Conchalí Lagoon: Coastal Wetland Restoration Project (Chile)

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Abstract

Conchali Lagoon is a coastal wetland located at the northern part of Chile (31° 52.757° S; 71° 29.769° W). This ecosystem is hydrologically dynamic since its catchment receives contributions of water and salt from both rivers and the sea. During periods of high recharge, the lagoon connects to the sea across a sand barrier and waters enter into a euryhaline condition. This contrasts with a mainly freshwater lagoon, disconnected from the sea, during low recharge periods. This hydrodynamic connection/disconnection process generates inter and intra-annual patterns in the aquatic flora and fauna, such as the dominance of aquatic plants and marine algae during periods of low and high salinity, respectively. In 1998 several management actions were implemented in order to improve its ecological status, mainly for controlling local threats. Comparative studies have shown that the area has significantly improved its ecological indicators, including a progressive

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increase in the number of bird species. From a management perspective, the plan implemented to control local threats was successful. However, new threats at a cathment and global scale are affecting the lagoon and they have implications to the maintenance of the lagoon's ecological character. Therefore, for the conservation of this Ramsar Site, the local management actions are by themselves insufficient and measures must be undertaken to develop a new plan for the sustainable use of water resources at a catchment scale.

Keywords
Wetland · Coastal Lagoon · Biodiversity · Watershed water balance · Eutrophication

Introduction

Conchalí Lagoon (Fig. 1, 31°52.757′ S; 71°29.769′ W) is located 4 km north of the town of Los Vilos Region of Coquimbo (Wetlands International 2004). This water body is hydrologically dynamic since its catchment receives contributions of water and salt from both rivers and the sea. During periods of high recharge, the lake connects to the sea across a sand barrier and waters enter into a euryhaline condition. This contrasts with a lagoon characterized by freshwater during low recharge conditions and disconnected from the sea. This hydrodynamic connection/disconnection process generates inter- and intra-annual patterns in the aquatic flora and fauna, such as the dominance of aquatic plants and marine algae during periods of low and high salinity, respectively. As the sand barrier opens, fish migrate from the

Fig. 1 Aerial view of Conchalí Lagoon (Photo Credit: © Centro de Ecología Aplicada, with permission)

sea toward the lagoon to feed. The lagoon is surrounded by a belt of riparian vegetation maintained by high groundwater levels generated by the presence of the lagoon, and which may be either reeds or halophyte plants depending on the salinity of the soil.

Like most coastal lagoons worldwide, Conchalí Lagoon has a high human population in its immediate surroundings using its resources and ecosystem services (see: Millennium Ecosystem Assessment 2005). During winter, local fisherman harvested the lagoon for food resources (mainly *Mugil cephalus* and *Odonthestes brevianalis*) even though Chilean law prohibits sport fishing on inland waters. Livestock were pastured year-round along the edges of the lagoon, feeding on the riparian vegetation. Hunters assisted by dogs caught birds and mammals which are fed and reproduced near the lagoon. The lagoon as a result of this human-related pressure existed in a poor ecological state, with a low species richness of terrestrial and aquatic flora and fauna.

In 1998, the mining company "Los Pelambres" bought the land where the lagoon is located and presented to the authorities the following management actions for the water body: (i) a fence around the lagoon; (ii) the creation of areas with restricted public access; (iii) implementation of an environmental education program; (iv) construction of paths; and (v) monitoring of the flora and fauna around the lagoon. In 2000 the lagoon was declared "Santuario de la Naturaleza," and in 2004 it was designated as a Ramsar Wetland of International Importance, due to the presence of eight species of conservation concern, three reproducing native fish species, 84 bird species, and a reproduction and feeding ground for migratory birds.

Studies comparing the period before the area was protected (between 1990 and 1992; Tabilo and Mondaca 2011), with those obtained after 1998 (Fig. 2) showing a progressive increase in the number of bird species. This indicates that the implementation of the management actions caused a positive change in biodiversity and ecological character, mostly due to the control of local threats and the recovery of riparian vegetation.

