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Fish assemblage of a Pampasic stream (Buenos Aires, Argentina): temporal variations and relationships with environmental variables

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In the Argentine Pampa fertile soils were originally covered by grasslands, but at present are intensively cultivated. We assessed the specific composition of the fish assemblage of El Pescado stream and compared it with that recorded in 1991–1993, when land use in the watershed consisted in natural pastures. The persistence of the fish assemblage between the two studies was rather high: 0.76. Abundance, biomass and species richness were higher during drought periods. Connectivity with the huge Río de la Plata hydrographic system seems the most important contribution to the high and stable species richness of El Pescado stream.

Keywords: Argentina; El Pescado stream; Río de la Plata; fish assemblage

Introduction

Human population growth and increased consumption produced a deterioration of natural systems (Abell et al. 2008). Freshwater ecosystems have lost a proportionally larger amount of habitats compared with terrestrial and ocean environments (Revenga et al. 2005) and show substantial impacts from land use and biotic and climate change (Sala et al. 2000). Identification of anthropogenic impacts on aquatic ecosystems requires a detailed knowledge of the system and its long-term variability before the impact. Long-term data are often not available (Schaefer et al. 2005). Studies of fish assemblages generally include analyses of spatial variation but rarely incorporate temporal variation. This is due largely to a lack of long-term historical community data (Jacquemin & Pyron 2011).

In Argentina, present knowledge of fish assemblages in lotic environments is scarce. Some work on fish assemblages was performed in the central, northern and northeastern parts of the country (Bistoni et al. 1999; Bistoni & Hued 2002; Butí & Cancino 2005; Menni et al. 2005; Rosso et al. 2013). The Argentine Pampa is an extensive plain covering most of the central part of the country. Fertile soils were originally covered by grasslands, but are now intensively cultivated. A few surveys are available about fish assemblages of inner, small Pampasic streams (Di Marzio et al. 2003; Fernandez et al. 2008; Colautti et al. 2009).The most detailed survey was performed by Almirón et al. (2000) in El Pescado stream, throughout 1991–1993, at a site located 8.7 km from the Río de la Plata. Almirón et al. (2000) recorded 55 species belonging to 23 families and six orders. Soil use has changed since then in the upper basin. Land use previously was extensive livestock farming on natural pastures; 82% of the surface corresponded to natural grazing while the crop area represented less than 10% of the total (Sanchez et al. 1976). In the last decade a gradual replacement by crops has been observed. Currently, crops and orchards cover most of the upper basin, accounting for 27% of the watershed surface (Mugni 2009).

The aim of this study is to assess the present fish assemblage composition of El Pescado stream, to determine its relationship with environmental variables and to compare it with that recorded by Almirón et al. (2000).

Materials and methods

Study site

El Pescado stream runs for 36 km through the lower Pampa until its mouth in the Río de la Plata (Figure 1). The basin comprises 211 km^2 (Hurtado et al. 2006). The stream counts with extensive riparian habitats and goes through an extended wetland. Close to the mouth the river enters the Río de la Plata coastal plain (Cavallotto 2002); the sampling site is located at the entry to the coastal plain (34°57′46.63″ S;

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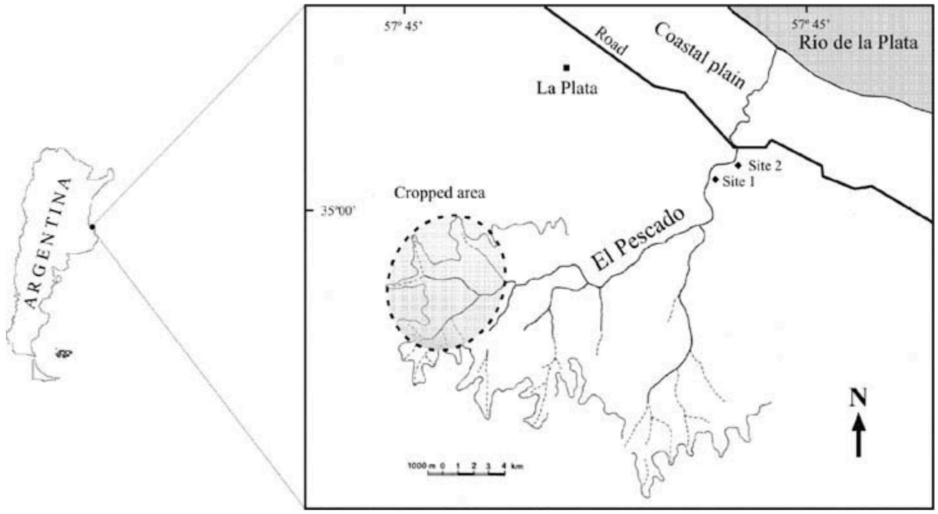

Figure 1. El Pescado stream basin and sampling sites, Buenos Aires province, Argentina.

