Research Article

Regime shifts of Cruces River wetland ecosystem: current conditions, future uncertainties

Víctor H. Marín[1], Luisa E. Delgado[1, 2], Irma Vila[3], Antonio Tironi[2]
Vilma Barrera[3] & Carlos Ibáñez[1]

[1]Laboratorio de Modelación Ecológica, Departamento. Ciencias Ecológicas, Facultad de Ciencias
Universidad de Chile, P.O. Box 653, Santiago, Chile
[2]Fundación Centro Transdisciplinario de Estudios FES-Sistémicos
Av. Suecia 84, Depto. 93, Santiago, Chile
[3]Laboratorio de Limnología, Departamento Ciencias Ecológicas, Facultad de Ciencias
Universidad de Chile, P.O. Box 653, Santiago, Chile

ABSTRACT. During April-May 2004 the Cruces River wetland ecosystem, located in Valdivia (40ºS), southern Chile, was described as shifting from a clear water regime, dominated by the exotic macrophyte *Egeria densa*, to turbid waters and absence of submerged macrophytes. We analyzed the trophic status and ecological regime of the wetland from November 2011 through January 2013. The trophic status was determined comparing values of selected variables (nutrients, chlorophyll-*a* and transparency) with OECD criteria. The ecological regime was determined comparing the same variables with the criteria proposed by Ibelings *et al.* (2007). We further compared the concentration of nutrients and suspended solids with previous measurements. Current trophic status of the wetland is between eutrophic and hypereutrophic, as shown by results, and its ecological regime intermediate, between clear and turbid waters, with a considerable risk of returning to turbid waters. In this article we discuss the potential relationship between the watershed land use (agriculture, cattle feeding and forestry), the change in wetland's trophic level and future conditions.

Keywords: regime shift, macrophytes, nutrients, eutrophication, wetland, ecosystem, southern Chile.

Cambios de régimen en el ecosistema del humedal del río Cruces: condiciones actuales, incertezas futuras

RESUMEN. Durante abril-mayo 2004 el ecosistema del humedal del río Cruces, localizado en Valdivia (40ºS), en el sur de Chile, fue descrito como cambiando de un régimen de aguas claras, dominado por la macrófita introducida *Egeria densa*, a aguas turbias con ausencia de macrófitas. En este artículo se analiza el estado trófico y el régimen ecológico del humedal entre noviembre 2011 y enero 2013. El estado trófico se determinó comparando los valores de variables seleccionadas (nutrientes, clorofila-*a* y transparencia) con los criterios de la OECD. El régimen ecológico se determinó comparando las mismas variables con los criterios propuestos por Ibelings *et al.* (2007). Asimismo, se comparó la concentración de nutrientes y de sólidos en suspensión con mediciones previas. Los resultados muestran que el estado trófico actual del humedal es entre eutrófico e hipereutrófico, y su régimen ecológico intermedio, entre aguas claras y turbias, con un considerable riesgo de retornar a aguas turbias. Además se discute la posible relación entre el uso del suelo de la cuenca (agricultura, alimentación de ganado y silvicultura), el cambio en el nivel trófico del humedal y su condición futura.

Palabras clave: cambio de régimen, macrófitas, nutrientes, eutrofización, humedal, ecosistema, sur de Chile.

Corresponding author: Víctor H. Marín (vmarin@antar.uchile.cl)

INTRODUCTION

Ecological regime shifts are sudden changes in the structure, function and dynamics of an ecosystem (Scheffer *et al.*, 2012). Such changes occur when the ecosystem, affected by a perturbation or aging, surpasses a critical threshold -or tipping point- going from one domain of dynamic equilibrium to another.

Numerical models have shown that an equilibrium state will respond differently to changes in a given system variable depending on the shape of its stability domain, low or high resilience and the magnitude of the perturbation (Scheffer et al., 2009).

Although the concept had its origin in the analysis of coastal marine ecosystems (Isaacs, 1976; Jiao, 2009), the ecology of these abrupt non-linear changes has largely advanced through the study of shallow water (depth ≤3 m) continental ecosystems (Wetzel, 2001; Scheffer & Van Nes, 2007). Their fast responses to human-induced perturbations, such as eutrophication, have provided the bases for most of the theoretical constructs used today in this field of ecology (Scheffer & Carpenter, 2003; Scheffer & Van Nes, 2004).

One of the most studied regime shifts in shallow lakes is the abrupt transition from clear waters (dominated by aquatic macrophytes) to turbid waters (dominated by high phytoplankton biomass), especially related to the dynamics of macronutrients: nitrogen and phosphorus (Tironi, 2012). Although there are records of shallow water ecosystems shifting from clear to turbid waters and back (Hargeby et al., 2004), in many cases when an ecosystem shifts to the turbid condition it tends to remain in this regime (Jacoby et al., 2001; Van Geest et al., 2007).

Several processes facilitate the maintenance of and trigger the shift from each regime (Fig. 1). The turbid water regime is maintained mainly by the resuspension of solids, mediated by wind, hydrodynamics, benthivorous fish and high abundance of phytoplankton. On the other hand, the clear water regime is maintained by submerged macrophytes coverage above 50%, inhibiting sediment resuspension, top down control on phytoplankton by zooplankton and indirectly by piscivorous fishes (Scheffer, 2004; Brönmark et al., 2010).

