layer to the water column (Håkanson 2003; Carpenter 2005), supported by the concept that trophic state can be substantially influenced by the release of P from the sediments (Carey and Rydin 2011). Maassen *et al.* (2005) showed that pore water can influence the water body trophic state because of the presence of usually high concentrations of soluble reactive phosphorus (SRP), alkalinity and ammonium. Moreover, there are other parameters that affect the trophic state of an aquatic environment which are linked to the sediment, such as the ratios of iron (Fe) to P (Fe:P) and aluminium (Al) to P(Al:P), and sediment P fractions. These authors propose that sediments can be used as an additional tool to evaluate the water body trophic state. Although they did not find a direct relationship between the sediment TP and the water column TP, they suggest that the surface sediment layer TP represents the P of the settled particles from the water column and not the P of diagenetic processes occurring in the sediment (Golterman 2001). Carey and Rydin (2011) suggest that, to determine the relationship between the sediment P and the water column, it is necessary to compare the TP concentration in the surface sediment layer with a reference concentration, or the TP concentration at which diagenetic processes in the sediment are stabilized. These authors call "stabilization point" (SP) to the depth at which the sediment TP becomes constant. SP is dependent on sedimentation rates, which are determined by external and internal loading, resuspension and internal focusing of sediments (Søndergaard *et al.,* 1993; 1996; Weyhenmeyer *et al.,* 1997). Above the SP values, the mobile P is released into the water column while below the SP, the P remains trapped (Håkanson 2003). In this regard, the release of P to the water column in oligotrophic lakes is significantly less than that in eutrophic lakes (Nurnberg *et al.,* 1986). Carey and Rydin (2011) analyzed a database of 94 lakes (oligotrophic, mesotrophic and eutrophic) in North America and Europe. They hypothesize that TP depth patterns in lake sediments can vary significantly between oligotrophic and eutrophic environments, which may explain the trophic state of aquatic environments.

The aim of this study was to determine the depth distribution of sediment TP in Patagonian Argentinean lakes in relation with their trophic state.

MATERIALS & METHODS

The water bodies considered in this study are distributed between 35° and 50° S and 40° and 72° W (Fig. 1). Most of them (8 lakes) are located in the Patagonian region, and only one reservoir at the south of Mendoza province (site 1). The Patagonian region can be divided into two sub-regions: Patagonian Andes and Patagonian Steppe (De Aparicio and Difrieri 1985). The soils in this region, derived primarily from volcanic ash, are poorly developed and rich in allophones. In contrast, the Patagonian steppe soils are typically alkaline with high salt content, negative water balance and dominant salinization. Water bodies in the Patagonian Andes are of glacial origin, chemically poor and, in general, dominated by silica (Pedrozo *et al.,* 1993). According to Quirós and Drago (1985), the Patagonian lakes have been classified as warm monomictic, with a stratification period during the summer. The climate in the Andean-Patagonian region is continental, classified as humid cold temperate in the mountain Andes to arid in the steppe region (Speck *et al.,* 1982). Periods of rain occur primarily between late winter and early spring. Due to the loss of moisture from the prevailing western winds, a strong west-east gradient in annual rainfall is found, ranging from 2700 mm/year at the Argentine-Chilean border (altitude 1020 m) to 500 mm/year in the Patagonian steppe (800 m) within a distance of only 50 km to the east. The average annual temperature varies between 20 °C at high altitudes (above 2000 m) and 8.0 °C in protected valleys, and between 7.5 and 12.5 °C in the Patagonian steppe. Table 1 shows the physical and chemical parameters, trophic classification and history, of the 9 environments studied (8 lakes and 1 reservoir). The surfaces ranged from 0.6 to 1892.0 km^2, while the maximum depths ranged from 5 to 550 m. The selected environments are located in a pH gradient from 2.50 (Lake Caviahue) to 9.21 (Lake Cardiel). According to the TP concentration in the water column, the environments are classified as oligotrophic (TP <10 µgP/L), mesotrophic (TP between 10 and < 30 µgP/L) and eutrophic (TP > 30 µgP/L) (Table 1). The sediment cores were extracted between 2006 and 2008 using a Uwitec-type corer with a diameter of 6 cm at depths ranging from 5 m to 20 m with the exception of Lake Caviahue (90 m) (Table 1). Each core was cut into layers of 2 cm thickness from the surface and up to 14 cm depth. Immediately after cutting them, the pH and redox potential (ORP) were measured in each layer using an Orion 920 A specific electrode with automatic temperature compensation.