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57°46′41.2″ W). The climate is mild and humid; mean monthly temperatures range from 9.9°C in July to 22.4°C in January. Mean annual rainfall is 1010 mm featuring small seasonal variations.

Sampling

In order to compare species composition of the current assemblage with that registered by Almirón et al. (2000), sampling was conducted at the same sites using the same gear and fishing effort. Nineteen samplings were conducted at sites 1 and 2 from Almirón et al. (2000), where the authors recorded the highest number of species during the 1991–1993 survey. At sampling site 1, the stream was 1.1 ± 0.2 m deep and 18.7 ± 2.0 m wide. Site 2, located approximately 300 m downstream, was 0.8 ± 0.2 m deep and 9.7 ± 1.0 m wide. These sites were sampled from January 2009 to May 2011, using a seine net of 15 m width × 1 m height, cod end 1.5 m, and mesh of 5–10 mm; three hauls of 50 m were performed at each site. Three additional samplings were performed at site 4 of Almirón et al. (2000) in March and December 2009 and November 2010. This site is shallow and has a hard bottom substrate comprised mainly of pebbles. Sampling was conducted by removing pebbles and passing a dip-net. This was done to assess the presence of *Ancistrus cirrhosus* and *Synbranchus marmoratus* reported by Almirón et al. (2000) only at this site. These data were not used for comparison of abundance and biomass because they were obtained with different fishing gears and sampling efforts.

Collected fish were weighed with an Ohaus precision balance (0.5 g). Fish were identified following Ringuelet et al. (1967), Azpelicueta and Braga (1991); Braga (1993), Braga (1994), Aquino (1997), Reis and Pereira (2000), Almirón et al. (2008), Casciotta et al. (2005), Miquelarena and Menni (2005). Changes in taxonomy of family groups, genera and species names occurred between surveys were reviewed and updated by Van der Laan et al. (2014) and Eschmeyer (2014) respectively.

For an easier interpretation of changes in the fish assemblage, fish species were sorted into two groups; those typically recorded in Pampasic streams (Di Marzio et al. 2003; Fernandez et al. 2008; Colautti et al. 2009) are referred to as "Pampasic" species hereafter, while those most commonly reported in the Río de la Plata are referred to as "Río de la Plata" species.

Voucher species were kept in the ichthyology collection of the Raúl Ringuelet Limnology Institute (Instituto de Limnología Dr. Raúl A. Ringuelet, Argentine National Scientific and Technical Research Council (CONICET) and National University of La Plata.

Physical and chemical parameters were measured *in situ* at both sites in each sampling. Since recorded values were almost identical, measurements at both sites were pooled together and reported as means. Water temperature and dissolved oxygen were measured with an oxymeter YSI 51B (YSI Incorporated, Yellow Springs, OH, USA), pH with a Hanna checker (Hanna Instruments, Woonsocket, RI, USA), conductivity with a Hanna HI 8733 conductivity meter, and Secchi depth and depth with a gage rod. Water samples were also taken for nutrient analysis at the upstream site. Water samples were immediately

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filtered through Whatman GF/C (Whatman Incorporated, Clifton, NJ, USA) and transported to the laboratory in coolers with ice. The concentration of soluble reactive phosphorus (PRS), ammonium and nitrate were measured following APHA (1998). Suspended solids were determined as the filter weight difference after filtering a measured volume of water through Whatman GF/C.

The rainfall data were obtained from the experimental field station of the School of Agronomic Science at La Plata University, La Plata, Argentina.

Statistical analysis

To compare the abundance and biomass of the species recorded in common in sites 1 and 2 by Almirón et al. (2000) and the current survey a nonparametric comparison test of paired samples (Wilcoxon test) was performed for each site. The level of significance used was $p < 0.1$.

