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María Laura Miserendino* and Miguel Archangelsky

CONICET-Laboratorio de Investigaciones en Ecología y Sistemática Animal (LIESA).
Universidad Nacional de la Patagonia. Sede Esquel. Sarmiento 849. 9200 Esquel. Chubut. Argentina;
e-mail: mlau@ar.inter.net

Aquatic Coleoptera Distribution and Environmental Relationships in a Large Patagonian River

key words: benthos, longitudinal gradient, abundance, dam, land use

Abstract

The benthic coleopteran assemblages of the Chubut River basin were studied in order to assess the main factors affecting species composition and distribution along the upper, middle and lower catchments. A total of 13 sampling sites were selected and sampled seasonally. Eight taxa and 1,601 individuals were collected during the study. Richness was higher in the main channel of Chubut River at the upper basin than at the middle basin. Beetles were completely absent at the lower basin. Mean monthly density per sites varied from 0 to 85 ind m^{-2}. *Stethelmis kaszabi* had a more restricted distribution whereas *Hemiosus dejeanii*, *Austrelmis* sp. and *Austrolimnius* spp. were more frequent and abundant. *Austrelmis* sp. appears as the most tolerant species, especially to higher TSS, ammonia, and conductivity values. *Luchoelmis cekalovici* was absent in stations associated with urban areas. A Canonical Correspondence Analysis shows that conductivity, total suspended solids, wet width, water temperature and pH were the most important variables structuring beetle assemblages. Land use related variables such as NH_4, TP, and NO_3 were less important but still significant. An increase in TSS affected negatively the coleopteran community; this could be related to both hydrogeological characteristics and agricultural activities (including overgrazing).

This is the first approach to the knowledge of the ecological range of distribution of the coleopteran species in Patagonian rivers.

1. Introduction

Coleoptera are the largest order of insects. There are more than 10,000 species of aquatic beetles; this makes them one of the most important components among freshwater invertebrates. Furthermore, water beetles are one of the most common groups in benthic communities of streams and rivers of temperate regions. Despite this, the use of water beetles as indicators of environmental conditions has been neglected due to a variety of reasons (Ribera and Foster, 1992). Nevertheless in the last few years their value as bioindicators is becoming more significant both in Europe and USA (Eyre *et al.*, 1986; García Criado and Fernández Aláez, 1995; Bowles *et al.*, 2003). Water beetle species distribution seems to be strongly affected by land use (Johnson *et al.*, 1993). For example, livestock management and practices in arable agricultural areas have negatively impacted aquatic Coleoptera assemblages (Eyre *et al.*, 1986; Ribera and Foster, 1995). Specific industrial activities such as mining seem to alter water beetle populations (Eyre *et al.*, 1992) and the deleterious impact of additional sediments on elmids has also been well documented (Doeg and Koehn, 1994).

* Corresponding author

In the last decade, in Patagonia, studies on the spatial structure of aquatic insect communities and their environmental relationships have become increasingly important (MISERENDINO and PIZZOLÓN, 2001, 2003, 2004). Due to their value as indicators of water quality, and following the most traditional works from other regions, most studies have been focused on the EPT group (Ephemeroptera, Plecoptera, and Trichoptera) (MISERENDINO, 1999; 2000; MISERENDINO and PIZZOLÓN, 1999). Additionally, in the majority of macroinvertebrate inventories carried out in Patagonian rivers, water beetles have received much less attention. Reasons for this are related mostly to the lack of regional systematic studies of the beetle fauna (especially of the family Elmidae), and of studies associating larval and adult stages. Nevertheless some of these problems are being dealt with (ARCHANGELSKY, 2004; ARCHANGELSKY and FERNÁNDEZ, 2005; MANZO, 2005; ARCHANGELSKY and MANZO, in press). This recent improvement in our knowledge of the beetle fauna in Patagonian lotic environments allows us to use these organisms as indicators of environmental variables. Elmids are recognized as one of the most abundant and frequent organisms within the macroinvertebrate community in lotic systems of the Cordillera, and the Plateau (MISERENDINO, 2001; MISERENDINO and PIZZOLÓN, 2003).

Although a large number of scientific papers about rivers have been produced in temperate regions, rivers in arid/semiarid areas remain largely undescribed. The Chubut River is certainly the most important watercourse in the Province. This river system in the Patagonian Plateau provides an excellent opportunity to examine the longitudinal pattern of benthic Coleoptera over an extensive elevational (1000 m) and longitudinal (>1000 km) gradient across the arid and semiarid region. In addition to this, the basin is subjected to multiple activities, which include agriculture, cattle grazing, irrigation and river regulation. The study of physicochemical conditions, including chlorophyll-*a*, provides a detailed database of habitat conditions along the longitudinal profile. We examined benthic coleopteran data in relation to the environmental variation from the Chubut River tributaries in the upper basin to the outlet in the Atlantic Ocean.