Biodiversity

On a regional scale, Conchalí Lagoon is recognized as the site with the highest number of bird species in the area. The 95 recorded species are divided among terrestrial (34), aquatic (20), riparian (31), and marine (9) species; 33 are described as permanent, 40 as frequent, 7 as rare, and 15 as occasional residents.

In the time series of avian abundance and richness, temporal changes can be observed with annual maxima abundance and richness occurring in autumn (March–April) and minima in summer (December–February; Fig. 3). In 2010, the lowest abundance was recorded (316 individuals), with an average richness of 37 species. However, in the last few years some aquatic species, e.g., *Fulica leucoptera*, *F. rufifrons*, *F. armillata*, *Anas platalea*, and *Egretta thula*, have

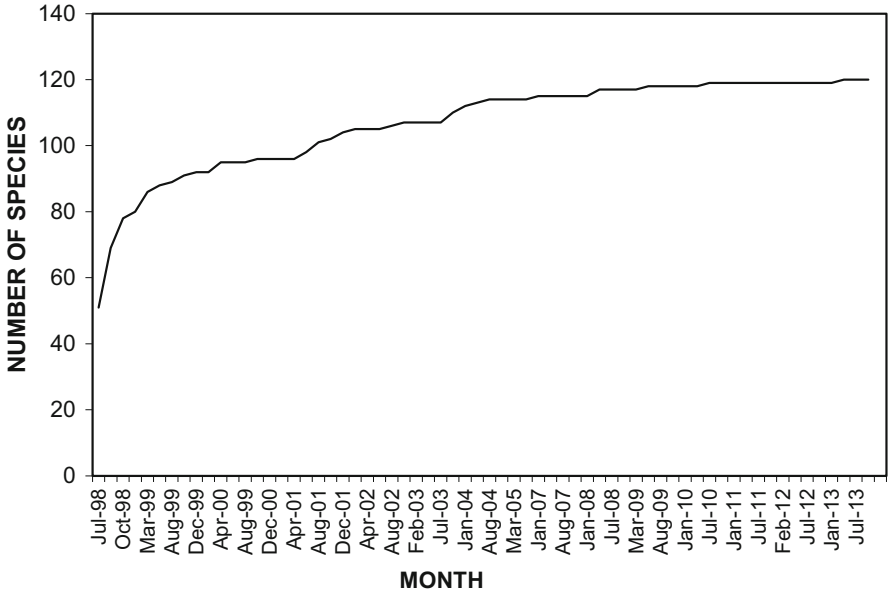

Fig. 2 Cumulative species richness curve of avifauna in Conchalí Lagoon (Data: © Centro de Ecología Aplicada, with permission)

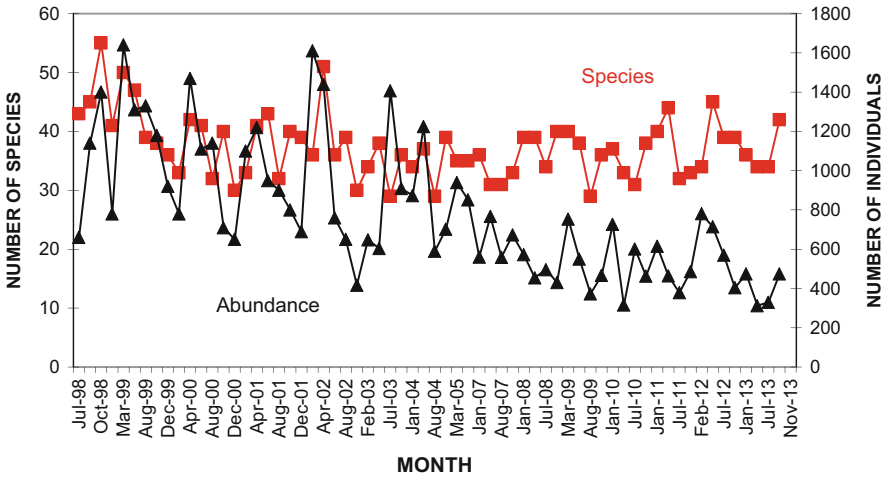

Fig. 3 Changes in the number of species and number of bird individuals observed during the period from July 1998 to November 2013 (Data: © Centro de Ecología Aplicada, with permission)