All other analyses were performed pooling together the data from the two sampling sites because no significant differences between environmental variables at each site were detected.

To evaluate the temporal persistence (P) of the assemblage the inverse of the exchange rate (T) was used (P = 1 – T). The exchange rate quantifies the extinction and immigration in the assemblages (McArthur & Wilson 1967) and the relative change in a time interval is defined by Schoener and Spiller (1987) as:

$$T = (E + I)/(LSR\ t_1 + LSR\ t_0), \qquad (1)$$

where E = extinctions of species already present, I = immigrations of new species, LSR t_0 = local species richness at time t_0 and LSR t_1 = local species richness at time t_1. In this study we consider t_0 as the survey conducted by Almirón et al. (2000) and t_1 the present work. Therefore persistence (P) is low if the value is close to zero and high if it is close to 1.

Correlations between attributes of assemblage and environmental variables were evaluated by the correlation of Pearson product moment (r).

Relationships between environmental variables and species were studied by multivariate analysis. The species whose total relative abundance was lower than 0.1% were eliminated from the analysis to reduce the influence of rare species. In the first run a detrended correspondence analysis (DCA) was performed. Because the length of the gradient was 2.881 units of standard deviation for the first axis, a redundancy analysis RDA was performed (Ter Braak & Smilauer 1998; Leps & Smilauer 2003).

Results

Comparison of fish assemblages between 1991–1993 and 2009–2011

Fifty-six fish species were recorded in the present study, belonging to 24 families and eight orders. The order Characiformes showed the largest species richness with 28 species (50%), followed by the Siluriformes, with 17 (30.3%), the Perciformes with five (8.9%), Cyprinodontiformes with two, and Clupeiformes, Cypriniformes, Synbranchiformes and Atheriniformes with a single species each. Table 1 compares the current composition of the assemblage with that recorded in 1991–1993. Differences in the number of orders and families were due to the appearance of the exotic invasive common carp *Cyprinus carpio* (Cypriniformes, Cyprinidae), the mandufia *Ramnogaster melanostoma* (Clupeiformes, Clupeidae) and the family Parodontidae in the present study. Two families recorded in 1991–1993 were not recorded in the present survey: Rivulidae and Acestrorhynchidae. Temporal persistence of the fish assemblage between the two studies was rather high (P coefficient: 0.76). Of the 56 species registered in 2009–2011, 42 were present in 1991–1993 (Table 2), and 14 species were newly recorded (Table 3), while 12 species present in the 1991–1993 survey were not recorded in the recent survey (Table 4). *Synbranchus marmoratus* was collected at sites 1 and 2 while *Ancistrus cirrhosus* were captured in the additional samplings removing pebbles at site 4.

Fish abundance in each period is compared in Figure 2. Abundance at site 1 was significantly higher (p = 0.097) in the present study. Río de la Plata species contributed 84.6% to the total abundance, while in 1991–1993 Pampasic species represented 72.6%. Fish abundance at site 2 did not emerge as significantly different (p = 0.883) between studies. Biomass was significantly higher in the present study at both sites: (p = 0.012) and (p = 0.088) for site 1 and 2 respectively.

Table 1. Number of orders, families and species of fish recorded at all sites of the El Pescado stream, Buenos Aires, Argentina.

	Orders	Families	Species
1991–1993*	6	23	55
2009–2011	8	24	56
In common	6	21	42
Recorded only in 2009–2011, not in 1991–1993	0	2	12
Recorded only in 1991–1993, not in 2009–2011	2	3	14

*Almirón et al. (2000)

Table 2. Abundance and biomass of fish species recorded at sites 1 and 2 of the El Pescado stream, Buenos Aires, Argentina. Species in bold correspond to species commonly recorded in the Río de la Plata and those not in bold to commonly recorded in Pampasic streams. Species names are reported following the recent reviews of Eschmeyer (2014) and Van der Laan et al. (2014). Names given by Almirón et al. (2000) that later changed are also given and signaled by an asterisk.