Although there can be many triggers, the most documented mechanism for the shift from clear to turbid waters is the development of a phytoplankton bloom induced by eutrophication (Marín et al., 2009). This proliferation in phytoplankton biomass increases light attenuation killing submerged macrophytes by shadowing. This, in turn, starts a reinforcing loop, or positive feedback, increasing turbidity. That is, macrophyte-free areas are more susceptible to solids resuspension by wind or other drivers, further increasing turbidity. Other triggers with the same effect (i.e., decrease of macrophytes coverage) are storms, drawdown and climatic anomalies (Blindow, 1992; Hagerby et al., 2004; Beklioglu et al., 2006; Marín et al., 2009). Thus, the concentration of macronutrients, suspended solids and chlorophyll-a, plus water transparency, are key to understanding shallow water ecosystem regime shifts and macrophytes ecology (Barko & James, 1998; Faafeng & Mjelde, 1998; Jeppesen et al., 1998). Most of these variables have been used as criteria to define the trophic status of lakes and wetlands (Galvez-Cloutier & Sanchez, 2007) and to characterize each ecosystem regime (Ibelings et al., 2007).

The Cruces River wetland is a shallow water (<3 m) continental ecosystem, with a river (average depth between 4-6 m) that runs through it, located in the coastal zone of Valdivia (ca. 40ºS), southern Chile (Fig. 2). This ecosystem is also a wetland of international importance, under the Ramsar Convention, due to its water bird diversity (Ramsar, 2013). During 2004 it experienced a regime shift from clear waters (dominated by the exotic macrophyte *Egeria densa* Planchon) to turbid waters, with an increased load of suspended solids (Hauenstein, 2004; UACH, 2005; Lopetegui et al., 2007; Lagos et al., 2008; Marín et al., 2009). Although there were different hypotheses about what triggered the shift (Marín & Delgado, 2013), its characterization was non-controversial: (1) macrophytes coverage, mostly *E. densa*, disappeared between April-May 2004, (2) subsequently the Black-necked swan (*Cygnus melancoryphus*) breeding population, *E. densa* consumers, decreased from a total of 5000 ind to 289 mostly by emigration (Lopetegui et al., 2007).

The shift in this wetland ecosystem generated several societal responses and scientific debates (Delgado et al., 2009). However, in spite of that, there have been no scientific articles about changes in the ecological conditions of the ecosystem after 2004. Recently, Delgado & Marín (2013) have proposed, by means of an interannual analysis of satellite images, that swan habitat (i.e., rushes and macrophytes) has recovered since 2011. In this article we describe current (2011/2013) ecological conditions of the wetland, compare them with information from previous years and discuss the potential effects of watershed's productive activities.

MATERIALS AND METHODS

Analysis of Cruces River wetland ecosystem, from November 2011 through January 2013

