THE LAGUNAS ENCADENADAS DEL OESTE

PEARLS OF THE PAMPAS

ECOLOGICAL ASPECTS OF FLOODCONTROL ALTERNATIVES FOR THE LAGUNAS ENCADENADAS

Ministry of Transport, Public Works and Watermanagement
Directorate Flevoland, The Netherlands

Province of Buenos Aires, Argentina

drs. M.R. van Eerden
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Preface

This report has been accomplished by the Ministry of Transport, Public Works and Watermanagement in the Netherlands, Directorate Flevoland on behalf of the Ministry of Public Works of the province of Buenos Aires, Argentina. As part of the master plan for the Lagunas Encadenadas and the upper Vallimanca basin, carried out by IATASA, a global ecological impact assessment has been made for different flood control alternatives. The mission was carried out from 1-21 November 1993.

Acknowledgements

This mission was supported by a number of people without whose help and cooperation this study could not have been undertaken as it was now. During our stay in Argentina we acknowledge greatly the continuous enthusiasm and support by J. Loschacoff. In Buenos Aires J. Speziale of IATASA was of great help in arranging logistic matters. F. Borelli of ABS at La Plata and J.H. Marcolini of IATASA cooperated by providing hydrological data, maps and computer simulations. A. Valla of IATASA kindly showed us around in the area. His keen knowledge of the system, the roads and the people were of great help during the phase of data collection. We wish to express our gratitude also to the workers at the Instituto de Limnología at La Plata. The long experience of H. Lopez, O. Padin and J. Iwaskiw and others made it possible for us to focus on the critical measurements that had to be taken in order to make the ecological analysis more appropriate. Our discussions were open minded and of great help.

At home at Directorate Flevoland Bart Fokkens and Nel ter Haak kindly "let us go" and gave various logistic support. Wouter Dubbeldam, Willem Oosterberg, Herman Winkels and Henk Bos gave additional advise or made nice drawings from our data. Oranjewoud Laboratories quickly analyzed water, bottom and zooplankton samples. Maarten Platteeuw showed his skill in Spanish with his translation of the summary. Jos Dijkman (Delft Hydraulics) shared his experience with us by commenting upon chapter 5 and 6.

0. Summary

This report is an investigation of the available knowledge about the ecology of Lagunas Encadenadas, province of Buenos Aires, Argentina. Besides a field trip was carried out between 7-9 November 1993 in order to measure additional parameters. Because of the complexity and scale of the entire system (60,000 ha of water in five main lagoons, differing in water quality), a top down approach was chosen for.

The existing gradient in salinity between the lagoons seems important to the overall bio-diversity. The area could be divided into three main ecological zones corresponding to the salinity of the water. The brackish zone, in 1993 present in Laguna Del Monte, Laguna del Venado and partly Laguna la Paraguaya was found very rich in terms of fish production and bird abundance.

Within the individual lagoons three ecological habitats could be determined: the inundated zone, the upper layer of the open water and deep open water. Especially the periodically inundated zone plays an important role in the ecology of the system. Seasonal inundations are essential for the ecological functioning of this zone.

Long term cyclic changes in watertable and, associated with this, in salinity give rise to colonization and degradation phases which seem important to the productivity and diversity of the system as a whole. At present the area is a wetland of international importance as measured by the number of birds (Intermezzo 2). Eutrophication is a serious problem in all lagoons.

For a sustainable development of the Lagunas Encadenadas it is essential to maintain the natural dynamics and gradients in waterlevel and salinity as much as possible with respect to safety against flooding and human use. Against this background the various solutions to alleviate the problem of flooding have been evaluated. From an ecological point of view the alternatives with a flexible canal collector from A.Pigue to Venado or Del Monte and pumping between Venado, Del Monte, Cochico and Alsina is preferred. Also it is recommended to evaluate two other alternatives in the final masterplan: the option of just reinforcing the dikes around Carhué and Guamini and the option of the construction of a storage basin in A.Pigue.

0. Resumen

Este informe consiste de una recopilación de los conocimientos disponibles sobre la ecología de las Lagunas Encadenadas, Provincia de Buenos Aires, Argentina. Además, una expedición al campo fue realizada entre el 7 y el 9 de noviembre de 1993 con el fin de acoger medidas adicionales de algunos parámetros. Teniendo en cuenta la complicidad y la escala del sistema entero (60.000 hectáreas de agua en cinco lagunas principales, variando en cuanto a calidad del agua), se optó por una descripción basada en relaciones de los niveles tróficos superiores hacia niveles más bajos.

El gradiente de salinidad que existe entre las lagunas parece ser importante para la totalidad de la biodiversidad. El área se podía dividir en tres principales zonas ecológicas según la salinidad del agua. La zona salobre, presente en el 1993 en las lagunas Del Monte, Del Venado y parcialmente en la Paraguaya, se encontraba muy productiva en términos de abundancia de peces y de aves.

Entre cada una de las lagunas se identificaron tres hábitats ecológicos diferentes: la zona inundada, la capa superficial del agua abierta y agua abierta y profunda. Sobre todo, la zona temporalmente inundada hace un importante papel en la ecología del sistema. Inundaciones estacionales son esenciales para el funcionamiento ecológico de esta zona.

Cambios a largo plazo en régimen hidrológico y, asociados con esto, en salinidad producen fases de colonización y degradación que parecen ser fundamentales para la productividad y la diversidad del sistema entero. Actualmente, el área es una zona húmeda de importancia internacional, teniendo en cuenta el número de aves que lo habita (intermezzo 2). Eutroficación es un mayor problema en todas las lagunas.

Para un desarrollo duradero de las Lagunas Encadenadas es preciso mantener tanto la dinámica natural como los gradientes en nivel de agua y salinidad en la mayor medida posible con respecto a la seguridad contra inundaciones y al uso humano. Teniendo esto en cuenta, las diferentes soluciones para aliviar el problema de las inundaciones han sido evaluadas. Desde un punto de vista ecológico, las posibilidades con un flexible canal colector entre A.Pigue y Venado o Del Monte y una bomba de agua entre Venado, Del Monte, Cochicó y Alsina son las más aconsejables. Dos opciones más tendrían que evaluarse también en el Plan Maestro: sólo reforzar los diques alrededor de Carhué y Guamini o la construcción de un embalse en A.Pigue.

1. Introduction

Ecology as part of an integrated approach of flood control of the Lagunas Encadenadas

As a result of a series of wet years the area of the Lagunas Encadenadas (and other parts in the province of Buenos Aires) suffers from flooding. The main problem of flooding concerns the villages of Guamini and Carhué (fig. 1).

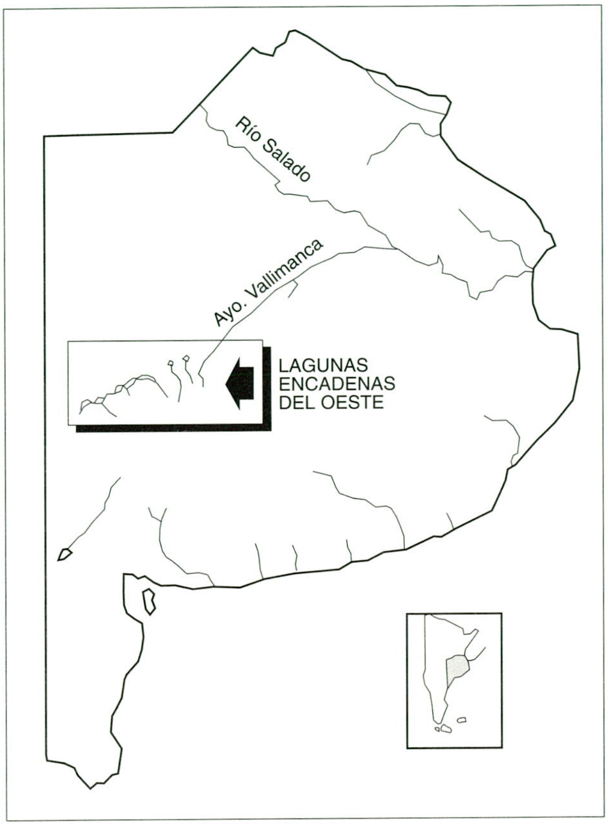


Fig. 1 Lagunas Encadenadas del Oeste within Argentina and the province of Buenos Aires.

In order to solve these problems the Ministry of Public Works of the Province of Buenos Aires has ordered IATASA to work out a master plan for flood control including environmental aspects. In cooperation with ABS, Delft Hydraulics and NEDECO a preliminary evaluation of flood control alternatives has been carried out by IATASA. (IATASA, 1993; Delft Hydraulics/ NEDECO, 1993). Within the framework of the masterplan also studies have been undertaken concerning waterquality (Dr. Ferrero), limnology (Dr. H. Lopez) and agronomy (Ing. Maiola & Pastor).

The Ministry of Public Works of the province of Buenos Aires strives for an integrated solution of the problem with attention to all interests involved including the ecological aspects of the laguna system. In order to achieve this the instrument of the policy analysis is used, so different alternatives and their effects on all functions can be presented to politics. Because of her experience in this field the Dutch Ministry of Transport, Public Works and Watermanagement has been asked to assist in incorporating an ecological approach in the project.