	Abundance		Biomass (g)	
In common	2009–2011	1991–1993*	2009–2011	1991–1993*
Cyphocharax voga (Hensel 1870)	191	5	5084	127
Charax stenopterus (Cope 1894)	15	242	57	836
Pseudocorynopoma doriae Perugia 1891	4	52	7	109
Astyanax eigenmanniorum (Cope 1894)	16	88	70	194
Astyanax rutilus (Jenyns 1842) *A. fasciatus**	1752	195	6223	844
Bryconamericus iheringii (Boulenger 1887)	609	121	844	180
Hyphessobrycon meridionalis Ringuelet, Miquelarena & Menni 1978	1	8	3	28
Oligosarcus jenynsii (Günther 1864)	36	18	309	248
Oligosarcus oligolepis (Steindachner 1867)	121	3	1322	39
Cheirodon interruptus (Jenyns 1842)	344	287	320	198
Hoplias malabaricus (Bloch 1794)	4	2	1277	30
Corydoras paleatus (Jenyns 1842)	236	457	754	1229
Otocinclus arnoldi Regan 1909 *O. flexilis**	83	153	88	100
Loricariichthys Anus (Valenciennes 1835)	29	9	3272	1403
Hypostomus commersoni Valenciennes 1836	14	63	4118	2856
Pimelodella laticeps Eigenmann 1917	56	577	123	1242
Rhamdia quelen (Quoy & Gaimard 1824) *R. sapo**	1	2	703	331
Jenynsia multidentata (Jenyns 1842)	17	11	27	7
Cnesterodon decemmaculatus (Jenyns 1842)	40	1858	7	163
Gymnogeophagus meridionalis Reis & Malabarba 1988	9	38	15	139
Characidium rachovii Regan1913	1	15	1	7
Steindachnerina biornata (Braga & Azpelicueta 1987)	2	19	50	275
Prochilodus lineatus (Valenciennes 1837)	1596	6	119,452	2017
Schizodon platae (Garman1890)	3	1	381	25
Salminus brasiliensis (Cuvier 1816)*S. maxillosus**	14	1	3159	56
Diapoma terofali (Géry 1964)	1	40	1	49
Rhaphiodon vulpinus Spix & Agassiz 1829	19	43	182	1171
Auchenipterus osteomystax (Miranda Ribeiro 1918) *A. nuchalis**	20	62	67	36
Trachelyopterus striatulus (Steindachner 1877)	1	2	12	5
Iheringichthys labrosus (Lütken 1874)*I. westermanni**	759	15	2584	127
Parapimelodus valenciennis (Lütken 1874)	16,242	4	19,052	24
Pimelodus maculatus Lacepède 1803	494	12	6106	343
Microglanis cottoides (Boulenger 1891)	1	4	2	6
Bunocephalus doriae Boulenger 1902 *Disichthys* sp.*	18	12	43	40
Pseudobunocephalus iheringii (Boulenger 1891) *Disichthys iheringi**	1	1	13	6
Odontesthes bonariensis (Valenciennes 1835)	22	1	35	4
Pachyurus bonariensis Steindachner 1879	171	10	338	94
Plagioscion ternetzi Boulenger 1895	57	1	141	12
Crenicichlasp.(Eigenmann 1907)	1	1	86	0
Mugil liza Valenciennes 1836	1	1	1	0
Total no. of species	40	40		
Total nº of specimens	23,002	4440		
Total biomass			176,329	14,600

*Data from Almirón et al. (2000).

Relations of the assemblage to environmental variables

Table 5 summarizes measured environmental variables. Oxygen concentration was always high, in the 7.2–15 mg l^{-1} range. Water pH and conductivity showed an extended variation range: 7.2–9.3 and 440–6150 μS cm^{-1}, respectively. High suspended matter content resulted in high turbidity year round; the Secchi depth range was 5–26 cm. Mean nutrient concentrations showed comparatively high PRS concentrations, 369 ± 186 μg l^{-1}, together with comparatively low inorganic nitrogen concentrations, 37 ± 58 μg N-NH_4^+ l^{-1} and 59 ± 52 μg N-NO_3^- l^{-1}.

Fish abundance, biomass and species richness were inversely correlated with the rain fallen in the three months prior to each sampling, pointing to the influence of the stream's hydrological condition on

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Table 3. Abundance and biomass of fish species recorded at sites 1 and 2 of the El Pescado stream, Buenos Aires, Argentina in 2009–2011. Species in bold correspond to species commonly recorded in the Río de la Plata and those not in bold to commonly recorded in Pampasic streams.

