas del agua constituyen aportes que pueden ser antecedentes para enfrentar lo propuesto para este grupo taxonómico, es decir ser indicadores de cambios en hábitats acuáticos.

Palabras clave: Patagonia, sistema de irrigación, variables ambientales, Corixidae

INTRODUCTION

The Corixidae are aquatic Heteroptera commonly called "water boatmen". They have a high dispersal potential, which allows them to utilize various available habitats: still and running, stable and temporary, and fresh and saline water bodies (Jansson, 1986). They seem to be ecologically adaptable to a wide range of environmental conditions, but some studies document that individual species of Corixidae show distinct preferences for water habitats of a certain water quality (Savage, 1994). Some variables like the substrate type, the percent vegetation cover, the size/stability of the systems and some chemical characteristics (salinity, hardness, pH and oxygenation), can regulate the Corixidae populations and distribution. The Corixidae generally inhabits waters with neutral to alkaline pH, and some species inhabit almost unoxygenated waters or with extreme salinity (Bachmann, 1981).

Some authors (Jansson, 1977; Savage, 1982) considered them as water quality (Macan, 1954; Savage, 1971, 1977; Merritt & Cummins, 1984; Jansson, 1987) and environmental stability degree indicators, as they present a winged morph associated with unstable environments and a wingless morph associated with stable environments (Brown, 1950). They also have the potential to be used in the classification of lentic water bodies (Macan, 1955; Savage, 1982; Resh & Rosenberg, 1984), establishing a valuable tool in conservation studies.

The studies in Patagonia Argentina on ecological aspects of corixids are scarce. Although the taxonomic ones with bionomics, distributional data and faunistic lists most abundant (Berg, 1881; Bachmann, 1962, 1963; Contartese & Bachmann, 1986; Muzón *et al.* 2005, 2010; Melo, 2009). Berg (1881), presented a list of insects collected during the Desert Campaign being this the first work referred to Heteroptera from Patagonia. Bachmann (1962) refers to the Heteroptera of Patagonia present in Lanin, Nahuel Huapi and Los Alerces National Parks, recording a few species of Nepomorpha belonging to the families Corixidae, Belostomatidae and Notonectidae. One year later Bachmann (1963) the last author mentioned the species from the extracordilleran Patagonia, highlighting a low richness of the fauna from north to south. Contartese & Bachmann (1986) presented distributional maps of the species of Corixidae from Argentina. Muzón *et al.* (2005, 2010) presented a preliminary inventory of the aquatic insects from the Somuncura plateau and its area of influence (Patagonia, Argentina). Finally, Melo (2009) presented a list and distributional maps of the aquatic and semiaquatic Heteroptera species cited from the argentinian Patagonia. only two works describe the environmental conditions and the ecological requirements of two species of corixids from Argentina (Scheibler & Melo, 2010; Melo & Scheibler, 2011). Five species of corixids were recorded from Chubut province: *Ectemnostega (Ectemnostega) quadrata* (Signoret 1985), *Sigara (Tropocorixa) rubyae* (Hungerford 1928), *Sigara (Tropocorixa) santiagiensis* (Hungerford 1928), *Sigara (Tropocorixa) trimaculata* (Le Guillou 1841) and *Sigara (Tropocorixa) vuriloche* (Bachmann 1960) (Melo, 2009), being only *S. rubyae* and *S. vuriloche* recorded before from Sarmiento city (Bachmann, 1963, 1981).

The aim of this work is to study the presence of populations of different species of corixids in wetlands of an urban area and an associated agroecosystem placed in central Patagonia (Chubut province) in different types of water bodies, and the relationship between the most frequent and abundant species and the environmental variables.

Fig. 1. Location of Sarmiento, province of Chubut, Argentina where the study was carried out.

MATERIALS AND METHODS

Study area

Central Patagonia is found from Mendoza to the south of Santa Cruz (Argentina) and south of Chile (Morrone, 2001). In this region, the steppe biome predominates (Cabrera, 1971) which is characterized by having few shallow lentic water bodies (Paruelo, 1998).

The town of Sarmiento (45° 35'S - 69° 05'W), is located in the south of Chubut province. This town is located in a floodplain of the Senguer River, at 268 m. a. s. l., in the center of the Patagonian plateau (Fig. 1). The xerophytic steppe vegetation contrasts with shrubby species and the bushes of the valley (Cabrera, 1971). Moreover, agricultural and livestock activities are very important in the area. Farms and grazing areas are irrigated by canals that run from the Senguer River. The most common method of irrigation is by flooding since given the irregularity of the terrain, numerous bodies of water are produced with different durations and sizes, which would be rare without this irrigation system.