2. Methods

2.1. Study Area

The Chubut River flows from West to East through the Patagonia ecoregion and drains into the Atlantic Ocean (Fig. 1). The Chubut River basin (25,225 km^2) is located in two main biozones: the Extra-Andean oriental and Extra-Andean occidental (DEL VALLE *et al.* 1995; PARUELO *et al.*, 1999). Geomorphologic features and local climatic characteristics allow us to divide the basin in three areas. The higher basin (7,000 km^2) is characterized by a strong west-east rainfall gradient (500–100 mm y^{-1}) and being near the cordillera shows the lowest temperatures (mean annual temperature 8.5 °C). The middle basin (12,000 km^2) is the driest area with a rainfall of 150 mm y^{-1} and a mean annual temperature of 13.2 °C. The lower basin, the regulated section of the river, has the smallest area (6,000 km^2) with a rainfall of 150 mm y^{-1} (CORONATO and DEL VALLE, 1988). Dominant orders of soils in the basin are aridisols, entisols and vertisols (DEL VALLE *et al.*, 1998), characteristic of the arid and semiarid areas of Patagonia. Most of the river is located in the Patagonian Steppe, were the lack of precipitation on the Patagonian Plateau causes vegetation coverage of xerophytic forms. *Mulinum spinosum*, *Stipa* spp., *Senecio filaginoides*, *Colletia spinosissima, Adesmia campestris*, *Fabiana imbricata* and *Chuquiraga avellanedae* represent the herbaceous-shrub-like steppe (TELL *et al.*, 1997). In several sections of the river at the upper and middle basins, the riparian corridor has been completely invaded by the exotic *Salix fragilis*, in some lower sections the native *S. humboldtiana* is also present.

The adjacent land management is mainly agricultural, with extensive livestock in the upper and middle sections, and predominantly farms and industries in the lower section. Chubut Province produces 4,000,000 sheep per year. Livestock numbers in the section between Paso de Indios and Rawson is lower than in the section from Paso de Indios to the Cordillera (RIMOLDI, pers. com.). All those farms are close to the river, and even though that the stocking rate is relatively low, cattle spend proportionately more

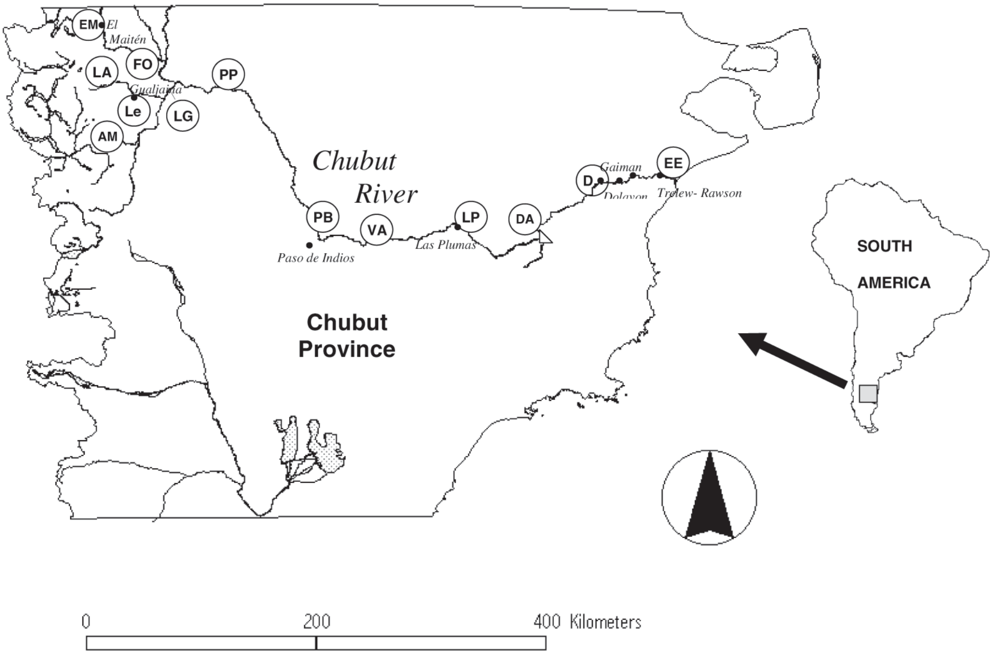

Figure 1. Study area showing the location of the 13 sampling sites on the Chubut River, Patagonia Argentina. Names of the sites are listed in Table 1. Triangle: position of the Florentino Ameghino Dam.

time grazing riparian areas than adjacent plateau lands. In the middle basin, anthropogenic activities in the last century (overgrazing, wood collection) have accelerated land cover degradation in the adjacent zones, and broad areas exhibit extreme land degradation as is shown by the status of desertification that ranges from moderate to very severe (DEL VALLE *et al.*, 1998). This situation results in low productivity of the land and landowners have recently started to cultivate potatoes, corn, and alfalfa. Therefore, various segments of the river are used for watering, particularly during the low water period in summer. For example, in the agricultural middle valley, water is pumped from the Chubut River for water supply in the alfalfa fields. No fertilizers or herbicides are used and water returns into the river by natural gravity (LUQUE *et al.*, 2000). Main cities next to the river in the lower basin use water from the Florentino Ameghino Dam mainly as potable water and irrigation via a channel network in the lower valley. Gaiman, Trelew and Rawson together comprise more than 250,000 inhabitants. This corresponds with the most urbanized area since 77% of the Chubut Province population is concentrated on the coast. The Chubut River outlet is on the estuary next to Playa Union town.