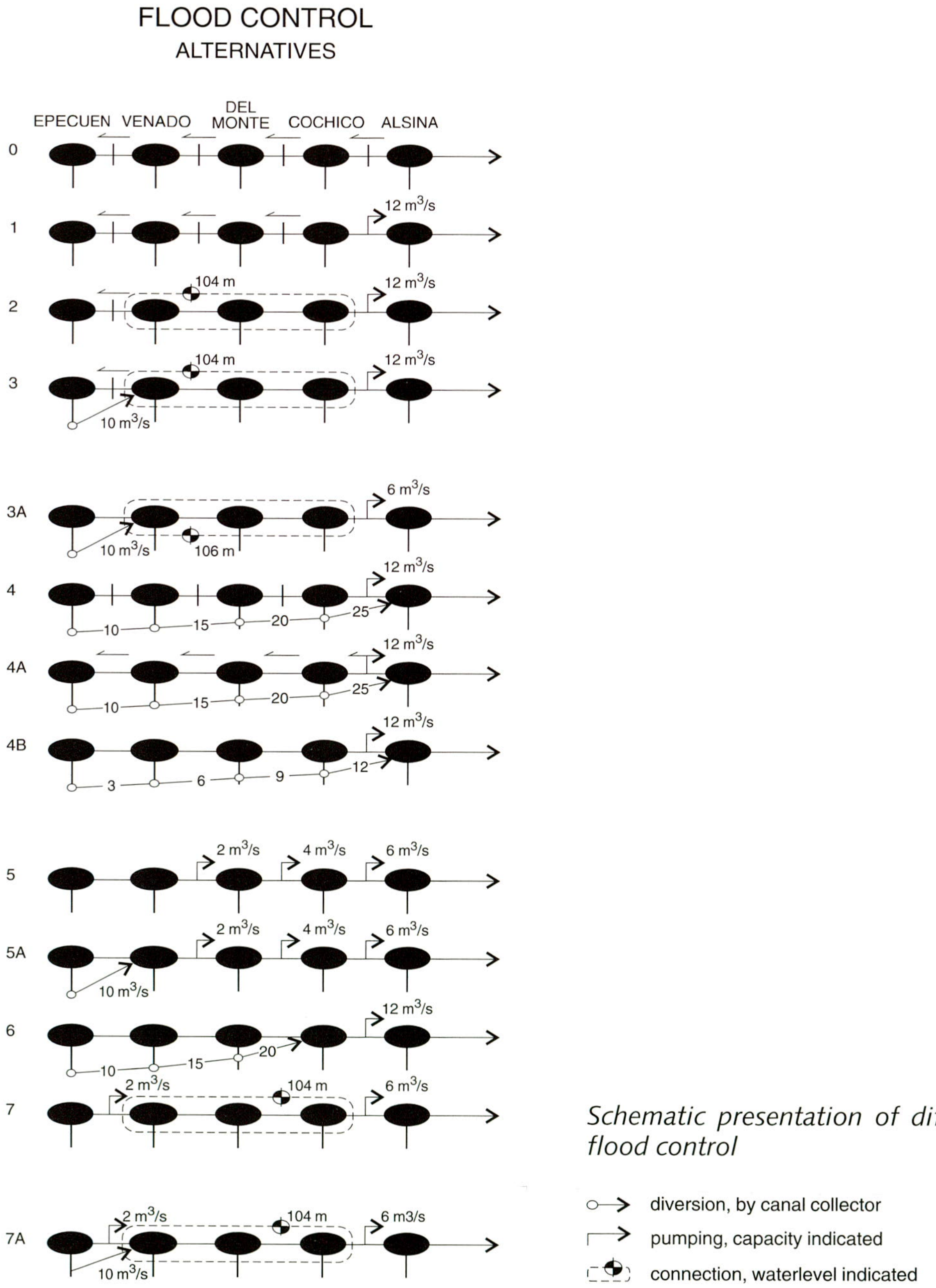
This led to the main objectives of this mission:

- to give a global indication of the ecological values and the biological functioning of the lagoon system
- to determine ecological key stone processes
- to assess the ecological effects of the flood control alternatives.

INTERMEZZO 1: flood control alternatives

From a hydrological point of view different solutions have been studied for flood control in the Lagunas Encadenadas (IATASA 1993; Delft Hydraulics, 1993). Basically the alternatives concern:
- *pumping, with or without connection of lakes*
- *diversion of the inflow with or without connection of lakes*
- *combinations of these measures*

All these alternatives have potential effects on the ecology of the lakes, because they change ecological conditions:
- *waterlevel fluctuations (min-max)*
- *salinity*
- *connection or isolation of lagoons*
- *ecological relations*



Schematic presentation of different forms of flood control

2. Approach

A top down approach has been chosen to get a global insight in the diversity and productivity of the laguna system and to evaluate the potential impact of flood control alternatives

Because of the short time available the assessment study mainly has been focussed on ecological aspects related to environmental conditions that may be changed by flood control alternatives:

- waterlevel fluctuations and their impact on habitat development, biodiversity and productivity
- salinity and its effect on biodiversity
- ecological connection or isolation of lagoons
- ecological relations between the lagoons and inflowing rivers

As specific literature about the ecology of the lagoons turned out to be scarce, a top down approach was chosen for the study. The framework was formed by a field study focussing on ornithological aspects as a measure of habitat functioning, biodiversity and productivity. Other available ecological information, literature and a limnological study carried out by the "Instituto de Limnología" in La Plata, were integrated within this framework. In addition to the other studies the field study was also aimed at gaining a global insight in the water quality and zooplankton biomass of the inundated zones bordering the lagoons. In Appendix 1 more detailed information about the set up of the field study can be found.

Information about seasonal and long term ecological changes as well as about ecological processes in the laguna system was not available. In order to make an analysis of the ecology of the laguna system in relation to seasonal and long term changes in hydrology and salinity, analogies were made with comparable systems elsewhere. The ecological analysis developed in this way was adjusted after discussions with specialists of the Instituto de Limnología in La Plata.

Ecological key stone processes and conditions for water management were derived from the ecological analysis. On the basis of these findings the flood control alternatives have been evaluated.

INTERMEZZO 2: Birds as indicators of habitat functioning and wetland quality

Birds form a conspicuous part of wetland ecosystems. Their migratory habit makes them dependent upon different wetlands through their annual cycle. Often breeding, moulting and wintering places are far apart which makes them vulnerable in their annual cycle (uncertainty of habitat availability, costs of migration). On the other hand some species may depend all year long upon just a single spot which serves to fulfil all their biological needs. Aquatic birds are well studied which make them good indicators of the biological functioning of wet ecosystems. By comparing different sites during breeding and wintering the relative importance of a site can be assessed. This has led to internationally accepted criteria of using bird numbers in order to assess the "quality" of a given wetland. Within this context the basic criteria for international importance to populations and species are:

1. *If it regularly supports 1 % of the flyway or biogeographical population of one species of waterfowl*

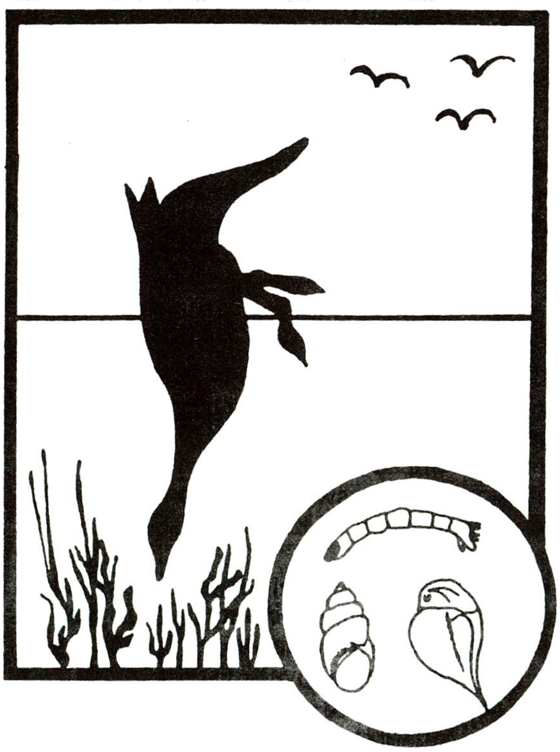
or 2. *If it regularly supports either 20,000 ducks, geese, swans and other waterfowl*

or 3. *If it supports an appreciable number of an endangered species of plant or animal*

or 4. *If it is of special value for maintaining genetic and ecological diversity because of the quality and the peculiarities of its flora and fauna*

or 5. *If it plays a major role in its region as the habitat of plants and of aquatic and other animals of economic importance within the concept of sustainable use and habitat conservation*

Moreover birds may be of great help in identifying the keystone processes which occur in a given wetland. Their specific needs being for example food, shelter or nesting sites is directive in this respect.



3. The Lagunas Encadenadas: geography, morphometrics and hydrology

The Lagunas Encadenadas form a dynamic system with seasonal and annual changes in waterlevel and salinity caused by sometimes strong fluctuations in precipitation and evaporation

The Lagunas Encadenadas are situated in the upstream area of the rivers Vallimanca and Salado in the province of Buenos Aires (62° W 36° S. They consist of a series of five large lakes and three smaller lagoons. There is a gradient in elevation being high in the east and low in the west, the difference at the lake bottom being 15 m (fig. 2).

river, the hydrology of the lagoons was almost separated from that of the river system. Between the lagoons sluices have been built, which make it possible to let the water go from the higher lagoons in the east to the lower ones in the west.