Pore water was removed from each layer of sediment by centrifugation at 4000 rpm for 15 minutes. The supernatant was removed and filtered through membrane filters of 0.45 µm pore. Each fraction obtained was integrated into a single sample for each of the cores collected, kept in the dark and refrigerated, and taken to the laboratory. Similarly, each sediment sample was also transferred to the laboratory where they were dried at 60 °C, homogenized in ceramic mortar and sieved through a 500 µm sieve (Newark, ASTM N 36 USA Standard Series Sieves) to remove less reactive fractions. Pore water samples were analyzed for soluble

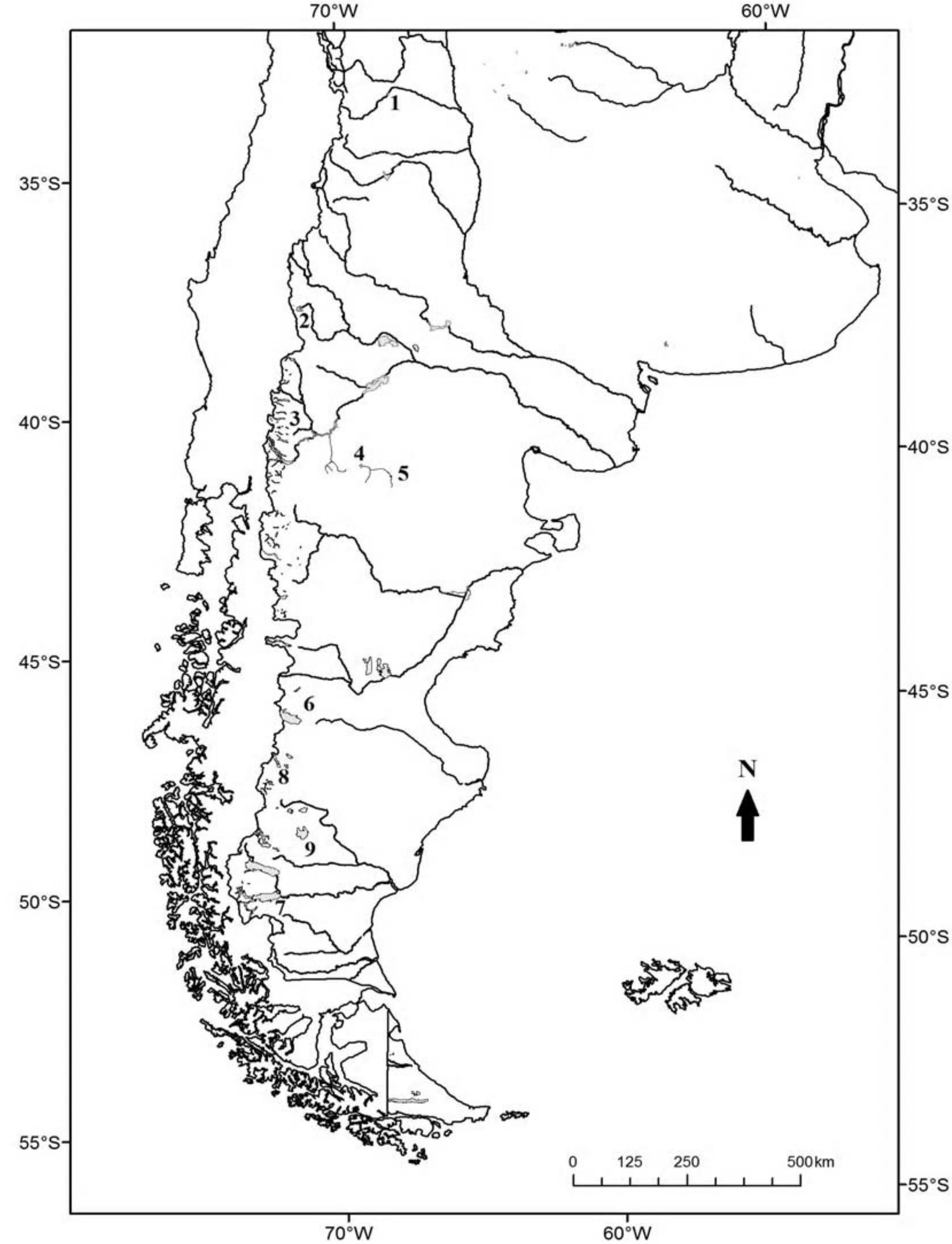

Fig. 1. Location of sampling sites

reactive phosphorus (SRP) and ammonium ($N\text{-}NH_4^+$), in compliance with APHA (1995). Dried sediment samples were analyzed for the following parameters: **a)** Total phosphorus (TP): a sediment fraction was digested with SO_4H_2 and 30% hydrogen peroxide (H_2O_2) (Carter 1993). After digestion, the dissolved P was determined by the Murphy and Riley method (1962). **b)** Chemical characterization of sediments: silica (Si), Al, Fe, sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), titanium (Ti), (expressed as oxides of each element) was determined by the SEM-EDAX method (Last, 2001; Saarinen and Petterson, 2001). The Fe and Al concentrations were estimated from the concentrations of the respective oxides. **c)** Different P

Table 1. Geographic position, morphometric date, physic and chemical parameters, and trophic classification for the 9 lakes analyzed. Zmax: Maximum depth of water bodies, SD: Secchi Disk; Water EC: Electric conductivity of water, Water TP: Total Phosphorus concentration in water, Water SRP: Soluble phosphorus reactive concentration in water, Chlo-a: Chlrophyll a concentration. (Dates from: 1) Baffico *et al.*, 2007; 2) Pedrozo *et al.*, 2001; 2010; 3) Temporetti *et al.*, 2009; 4) Macchi *et al.*, 2001; 5) Pedrozo 2006).

	Geographic location	Altitud (m.a.s.l)	Area Km^2	Zmax (m)	Sediment core extraction depth (m)	SD (m)*	pH	Water EC (µS/cm)	Water TP (µg/L)	Water SRP (µg/L)	Chlo-a (mg/m^3)	Trophic state	Eutrophication history