2.2. *Sites and Sampling*

Thirteen sampling sites were established within the river system (Fig. 1), LA (Lepá River) and AM (Madera Stream) were located on upper tributaries, site EM was placed on the Chubut River next to the locality of El Maitén (3,500 inhabitants) and FO on the Chubut River further downstream. Le (Lepá River) was located by the side of Gualjaina City (1,000 inhabitants) and LG further down, after Gualjaina River joins Lepá River. To assess possible changes in response to land use on the upper and middle basin, four sites on the Chubut main channel were established: PP, PB, VA and LP, the sampling site LP was next to the rural town of Las Plumas (500 inhabitants). DA was placed just below the impoundment. D and EE were located in the more developed and urbanized lower Chubut River basin.

Sites were sampled in February, May, September and December of 2004 (Fig. 1). Insects were collected taking three quantitative replicates on run/riffles sections with a modified kick net sampler with a bottom sampling frame (surface of the frame: 0.25 m^2, mesh size 250 μ) (HAUER and RESH, 1996). Samples were fixed with 4% formaldehyde solution. A total of 156 replicates were analyzed. At the laboratory samples were sorted out under 5 × magnification and then stored in 70% ethyl alcohol. Adult specimens were identified using available keys (HINTON, 1970; BRINCK, 1977; SPANGLER and BROWN, 1981; OLIVA, 1994; SPANGLER and STAINES, 2002; MANZO, 2005); larvae were associated to adults using published descriptions and also by rearing (BACHMANN, 1961, 1966; ARCHANGELSKY and FERNÁNDEZ, 2005; ARCHANGELSKY and MANZO, in press).

2.3. Environmental Variables

Substrate composition was estimated as percentage of boulder, cobble, gravel, pebble, and sand using a 1 m^2 grid (GORDON *et al.*, 1994). Stream order was obtained from CORONATO and DEL VALLE (1988). Average depth was calculated from five measurements from one transversal profile across the channel with a calibrated stick. Surface current speed was obtained by timing a bobber (average of 3 times) as it moved over a distance of 10 meters (GORDON *et al.*, 1994). At each site air and water temperatures were measured with a mercury thermometer (–10/+60 °C). Discharge data from the Chubut River and tributaries were kindly provided by the Secretaría de Recursos Hídricos de la Nación.

Water samples were collected below the water surface and kept at 4 °C prior to analysis. Specific conductance, pH, total alkalinity, total suspended solids, and main nutrients were analyzed in the laboratory. Specific conductance was measured with a Horiba U2-probe, and pH with an ORION 720 SA meter, both at 20 °C. Total alkalinity (eriocrome black) was determined by titration with colorimetric end-point; total nitrogen (TN) and total phosphorus (TP) were determined on unfiltered samples digested with persulphate, nitrate plus nitrite nitrogen (NO_3), ammonia (NH_4), and phosphate reactive soluble (PRS) were analyzed following APHA (1994).

Algal biomass (as chlorophyll-*a*) was determined by scraping algae from five rocks within a 20 m reach at each site. Samples (120 ml) were kept on ice in the dark until they were brought back to the laboratory and filtered onto GF/FF filters. Chlorophyll-*a* was extracted from filters in 90% acetone, filters were pulverized and the extract was measured spectrophotometrically (WETZEL and LIKENS, 1991).

2.4. Data analysis

Longitudinal variability of Coleoptera richness was assessed by computing the frequency of occurrences of the taxa at each site, in the procedure replicates were considered as samples ($n = 12$). Canonical Correspondence Analysis (CCA) was performed using the package CANOCO (TER BRAAK and SMILAUER, 1999) to assess the relationships between Coleoptera assemblages and environmental variables. In the analysis the average of the three replicates obtained at each sampling site was used in order to know the spatial and seasonal variability (13 sites, 4 seasons, $n = 52$). The number of occurrences (non-zero values) that the program computed in the ordination procedure was $n = 22$. We included the basin and reach descriptors and land use related variables in the analysis. All variables presented on tables 1 and 2, except land use were used in the analyses. CCA is a direct gradient analysis that assumes a unimodal model for the relationships between the response of each species to environmental gradients and ordination axes are linear combinations of the environmental variables (TER BRAAK, 1986).

Variables (except pH and chlorophyll-*a*) and species density were transformed as log (x + 1), prior to analysis. Where a variable is highly intercorrelated with others, a high inflation factor (>20) is identified for that variable during initial analysis. These variables were then removed (dry width, stream order, depth, discharge, SRP, TN) and reanalyzes carried out on the thirteen remaining environmental variables (see Tables 1, 2). Forward selection was carried out on the environmental data set during analysis in order to identify those variables that explained a significant ($P < 0.05$ using Monte Carlo permutations) amount of variation in the site and taxa data. The CCA was then run using the significant environmental variables (TER BRAAK and SMILAUER, 1998).