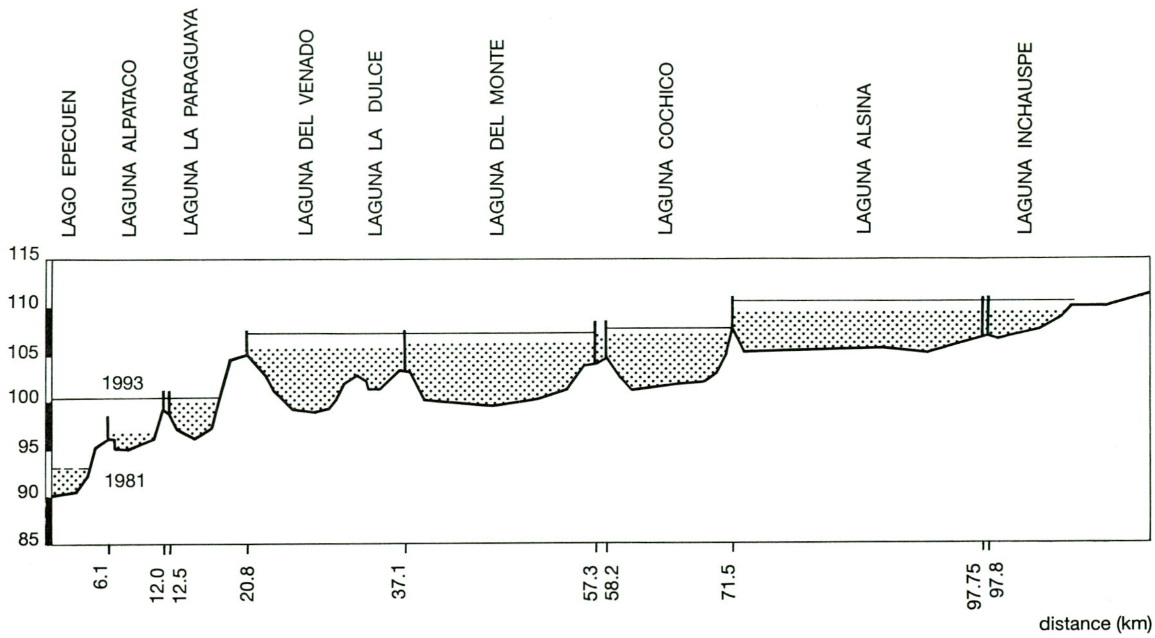


Fig. 2 Position of the Lagunas Encadenadas with respect of height above sea level. Waterlevels of 1981 and 1993 indicated.

The inflowing rivers originate in the hilly south of the lagoons (Sierra de la Ventana) and flow up to 75-100 km through extensively managed pasture and arable land where the soil is clayey. The area north of the lagoons is more flat and sandy. The bottom of the lagoons is flat and consists of loamy sand. Some years ago the canal Ameghino was constructed in order to bring water from the Salado catchment area to the laguna system in dry periods. Because of the inundations this canal is temporarily closed now. Until the construction of the canal Aliviador, which improves the connection of the most eastern lake Alsina with the Vallimanca

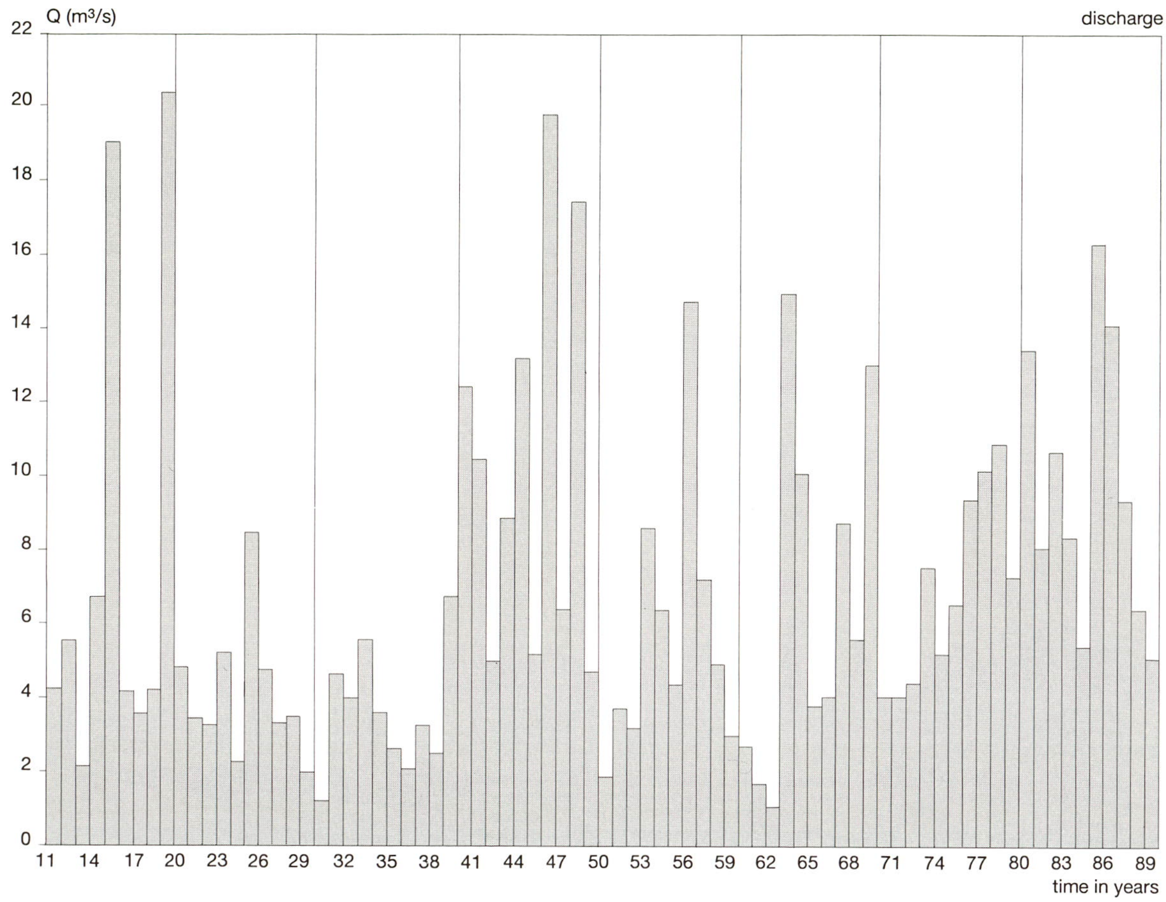


Fig. 3 Discharge by different streams entering the Lagunas Encadenadas as based on almost 80 years of weather data.

The hydrology[1] of the lagoons is mainly determined by direct precipitation, inflow of the rivers and by evaporation. Overall the inflow of the rivers is about 30-50% of the direct precipitation on the lagoons. Because of strong differences in precipitation and evaporation within years and between years, there are seasonal as well as annual waterlevel fluctuations (fig. 3 and 4). These fluctuations determine at the same time the size, depth and salinity of the lagoons. The total size of the all lagoons together may vary between ca 60,000 ha after a period of wet years and about 35,000 ha under drier conditions (fig. 5). The average depth of the shallow lagoons can range from 2-5 (max 10) m.

1 all information about hydrology and salinity has been derived from the report of Delft Hydraulics and NEDECO, oct 1993