Pueyrredón[5]	47º 26' 20.2'' S 71º 55' 18.4'' W	112	320.0	280	10	8.0	8.30	174	2	0.45	0.42	Oligotrophic	Deep glacial lake. Very wide and partially wooded basin. No significant human activity. Land used for livestock.
Argentino[5]	50º 07' 40.1'' S 72º 06' 51.9'' W	187	1466.0	500	20	2.0	7.53	40	3	0.52	0.28	Oligotrophic	Deep glacial lake. Very wide and partially wooded basin. City of 20,000 inhabitants on one of its banks. Important tourist centre. Livestock use of the land
Buenos Aires[5]	46º 18' 14.0'' S 71º 42' 57.1'' W	200	1892.0	550	15	3.3	7.82	77	9	2.00	0.44	Oligotrophic	Deep glacial lake. Very wide and partially wooded basin. No significant human activity. Land used for livestock.
Lácar[3]	40º 09' 37.8'' S 71º 21' 47.3'' W	625	49.0	279	10	19.0	7.75	60	9	1.10	1.89	Oligotrophic	Deep glacial lake. Forested basin. City of 25,000 inhabitants. Important tourist centre. Overturning of effluents with different degrees of treatment on the main watershed.
Nihuil[1]	35º 04' 21.0'' S 68º 41' 13.7'' W	1251	72.0	17	6	0.7	8.29	1032	23	2.00	3.74	Mesotrophic	Reservoir of anthropic origin for power generation. Sparsely vegetated basin. Small urban settlements. Land used for agriculture.
Cari-Laufquen Chica[4]	41º 13' 04.6'' S 69º25' 54.3'' W	150	5.0	5	5	0.3	8.40	440	191	46.40	6.50	Eutrophic	Wind-formed shallow lake. Sparsely vegetated basin. No nearby urban settlements. Land used for livestock.
Ñe-Luan[4]	41º 30' 15.9'' S 68º 37' 32.3'' W	1000	0.6	15	9	0.7	8.20	324	200	26.30	5.60	Eutrophic	Wind-formed shallow lake. Sparsely vegetated basin. No nearby urban settlements. Land used for livestock.
Cardiel[5]	48º 48' 38.6'' S 71º 11' 57.9'' W	300	460.0	49	10	1.3	9.21	4512	360	342.70	0.71	Eutrophic	Wind-formed shallow lake. Sparsely vegetated basin. No urban settlements. Land used for livestock.
Caviahue[2]	37º 52' 17.0'' S 71º 00' 53.0'' W	1650	9.2	90	90	3.6	2.50	1259	370	230.00	0.35	Eutrophic	Natural acidic lake of volcanic and glacial origin. Sparsely vegetated basin. Stable population of 1000 inhabitants that increases during tourist seasons.