The climate of this region is dry and cold (Paruelo *et al.* 1998). The absolute temperature recordings ranged from a maximum of 39.3oC and a minimum of -33oC, with average temperatures between -0.2°C and 23.9°C, and annual average precipitation of 147.2 mm. (1931-1960). The 65% of the prevailing winds are from the west, especially in summer (Elissalde *et al.* 1998), and in winter the lowest wind were recorded (Coronato & Del Valle, 1988).

Sampling collections

Different water bodies were studied in urban and rural areas in Sarmiento during the period from 9 to 23 January 2023.

A sample of aquatics insects with a hand net of 350 µm was collected in each aquatic habitat. The number of times that the hand net was passed (one meter length) was proportional to the surface of the water body, from 0.5 m. for a surface of 0.1-1 m2 to 18 m. for surfaces larger than 1000 m2 (Fontanarrosa *et al.* 2004). All the material was fixed *in situ* in 80% ethyl alcohol. The material collected in the field (adults and nymphs) were identified based on the works of Bachmann (1981) and Konopko (2013a, b) through the use of a stereoscopic microscope in the laboratory.

Environmental variables

The studied habitats were classified into three categories according to the water permanence: a) temporary: water bodies generally as a product of flood irrigation on irregularities in the land, which last from a few days to a few weeks; b) semipermanent: bodies of water that are produced by irrigation due to flooding or overflow of the Senguer River, and that have a duration of several months to a year, and c) irrigation and drainage canal: canals that carry water from the Senguer river to the farms and from them to the river. Besides, they were categorized by being within the urban area or outside it.

In each habitat, the surface area of water was recorded and estimated by measuring the area of a rectangle containing the water body, multiplied by the percentage of this geometric shape covered by water. In addition, the maximum depth (taken with stick calibrated), the percentage of vegetation that covered the body of water (using the Braun-Blanquet cover scale -Braun-Blanquet, 1932), and the degree of insolation were measured as the percentage of insolation according to the height of the sun and environmental vegetation (type and size) between 0% (shade) and 100% (full sun).

The following physical and chemical variables of the water were recorded in each habitat: pH (measured with a digital pH meter pHep-Hanna), conductivity (measured with a digital conductimeter Lutron (CD–4303), dissolved oxygen (measured with a digital oximeter Lutron CD-4303), salinity (measured with a portable refractometer VISTA A366ATC), and temperature (measured with a digital thermometer TFA). The water turbidity was estimated by placing 5 l of water sample in a white container (20 cm. diameter by 15 cm. deep), and using a scale from 0 (nothing turbid) to 1(very turbid).

Statistical analysis

The effect of predictor variables (habitat characteristics) on the abundance of the species more abundant and frequent was evaluated using generalized linear models (GLM) (Crawley, 2013; Zuur *et al.* 2009) with negative binomial error distribution and log link function. Statistical analyses were carried out using R software, Version 3.6.2 (R Development Core Team 2021).

Wetland type	N	Characteristics	Species recorded
Temporary habitat	69	Shallow, in general with presence of plants with longer temporary persistence (*Juncus* sp.) and grasses. In other cases, they are flooded quarries as a result of the construction of roads with a gravel substrate and little or no vegetation.	*S. santiagiensis* *S. rubyae*
Semi permanent habitat	12	In depressed lands areas. In some cases, had rooted (*e.g.* some *juncaceas*, *Typha* sp.) and floating aquatic plants (*e.g. Azolla* sp., *Salvinia* sp., *Lemna* sp., *Wolffiella* sp.).	*S. santiagiensis* *E. quadrata*
Irrigation and drainage canals	18	Bodies of water with varying riverbed and depth. Usually, irrigation ditches of a little more higher water speed and lower drained.	*S. santiagiensis* *S. vuriloche* *S. rubyae*

Table 1. Environmental characteristics, species of corixids in the wetland sampled in Sarmiento, Chubut province, Argentina.

The habitat type (three levels: "semi-permanent", "temporary" and "canals") and the urbanization (two levels, "urbanized areas" and "non urbanized areas") were included as categorical variables. On the other hand, the variables surface area of water, maxim depth, percentage of vegetation, sunshine degree, pH, dissolved oxygen, conductivity, salinity, temperature and turbidity of water were included as quantitative variables.