We measured macronutrients (total phosphorus and total nitrogen), chlorophyll-a, suspended solids and water transparency in four stations, duplicate water samples, within Cruces River wetland (D1-4, D2-1, D2-4 and D3-1; Fig. 2) during November 2011, January, May, October and December 2012 and January 2013, plus three stations on tributaries to the wetland (Cruces River, D3-2; Pichoy River, D2-3 and
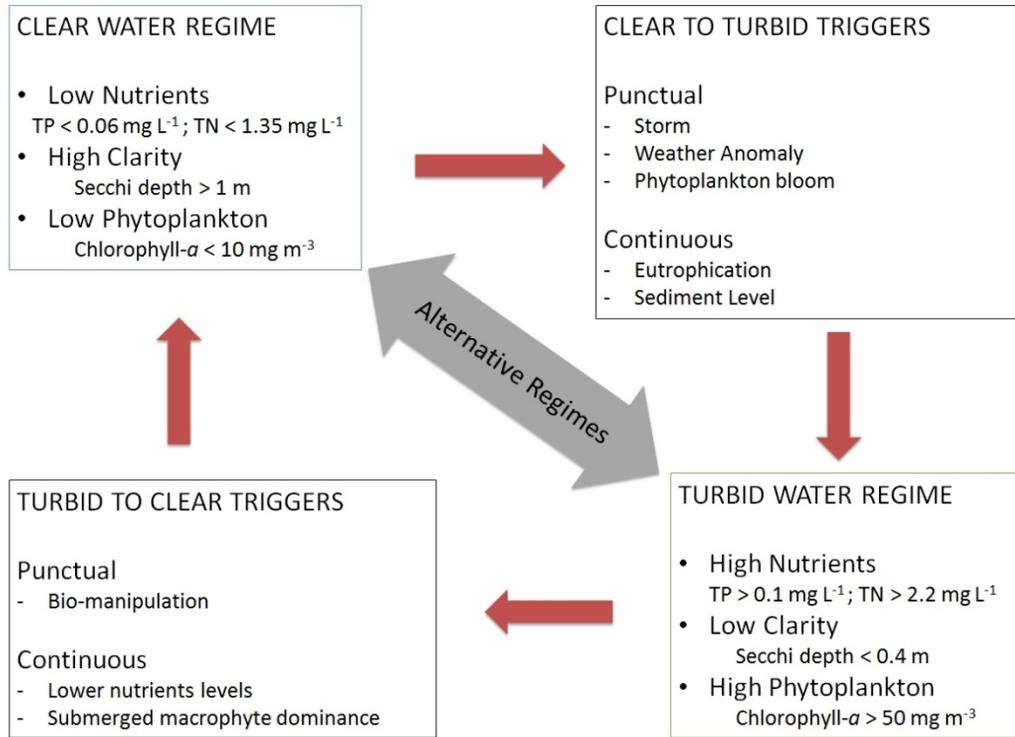
Figure 1. Simplified conceptual model of regime shifts in shallow lakes. Triggers and threshold values were taken from the literature. TP: total phosphorus, TN: total nitrogen. (modified from Tironi, 2012).
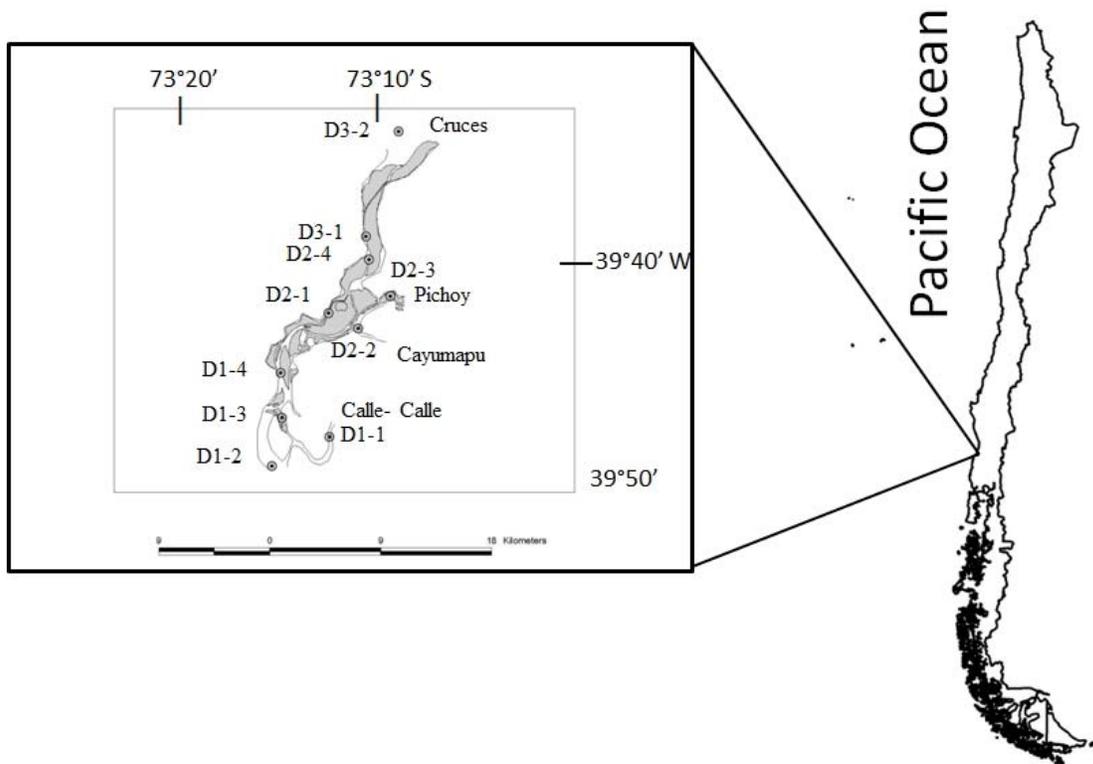
Figure 2. Geographic location of sampling stations in the Cruces River wetland, Carlos Anwandter Sanctuary (shaded area). Cruces, Pichoy and Cayumapu are the main rivers flowing into the wetland. Data from stations D1-4, D2-1, D2-4 and D3-1 were averaged to generate the graphs in Figures 3 through 5. Station D3-2 is located in the Cruces River near Fuerte San Luis del Alba.

Río Cayumapu, D2-2) and one station at Calle-Calle River (D1-1).

Total nitrogen and phosphorus were determined according to APHA methods (APHA, 2005). Total nitrogen was determined using a variation of the Kjeldahl method, where nitrogen is transformed into ammonium, which is then measured by colorimetry (Mülhauser *et al.*, 1987). Although we also determined all forms of inorganic nitrogen (nitrite, nitrate and ammonia) they all fell below detection or quantification levels. Similar results were obtained with orthophosphate.

Turbidity and chlorophyll-*a* were measured *in situ* using two sensor systems: an Aanderaa Seaguard ® RCM SW and an YSI 600 sonde. The RCM SW system was used to estimate turbidity by means of a sensor, calibrated by Aanderaa, which delivers data as Formazine Turbidity Units (FTU). However, macrophytes literature (*e.g.*, Yarrow *et al.*, 2009) analyzes turbidity in terms of suspended solids (SS). Consequently, during November 2011 we collected samples (n = 13) to determine total suspended solids in order to calibrate the turbidity sensor of the Aanderaa RCM SW sensor system. Suspended solid concentrations were measured using a gravimetric technique according to APHA methods (APHA, 2005). We then generated a calibration equation by means of linear regression, to transform FTU into SS (SS = 1.04 x FTU – 0.667; r^2 = 0.93). Subsequently, we measured turbidity using the RCM SW sonde and calculated suspended solid's concentration, in mg L^{-1}, using the calibration equation. The YSI sonde was used to measure *in situ* chlorophyll-*a* concentration. We calibrated sonde chlorophyll values by means of spectrophotometry.

Wetland trophic status was assessed using the criteria (mean values) from the Organization for Economic Co-operation and Development (OECD), for total phosphorus, chlorophyll-*a* and transparency (Secchi disk depth). In the case of total nitrogen, not included within OECD values, we used Nürnberg criteria (Galvez-Cloutier & Sanchez, 2007). Values for each trophic status are provided in Table 1. In addition, we classified the wetland ecosystem regime (Table 2) using the values proposed by Ibelings *et al.* (2007).