fractions were determined according to the fractionation scheme proposed by Hieltjes and Lijklema (1980), discriminating the labile fraction (P-Labile) (extracted with 1 M $ClNH_4$), the fraction bound to Al/ Fe oxy-hydroxides (P-Al/Fe) (extracted with 0.1 M NaOH), the fraction bound to calcium compounds (P-Ca) (extracted with 0.5 M HCl) and the organic fraction (P-MO) (calculated as the difference between the sediment TP and the sum of the previous/mentioned fractions).

To evaluate the association between the chemical variables determined in sediment cores at different depths, a Principal Component Analysis (PCA) was performed. This analysis, as every multivariate descriptive technique, is an exploratory study used to describe behavior structures in observations (Lebart *et al.,* 1995). The matrix of observations consisted of 10 columns representing the variables measured in sediments: pH, PT, SiO_2, Al_2O_2, Fe_2O_3, MgO, CaO, Na_2O, K_2O and TiO_2 and 9 rows representing lakes and reservoir studied: Caviahue, Argentino, Buenos Aires, Pueyrredón, Nihuil, Lácar, Cardiel, Cari-Laufquen Chica and Ñe-Luan. This analysis was repeated for the following layers of the core: 0-2 cm, 2-4 cm and 8-10 cm. All variables were active in the PCA. Values of sediment TP with depth in each core were fitted to different regression models in order to determine the distribution pattern and estimate the most appropriate fitting model which describes the relationship between sediment TP and core depth. We used the criterion proposed by Carey and Rydin (2011) where the data are fitted to two different models: *a)* linear model ($\mathbf{Y = \beta_0 + \beta_1 * Z}$) and *b)* exponential model ($\mathbf{Y = c * e^{\beta 1 * Z}}$) where: **Y** is the sediment TP, **Z** is the depth of the cores, β_0 is the intercept, β_1 is the slope and **c** is a constant value. The linear model was used in oligotrophic lakes and the exponential model in eutrophic ones (considering linear increase, exponential increase, linear decrease and exponential decrease).