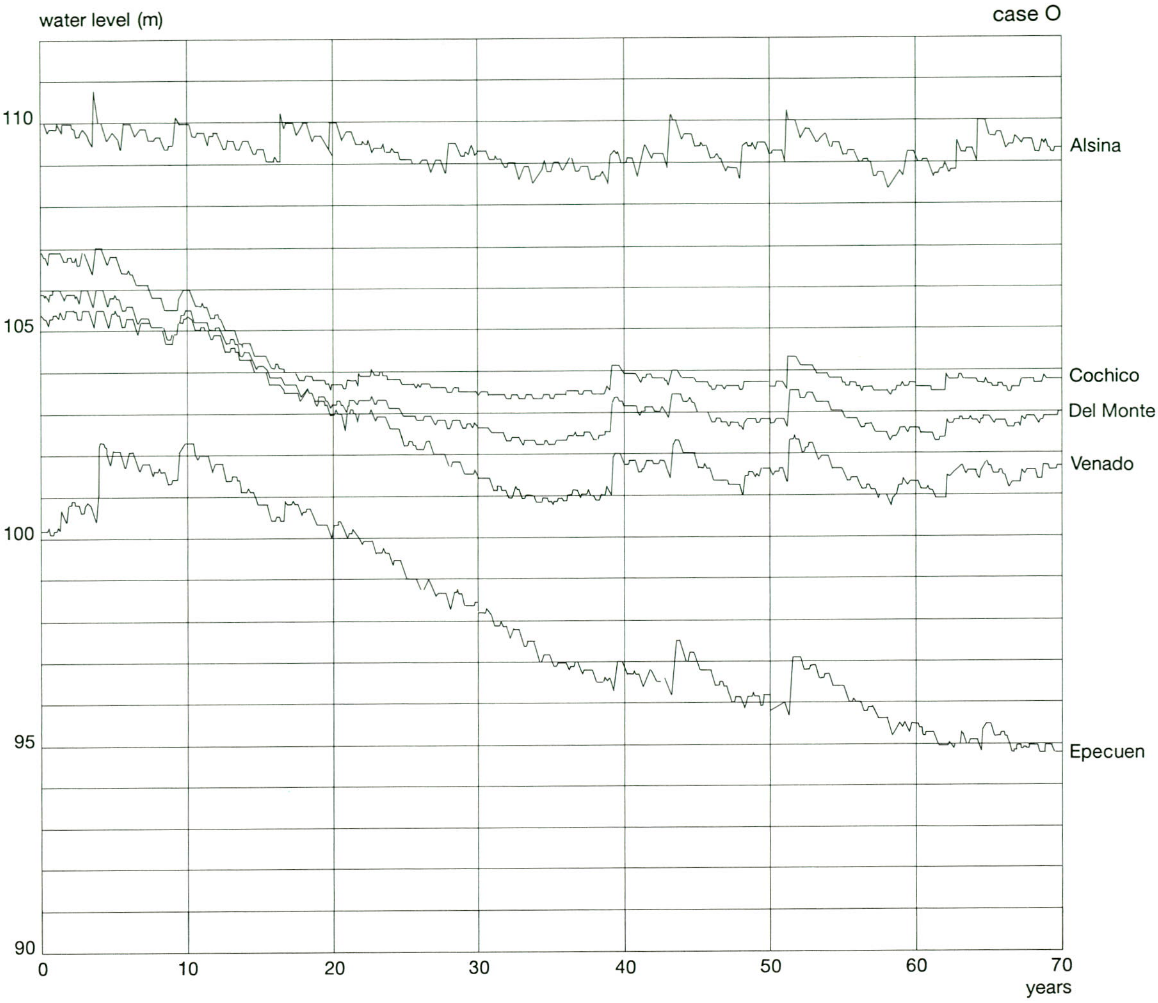


Fig. 4 *Simulation of waterlevels in 5 different lagoons at case 0, without any interference. As can be seen all levels stabilize at lower levels than at present (year 0), even though the so called worst case has been presented using the period of superfluous rainfall during the last ten years at the beginning of the run.*

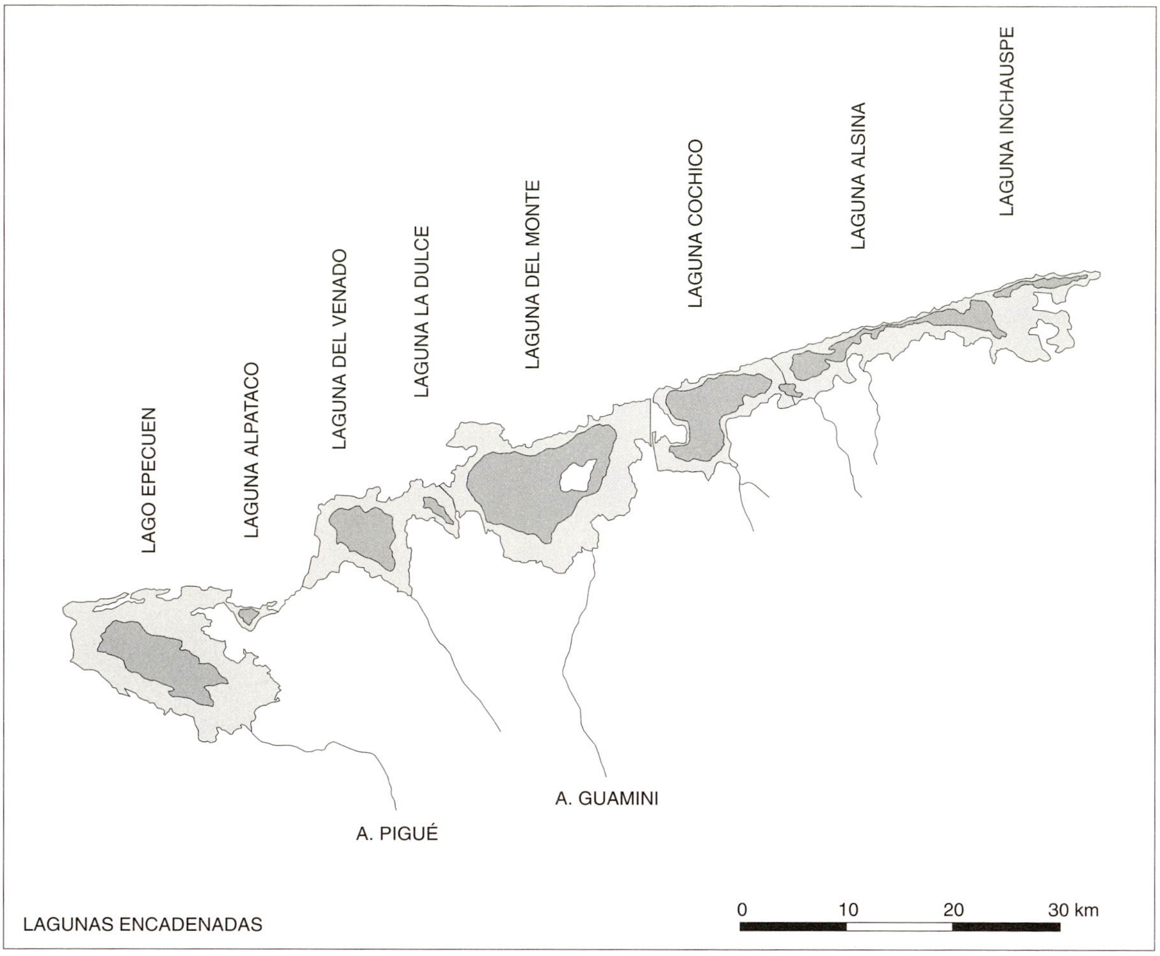


Fig. 5 *Lagunas Encadenadas showing the range of extension of water over the period 1981 and 1993.*

4. Ecology of the Lagunas Encadenadas

4.1. An ecological description

The Lagunas Encadenadas can be divided in three different ecological areas based on differences in salinity. Within the individual lagoons three ecological zones may be distinguished, from which the inundated fringe is ecologically very important.

This paragraph focusses on a description of the ecology of the lagoons based on the field study in November 1993, the study of the "Instituto de Limnología" (Lopez et al. 1993) and other sources of information. In the next paragraph an interpretation will be given of the ecological functioning in relation with fluctuations in waterlevel and salinity.

birds, at the end of the food chain

The integral aerial count on 12 November 1993 combined with a field survey from 5-10 November 1993 showed that the area of the Lagunas Encadenadas is rich in wetland birds. In total 100 species were recorded (Appendix 2). Rare or typical birds include Greater Rhea (Nandu) *Rhea americana*, breeding close to Laguna Paraguaya and two Least Grebes (Macacito Gris) *Podiceps dominicus* at Laguna Del Monte, far south of its normal breeding distribution (Narosky & Yzurieta 1989). Herons, egrets and ducks form the most conspicuous part of the avifauna. By number (given in brackets) the area is especially important for Neotropical Cormorant (Biguá) *Phalacrocorax olivaceus* (15,800), Great White Egret (*Garza Blanca*) Casmerodius albus (1120), Snowy Egret (Garcita Blanca) *Egretta thula* (2440), White faced Ibis (Cuervillo de Canada) *Plegadis chihi* (2840), Roseate Spoonbill (Espatula rosada) *Ajaia ajaja* (50), Coscoroba Swan (Coscoroba) *Coscoroba coscoroba* (2760), Black-necked Swan (Cisne Cuello Negro) *Cygnus melancoryphus* (3850) and White winged Coot (Gallareta Chica) *Fulica leucoptera* (10,560). Probably the high number of swans indicates the building up of a moult concentration. In total it was estimated that over 40,000 waterbirds were present in the entire area of Lagunas Encadenadas. This means that the area has to be considered a wetland of international importance (intermezzo 2).

Waterbirds were not evenly distributed over the lakes. Fig. 6 shows that different species have a different scope with respect to salinity and food. The high density of fish which was reported by Lopez et al (1993) in Venado and Del Monte is reflected by the presence of *Podiceps major, Phalacrocorax olivaceus* and *Ardea cocoi* in these lakes, all known to be fish eaters. Typical confined to freshwater habitat during this time of year were the ducks *Anas versicolor* and *Netta peposaca*. Dominant in the brackish lagoons were flamingo's *Phoenicopterus chilensis* and the two swan species *Coscoroba coscoroba* and *Cygnus melancoryphus*. Few species occurred at the saline conditions of Lago Epecuen. Neither of these were of special importance, nor were typical for saline conditions alone, however.

Most birds showed a strong linkage to certain habitat characteristics. From the aerial count it was clear that both the abundance of waterplants as the condition of the shore is of great importance to the presence of waterbirds. *Cygnus melancoryphus, Anas sibilatrix* and *Fulica leucoptera* correlated with macrophyte abundance (mainly *Potamogeton fig. 7). In Epecuen floating Enteromorpha* blankets had a similar effect. Most species reacted strongly upon the shore conditions. Helophyte vegetations, inundated meadows contributed positively to the presence of most waterbirds. Some examples are given in fig. 7.