Interannual comparisons

The most recent document with ecological information from the wetland, prior to our sampling, is the report on bird mortalities during 2004-2005 which contains limnological data collected during November-December 2004 and January 2005 (UACH, 2005). Another source of data is the monthly water quality

monitoring by the forestry company Celulosa Arauco y Constitución (CELCO). This monitoring includes a sampling station located near Fuerte San Luis del Alba (station 3 at UACH, 2005) that corresponds to our most upstream station (D3-2; Fig. 2). We requested this data from the Chilean Environmental Evaluation Service (http://www.sea.gob.cl) using the mechanisms available in the Chilean Transparency Law. The data corresponded to a time series between April 2004 and December 2012, with some information from previous years (June 1995-February 1996, September 2002 and 2003). CELCO's monitoring data analysis and determinations for variables included in our analysis (total phosphorus, total nitrogen, and suspended solids) follows the same protocols used in our sampling (see above). A comparison between the data included in UACH (2005) report and those of CELCO monitoring showed similar values for common months (*e.g.*, summer 2004/2005). Furthermore, a comparison between data from station D3-2 and CELCO's monitoring for the same months showed no significant differences for total phosphorus and suspended solids (Table 3). Although total nitrogen measured in CELCO's monitoring was lower than our measurements, they nevertheless were within the same order of magnitude. Thus, we used CELCO's data to analyze changes in the main tributary to the wetland ecosystem for the period 2004-2012. We analyzed trends in the data through time series analysis, fitting 3-month running averages to the three variables. Since the analysis of CELCO's data corresponded to only one station upstream, we also used data included in UACH (2005) in order to compare other locations within the wetland. However, in the latter case, comparisons were only between January-2005 (UACH data) and January 2012 and 2013 (our results) for two locations: Cabo Blanco (station D1-4; Fig. 2) and Santa María (station D2-4; Fig. 2).

RESULTS

All analyzed variables showed seasonal changes (Figs. 3-5). Chlorophyll-*a* concentrations were highest (18-20 µg L^{-1}) during summer months within the wetland, while values for winter and early spring in the wetland and in Pichoy and Cayumapu tributaries decreased below 8 µg L^{-1}. Cruces and Calle-Calle rivers chlorophyll-*a* remained below 2 µg L^{-1}, during the whole sampling period (Fig. 3a). Transparency was lower (below 1.2 m) at the Pichoy tributary during the whole period followed by Cayumapu and the wetland, while the highest transparencies were found in the Calle-Calle during January 2013 (Fig. 3b). Total phosphorus, (Fig. 4a), total nitrogen, (Fig. 4b) and suspended

Table 1. Criteria for trophic status classification of lakes. Values for all variables, with the exception of total nitrogen, correspond to the OECD criteria. Total nitrogen corresponds to the Nurnberg criteria (Galvez-Cloutier & Sanchez, 2007).

Trophic status	Total phosphorus (μg L^{-1})	Chlorophyll-a (μg L^{-1})	Transparency (m)	Total nitrogen (μg L^{-1})
Ultra-oligotrophic	<4	<1	>12.0	---
Oligotrophic	<10	<2.5	>6.0	<350
Mesotrophic	10-35	2.5-8.0	6.0-3.0	350-650
Eutrophic	35-100	8.0-25 .0	3.0-1.5	650-1200
Hypereutrophic	>100	>25.0	<1.5	>1200

[a]Secchi disk depth

Table 2. Criteria for ecosystem regimes of shallow lakes based on Lake Veluwe (Source: Ibelings *et al.,* 2007).

Regime	Total phosphorus (μg L^{-1})	Chlorophyll-a (μg L^{-1})	Transparency (m)	Total nitrogen (μg L^{-1})
Turbid	>100	>50	<0.4	>2200
Intermediate	100-60	50-10	0.4-1.0	2200-1350
Clear	<60	<10	>1.0	<1350

Table 3. Results of comparing values for total phosphorus, total nitrogen and suspended solids (all units in mg L^{-1}) from samples collected at station D3-2 (see Fig. 2 for location) and data from CELCO's monthly monitoring at the same location. Only samples from common months were included (Nov. 2011; Jan., May, Oct., and Dec. 2012).

Variable	D3-2 average	CELCO average	P (two-tailed t-test, n = 5)
Total phosphorus	0.03	0.03	0.94
Total nitrogen	0.55	0.27	0.01
Suspended solids	6.13	1.98	0.06

solids (Fig. 5) showed similar trends in the wetland and in Pichoy and Cayumapu tributaries, with higher values during the summer season. The analysis of wetland data showed significant (n = 6, r^2 ≥ 0.84, P < 0.05) linear relationships between suspended solids and both nutrients. Cruces and Calle-Calle, on the other hand, showed different patterns for the three variables. Phosphorus and suspended solids tended to increase during winter in the Calle-Calle, while nitrogen had its highest value (577 μg L^{-1}) during January 2013. Both nutrients showed their highest values during January 2012 for Cruces, decreasing during the rest of the period (Fig. 4), while the largest concentration of suspended solids (18 mg L^{-1}) was found during May 2012 (Fig. 5).

The analysis of limnological variables (Figs. 3, 4) in relation to trophic status (Table 1) and regime classification criteria (Table 2) showed that sampling stations could be clustered in two groups: (1) one corresponding to wetland + Cayumapu and Pichoy tributaries and (2) a second corresponding to Cruces and Calle-Calle. Detailed results are graphically shown for each variable on Figures 3 and 4, and a summary in Table 4. Trophic status changed with season, being higher during summer and lower during winter. The first group was eutrophic to hypereutrophic during summer and mesotrophic to eutrophic during winter, while the second group was mesotrophic to eutrophic in summer and oligotrophic to mesotrophic in winter. Regarding the ecosystem regime, the first group showed characteristics of intermediate water in summer, except for nitrogen that fell in the clear water regime and clear water during winter. The second group showed characteristics of clear water in both seasons.