Moreover, the values of the different P fractions (P-labile P-Fe/Al, P-Ca and P-MO) in depth in each sediment core were fitted to different regression models to evidentiate a distribution pattern in data. As for the sediment TP, the following models were used: *a)* linear model ($\mathbf{Y = \beta_0 + \beta_1 * Z}$) and *b)* exponential model ($\mathbf{Y = c * e^{\beta 1 * Z}}$), where: **Y** is the P associated with the different fractions, **Z** is the depth of the core, β_0 is the intercept, β_1 is the slope and **c** is a constant value. The linear model was used for oligotrophic lakes and exponential model for eutrophic (considering linear increase, exponential increase, linear decrease and exponential decrease). To assess whether the pattern of sediment TP can predict the water column TP concentration, a polynomial regression model that included a quadratic term for linear slope (Carey and Rydin 2011) was used. To this purpose, TP data of the water column and sediments that were previously fitted to an exponential model were transformed (log_e). Then processed data were fitted to a linear model, where TP was the dependent variable and core depth was the independent variable. All the linear slopes obtained in the fittings were used to estimate the water TP according to the following model: $\mathbf{Y = \beta_0 + \beta_1 * Z + \beta_2 * Z^2}$, where: **Y** represents the water column TP, **Z** is the core depth, $\mathbf{Z^2}$ is the quadratic term of the core depth, β_0 is the intercept, and β_1 and β_2 are the parameters (slopes) of the model. To evaluate the existence of a relationship between the TP in the first two centimeters of sediment core and the TP in the water column (log_e transformed data) a simple linear regression analysis was performed. The regression model used was the following: $\mathbf{Y = \beta_0 + \beta_1 * Z}$, where: **Y** represents the water TP values, **Z** is the core depth, β_0 is the intercept, and β_1 is the slope of the model. The principal component analysis, linear and exponential settings and regression analyzes were performed using Infostat statistical package (Di Rienzo *et al.,* 2011).

RESULTS & DISCUSSION

The TP average concentrations for all cores and layers ranged from 693 µgP/g d.w. (Lake Argentino) and 1121 µgP/g d.w. (Reservoir Nihuil) (Table 2). Overall, we found a pattern in the TP depth distribution of the cores that was related to trophic state (Fig. 2). The oligotrophic environments showed an increase in TP concentration in the sediment profiles with depth, and fitted to a linear model with positive slopes (β_1 = 43.56, R^2 = 0.94) (Fig. 2). On the other hand, the eutrophic environments showed a decrease in TP concentration with depth and, when fitted to an exponential model, exhibited negative slopes (β_1 = -0.01, R^2 = 0.43) (Fig. 2). Reservoir Nihuil (TP_{water} = 23 µgP/L, mesotrophic) was the only environment where TP concentration with depth along the core did not follow a linear model (β_1 = -9.38, R^2 = 0.18) nor an exponential one (β_1 = -0.001, R^2 = 0.16) (Table 3). These results show that there is a relationship between the depth distribution of sediment TP and the trophic state of the studied freshwater ecosystems. Same results were obtained by Carey and Rydin (2001). However, two exceptions were noted to this general pattern: **a)** Lake Caviahue, which showed a sediment TP distribution pattern typical of oligotrophic environments, although according to the water column TP concentration, it should be classified as eutrophic. This distribution pattern had been observed before by Temporetti *et al.* (2013). This lake, also of glacial origin, is characterized by low transparency (2.8 to 3.6 m Secchi disk), low pH (2.0-3.0) and high electrical conductivity

(1.0 mS/cm) (Diaz *et al*., 2007), and is the only natural lake which is extremely acidic in South America because it receives the influence of volcanic acidity. The high concentrations of Fe_2^+ in the water column causing the SRP (Table 1) to remain in solution representing from 90 to 95% of TP (Pedrozo *et al.*, 2008). **b)** Lake Lácar is considered an oligotrophic lake (Table 1); however, its sediments behave like those in a typical eutrophic environment. This glacial lake is located within the Lanin National Park, and on the east margin of the lake the densely populated city of San Martin de los Andes is settled. The city is located at the drainage point of its main tributary on which all effluents are discharged and, after several levels of sewage treatment, are carried into the Lake Lácar (Werner 2007).