3. Results

3.1. Environmental Features of the Chubut River

River orders ranged from 3 to 6 and elevation of the sites was between 4 and 936 m.a.s.l. Substrate size was similar at most sites and consisted mostly of boulders, cobbles, and pebbles (Table 1). Sites PB, VA, and EE had more sand in the substrate composition than the other sites. Water temperature ranged from a minimum of 5 °C in May to a maximum of 22.2 °C in February (Table 1). Maximum current velocity recorded was 2.1 m s^{-1} during February (FO) and the minimum was 0.2 m s^{-1} also in summer (LA), at that section the river suffered water abstraction for irrigation. Discharge showed an exceptional peak in the Chubut main channel at upper and middle section as consequence of strong rains (July). The flow decreased in the lower basin after regulation in the Florentino Ameghino Dam (DA, D and EE).

Chemical and physical data provided a clear distinction among the upper catchment sites and those on the middle and lower catchments, the ranges of 10 environmental variables appear on Table 2. Conductivity in the middle basin ranged between 141–275 μs cm^{-1} whereas in the lower basin reached 2,960 μs cm^{-1}, something consistent with the ocean proximity (site EE). TSS (20.9–171.1 mg. l^{-1}), TN (154.5–511 $\mu g \cdot l^{-1}$), NH_4 values (9–72.6 $\mu g \cdot l^{-1}$) and TP (42.5–126.2 $\mu g \cdot l^{-1}$) were significant at middle basin sites, which could be related with livestock and agricultural activities at that section. The highest values of NH_4 and NO_3 were observed at EE, which probably reflected the important industrial and urban development in the area.

3.2. Longitudinal Distribution and Seasonal Patterns of Coleoptera

A total of 1,601 larvae and adults belonging to 3 families of Coleoptera were collected during the entire study. Eight taxa were recognized, Gyrinidae: *Andogyrus seriatopunctatus*; Hydrophilidae: *Hemiosus dejeanii*; Elmidae: *Hydora annectens*, *Stethelmis kaszabi*, *Luchoelmis cekalovici*, *Austrelmis* sp. (a new species currently being described), *Austrolimnius* spp. (at least two species whose larvae cannot be distinguished with the current knowledge), and Elmidae larva? (a morphotype of elmid larva that has not yet been associated to any adult). Water beetles were recorded all along the system in the upper basin and in lower numbers in the middle basin, but they were completely absent below the impoundment (DA, D and EE). Coleoptera richness was lower on tributaries than in the main channel of the Chubut River and the maximum richness was recorded at EM (Table 3). *Austrelmis* sp. and *Austrolimnius* spp. were recorded at most sampling sites, whereas *Stethelmis kaszabi* and Elmidae larvae? were recorded only in EM and FO. *Luchoelmis cekalovici* was present in tributaries (AM, LA) and on the main channel upper basin sites (EM, FO, PP) (Table 3).

Annual mean Coleoptera density ranged from 0 ind. m^{-2} (DA, D and EE) to 37.3 ind. m^{-2} (FO) (Table 3). *Hemiosus dejeanii* had maximum density in May at FO, LG and PP, *Luchoelmis cekalovici* peaked on February (AM), and in May (FO), whereas *Austrelmis* sp. maximum densities were recorded in December (EM, FO) (Fig. 2). The distributional range of the collected species in relation to the main environmental features is presented in Table 4.

3.3. Environmental Relationships

The CCA ordination showed a strong relationship between beetle species distribution and the measured environmental variables. The environmental variables selected in the analysis

Table 1. Environmental features measured at 13 sampling sites on the Chubut River basin, Patagonia, Argentina ($n = 4$). T; tributary, MC: main channel. U = upper, M: middle and L: lower basin. B: boulder, C: cobble, P: pebble, G: gravel, S: sand, c: coarse, f: fine, Ch: Chubut River. Land use codes: Cr: cattle raising, U: urban, A: agriculture, R: flow regulation.