decreased in numbers. Comparing the data in two periods, before and after connection with the sea (year 2004), there was neither a significant change in the richness of birds ($F = 1.52$; $p = 0.22$) nor in the number of species (richness). However, there was a tendency of decreasing avian abundance ($F = 3.65$; $p = 0.06$).

In terms of functionality, the bird community is composed of five groups: granivores, omnivores, piscivores, insectivores, and herbivores. Herbivores, followed by insectivores, are the most abundant functional group during the period of record, indicating that the food web of Conchalí Lagoon is sustained by primary producers, and that it comprises a fundamental feeding habitat for primary consumers. Looking at the temporal changes in functional groups as an indicator of habitat condition, there were no significant changes during the observed time period. Although the response in the composition of the avifauna appears species-specific, it could still indicate changing ecological properties.

Physical Process

The discharge of the principal tributary (Pupío stream) into Conchalí Lagoon has decreased since 2004 (Fig. 4), coinciding with the closing of the connection with the sea. However, the rate of decrease does not coincide with the variation in precipitation, since discharge is near zero even during the rainy period. In 2006 and 2007 the average annual discharge was 0.054 and 0.032 m^3/s, respectively. In 2009 and 2010 precipitation was higher than 2006–2007 but average discharge was 0.011 and 0.0098 m^3/s, respectively. The decrease was sustained in the baseflow period, in which flow is dependent of contributions from aquifers located in the upper part of the catchment. Between December 2010 and May 2011, discharge was zero, except in March during which discharge averaged 0.010 m^3/s. According to seasonal variation curves of the Pupío stream (CADE –

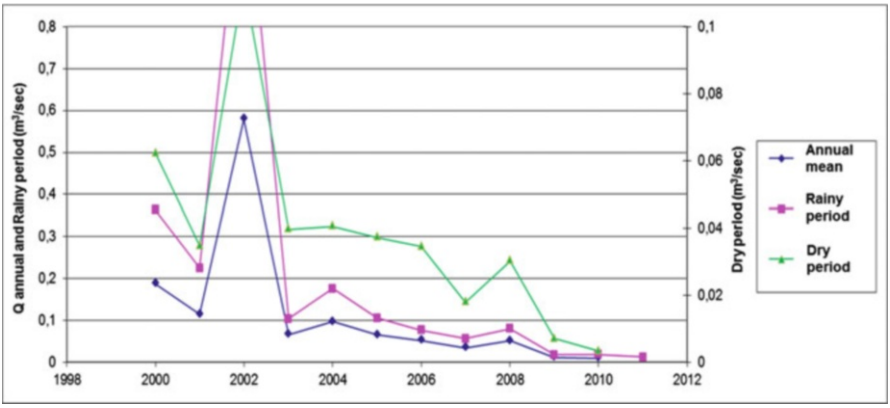

Fig. 4 Discharge of Pupío stream into Conchalí Lagoon (Data: © CADE-IDEPE 2004, with permission)