The element composition was dominated, firstly, by SiO_2, then by Al_2O_3, and finally by Fe_2O_3, except in Reservoir Nihuil and Lake Caviahue, where CaO and Na_2O, were dominant respectively (Table 2). In Fig. 3 are shown the principal component analysis (PCA) results of the following layers analyzed in sediments: 0-2 cm, 2-4 cm and 8-10 cm. In all three cases, the patterns of association between individuals (lakes) and variables were similar. For this reason the graphics only show the variables and individuals for the last layer (8-10 cm). For the PCA corresponding to 0-2 cm depth, factor 1 explained 39.7% of the total variance, which increased to 66.0% when adding the second factor. The most important variables that contributed to the formation of the factors were: SiO_2, MgO, Al_2O_3 and K_2O. The individuals (lakes/reservoir) were divided according to their trophic state along factor 2, and according to pH through factor 1. Regarding the PCA of the layer 2-4 cm made, factor 1 explained 43.5% of the total variance, while it increased to 68.3% when adding the second factor. The most important variables that contributed to the formation of the factors were: SiO_2, TP, Al_2O_3 and TiO_2. As in the uppermost layer, individuals were divided according to their trophic state, throughout factor 2 and according to pH, through factor 1. We described different associations: one of them between variables, and the other one between variables and individuals, for both layers mentioned above (0-2 and 2-4 cm). Considering the relationships between variables in the first two dimensions graph, it was observed that the pH is positively related to Fe_2O_3 and CaO and the TP, and negatively to SiO_2. Eutrophic lakes (lakes Ñe-Luan, Cardiel, Cari-Laufquen and Lácar) had higher contents of TP, Fe_2O_3 and CaO, high pH and low SiO_2. Moreover, the oligotrophic environments (lakes Pueyrredón and Argentino) showed high Al_2O_3content. In this case, Lake Buenos Aires was not well represented in the analysis. On the other hand, Lake Caviahue was separated from the rest of the environments in the graph and was characterized by high concentrations of SiO_2 and low TP, Fe_2O_3 and pH. Reservoir Nihuil, presented high values of TP and low Al_2O_3. In the PCA of the 8-10 cm layer (Fig. 3), factor 1 explained 41.7% of the total variance, increasing to 68.1% by adding the second factor. As in the most superficial layers, individuals were separated

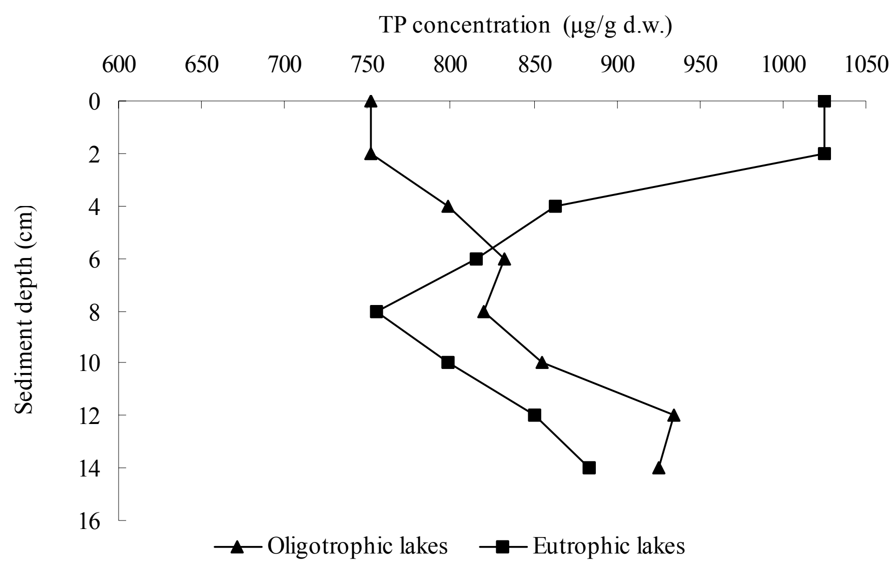

Fig. 2. Average TP concentrations observed in the cores analyzed. Oligotrophic (Water column TP <10 µgP/L) and Eutrophic (Water column TPe" 30 µgP/L). Lake Caviahue and Reservoir Nihuil were excluded \ (see explanation in the text)