Site codes	River location	Main land use	Altitude (m.a.s.l.)	Stream order	Dry width (m)	Mean Wet width (m)	Depth (min-max) (cm)	Discharge (min-max) ($m^3 s^{-1}$)	Velocity (min-max) ($m s^{-1}$)	Water temperature (min-max) (°C)	Substrate type
AM	Madera Stream (T, U)	Cr	936	3	12	8.5 ± 8	8–19.2	0.09–2.7	0.3–1.7	4.5–20	C/P
LA	Lepa River (T, U)	Cr	829	4	20	2.7 ± 3	17–40	0.26–5	0.2–1.2	5–20	B/C
EM	Ch (MC, U) El Maitén	U	702	4	100	51.7 ± 39	38–45	3.5–239	1.2–1.7	5–17	C/P
FO	Ch (MC, U) Fofo Cahuel	Cr	500	4	80	52.5 ± 24	36.6–45	3.4–239	1.1–2.1	8–21.4	P/G
Le	Lepa River (T, U) Gualjaina	U	518	5	100	32.4 ± 20	27.2–45	0.05–96.6	0.3–1.6	9–21	P/G
LG	Gualjaina River (T, U) After Gualjaina	Cr	476	6	50	30.5 ± 16	32.8–45	2.6–234.3	1–1.4	7–22.2	P/G
PP	Ch (MC, U) Piedra Parada	Cr	440	5	200	105 ± 65	45–53.7	10.2–773	0.9–1.2	7–21.4	C/P
PB	Ch (MC, M) Paso Berwyn	Cr/A	308	5	160	125 ± 56	23–45	10.2–773	0.5–1.6	6–21.4	C/P/S
VA	Ch (MC, M) Los Altares	Cr/A	243	6	200	117 ± 58	30–45	6.5–841.2	0.8–1.2	7–21.6	P/G/S
LP	Ch (MC, M) Las Plumas	U	158	6	300	215 ± 23	19.6–45	6.5–841.2	1.7–1.9	7–20.7	B/C
DA	Ch (MC, L) D. F. Ameghino	R	74	6	70	64 ± 5	45–60	4.8–119.7	0.7–0.9	8–15.5	C/P
D	Ch (MC, L) 28 de Julio	R-U	32	6	40	35 ± 4	46.7–60	31–79	0.9–1.4	8–18.1	cG
EE	Ch (MC, L) Estuario	U	4	6	160	151 ± 2	33–60	31–79	0.8–1.1	9–21.1	fG/S

Table 2. Range of physical, chemical and biological variables measured on the upper (AM, LA, EM, FO, Le, LG, PP), middle (PB, VA, LP) and lower (DA, D, EE) basin sites of the Chubut River, Patagonia, Argentina. Data correspond to four sampling dates (February, May, September, and December 2004).

	Range		
	Upper	Middle	Lower
pH	7.1–8.3	7.3–8.2	7.3–8.1
Conductivity (µs cm^{-1})	42–308	141–275	177–2,960
Total alkalinity (meq l^{-1})	0.11–3.39	1.45–2.05	1.52–1.94
Total Nitrogen (µg l^{-1})	13.6–387.8	154.5–511	150.1–695.9
Nitrate (µg l^{-1})	6.9–81.2	8.5–23.2	7.3–229.4
Ammonia (µg l^{-1})	1.9–42.8	9–72.6	3.3–176.3
Total phosphorus (µg l^{-1})	6.5–44.1	42.5–126.2	28.7–94.1
Phosphate Reactive Soluble (µg l^{-1})	3.1–11.6	3–22.1	8.3–43.8
Chlorophyll-*a* (mg m^{-2})	0.01–8.5	0.7–5.45	1.3–17.59
Total suspended solids (mg l^{-1})	0.2–27.8	20.9–171.1	2.1–55.3

are represented in the figure by arrows, which point in the direction of maximum change in the value of the associated variable (Fig. 3). The species-environmental correlation were: 0.98, 0.96 and 0.97 for the first, second, and third axis respectively (Table 5), suggesting a close relationship between the environmental variables selected. The Monte Carlo test of significance of canonical axes (to judge the significance of that relationship) produced signifi-

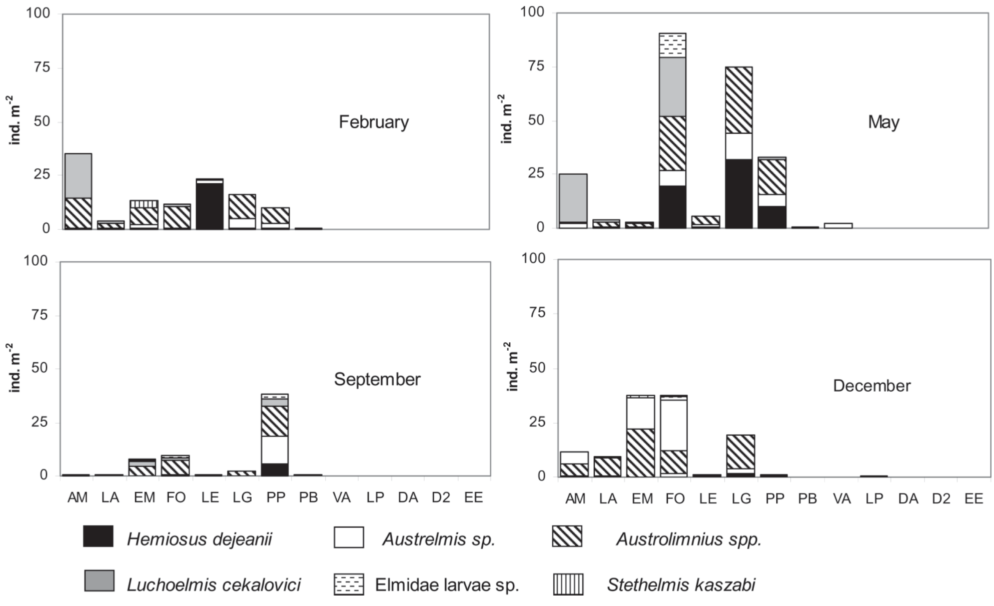

Figure 2. Seasonal density (ind m^{-2}) ± SD of the most important species of water beetles along the Chubut River and tributaries. ($n = 3$).