2009–2011	Abundance	Biomass (g)
Hyphessobrycon anisitsi (Eigenmann 1907)	10	31
Cyprinus carpio (Linnaeus 1758)	2	3563
Apareiodon affinis (Steindachner, 1879)	23	18
Cyphocharax platanus (Günther 1880)	42	876
Cyphocharax spilotus (Vari 1987)	1	31
Ramnogaster melanostoma (Eigenmann 1907)	133	98
Leporinus obtusidens (Valenciennes 1836)	9	579
Cynopotamus argenteus (Valenciennes 1836)	1	23
Triportheus nematurus (Kner 1858)	1	13
Astyanax abramis (Jenyns 1842)	7	43
Astyanax asuncionensis (Géry 1972)	10	45
Ctenobrycon alleni (Eigenmann & McAtee 1907)	2	18
Pimelodus albicans (Valenciennes 1840)	12	471
Pseudoplatystoma corruscans (Spix & Agassiz 1829)	2	520

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Table 4. Abundance and biomass of fish species recorded at sites 1 and 2 of the El Pescado stream, Buenos Aires, Argentina in 1991–1993 by Almirón et al. (2000). Species in bold correspond to species commonly recorded in the Río de la Plata and those not in bold to commonly recorded in Pampasic streams.

1991–1993	Abundance	Biomass (g)
Astyanax sp	38	41
Austrolebias bellotti (Steindachner 1881) *Cynolebias bellotti**	48	8
Phalloceros caudimaculatus (Hensel 1868)	24	11
Australoheros facetus (Jenyns, 1842) *Cichlasoma facetum**	2	9
Otocinclus vittatus Regan 1904	8	3
Rineloricaria lima (Kner 1853)	13	46
Heterocheirodon yatai (Casciotta, Miquelarena & Protogino 1992) *Odontostilbe yatay**	14	10
Ageneiosus militaris Valenciennes 1835 *A valenciennis**	4	173
Acestrorhynchus pantaneiro Menezes 1992	1	23
Pimelodella gracilis (Valenciennes 1835)	1	0
Luciopimelodus pati (Valenciennes 1835)	1	8
Hisonotus maculipinnis (Regan 1912) *Otocinclus maculipinnis**	3	1

*Name listed in Almirón et al. (2000).

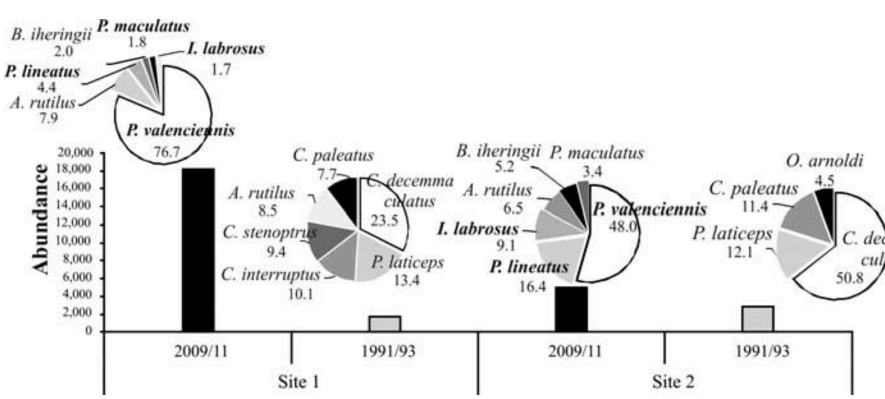

Figure 2. Total abundance of common species (bar chart), percentage of relative abundance of the most abundant species (pie chart), at each site for the two studies of El Pescado stream basin, Buenos Aires, Argentina. Species in bold correspond to "Río de la Plata" species; species not in bold belong to "Pampasic" species.

Table 5. Comparison of monthly means (± SD) of physical and chemical parameters recorded in El Pescado stream, Buenos Aires, Argentina throughout the study period. Data from sites 1 and 2 pooled.