Table 2. mean values (maximum and minimum values in parentheses), for all stratum, of pH, TP concentration and chemical composition of water body sediments

	pH	TP	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2
		(µgP/g d.w.)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
L. Pueyrredón	7.1	735	60.0	20.9	6.6	0.6	1.2	1.5	3.9	0.7
	(7.0-7.4)	(623-868)	(57.7-67.3)	(19.5-25.0)	(5.2-9.4)	(0.5-0.6)	(1.0-1.9)	(0.7-3.2)	(3.2-5.0)	(0.4-1.1)
L. Argentino	6.7	693	62.6	19.7	6.3	2.2	2.4	3.2	2.3	0.8
	(6.4-6.9)	(653-741)	(55.2-62.5)	(22.1-23.2)	(5.1-8.7)	(0.8-2.0)	(2.2-2.9)	(1.0-2.1)	(2.9-3.6)	(0.4-1.1)
L. Buenos Aires	6.8	1073	62.6	19.7	6.3	2.2	2.4	3.2	2.3	0.8
	(6.5-7.1)	(907-1255)	(60.4-65.8)	(17.5-21.2)	(4.3-11.7)	(0.9-5.5)	(1.9-3.0)	(1.7-6.0)	(1.7-3.3)	(0.5-1.5)
L. Lácar	6.3	1031	57.0	22.5	9.0	3.7	2.5	3.4	1.1	0.8
	(6.4-6.5)	(982-1091)	(55.6-58.1)	(21.2-23.1)	(8.3-10.1)	(3.0-3.9)	(2.2-2.6)	(2.9-4.0)	(0.9-1.2)	(0.7-1.1)
R. Nihuil	7.0	1121	58.0	19.8	5.6	7.7	3.4	2.6	2.2	0.6
	(6.8-7.1)	(997-1275)	(57.6-58.4)	(19.0-20.4)	(5.5-5.8)	(7.1-8.2)	(3.4-3.5)	(2.4-2.9)	(2.2-2.3)	(0.5-0.6)
L. Cari-Laufquen	7.7	953	56.6	17.4	7.0	7.4	4.0	1.4	1.4	0.8
Chica	(7.5-7.8)	(805-1096)	(64.2-66.9)	(16.4-18.0)	(4.8-6.1)	(2.3-3.3)	(2.7-3.8)	(2.7-3.9)	(1.5-1.8)	(0.7-1.0)
L. Ñe-Luan	7.6	964	62.3	20.7	7.5	3.2	3.1	0.7	1.4	0.8
	(7.4-7.8)	(808-1134)	(55.5-65.8)	(18.5-24.7)	(4.5-13.6)	(2.0-5.0)	(2.4-3.5)	(0.4-1.0)	(1.0-1.7)	(0.6-1.2)
L. Cardiel	8.6	714	65.4	17.3	5.7	2.7	3.3	3.2	1.7	0.8
	(8.4-9.0)	(563-846)	(64.2-67.0)	(16.4-18.0)	(4.8-7.0)	(2.3-3.3)	(2.7-3.8)	(2.7-3.9)	(1.5-1.8)	(0.7-1.0)
L. Caviahue	2.9	1064	73.3	11.5	2.4	1.1	0.7	2.6	0.9	1.3
	(2.6-2.9)	(378-1943)	(70.6-76.3)	(9.2-12.3)	(1.6-3.0)	(0.7-1.4)	(0.2-2.1)	(1.8-4.0)	(0.7-1.1)	(1.1-1.5)

Table 3. TP concentration in the water column (TP_{water}); best sediment TP model fit; the linear slope of the function of sediment total phosphorus with depth (linear slope); model equation and model R^2 for the 9 lakes analyzed. * = *p< 0.05*, n.s. = *p> 0.05*

	TP_{water} µgP/L	Model	Linear Slope (β_1)	Best fit equation	R^2
L. Pueyrredón	2	Linear	13.63	Y = 13.63***Z**+639.2	0.63*
L. Argentino	3	Linear	5.81	Y = 5.807***Z**+6.525	0.73*
L. Buenos Aires	9	Linear	21.4	Y = 21.4***Z**+9.227	0.78*
L. Lácar	9	Exponential	-10.81	$Y = 1085 * e^{-0.01Z}$	0.69*
R. Nihuil	23	Exponential	-0.001	$Y = 1178 * e^{-0.001Z}$	n.s.
R. Nihuil		Lineal	-9.38	Y = -9,386***Z** + 1186	n.s.
L. Cari-Laufquen Chica	191	Exponential	-14.71	$Y = 1053 * e^{-0.01Z}$	0.49*
L. Ñe-luan	200	Exponential	-10.38	$Y = 1025 * e^{-0.01Z}$	0.15
L. Cardiel	341	Exponential	-12.87	$Y = 797.8 * e^{-0.01Z}$	0.35*
L. Caviahue	370	Linear	133.3	Y = 133.3***Z**+130.5	0.92*