RESULTS

Ninety- nine permanent or semi-permanent water bodies were studied. A total of 2430 individuals of water boatmen (nymphs and adults) were counted. Any corixids were found in 24.1% of the aquatic habitats studied. Sixty-nine temporary habitats were found, of which 45 presented corixids in any of their states (nymphs or adults), with a total of 1957 individuals. About 12 Semi-permanent habitats were counted, with 83.3% of corixids. Finally, 18 Irrigation and drainage canals were studied finding 8.8% of corixids. Same characteristics of these habitats were recorded (Table 1).

Four species of Corixidae were recorded belonging to two genera: *E. quadrata, S. rubyae, S. santiagiensis* and *S. vuriloche*. Species richness of corixids fluctuated between 2 and 0, with a mean of 0.77 and a median of 0.51 (standard deviation 0.24). *Sigara santiagiensis* was dominant in frequency present in 69% of opportunities, and dominant in abundance, constituting the 94.90% of the individuals collected (Fig. 2). The rest of the species were present at frequencies that did not exceed six times, and their abundances were much lower. The 4.40% of individuals belonged to S. rubyae, 0.62% to E. *quadrata* and 0.08% to *S. vuriloche* (Fig. 2).

In 28% (27/98) of the studied wetlands no corixids were found. In the rest of the wetlands, low coexistence between species was recorded. In no body of water were three or four species found at the same time. The highest frequency of occurrence was for *S. santiagiensis*, followed by *S. rubyae,* while *S. vuriloche* and *E. quadrata* were only present on a single occasion (Table 2).

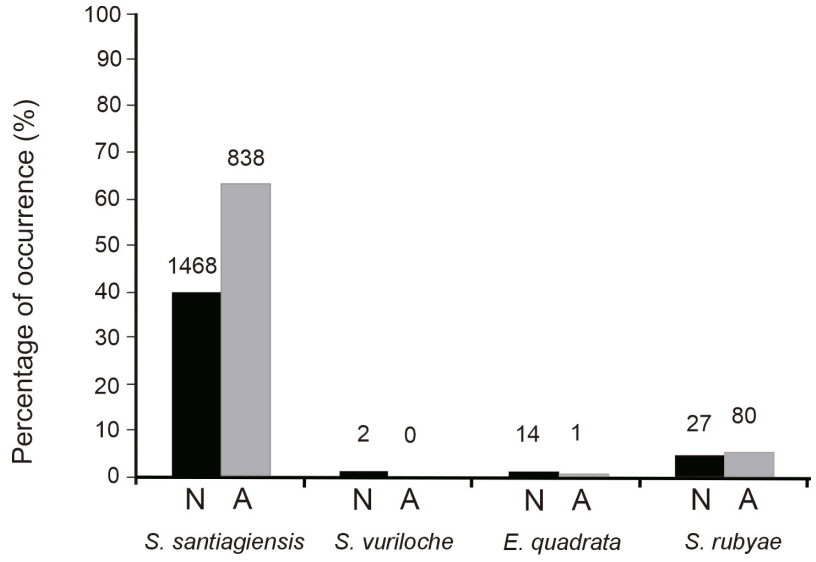

Fig. 2. Percentage of occurrence of nymphs and adults and number of nymphs and adults of corixids species in aquatic habitats in Sarmiento, Chubut province. N=nymphs; A= adults.

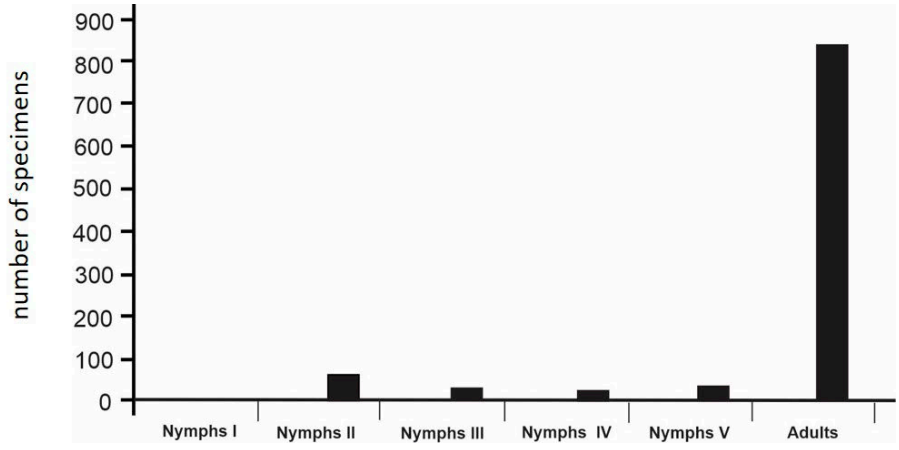

Fig. 3. Number of individuals of *S. santiagiensis*, discriminated by the nymphal and adult stadium in wetland agroecosystems in Sarmiento, Chubut province.