Table 3. Frequency of occurrence (total samples), total species richness and mean density ($n = 12$) of Coleoptera species along the Chubut river during the study (2004).

	AM	LA	EM	FO	Le	LG	PP	PB	VA	LP	DA	D	EE
Gyrinidae													
Andogyrus seriatopunctatus (Régimbart, 1882)						1	1		2				
Hydrophilidae													
Hemiosus dejeanii (Solier, 1849)			1	4	5	6	8						
Elmidae													
Hydora annectens Spangler & Brown, 1981			1										
Austrelmis sp.	5	5	2	7	6	8	8	2	2	1			
Austrolimnius spp.	8	10	11	10	7	12	9	2					
Luchoelmis cekalovici Spangler & Staines, 2002	11	4	8	10			6						
Elmidae *larvae?*			1	5			1						
Stethelmis kaszabi Hinton, 1970			5	1									
Coleoptera richness	3	3	7	6	3	4	6	2	2	1			
Mean Coleoptera abundance (ind m^{-2})	18	4.3	15.4	37.3	7.7	28.4	20.8	0.4	0.8	0.08			

Table 4. Range of environmental variables values for each Coleoptera species.

	Hemiosus dejeanii	*Austrelmis* sp	*Austrolimnius* spp.	*Hydora annectens*	*Luchoelmis cekalovici*	Elmidae larvae ?	*Stethelmis kaszabi*	*Andogyrus seriatopunctatus*
Altitude	440–702	158–939	308–939	702	440–936	500–702	500–702	476–243
pH	7.53–8.21	7.18–8.38	7.18–8.38	7.62	7.18–8.38	7.55–8.08	7.53–7.92	8.19–8.38
Conductivity (μs cm^{-1})	81–308	47–308	47–308	45	42–145	42–126	42–92	145–212
Total alkalinity (meq l^{-1})	0.72–3.39	0.37–3.39	0.11–3.39	0.11	0.37–1.29	0.56–1.28	0.11–0.91	1.29–1.84
Total Nitrogen (μg l^{-1})	31.2–387.8	31.2–511	13.6–387.8	138.7	13.6–264.5	88.4–401	53.2–138.7	169.8–249.6
Nitrate (μg l^{-1})	6.9–18.8	5.8–81.2	5.8–81.2	13.5	6.9–52.7	9–52.7	10.9–52.7	10.2–12.4
Ammonia (μg l^{-1})	5.6–42.8	2.8–60.2	3.3–60.2	3.7	1.9–9	5.1–9	3.7–5.6	5.6–6.5
Total phosphorus (μg l^{-1})	6.5–44.1	6.6–88.8	6.5–65.8	12.2	7.9–44.1	9.6–44.1	6.5–27.4	33.9
Phosphate Reactive Soluble (μg l^{-1})	3.1–11.6	2.8–12.7	2.8–16.5	5.9	2.8–13	3.3–11.6	3.1–9	11–13
Chlorophyll-*a* (mg m^{-2})	0.01–8.7	0.01–8.7	0.01–8.7	3.2	0.01–8.7	0.01–8.7	2–7.7	0.01–1.51
Total suspended solids (mg l^{-1})	0.4–27.8	0.2–96.9	0.2–66.5	0.6	0.2–27.8	2.4–27.8	0.4–7.6	7.6–11.4

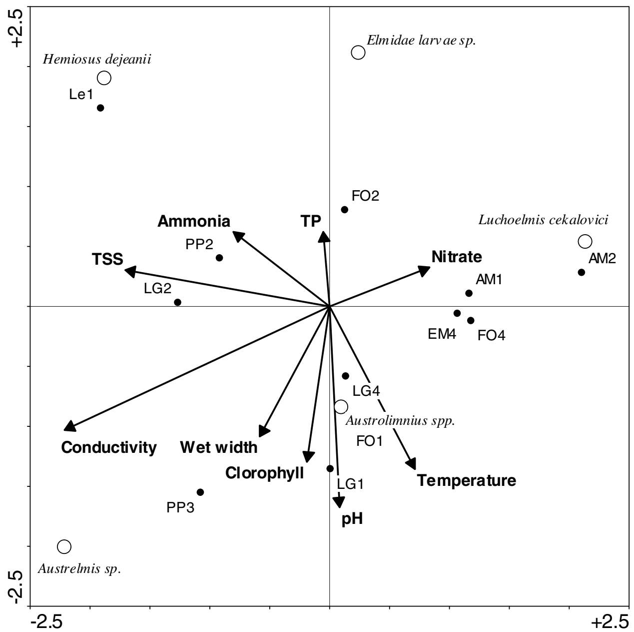

Figure 3. CCA ordination diagram of sites, Coleoptera species and environmental variables. Full environmental variables and sampling sites names are listed in Tables 1 and 5. Numbers next to site codes refer to months: 1: February, 2: May, 3: September and 4: December.

Table 5. Intraset correlation of environmental variables with the axes of CCA of Coleoptera species data in the Chubut river basin, Patagonia, Argentina. Codes for environmental variables in parenthesis.