according to their trophic state along to factor 2, and according to pH through factor 1 (Fig. 3A). The variables (Fig. 3B) that contributed to the formation of the factors were: pH, TP, Al_2O_3 and TiO_2. By analyzing the relationships between variables (Fig. 3B), we found that the pH is positively related with Fe_2O_3 and negatively with SiO_2, TP and MgO. Eutrophic lakes (lakes Cardiel, Cari-Laufquen and Lácar) showed higher Fe_2O_3 content, high pH and low SiO_2, TP and MgO (Fig. 6). In this analysis, Lake Ñe-Luan (also eutrophic) was not well represented in the plane. On the other hand, oligotrophic environments (lakes Pueyrredón, Argentino and Buenos Aires) showed high Al_2O_3 content and low CaO content (Fig. 3). Lake Caviahue was separated from the rest of the environments in the plan and was characterized by high concentrations of SiO_2, TP, MgO and low Fe_2O_3 and pH. Reservoir Nihuil showed high values of CaO and lower Al_2O_3 (Fig. 3).

Table 4 shows the results from the P fractioning made to cores and grouped in relation with trophic classification (now defined considering the P distribution pattern in sediment). In oligotrophic environments (lakes Buenos Aires, Pueyrredón, Argentino and Caviahue), the main fraction was bound to organic matter (P-MO), followed by the fraction bound to compounds of Ca (P-Ca). P fraction bound to Al and Fe oxy-hydroxides (P-Al/Fe) was the third fraction in importance, whereas the P-labile fraction was very low. By contrast, in eutrophic environments (lakes Cardiel, Cari-Laufquen, Ñe-Luan, Lácar and Reservoir Nihuil), the main P fraction was associated with Ca compounds, followed by the fraction linked to organic matter. As noted for the oligotrophic environments, the P fraction bound to Al and Fe oxy-hydroxides was the third fraction in importance while labile fraction was low. We observed a distribution pattern of P-labile fraction with depth in the cores analyzed and the trophic state thereof. The oligotrophic environments showed increased labile P concentration with depth (Table 5) and were fitted to a linear model, exhibiting a positive slope (β_1 = 0.804, R^2 = 0.92). On the other hand, the eutrophic environments showed a decrease in the P-labile concentration with depth (Table 5), conforming to an exponential model and showing negative slopes (β_1 = -0.08; R^2 = 0.59). Similarly, we observed the same pattern of depth distribution of the P fraction associated to Al and Fe oxy-hydroxides (P-Al/Fe) and the environment trophic state (Table 5): fitting oligotrophic environments to a linear model (β_1 = 9.38, R^2 = 0.50, $p > 0.05$) and eutrophic environments to an exponential model (β_1 = -0.04, R^2 = 0.85). The other two fractions (P-Ca and P-MO) did not fit any model used. While the P extraction method used in our work cannot differentiate between the P bound to Al from the P fraction bound to Fe, the results of the chemical composition of sediment indicate that the Al content (estimated from those Al oxides) was between 4.7 and 5.4 times higher than Fe content in all environments and all layers. Furthermore, the results of the P fractioning in the sediments of each environment studied indicate that oligotrophic lakes showed, on average, higher concentrations of P-Fe/Al fraction (111 µgP/g d.w.) than those in the eutrophic environments (81.3 µgP/g d.w.). Also, considering the associations observed in the multivariate analyzes, we can see that oligotrophic lakes were characterized by higher concentrations of Al_2O_3 (21%) than those in eutrophic lakes (17%). Likewise, we found a positive linear relationship between the P-Al/Fe concentrations with depth in sediments in oligotrophic environments