		S. santiagiensis	*S. rubyae*	*E. quadrata*	*S. vuriloche*
Temporaries		1855	102	-	-
Semipermanents		86	0	1	-
Canals		365	5	-	1
All habitats	Median	2306	3	15	2
	Max-Min	(410-1)	(64-1)	(15-15)	(2-2)

Table 2. Frequency of occurrence of each species in each type of wetland in Sarmiento, Chubut province., and median, maximum and minimum values corresponding to all types of habitats.

Table 3. Generalized linear model coefficients, standar error (SE) and Z values of these coefficients performed to study the effects of environmental variables of the habitat on *S. santiagiensis* abundance in wetlands of Sarmiento, Chubut province. Theta: 0.411 (SE= 0.643). Significance codes: p< 0.0001=***; p< 0.001=**.; p< 0.01=*.

Coefficients	Estimate	SE	Z value	
Intercept	1.848	0.9	2.05	
Habitat type (Semipermanent) [A]	-1.397	0.618	-2.257	*
Habitat type (Temporary) [A]	- 0.481	0.440	-1.094	
Urbanization (Non urbanized areas)[B]	-1.337	0.674	-1.983	*
Conductivity	- 0.0001	0.00005	-2.737	**
Sunshine degree	0.184	0.006	2.858	**
dissolved oxygen	0.169	0.030	5.714	***
Water temperature	- 0.079	0.031	-2.568	*
[A] Relative variable to value of Habitat type (Canal)				
[B] Relative variable to value of Urbanization (urbanized areas)				

Table 4. Median, maximum and minimum values of the environmental variables of the wetlands where the different species of corixids were found in Sarmiento, Chubut province.

	S. santiagiensis	*S. rubyae*	*E. quadrata*	*S. vuriloche*
Vegetation cover degree (%)	0,58 (1-0)	0 (0-0)	1	0
Sunshine degree (%)	86,70 (100-0)	100 (100-40)	100	40
Turbididity (%)	0 (1-0)	0,75 (0,88-0)	0	0
pH	8,56 (10,846,59)	9,05 (9,61-7,24)	7,64	7,24
Conductivity (uS)	764,91 (15160-1,07)	1044,45 (9490-1,076)	481	88,9
Dissolved oxygen (mg/l)	8,86 (27,1-0,3)	12,8 (12,8-4,30)	6,8	4,3
Salinity (‰)	6,75 (22-1)	9 (15-0)	9	9
Water temperature (°C)	20,48 (30,5-9,25)	22,55 (27,85-17,20)	25,6	15,75

The adults of *S. santiagiensis* showed a proportion of females higher than males (female-male proportion (F:M) of 0.57:0.43). And, of the total specimens found for *S. santiagiensis*, they were mostly adults, and a low portion were nymphs (Fig. 3). While those of *S. rubyae* showed the highest male proportion (female-male proportion (F:M) of 0.39:0.61). Only one male of *E. quadrata* and any adult of *S. vuriloche* were collected.

Relationships between the abundance of corixids with environment variables

The generalized linear model analysis only converged for one species, *S. santiagiensis*. This model identified factors affecting the abundance of *S. santiagiensis*, with a 39.1% of variability. A greater abundance of this species was negatively associated with semipermanent habitats and non-urbanized areas. The abundance of this species was also associated with higher sunshine degree, and higher values of dissolved oxygen, too. And there was a negative relationship, but slightly, with higher conductivity values and water temperatures (Table 3).

The specimens of *S. rubyae* were found mainly in temporary bodies of water of not urbanized sites. The specimens of *E. quadrata* (one male and 14 nymphs) were collected in no urbanized area, in a semipermanent water body of 40000 m^2, with an average depth of 30 cm.

The two nymphs of *S. vuriloche* were collected in an irrigation canal in the urban area. The canal had an average depth of 25 cm.. The environmental characteristics where these three species were found are detailed (Table 4).