Variable	Axis 1	Axis 2	Axis 3
pH	0.03	–0.63	0.06
Conductivity	–0.81	–0.39	0.25
Total suspended solids (TSS)	–0.62	0.11	–0.40
Ammonia (NH_4)	–0.29	0.23	–0.18
Nitrate (NO_3)	0.30	0.12	–0.16
Total phosphorus (TP)	–0.02	0.23	–0.39
Chlorophyll-*a* (CHLO)	–0.07	–0.48	–0.47
Wet width	0.21	–0.40	–0.48
Water temperature (TEMP)	0.26	–0.51	0.28
Eigenvalues	0.528	0.378	0.221
Species-environment correlation	0.98	0.96	0.97
Cumulative percentage variance of species data	39.3	67.4	80.8

P – values for Monte Carlo Permutation test
Axis1: $F = 1.29$, $p < 0.0048$
All canonical axes: $F = 5.84$, $p < 0.0044$

cant values for all axes (Table 5). The strongest explanatory factors were physico-chemical variables, and 67.4% of variation in the species data was accounted for by the environmental variables measured (first two axes) (Table 5). The main environmental gradient (axis 1) was determined by conductivity and total suspended solids, suggesting the existence of a hydro-geological gradient. Other secondary variables associated to this axis were ammonia and nitrates suggesting anthropogenic or land use effects (Fig. 3). Upper sites with more diluted waters, minor TSS values and ammonia but higher nitrate values were associated along the positive axis 1. Sites having less diluted waters, more suspended solids contents, and higher ammonia values were associated along the negative axis 1.

The second axis showed an environmental gradient associated mainly with factors that change seasonally, as shown by strong correlations with pH, water temperature and chlorophyll-*a,* but also with the wet width, a variable more related with river magnitude along the longitudinal gradient.

The triplot illustrates the position of the water beetle species along the same gradients. *Luchoelmis cekalovici* was placed on upper right quadrant, the species was abundant at AM, during the low water period in February and May. In an intermediate position was Elmidae larva? which peaked at FO in February*,* and *Austrolimnius* spp. the most abundant taxa at FO in February and at LG in December. On the other hand *Hemiosus dejeanii* and *Austrelmis* sp. were placed on the left. These species were abundant at sites with higher conductivity and TSS contents.

4. Discussion

As shown by several studies, land use has a strong influence on river chemistry. In temperate catchments total nitrogen, nitrate concentration; phosphorus, major anions and cations are often good indicators of land degradation (SPONSELLER *et al*., 2001; HALL *et al*., 2001). In the Chubut middle basin natural factors such as geology and agricultural land use in the arid area resulted in high TSS and TP values. SRP values were higher in the lower basin in concurrence with a more urbanized and developed area. It is possible that the observed increase in TSS at the middle section dramatically limited the transparency. The decrease in suspended solids and TP downstream of the reservoir is in agreement with one of the most common effects of impoundments (WARD and STANFORD, 1982), which is the increase in Chl-*a* as a consequence of higher water transparency (WARD and STANFORD, 1990).

Most literature supports the fact that Elmidae, and other benthic beetles, are quite sensitive to the degradation of streams (HILSENHOFF, 1988; THOMAS, 1988). Moreover, in temperate and cold regions their utility as indicators may be increased due to their long life cycles since it may take them as much as two or three years to complete the development from egg to adult (BROWN, 1987; KODADA and JÄCH, 2005). In an intensive study of a river system in the Patagonian Cordillera, MISERENDINO and PIZZOLÓN, (2000) found that elmids were never present in the impaired section of a river perturbed by sewage discharges. Altitude and chemical conditions seemed to influence distribution of elmids in the Orbigo Basin in Spain (GARCÍA CRIADO *et al*., 1999) and several species were intolerant to organic enrichment.

In the middle basin diversity dropped significantly (PP to PB). Except for a few records (*Andogyrus seriatopunctatus*, *Austrelmis* sp., and *Austrolimnius* spp.), most species were absent in the middle basin of the Chubut river. It is possible that elevation and biogeographical aspects are important in coleopteran distribution along this river; in fact the variable wet width, which is related with distance from the source, explained part of the variance in our dataset. However, there are other aspects that merit some discussion. Among physical factors affecting aquatic fauna, hydraulic and substratum conditions have profound effects on community composition, abundance and distribution (LLOYD and SITES, 2000;

REMPEL *et al.*, 2000). MISERENDINO and PIZZOLÓN (2003) found that elmids were absent in river sections dominated by unconsolidated cobbles and gravels after a high discharge, and in summer appeared in response to more stable conditions, and a greater variety of habitat. It is likely that a combination of high discharges and unstable substrates, plus a high amount of suspended solids affected benthic beetles in a significant way in the Chubut middle basin. As was shown by DOEG and MILLEDGE (1991) experimentally induced suspended solids sediments caused increase in drift in members of Elmidae. Also, an extreme reduction of *Austrolimnius* spp. larvae and adults was observed in a study after sediment releases from a small retaining weir from a tributary of the Yarra River (DOEG and KOEHN, 1994). Since adult elmids breathe by means of a plastron it is probable that the siltation process affects the breathing mechanism by blocking or obstructing this physical gill. Sediment increases in rivers have been associated with numerous human activities including agriculture and mining, forest harvesting, and road construction (MASON, 1991).