Previous studies conducted in the wetland, in relation to the regime shift from clear to turbid waters during the year 2004 (*e.g.*, Lagos *et al.*, 2008; Marín *et al.*, 2009), emphasized the relationship between macrophytes coverage (mostly *E. densa*) and suspended solids. Thus, we used information contained in the article by Tanner *et al.* (1993), relating *E. densa* growth rate to suspended solid's concentration, and analyzed if current wetland conditions would affect its growth rate. Results showed that suspended solid concentrations found at Pichoy tributary, and only during
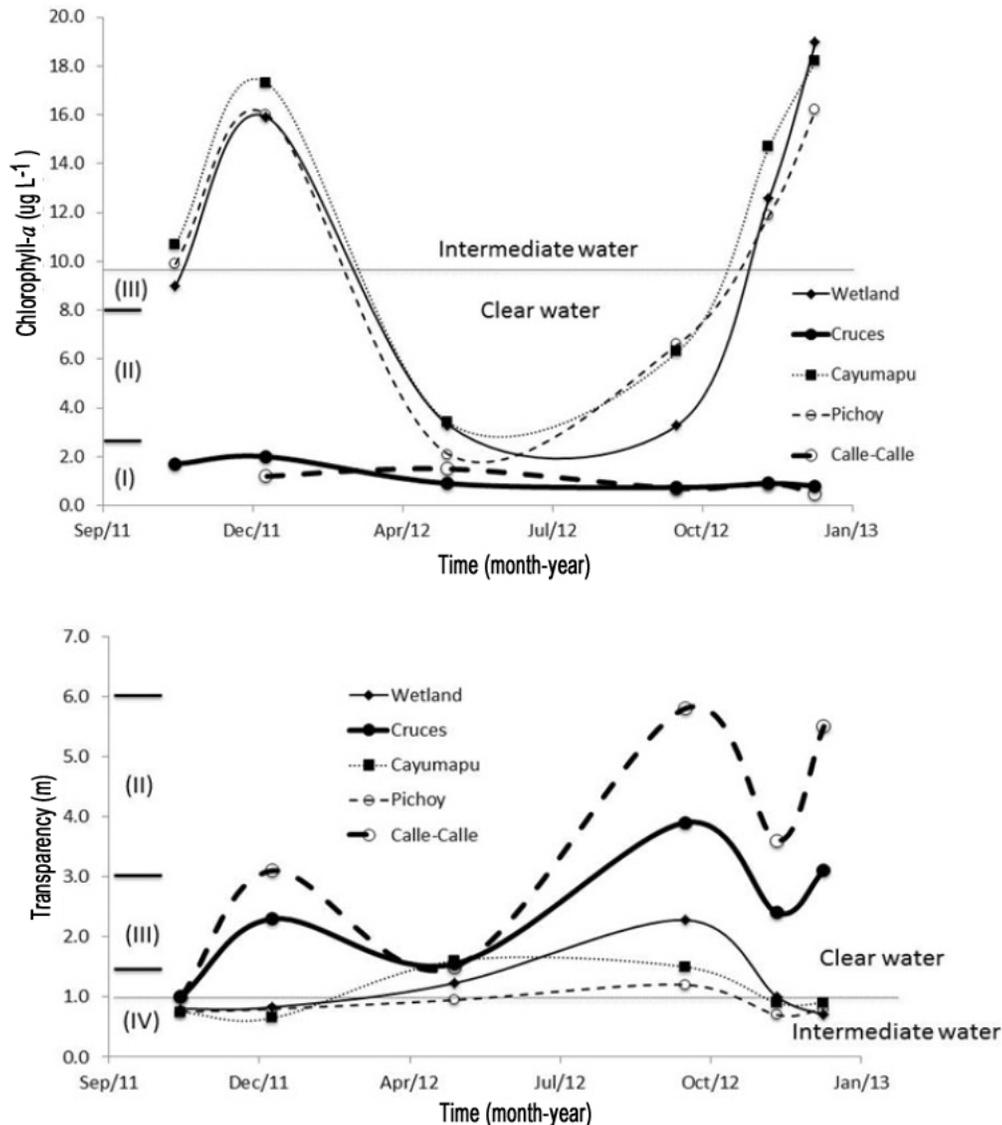
Figure 3. Seasonal changes in chlorophyll-*a* and water transparency during the period November 2011-January 2013 in Cruces River ecosystem. See Methods for station's information and Figure 2 for spatial distribution. The small horizontal lines on the y-axis and Roman numerals correspond to the values separating the different trophic categories (Table 2). I: oligotrophic, II: mesotrophic, III: eutrophic and IV: hypereutrophic. The horizontal dotted line separates clear and intermediate water regimes according to values from Table 3.

January 2013, could affect the growth rate of *E. densa* (Fig. 5). Concentrations for other stations and seasons would support growth of this macrophyte at 50% of its maximum rate (see Fig. 1 at Tanners *et al.*, 1993).