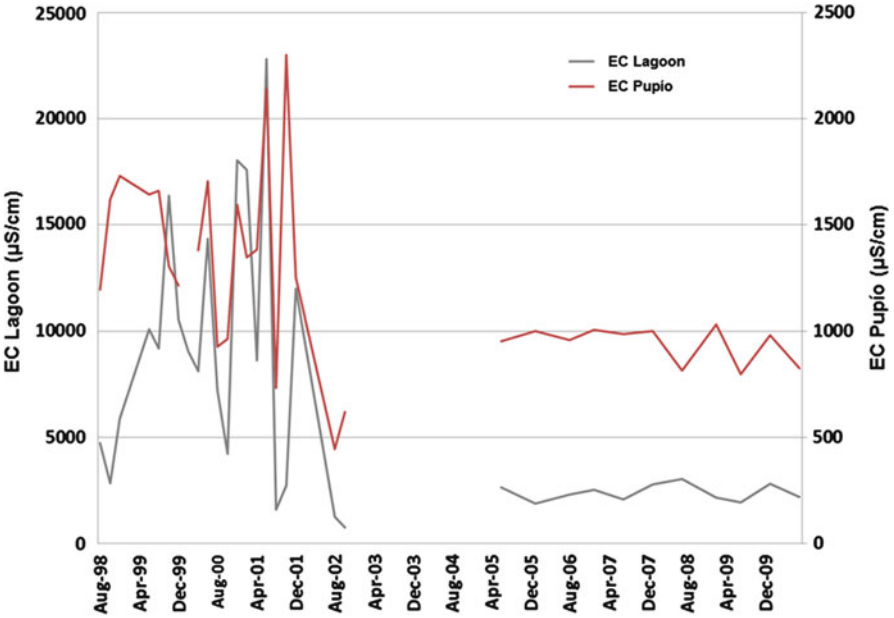

Fig. 5 Historical variation comparison of the EC (µS/cm) in Conchalí Lagoon and Pupío tributary (Data: © Centro de Ecología Aplicada, with permission)

IDEPE 2004), the average discharge measured during the 2010–2011 baseflow period has a 95% exceedance probability, while the rainy period of 2011 represents an exceedance probability in the order of 90%.

Between August 1998 and August 2002 monthly electrical conductivity (EC) values in the lagoon are highly variable but generally greater than 5,000 µS/cm with peaks reaching over 20,000 µS/cm (Fig. 5). The increase in EC and its variability is associated with events of marine water input breaking through the sand barrier separating the lagoon and the sea. These events caused changes in the internal dynamics of the lake, which can be seen in the seasonal variation and range in EC. The occurrence of maxima and minima during March and September, respectively, is related to the changes in contributions of freshwater and evaporation, which are factors that modify the lake's dilution capacity.

Landscape Process

Through air-photo interpretation, classification, and area of Conchalí Lagoon's water, dune, reed bed, and pasture habitats were determined for 2003 and 2012 (Fig. 6). Between these two dates, reed beds ("junco") increased in extent