The middle basin of the Chubut River has natural geomorphological factors characteristic of arid and semiarid areas and the source of fine sediments proceeds from the floodplain, which is washed during the river expansion (high flow). Additionally, for almost a century, an extensive cattle grazing has accelerated land cover degradation, and the desertification process in the region (DEL VALLE *et al.*, 1998). Furthermore, at this section most of the farms are close to the river, and cattle spend more time grazing riparian areas. In agreement with this scenario starting at PP, conductivity and nutrients, especially ammonia and TP, were two or three times higher than in the upper basin locations. The strong association of benthic beetle data with physical (TSS) and chemical (conductivity, NO_3, NH_4, pH) conditions in the CCA supports the hypothesis that hydrogeological factors represent a major physical gradient along which water beetles are distributed. This gradient probably also affects the availability of food, for example sediment deposition after flooding can cause algae and organic matter to become covered by fine sediment (REMPEL *et al.*, 2000). Characteristically high turbidity and sedimentation in the Chubut River middle basin probably limited algal productivity and accounted for the lack of the elmids that are predominantly grazers.

Since Coleoptera had practically disappeared upstream the impoundment, we were not able to determine the regulation effects of the dam on the beetle fauna. In contrast to what happened with beetles, there were several species of Plecoptera, Trichoptera and Ephemeroptera capable to maintain stable populations below the reservoir (MISERENDINO, 2006). Dispersal flights by adult elmids are carried out only after emergence and before entering the water; once adults enter the water they usually do not leave it (BROWN, 1987; KODADA and JÄCH, 2005). Therefore drifting is the predominant downstream mechanism of dispersion in elmids both for adults and larvae (BRUSVEN, 1970; NEWMAN and FUNK, 1984; BROWN, 1987; KODADA and JÄCH, 2005). A recent study on the longitudinal profile of a non regulated Patagonian river that runs through the arid area showed that *Luchoelmis* sp. was recorded all along the river including a study location in the outlet (MISERENDINO, 2005).

In this study, *Hydora annectens* and *Stethelmis kaszabi* seem to inhabit a narrow range of ecological conditions as is shown by the TP and ammonia ranges (Table 4). This is consistent with the known, restricted, distribution of these two species (HINTON, 1970; SPANGLER and BROWN, 1981; ARCHANGELSKY, 2004). The most tolerant species was *Austrelmis* sp. This can be appreciated by the frequency of records and because it had the greatest longitudinal distribution pattern. With regards to ammonia and TSS values, *Austrelmis* sp. tolerated a wider gradient than the rest of the benthic Coleoptera. It should be pointed out that this species has a fairly large distributional range, being found in at least three provinces (Neuquén, Río Negro and Chubut). *Austrolimnius* spp. had a similar pattern, although these taxa disappeared after PB. Larvae of the gyrinid *Andogyrus seriatopunctatus* were occasionally recorded in some sites in December; this is probably related to its life cycle. *A. seri-*

atopunctatus has a fairly fast larval development, being recorded mostly in medium to large size rivers from December to March or April in our area (BACHMANN, 1961, 1966; ARCHANGELSKY, 2004). The hydrophilid *Hemiosus dejeanii* was most characteristic in the main channel of Chubut River sites but it was also very abundant on the tributaries Le and LG. Being an obligate carnivorous, this species requires an appropriate offer of prey, and from all these locations high numbers of chironomids (Diptera) and leptophlebiids (Ephemeroptera) were recorded when the species peaked (MISERENDINO *et al*., 2005).

Luchoelmis cekalovici appeared in two of the tributaries (AM and LA) and in the first three stations on the Chubut River (EM, FO and PP); afterwards it disappeared. It was also absent in the stations Le and LG, which are placed between LA and PP. This absence is correlated with anthropogenic activities that disrupt the natural conditions in Le and LG (canalization, removal of streambed, and water abstraction) near the city of Gualjaina. This distribution suggests that *L. cekalovici* could be a good indicator of human impact. Additionally, *L. cekalovici* appeared in stations with low conductivity, alkalinity, and TSS. Elmidae Larva? showed a more restricted distribution, and was present only in the three upper stations of the Chubut River (EM, FO and PP), and could also be a good indicator of low values of conductivity, alkalinity, and TSS, but with a more restricted distribution than *L. cekalovici*.

Although we were not able to clearly separate natural from land use effects in any case this study provides a first look at natural and cultural controls on the Coleoptera community in a large Patagonian river. While the river shows a longitudinal gradient in hydrogeological features, our analysis suggests that land use also influenced coleopteran abundance and distribution through several pathways, involving discharge and fine sediments (sand and clays). Further studies are required in order to discern more distinctly the effects of landscape variables such as climate, elevation, and vegetation. We suggest extending these studies to riparian areas and connected environments such as marginal pools and meanders to establish the role of these areas as a refuge during hostile conditions such as flooding and sedimentation events.

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