Interannual comparisons were conducted on three variables: total phosphorus and nitrogen and suspended solids (Fig. 6, Table 5). The time series at Fuerte San Luis (Cruces River) showed an increase in nutrients from 1995-1996 (average values: 0.009 mg P L^{-1}, 0.11 mg N L^{-1}) to 2003-2012 (average values: 0.033 mg P L^{-1}, 0.31 mg N L^{-1}), but no long-term

trend in suspended solids (average values: 5.8 mg L^{-1} during 1995-1996 and 5.5 mg L^{-1} during 2003-2012). There was no significant correlation among the three variables. After January 2004 total phosphorus showed its highest value (0.11 mg L^{-1}) during May 2008 and a decreasing trend after July 2010 (Fig. 6a). Total nitrogen showed a peak in April 2004 followed by smaller oscillations without an interannual trend (Fig. 6b). Suspended solids showed high values during June-July, winter, 2005, 2009 and 2010 with lower values for the winter of 2011 and 2012. The running
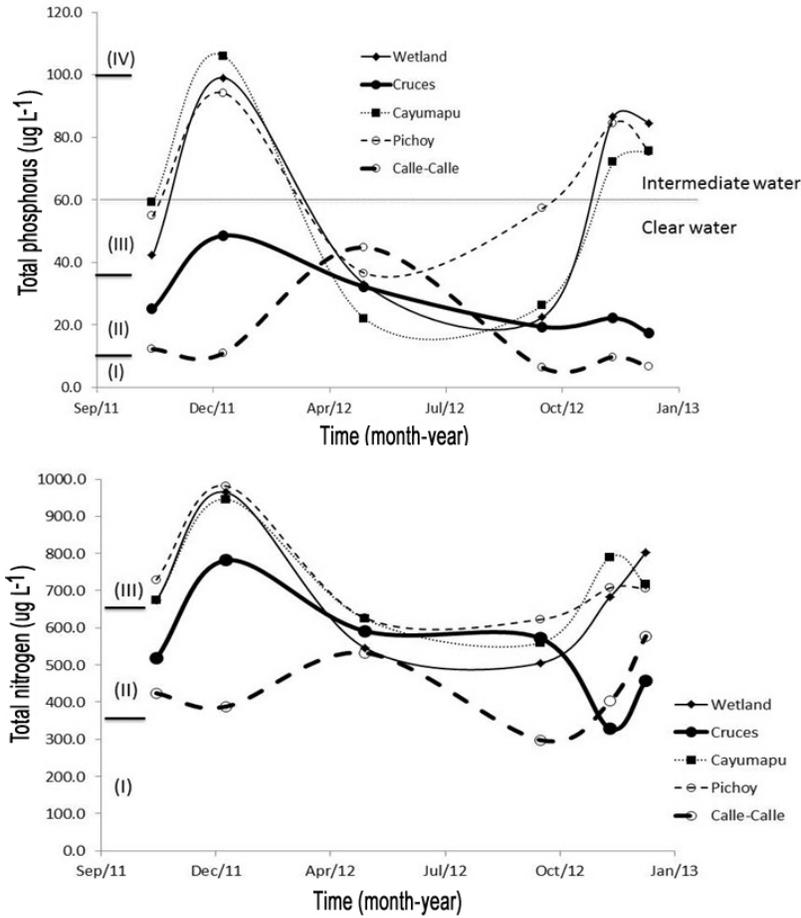
Figure 4. Seasonal changes in total phosphorus and total nitrogen during the period November 2011-January 2013 at Cruces River ecosystem. See Figure 3 legend for further details.
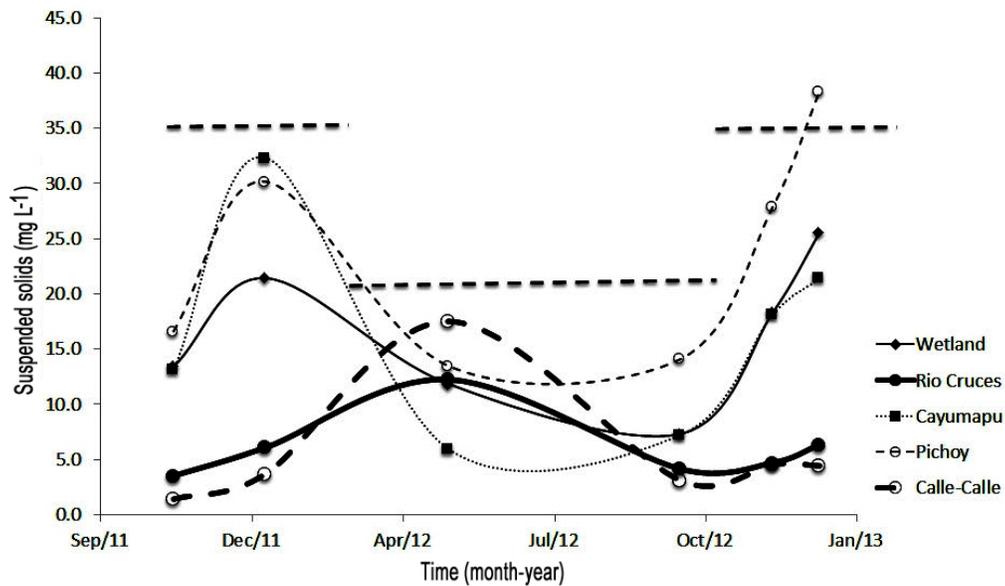
Figure 5. Seasonal changes in suspended solids (SS) during the period November 2011-January 2013 at Cruces River ecosystem. The horizontal lines correspond to suspended solid's value equal to 50% of the maximum growth rate for *Egeria densa* according to the data from Tanner *et al.* (1993). Higher SS values inhibit the growth of *E. densa*.

Table 4. Trophic status and ecosystem regime classification of sampling stations (see Results and Figs. 3 and 4 for details).