From the field investigation it can be concluded that the salt, brackish and freshwater lagoons have their own ecological character as shown by the use that different species make of the different lagoons. Within the lagoons the inundated zones are essential as feeding and breeding habitat. With this hypothesis in mind, the other ecological information about the lagoons was evaluated.

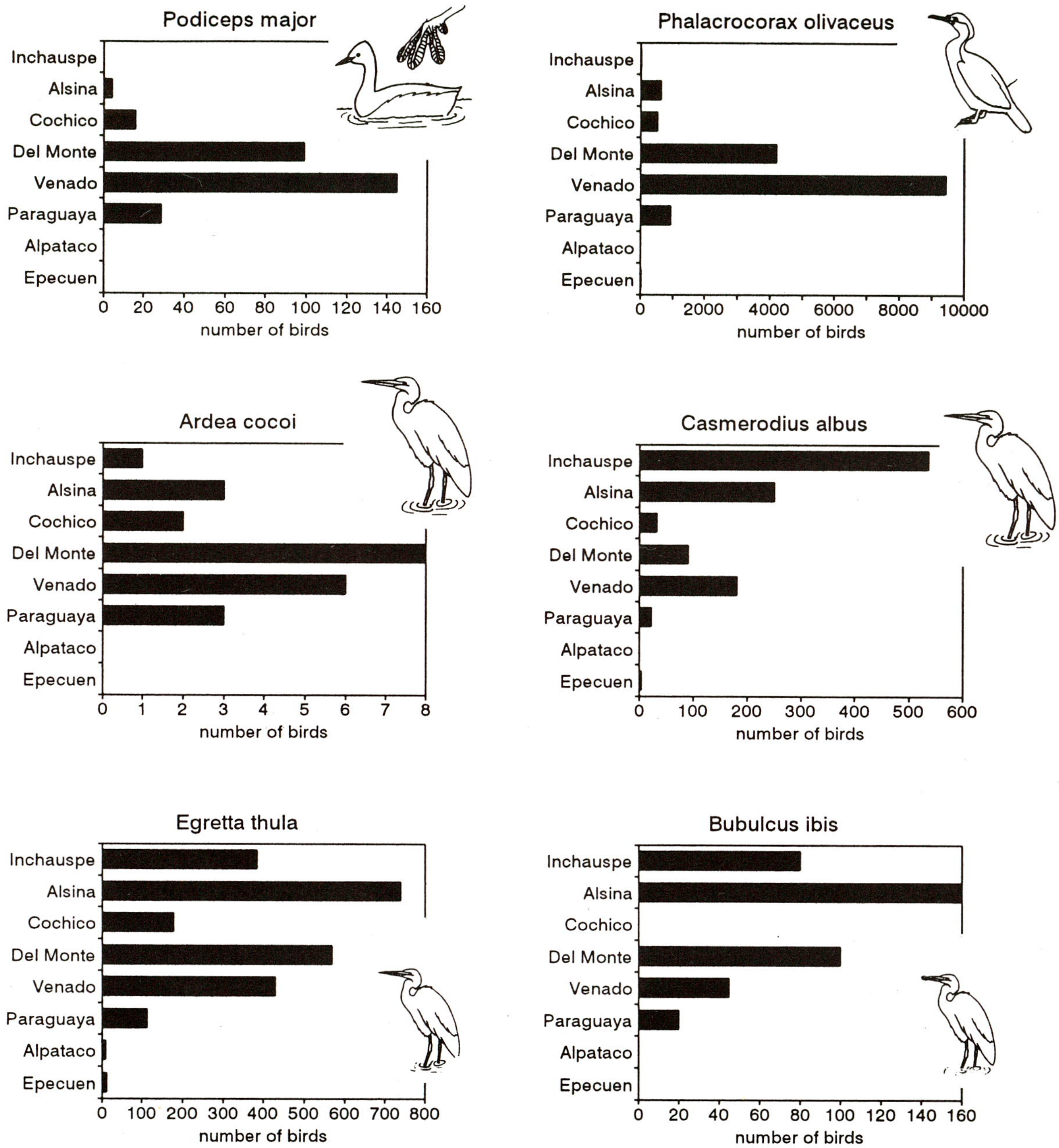


Fig. 6 Number of birds counted by plane in different lagoons, 12 November 1993.

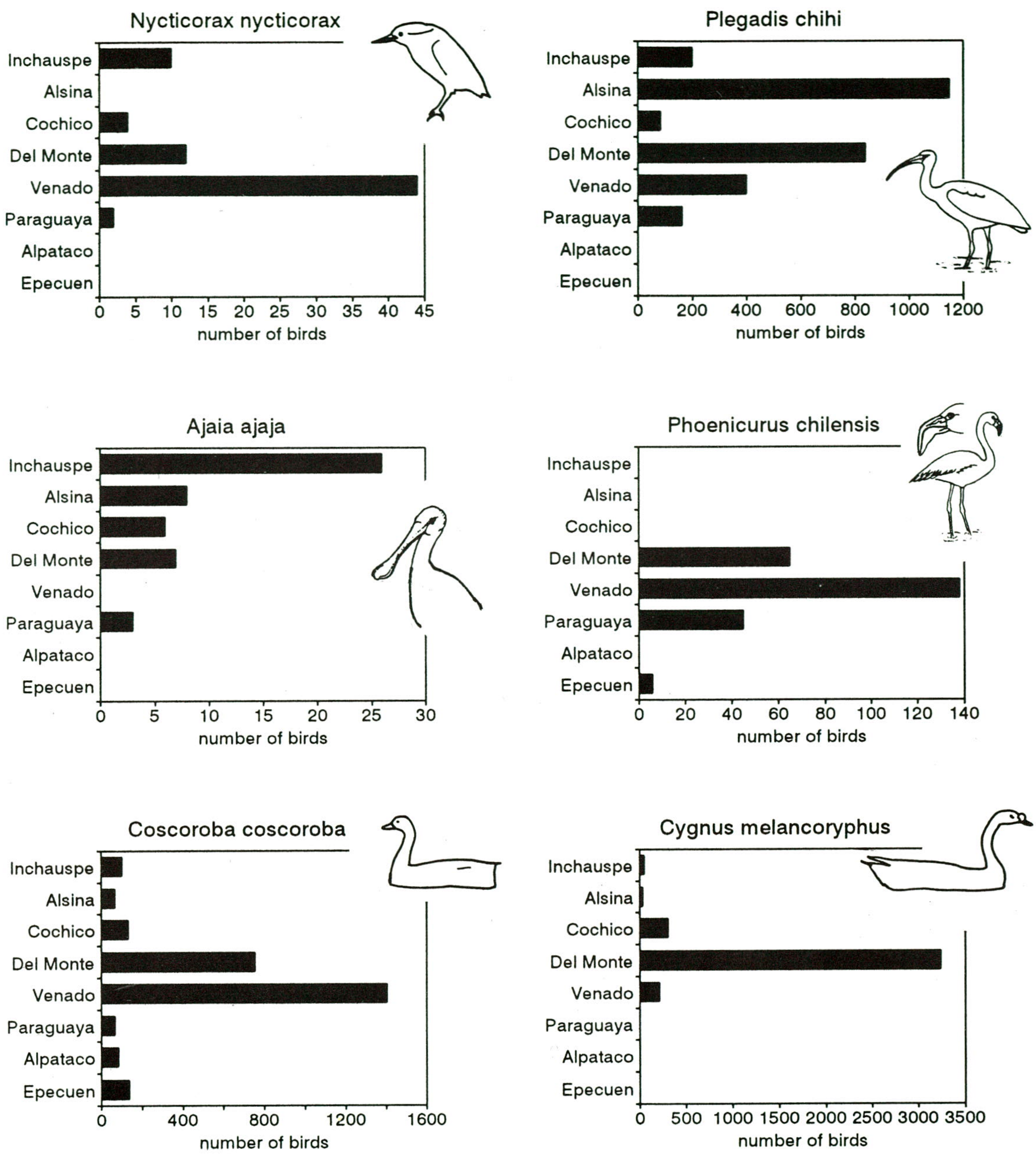


Fig. 6 cont. *Number of birds counted by plane in different lagoons, 12 November 1993.*