	Water depth (cm)	Temperature (°C)	pH	O_2 (mg l^{-1})	Conductivity (μS cm^{-1})	Secchi depth (cm)	Suspended matter* (mg l^{-1})	Rain† (mm)
January 2009	77 ± 12.7	29.8 ± 0.9	9.3 ± 0.6	>15	5060 ± 35.2	19 ± 1.7	–	86
March 2009	67 ± 25.5	29.0 ± 1.7	8.5 ± 0.2	9.4 ± 0.8	974 ± 19.8	16.5 ± 2.1	107	247.1
June 2009	75 ± 28.3	12.5 ± 0.7	7.4 ± 0.2	>15	2170 ± 99.0	19.5 ± 3.5	–	205.6
December 2009	83.5 ± 30.4	26.0 ± 1.4	7.7 ± 0.1	8.7 ± 0.4	440 ± 14.1	17.8 ± 1.8	99	485.8
March 2010	79 ± 39.6	24.5 ± 0.7	7.3 ± 0.1	7.2 ± 0.2	640 ± 29.0	9.3 ± 1.1	80	473.4
April 2010	87.5 ± 38.9	15.5 ± 0.7	7.4 ± 0.4	10.5 ± 0.7	812 ± 17.7	13.8 ± 1.1	53	430.5
May 2010	111 ± 29.7	12.0 ± 1.4	7.3 ± 0.2	10.2 ± 0.8	625 ± 7.1	24.0 ± 1.4	–	456.9
June 2010	102.5 ± 48.8	10.5 ± 0.7	7.4 ± 0.3	12.8 ± 1.1	525 ± 1.4	21.8 ± 1.1	29	305.3
July 2010	116 ± 39.6	12.4 ± 0.6	7.2 ± 0.3	12.9 ± 0.1	540 ± 35.4	19.5 ± 0.7	17	320.3
August 2010	90 ± 35.4	13.5 ± 0.7	7.6 ± 0.3	10.4 ± 0.8	975 ± 35.4	26.0 ± 1.4	25	260.1
September 2010	111 ± 19.8	22.0 ± 1.4	7.8 ± 0.2	10.5 ± 0.7	638 ± 16.3	19.3 ± 1.8	33	245.1
October 2010	89 ± 15.6	19.9 ± 1.2	7.5 ± 0.2	8.9 ± 0.8	1335 ± 91.9	11.3 ± 1.1	178	224.8
November 2010	87 ± 22.6	25.0 ± 1.4	8.5 ± 0.5	8.3 ± 0.4	2850 ± 70.7	5.0 ± 0.2	193	173.7
December 2010	79.5 ± 14,8	30.0 ± 1.4	8.4 ± 0.4	9.5 ± 0.7	5155 ± 91.9	9.3 ± 0.4	120	225.3
January 2011	102 ± 18.4	26.7 ± 0.5	8.7 ± 0.3	11.5 ± 0.8	6150 ± 70.7	5.5 ± 0.7	152	281.4
February 2011	101 ± 26.9	23.4 ± 0.8	8.2 ± 0.2	10.6 ± 0.6	5080 ± 56.6	10.0 ± 1.4	77	287.5
March 2011	82 ± 14.1	22.1 ± 0.6	7.8 ± 0.3	>15	5195 ± 134.4	7.0 ± 1.4	204	281.4
April 2011	94.5 ± 12.0	16.5 ± 0.7	7.5 ± 0.5	13.6 ± 1.0	3530 ± 42.4	10.6 ± 0.6	–	267.2
July 2011	87.5 ± 13.4	13.3 ± 1.1	7.3 ± 0.4	11.5 ± 0.6	686 ± 0.7	7.8 ± 0.4	112	326.9

*Suspended matter was only determined at site 1.
†Rain fallen in the three months prior to each sampling.

Table 6. Correlations among environmental variables of El Pescado stream, Buenos Aires, Argentina, in 2009–2011, and the fish assemblage attributes.

	Water depth (cm)	Temperature (°C)	pH	Conductivity (μS cm^{-1})	Secchi depth (cm)	Suspended matter (mg l^{-1})	Rain† (mm)
Abundance	−0.49*	—	0.69**	0.46*		—	−0.52*
Biomass	—	—	0.61**	0.83**	−0.67**	0.76**	−0.49*
Richness	−0.67**	0.60**	0.79**	0.68**	−0.48*	0.57*	−0.46*

*$p < 0.05$; **$p < 0.01$.
†Rain fallen in the three months prior to each sampling.

the main attributes of the fish assemblages. During droughts, stream water remained stagnant, while conductivity increased. Enhanced phytoplankton growth increased water pH. Suspended matter increased because of resuspended bottom sediments. Water pH and conductivity showed significant correlations with abundance, biomass and species richness (Table 6).