Criteria	Sampling period	Wetland, Pichoy and Cayumapu	Cruces and Calle-Calle rivers
Trophic status	Winter	Mesotrophic-eutrophic	Oligotrophic-mesotrophic
	Summer	Eutrophic-hypereutrophic	Mesotrophic-eutrophic
Ecosystem regime	Winter	Clear	Clear
	Summer	Intermediate; clear for Nitrogen	Clear
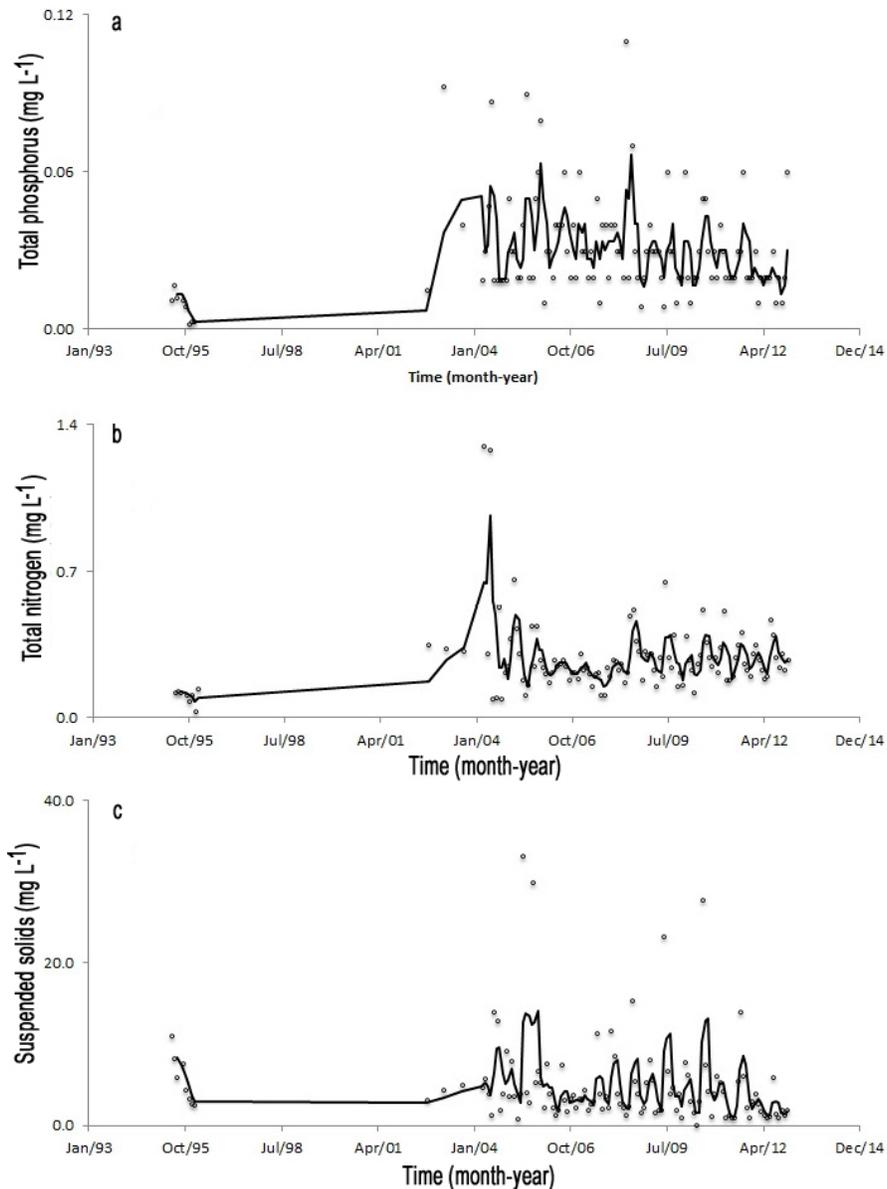
Figure 6. Time series for total phosphorus a) total nitrogen b) and suspended solids c) at Fuerte San Luis del Alba, Cruces River, from 1995 through 2012. The spatial location corresponds to our station D3-2 (See Fig. 2). Solid lines represent 3-month running averages.

average also displayed a decreasing trend after July 2010.

Finally, the comparison of values for January 2005 (UACH, 2005) and 2012 and 2013 (this article) within

Table 5. Comparison of January values for two wetland stations: D1-4 (Cabo Blanco on UACH, 2005) and D2-4 (Santa María on UACH, 2005). All numbers in mg L^{-1}.

Station-Year	Suspended solids	Total phosphorus	Total nitrogen
D1-4/Jan. 2005	24.5	0.06	0.15
D1-4/Jan. 2012	4.8	0.07	0.76
D1-4/Jan. 2013	22.3	0.08	0.85
D2-4/Jan. 2005	14.6	0.05	0.16
D2-4/Jan. 2012	31.6	0.08	0.94
D2-4/Jan. 2013	27.3	0.07	0.72

the wetland showed a small increase in suspended solids (average change = +1.95 mg L^{-1}) and total phosphorus (average change = +0.02 mg L^{-1}) and a marked increase in total nitrogen (average change = +0.66 mg L^{-1}). Furthermore, an analysis of the difference in the concentration of inorganic forms of phosphorus (orthophosphate) and nitrogen (nitrate and ammonium) between January 2005 (Table 68, page 219; UACH, 2005) and the data collected during 2012-2013 (all forms below detection levels; see Methods) revealed a decrease near one order of magnitude despite the increase in total nutrients.

DISCUSSION

The results described in this article support the hypothesis that during the year 2011 Cruces River wetland ecosystem started changing from a turbid state to clear water conditions. We have shown that current chlorophyll-*a*, total phosphorus and nitrogen concentrations plus water transparency measured by a Secchi disk, correspond to Ibelings *et al.* (2007) intermediate regime during summer and clear waters in winter for stations located within the wetland and Pichoy and Cayumapu tributaries (Figs. 3, 4).