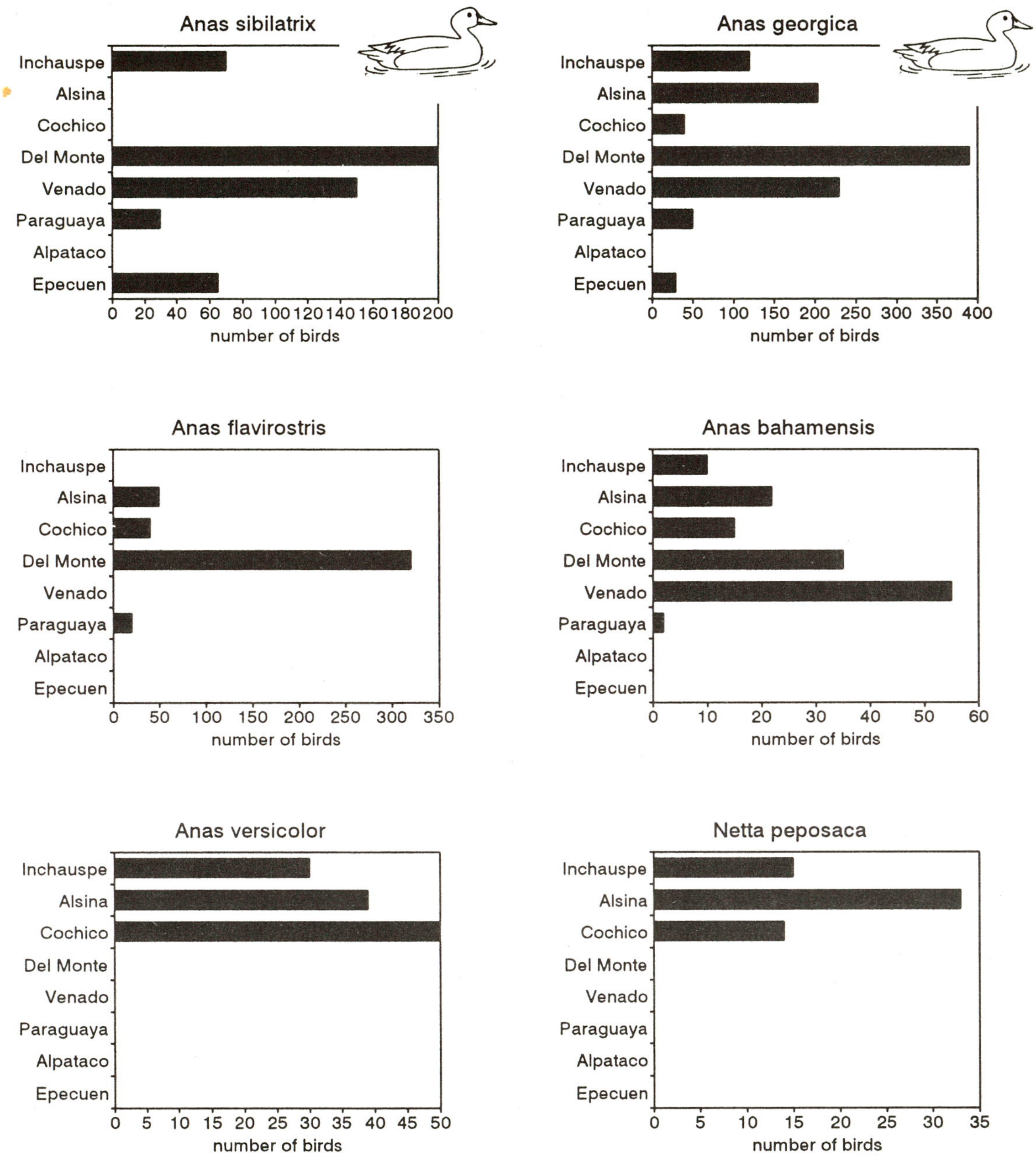


Fig. 6 cont. Number of birds counted by plane in different lagoons, 12 November 1993.

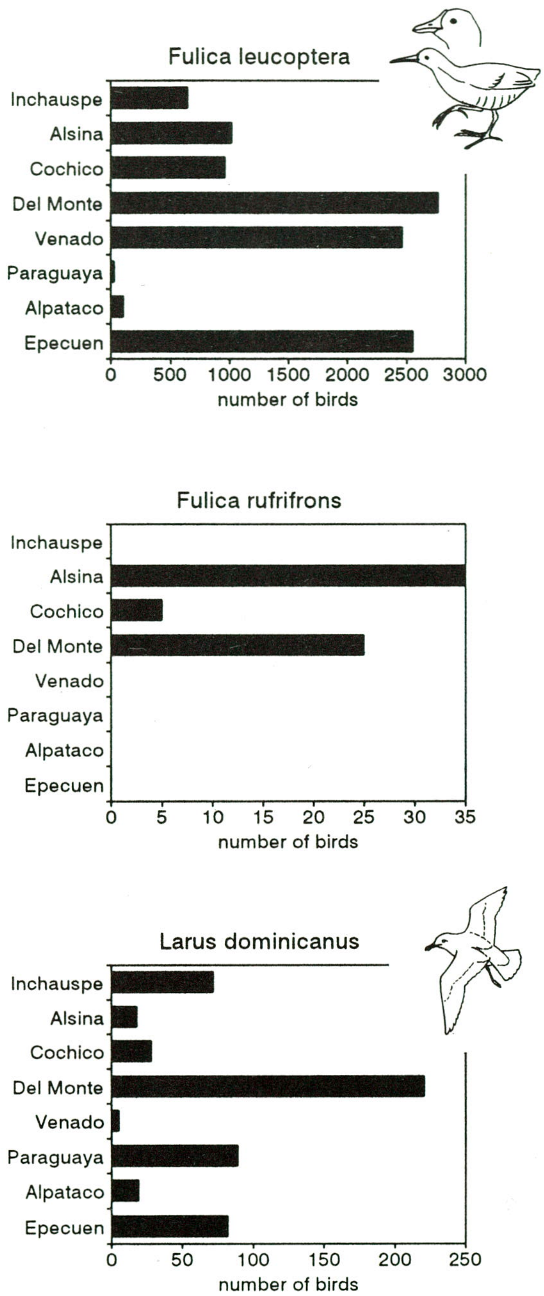


Fig. 6 cont. Number of birds counted by plane in different lagoons, 12 November 1993.

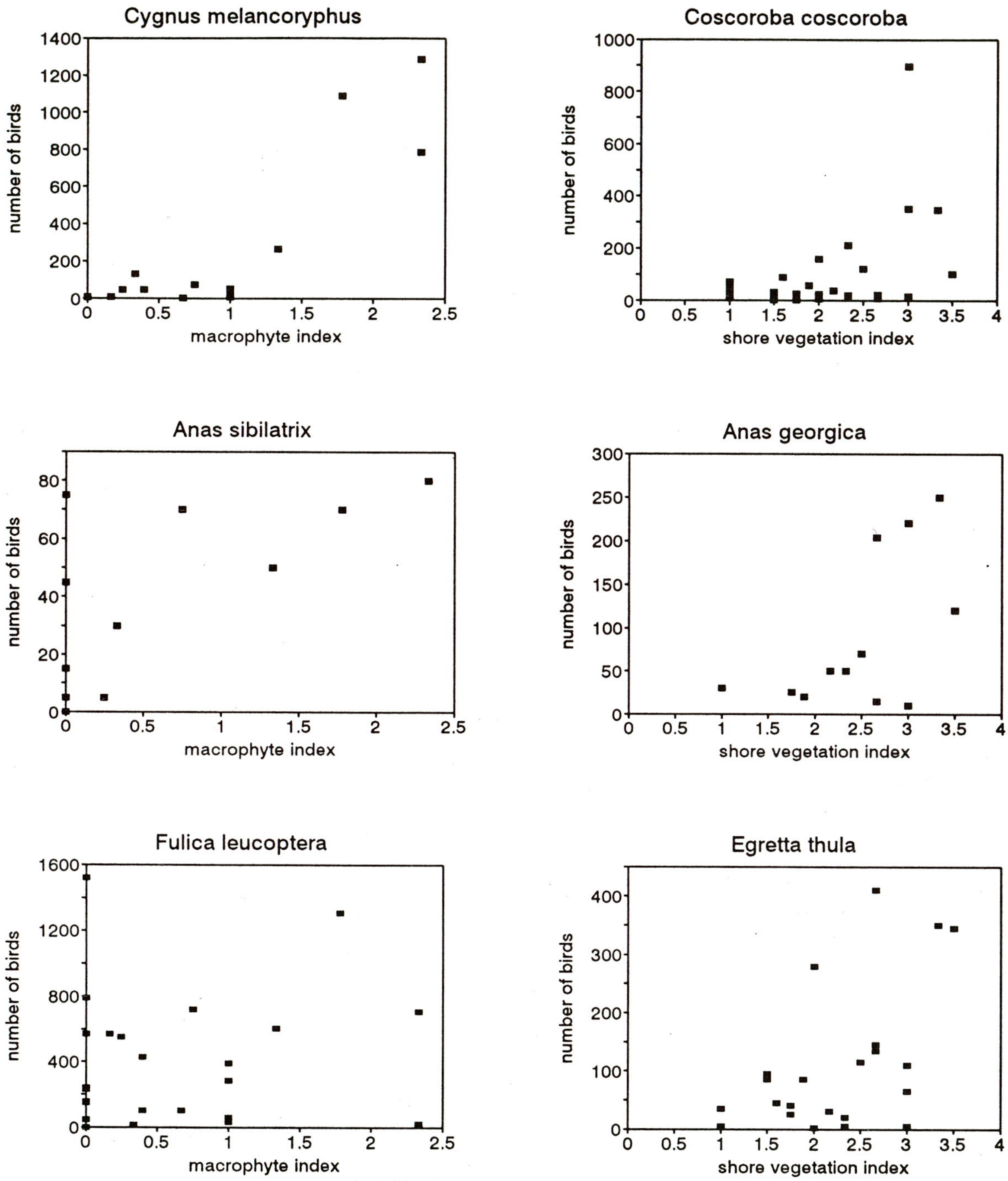


Fig. 7 *Relationship between bird density and the abundance of (left) macrophytes (Potamogeton) and (right) shore vegetation. All lagoons have been divided in 30 transects of equal size. Shore vegetation includes inundated meadows and the presence of helophytes (Juncus, Scirpus).*