In the RDA analysis the first and second axis accounted for 72.9% of the relationship between species and the environment. Conductivity, pH and temperature were positively related with axis 1, associated to drought periods. Rainfall, depth and Secchi depth showed the opposite trend associated with wet periods (Table 7).

Biplots of the RDA including the species, samplings and physicochemical variables are shown in Figure 3. In periods of higher conductivity, pH and temperature (drought), Río de la Plata species were dominant (*P. maculatus, P. valenciennis, I. labrosus, R. melanostoma, P. bonariensis*, and *P. ternetzi)* over the Pampasic species (*C. interruptus, O. jenynsii, C. decemmaculatus, A. rutilus, B. iheringii, C. voga*, and *L. anus*).

Table 7. Relation of environmental variables of El Pescado stream, Buenos Aires, Argentina, in 2009–2011 to the first two axes of the redundancy analysis.

	Environmental variables					
Axes	Temperature (°C)	pH	Conductivity (μS cm^{-1})	Secchi depth (cm)	Depth (cm)	Rainfall (mm)
1	0.66	0.83	0.86	−0.51	−0.67	−0.48
2	0.28	0.23	−0.32	0.37	−0.39	−0.12

Discussion

Species richness

The species richness in El Pescado stream (56) is high in comparison with other temperate environments.

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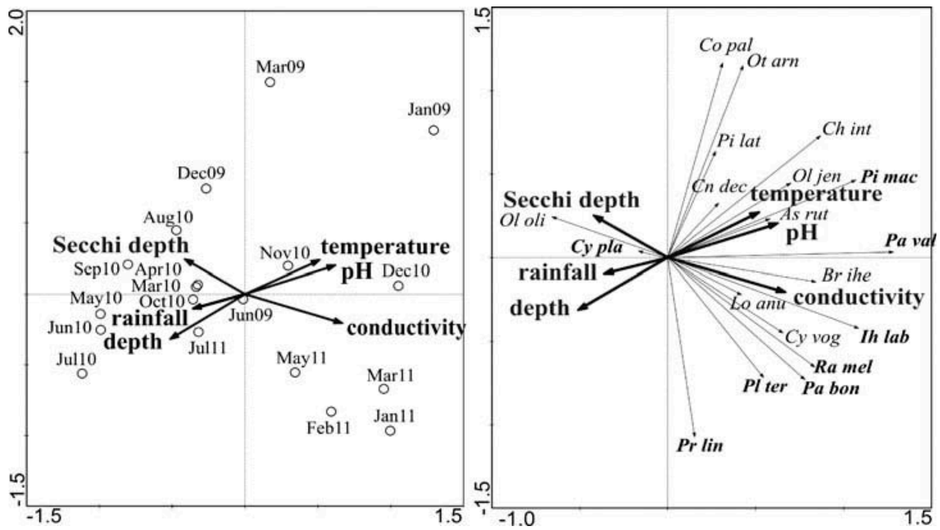

Figure 3. Biplots of samples and environmental variables (left graph), species and environmental variables (right graph) of El Pescado stream basin, Buenos Aires, Argentina. Species in bold correspond to Río de la Plata species and those not in bold to Pampasic species. ***Pa val = Parapimelodus valenciennis***, *As rut = Astyanax rutilus,* ***Pi mac = Pimelodus maculatus***, *Co pal = Corydoras paleatus, Br ihe = Bryconamericus iheringii, Cn dec = Cnesterodon decemmaculatus, Ch int = Cheirodon interruptus, Cy vog = Cyphocharax voga, Ol oli = Oligosarcus oligolepis,* ***Pr lin = Prochilodus lineatus, Cy pla = Cyphocharax platanus, Ih lab = Iheringichthys labrosus, Ra mel = Ramnogaster melanostoma, Pa bon = Pachyurus bonariensis***, *Pi lat = Pimelodella laticeps, Pl ter = Plagioscion ternetzi, Ol jen = Oligosarcus jenynsii.*