Additionally, 17 nymphs of Notonectidae were collected in five habitats (four temporary wetland and one drainage canal). Two specimens of *Notonecta vereertbruggheni* were collected in two different aquatic temporary environments coexisting with *S. santiagiensis*.

DISCUSSION

Of the five species of corixids that are cited for the province of Chubut, in our study we recorded four. No specimens of *S. trimaculata* were detected. In the distributions of the four recorded species of corixids, the province of Chubut is included. *S. santiagiensis* is distributed in Argentina (from Buenos Aires and Neuquén to Santa Cruz provinces and Malvinas Islands) and Chile (Morrone *et al.* 2004). *S. rubyae* is distributed in Argentina (from Córdoba and Entre Ríos to Chubut provinces) and Uruguay (Morrone *et al.* 2004). *S. vuriloche* is distributed in Argentina, Rio Negro province, the cordilleran area and Chubut province (Sarmiento and Cholila), and in Chile (probably in Valdivia) (Bachmann, 1981). *E. quadrata* is distributed in Argentina and Chile along the Andes Mountain range, from high altitudes in San Juan Province to sea level in Cabo de Hornos, Tierra del Fuego Province (Contartese & Bachmann, 1986; Bachmann, 1998; Melo, 2009).

Sigara santiagiensis and *E. quadrata* were recorded from Chubut province (Bachmann, 1960, 1961, 1962, 1963, 1981; Contartese & Bachmann, 1986; Miserendino & Pizzolón, 2000; Muzón *et al.* 2005, 2010; Melo, 2009) but not from Sarmiento city, being these the first records of the species in this city. *S. rubyae* and *S. vuriloche* were recorded before from Sarmiento city, Chubut Province (Bachmann, 1961, 1962, 1963, 1979, 1981).

The marked dominance in the frequency of occurrence and abundance of *S. santiagiensis* in the studied aquatic habitats has also been mentioned by Bachmann (1981), who calls it dominant and characteristic in the valleys of the Negro and Chubut rivers, in the region where it is found. conducted the present study.

Relationships between the abundance of corixids with environment variables

According to Bachmann (1981) *S. santiagiensis* would be a highly ubiquitous species, living both in mountainous and lowland rivers and in lentic water bodies. In our study, we did not observe homogeneous abundances between the different types of habitats. However, they coincide with those general characteristics just mentioned. In addition, the lack of association with the degree of vegetation cover recorded in our work coincides with what was mentioned by Bachmann (1981). In relation to the water temperature, this species was also found by Bachmann (1981) for a wide range of temperatures, in agreement, in the present work it was recorded within a wide range (9.25-39.95°C). However, according to the statistical model obtained, its abundance would be lower at higher temperatures, agreeing with the geographical distribution, especially in Patagonia (Melo, 2009).

S. rubyae is a very frequent and characteristic species of semi-permanent and temporary bodies of water, with frequently turbid waters, especially in the provinces of Buenos Aires, La Pampa and Rio Negro (Bachmann, 1981). In our work we found it also associated with high turbidity and was found mostly in temporary water bodies.

Regarding *S. vuriloche*, in the province of Río Negro Bachmann (1981) found this species in small shallow lagoons between lakes Nahuel Huapi and Moreno, and in the province of Chubut in overflows of the Senguer river, in both cases in bodies of sunny water, with abundant vegetation. We recorded only two specimens in the nymphal stage. It coincides with the locality where this author found this species, and although in our case it is an irrigation canal, it comes from the Senguer River, and for this reason the water has movement. Unlike what was found by this author, we found this species in a place without vegetation.

E. quadrata lives on the margins of Andean lakes, in overflows and drainage canals, in small lagoons of shallow deep, and in streams basins, such as in Valcheta, Río Negro province, generally in cold waters with submerged aquatic vegetation (Bachmann, 1981). In this way we find this species in non-urbanized areas, totally vegetated. Although this species was recorded in low abundance, it is a special one that is widely distributed in Patagonia (Melo, 2009), living in habitats where water temperature is low, the species is considered to be cold stenothermal (Bachmann, 1981).

For the different species of corixids found in this study, the records of the characteristics of the environment and physical-chemical variables of the water constitute contributions that can be antecedents to face what has been proposed for this taxonomic group. Is that from an ecological point of view this group integrate the middle part of trophic chains and are very vulnerable to environmental changes, and for this reason their monitoring can be key to assessing the degree of pollution of water bodies (Bachmann, 1998).

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