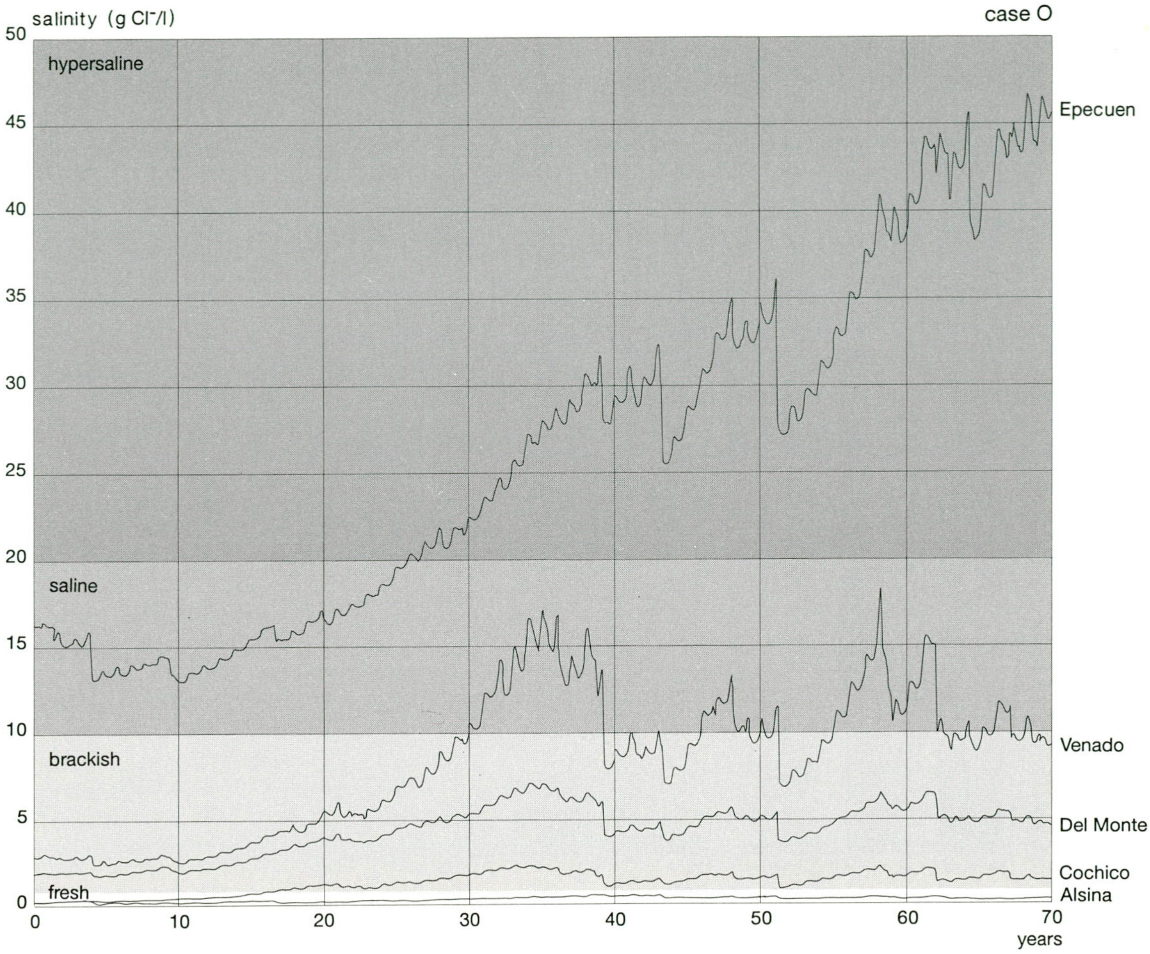


Fig. 8 Simulation of salinity (g Cl^-/l) in five different lagoons based on longterm weather data, without any interference (Case 0 see Fig. 4). The transition of one salinity level to another is more gradual than the figure shows.

water quality, the basis for wetland functioning

Two parameters in the water quality seem dominant with respect to the ecology of the lagoons: salinity and trophic level.

In 1993 the gradient in salinity between the lagoons varied from salt (15000 mg Cl^-/l) in the most western lake (Epecuen), via brackish (1400-2000 mg Cl^-/l) in Venado and Del Monte to fresh (300 mg Cl^-/l) in the most eastern lakes (Cochico and Alsina). The salinities are strongly depending on the hydrological conditions. Under wet conditions salinity goes down, under dry conditions salinity goes up (fig. 8). The higher the salinity of the lagoon, the greater the fluctuations over the years (fig. 9). Because the inflowing water from the rivers is fresh, especially in the brackish and salt lagoons there is a gradient in salinity in the mouth of the inflowing river, which forms a special habitat in these brackish and saline systems. This is most striking in the inlet of the Aroyo Pigué in Lago Epecuen (fig. 10).

If the concentration of Cl^- is considered being conservative, without any changes in its occurrence over time, then there is a relative decrease in the presence of bi-carbonates, sulphates as well as Ca^{2+} and Mg^{2+} over the traject Alsina - Epecuen. This decline is caused by the precipitation of salt, especially in Del Monte and Epecuen.

All lagoons have to be considered eutrophic (table 1). Although there are differences between the lagoons the nutrient concentrations

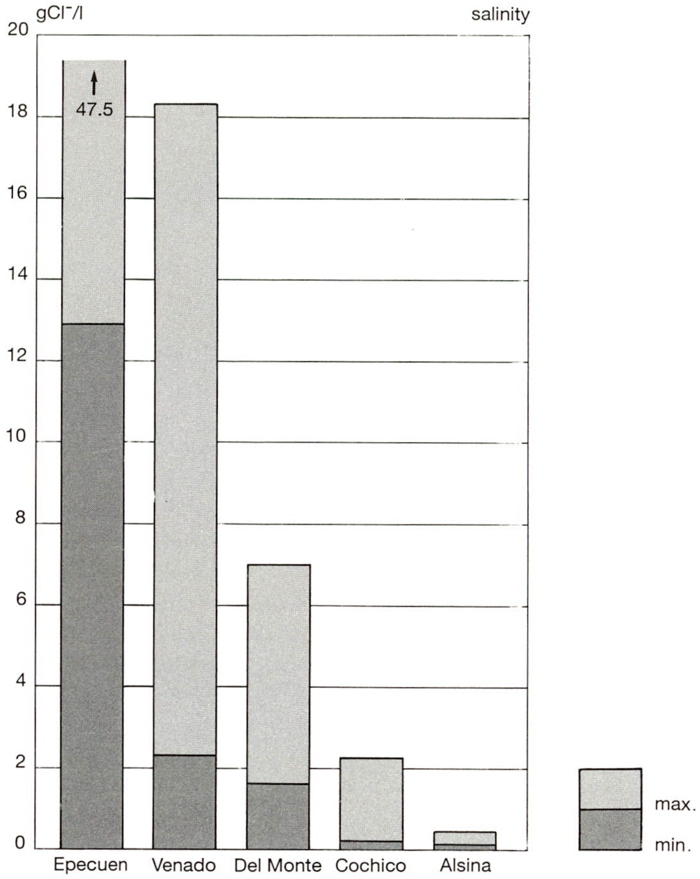


Fig. 9 Longterm extremes in salinity for five different lagoons, based on simulation of evaporation and precipitation data of case 0 (see Fig. 8).

are high, the transparency is low and algae are abundant. Alsina and Cochico are mediocre in all these aspects. Del Monte and Venado both are characterized by very high chlorophyll concentrations and a very low transparency. Epecuen is even hypertrophic with respect to the phosphate concentration being a factor 6 higher than the other lakes probably caused by the continuous evaporation.

Total phosphorus found in the traject Alsina-Venado was 0.17 - 0.38 mg P/l (all measurements incl. Lopez et al.), which is above the Dutch standard (0.15 mg P/l). In Epecuen total phosphorus even reached 1.23 mg P/l. P-ortho, the fraction directly available for algal production is obviously high (0.13 - 0.20 mg P/l). Concerning total nitrogen the values measured are between 0.51 - 3.60 mg N/l (Dutch standard 2.2 mg N/l). Especially Epecuen shows low concentrations of N possibly caused by denitrification. The fraction of soluble N is low (NOX and NH4). Comparing the levels of P-ortho to soluble N, we conclude that algae production in the lagoons is limited by nitrogen. This limitation increases over the traject Cochico - Epecuen.

Obviously higher concentrations, up to a factor two were found close to the shore than more in the open water of the lakes as measured by Lopez et al. (1993). This might be caused because of mineralisation of plant material due to the inundation.

The nutrient levels concern the levels in winter (Lopez et all) and spring. In general nutrient levels are highest in winter and lowest in late summer.