Van Donck *et al.* (1993), studying a small lake in The Netherlands, have shown that as macrophytes coverage increases, the concentration of ammonium and nitrate in the lake decreases below detection levels. Our results indeed show that although total nitrogen and phosphorus are found in concentrations comparable to eutrophic and hypereutrophic conditions (Tables 1 and 3), ammonium, nitrite, nitrate and orthophosphate were below detection levels. These results are consistent with an increase in macrophytes dominance within the wetland (Delgado & Marín, 2013), as compared with the conditions during January 2005 (UACH, 2005).

However, intermediate ecosystem regimes may either last for extended periods (Scheffer & Van Nes, 2007; Van Geest *et al.*, 2007), quickly change to a classic regime (either clear or turbid) or show a cycling behavior (Van Nes *et al.*, 2007). The dynamics of these transitions are complex, from the standpoint of the potentially large number of variables involved. That is one of the reasons to propose that this field of research requires a whole suite of tools, including models, experiments, long-term sampling and management programs (Marín *et al.*, 2009; Briske *et al.*, 2010). Still, although based on a sampling program in our case, some trends are emerging.

The analysis of our data suggests that there is a considerable risk of a shift back to a turbid state. The current trophic status of the wetland is between eutrophic and hypereutrophic. Experimental studies conducted in lakes from Spain have shown that while dense macrophytes beds significantly increase water clarity, at high total phosphorus levels (>0.25 mg L^{-1}) submerged plants did not prevent deterioration in water transparency in some shallow lakes (Beklioglu *et al.*, 2007). During January 2012 we already found a total phosphorus level of 0.18 mg L^{-1} in one wetland station (D2-1, Fig. 2); thus, any further nutrient increase could in fact generate a shift back to a turbid regime within the wetland.

Agriculture and cattle feeding (prairies) are among the most commonly identified stressors causing changes in aquatic ecosystems, especially due to the input of excess nutrients that drive systems to eutrophication, shifting them to a turbid regime (Ongley, 1996; Ludovisi & Poletti, 2003; Galvez-Cloutier & Sanchez, 2007; Ibelings *et al.*, 2007; Figueroa *et al.*, 2009; Davis *et al.*, 2010). Land use within Cruces River wetland watershed (CONAF, 2012), is clearly dominated by cattle feeding prairies and forestry, adding up to 57.9% of the watershed surface. Furthermore, these activities are benefited from governmental programs oriented to the recovery of degraded soils, which include fertilization initiatives (MINAGRI, 2005). In fact, fertilization is the second largest program nationwide and between 1996 and 2005 the political region where Cruces River wetland is located corresponded to the largest surface

area for the entire program. This prairie-forestry land use dominance of the watershed provides a partial explanation for the current trophic status of the wetland and the increase in nutrient concentrations at Cruces River between 1995 and 2004 (Fig. 6). However, the input of excess nutrients from the watershed may not be the only mechanism explaining wetland eutrophication. We also found nutrient concentrations positively correlated with suspended solids. It is likely, considering that such a relationship occurred only inside the wetland and not in the tributaries, that the increment in suspended solids is due to local, wind induced, mixing. In this regard, it is important to note that the orientation of the main geographic axis of the wetland is SW (Fig. 2) and that the climatology of the area, as deduced from Internet records available from the Chilean Meteorological Directorate (http://www.meteochile.gob.cl), shows that during spring-summer dominant strong winds come from South and Southwest directions. Thus, periods of high wind intensity could mix the water column re-suspending sediments from the bottom especially in shallow areas with low macrophytes coverage. Such a mechanism has in fact been analyzed for other ecological systems (Madsen *et al.*, 2001). Both mechanisms, nutrient input from adjacent areas (long-term effect) and local re-suspension of sediments (short-term effect), could further increase nutrient levels within the wetland.

Additionally, although suspended solid concentrations are below level that could inhibit the growth of *E. densa* (<40 mg L^{-1}), its growth rate should show decreases up to 50% during the spring and summer seasons in areas with suspended solid concentrations above 15 mg L^{-1} (Tanner *et al.*, 1993). This evidence support qualitative observations during fieldwork showing that currently *E. densa* does not dominate the wetland and that it seems to have been replaced by *Potamogeton* spp., a macrophyte genus more resistant to turbid conditions (Carpenter *et al.*, 1998; Tironi, 2012). This could be another case where ecosystem stability is determined by the dominant primary producer (Sasaki & Lauenroth, 2011).

Nonlinear changes, thresholds and regime shifts are all concepts currently used to describe the dynamics of ecological systems (Briske *et al.*, 2010; Davis *et al.*, 2010; Dodds *et al.*, 2010). Furthermore, as noted by Ibelings *et al.* (2007) and by Schmitz (2010), ecosystem behavior is largely unpredictable. Thus, we should improve our knowledge about them, accepting that full control is highly unlikely and that abrupt changes may indeed be the rule rather than the exception. Our research shows that Cruces River wetland has shifted from clear to turbid and then to an intermediate regime, during a period of eight to twelve years. We do not know what or when the next shift will be. However, results strongly suggest that macronutrients, suspended solids, chlorophyll-*a* and water transparency should be monitored closely in order to understand the fluctuations within this ecosystem. Still, if the trophic status and ecological regime of wetland ecosystems such as Cruces River are matters of public concern, there is an urgent need to generate integrated watershed management plans including agriculture, prairies, forestry, domestic sewages and other anthropogenic activities. We conclude by proposing that integrated watershed management provides the framework necessary to deal with problems such as wetland eutrophication and its control without negatively affecting productive activities within watersheds.

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