Few temperate streams exceed 30 species (Matthews 1998). Species richness remains high even compared with tropical Brazilian streams amounting to 7–52 species (Araújo-Lima et al. 1995). El Pescado species richness is higher than that reported for other Pampasic streams. Fernandez et al. (2008) recorded 17 and 20 species in two affluents of the Samborombón River. Di Marzio et al. (2003) recorded 27 species in a tributary of the Luján River, and Colautti et al. (2009) recorded 23 species in a stream belonging to the basin of the Reconquista River. All studied streams belong to the Río de la Plata hydrographic system; studied sites are located at 80–200 km from the confluence with the Río de la Plata. The high species richness found in El Pescado stream is due to the close distance of the sampling site to the confluence with the Río de la Plata, as shown by the different composition from that of other Pampasic streams. The number of species tends to increase considerably in river and stream sites near the confluence with courses of major basins (Schaefer & Kerfoot 2004; Hitt & Angermeier 2008). Osborne and Wiley (1992) reported that the number of species was significantly higher in streams located in the lower basins connected with systems of greater size than in headwaters and Smith and Kraft (2005) observed that the position in the basin was decisive in structuring assemblage complexity, increasing with stream order.

Variations in fish assemblage composition in relation to environmental variables

The present study reveals a strong interaction between the Río de la Plata and El Pescado stream. Thirty-one (55.3%) of the total collected species belong to the Río de la Plata species. This relationship was also important for the changes in fish assemblage composition during the studied period. During drought periods, abundance and richness increased mainly due to the presence of small size fishes from the Río de la Plata such as *P. maculatus, P. valenciennis, I. labrosus, R. melanostoma, P. bonariensis* and *P. ternetzi*. This pattern was also observed by Llompart et al. (2012) in streams of the Punta Lara Natural Reserve, adjacent to the Río de la Plata, about 36 km upstream from the El Pescado mouth. The authors observed that 20 of 59 species collected were juveniles, *P. maculatus, P. valenciennis* and *I. labrosus* being the most abundant. Results of the present study are consistent with that of Llompart et al. (2012) in that juveniles of several species inhabiting the Río de La Plata enter the lower reaches of Pampasic streams during droughts, possibly searching for food and shelter, increasing species richness. During rainy periods water flow becomes turbulent, resulting in decreased richness and abundance. Grossman et al. (2010) reported a negative correlation between fish diversity, mean depth and water velocity in a southern Appalachian stream (USA). The authors conclude that

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increased diversity is due to species migrating upstream during droughts.

The present results are consistent with those of Almirón et al. (2000) and show that the alternation of drought and high flow conditions appears to be the major source of local variation of the assemblage of El Pescado stream and contributes to maintain a high diversity in the stream. Medeiros and Maltchik (2001) highlight the importance of floods limiting the increasing dominance of abundant species.

Temporal persistence of the fish assemblage

There were 12 species quoted by Almirón et al. (2000) that were not recorded in the present survey and 14 species recorded in the present survey not reported by Almirón et al. (2000). This is related to the presence in the fish assemblages of rare species occurring with low frequency and abundance. Matthews et al. (1988) reported that the most common or abundant species are typically persistent while rare species are not. Ibarra and Stewart (1989) determined the presence of 208 species in the Napo River, in Ecuador, 46 species (22%) being represented by a single individual throughout the whole study.

Soil use has changed in El Pescado basin in recent decades. Extensive cattle breeding was replaced by intensive crop and orchard farming in the upper basin. Mugni et al. (2011) reported toxicity pulses produced by insecticides in coincidence with rain events in a small, first order El Pescado affluent running through a cultivated plot. The high coefficient of persistence (P) suggests that agricultural impact in the upper basin did not affect species richness of the lower El Pescado stream. Several features probably contribute to the observed high persistence. Agriculture is confined to the upper stretch and represents a comparatively minor portion of the basin (27%). The sampling site was located about 30 km downstream from the agricultural area and only 8.7 km from the confluence with the Río de la Plata. The stream goes through a wetland between the two stretches and contains conspicuous riparian vegetation. Wetlands and riparian vegetation might attenuate downstream transport of agrochemicals.

Overall, the high coefficient of persistence and similar specific richness compared to the early 1990s suggest a large resilience capacity of the El Pescado fish assemblage. Connectivity with the huge Río de la Plata hydrographic system seems the most important contribution to the high and stable species richness of El Pescado stream.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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