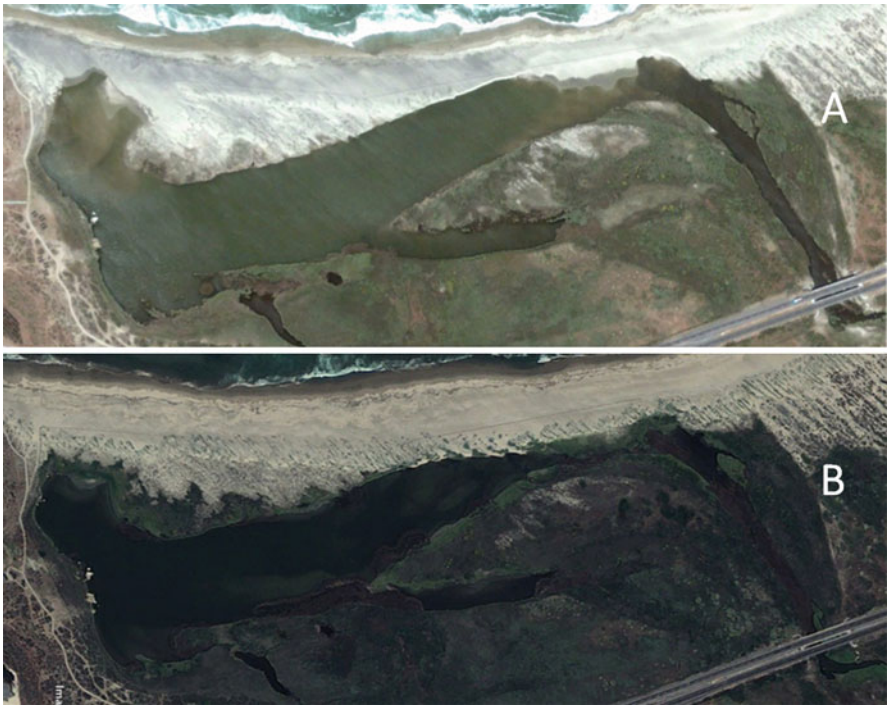

Fig. 6 Conchalí Lagoon in (**a**) December 2003 and (**b**) December 2012. Google earth V 7.1.2.2041. (July 13, 2007). Conchali Lagoon, Chile. 31°52′45.30″S, 71°29′46.42″W, Eye alt 1.896 ft. DigitalGlobe 2003. http://www.earth.google.com (December 10, 2003). DigitalGlobe 2012. http://www.earth.google.com (December 5, 2012)

Table 1 Area (ha) of Conchalí Lagoon habitats in 2003 and 2012

Habitat	Area (ha) by year		Difference (ha)
	2003	2012	
Water	11.69	8.27	−3.42
Dunes	4.1	3.87	−0.23
Reed Bed	0.28	2.35	2.07
Pasture	0	1.31	1.31

surrounding the lagoon, dunes were displaced toward the center of the lagoon, and a pasture formed upon the sand barrier which isolates the lagoon from the sea. The area of water decreased by 3.42 ha while reed beds increased by 2.07 ha (Table 1).

Conchalí Lagoon experienced a periodic connection-disconnection process as the sand barrier was repeatedly opened and closed. In 2004 however, this dynamic stopped, and the lake has since been continuously isolated from the sea. This change resulted in a change in the trophic state of the lake from mesotrophic (in 1998) to hypertrophic (2012).

Threats and Future Challenges

Possible factors that explain the decrease in richness and abundance of the lagoon's avifauna are: (i) the decreased area of water; (ii) the advance of the dunes; (iii) the strengthening of the sand barrier separating the lagoon from the sea; (iv) the decrease in discharge from the Pupío tributary into the lagoon; and/or (v) the decrease in area covered by aquatic plants. The ecological character of the lagoon is changing, from a condition of variable estuary- and freshwater-like periods to a condition of continued freshwater, decreasing the heterogeneity of the habitat both spatially and temporally. This change in the ecological state will result in changes in the present biodiversity of Conchalí Lagoon.

From a management perspective, the plan implemented to control local threats was successful. However, threats affecting the lagoon originate at a catchment and even global scale and have implications to the maintenance of the lagoon's ecological character. Threats currently affecting Conchalí Lagoon are likely to cause, directly or indirectly, a decrease in the water recharge to the lake and thus move the ecosystem into a hypereutrophic condition.

This process, which probably affects other water bodies' level globally, is likely to be stronger in coastal water bodies due to their transitional character, changing between fresh- and marine water (estuary) conditions. This is a fundamental property which is a basis for their ecological character. As water contributions decrease due to increasing water demands within their catchments (human use and less recharge), a likely first impact to systems of this type is the loss of the dynamic pattern of sea-lagoon interchange of water and salt, initiating an accelerating process of eutrophication and biodiversity loss within the system. Therefore, for the conservation of this Ramsar Site, the local management actions are by themselves insufficient and measures must be undertaken to develop a plan for the sustainable use of water resources at a catchment scale. In addition, implications of global climate change confront us with an urgent necessity to assess the adaptability of Conchalí Lagoon to future environmental conditions and its ecological character.

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