With the available information it is not possible to determine a complete nutrient balance. Yet it seems obvious that the nutrient load of the rivers plays an important role in the eutrophication of the lagoons. Downstream very high concentrations of phosphorus and nitrogen were found.

Upstream lower levels occur whereas near the origin of A. Pigué the lowest levels have been found. The origin of the high nutrient load is not clear yet. It is likely that agriculture is a source for nutrients, although fertilizer is not intensively used in the area (Maiaola, pers.comm.). Mineralisation of peat (water colour !) is a possible source as well. Because of the fact that especially P total increases strongly it is not unlikely that human wastewater is an important source as well. More study is needed to analyze the problem of the high nutrient load. It seems that the lagoons are very susceptible to eutrophication because of the long residence time, which makes the lagoons function as a sink for nutrients.

Because water samples only give an impression of the waterquality at one particular moment, two samples of mud have been taken. Sedimentated silt may be used as a reflection of the history of pollution with micro pollutants. Both samples were taken in a recent sedimentation area of the streams A. Pigué and A. Guamini where they enter the lagoon. The samples were analyzed with respect to EOX (pesticides), Phenolics, 6 PAC's and heavy metals. No indication of any serious pollution due to the discharge of industrial waste water or other sources of toxic compounds could be detected (Appendix 3).

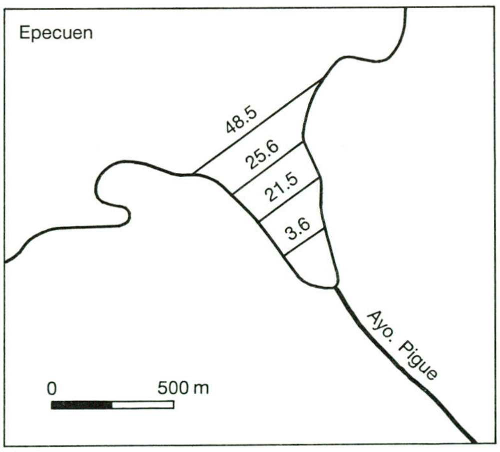


Fig. 10 Example of gradients in salinity at the mouth of the different streams entering the lagoons. Data refer to A. Pigué, 9 November 1993.

Table 1a *Water quality parameters in two streams entering the Lagunas Encadenadas, as measured 7-9 November 1993.*

Streams				
	A. Pigué upstream	A. Pigué downstream	A. Guamini halfway	A. Guamini downstream
Chloride, mg/l	6	630	29	42
Total P, mg P/l	0.05	0.58	0.30	0.62
P-ortho, mg P/l	0.029	0.367	0.254	0.489
Silicate, mg/l	21	37	54	37
PH	7.7	8.0	8.2	8.0
NH4+N-org., mg N/l	0.6	1.1	1.1	3.2
NH4, mg N/l.	<0.05	<0.05	<0.05	15
NO3 + NO2, mg N/l	0.74	1.10	1.84	1.16

Table 1b *Water quality parameters of the lagoons, measured along the shore unless stated otherwise, 7-9 November 1993.*

Lakes					
	Alsina shore	Del Monte shore	Del Monte lake	Venado shore	Epecuen shore
Chloride, mg/l	105	530	990	2010	14780
Total P, mg P/l	0.38	0.33	0.26	0.18	1.2
P-ortho, mg P/l	0.131	0.212	0.180	0.136	1.18
Silicate, mg/l	1.5	5.8	16	13	20
PH	8.3	8.3	8.9	9.1	9.1
NH4+N-org., mg N/l	2.1	1.9	2.8	3.6	1.7
NH4, mg N/l	<0.05	<0.05	<0.05	0.16	0.14
NO3 + NO2, mg N/l	0.20	0.28	0.95	0.42	0.06

algae

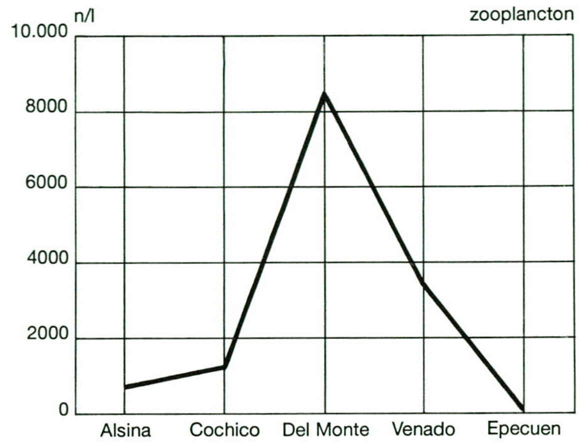
Blue green algae (Cyanobacteria) are dominant in all lakes. In general it concerns species adapted to strongly fluctuating conditions, with a relatively high tolerance for salt. Blue green algae are considered as an indication of the high level of eutrophication of the system.

With respect to the dominant algal species Cochico, Del Monte and Venado are comparable with a dominance of *Microcystis pulverea*. Alsina (*Gomphosphaeria lacustris*) and Epecuen (*Coelosphaerium aff. palidum*) are both dominated by different blue green algae (Lopez et al. 1993).

In the field study of November 1993 the inshore dominance of filamentous macro algae (*Oscillatoria, Nostoc, Spirogyra, Enteromorpha*) was striking. Filamentous algae, often attached to macrophytes, are also the result of accumulation of nutrients in the lakes. Where algae concentrate due to wind effects and subsequently decay at the shorelines they may cause locally oxygen depletion and a bad smell. This can make the lakes unattractive for recreational purposes. Moreover several bluegreens are known to produce toxins which may cause fish to die under extreme conditions.

zooplankton

The study by Lopez et al.(1993) shows that the number of zooplankton species present in the open water of the lakes decreases from 16 in the easternmost freshwater lake Alsina to 6 in the westernmost saline lake Epecuen; the density was found highest in the brackish lake of Del Monte (fig. 11, adapted from Lopez et al. 1993). Furthermore it was concluded that under the present conditions some lagoons are comparable with respect to the zooplankton communities. Alsina and Cochico resemble each other in species composition as well as in relative abundance and are comparable with other lakes in the province of Buenos Aires. The dominant species can be divided in three main groups: *Filinia longiseta* (Rotifera), *Bosmina huaronensis* and *Ceriodaphnia sp.* (Cladocera) and *Notodiaptomus incompositus* (Copepoda). Del Monte and Venado differ from Alsina and Cochico. They resemble each other in species composition and relative abundance of the zooplankton community. Dominant species are *Alona karua* en *Leydigia acanthocercoides* (Cladocera), with a preference for near bottom or macrophyte habitat. Moreover *Collotheca sp* and *Brachionus plicatilis* (Rotifera) were abundant as well as *Metacyclops mendocinus* (Copepoda). Lake Epecuen has its own characteristics. The zooplankton here is typical for hypersaline environments, the dominant species being *Moina eugenie* (Cladocera) and *Boeckella poopoensis* (Copepoda).



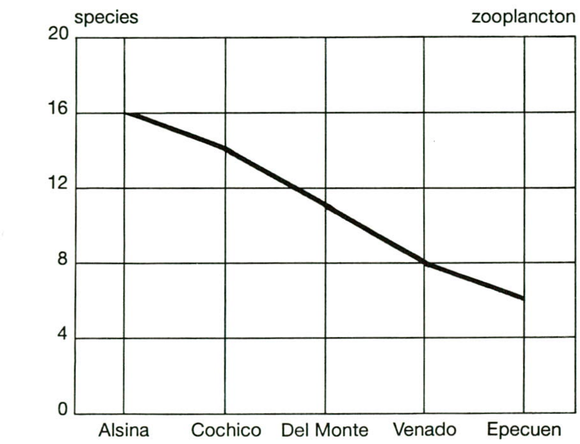


Fig. 11 Density and number of species identified in samples of the open water of five different lagoons in 1993. Data adapted from Lopez et al. (1993)

The near shore habitat of inundated meadows and macrophyte vegetation was sampled during the field visit 7-9 November 1993. Bottom-dwelling, harpactoid copepods were dominant in Epecuen indicating the usage of detritus instead of algae. Few zooplankters occurred in the inshore area of Del Monte and Venado, associated with high densities of young fish. Proportionally many small rotiferans were met here probably also as a reaction upon the abundance of 0+ fish. On the other hand high densities of zooplankton were recorded in Laguna la Paraguaya, in a part recently inundated not connected to the main lagoon and without any

fish present. Copepods but also large cladocerans of the *Daphnia hyalina/galeata* complex were super abundant here (fig. 12).
Species composition along the shores in the rest of the lakes showed more overlap than differences. *Moina macropa* (Cladocera) was found both in Epecuen and Paraguaya whereas *Alona karelica* and *Bosmina coregoni* (Cladocera) were found both in Del Monte as in Alsina. Probably the gradient in salinity across the inundated meadows with almost fresh water has caused these parallel developments.

vegetations consisting of *Potamogeton* spp. Species composition and densities indicate the effects of eutrophication of the lagoons. Epiphytic algae may diminish the conditions for waterplants; in deeper water the transparency of the water is too low.

At the time of the field survey helophytes were poorly developed. This may have been caused partly by the continuous rise in waterlevel during the past few years. Only the freshwater systems Inchauspe, Alsina and partly Del Monte had helophyte vegetations of significant size.

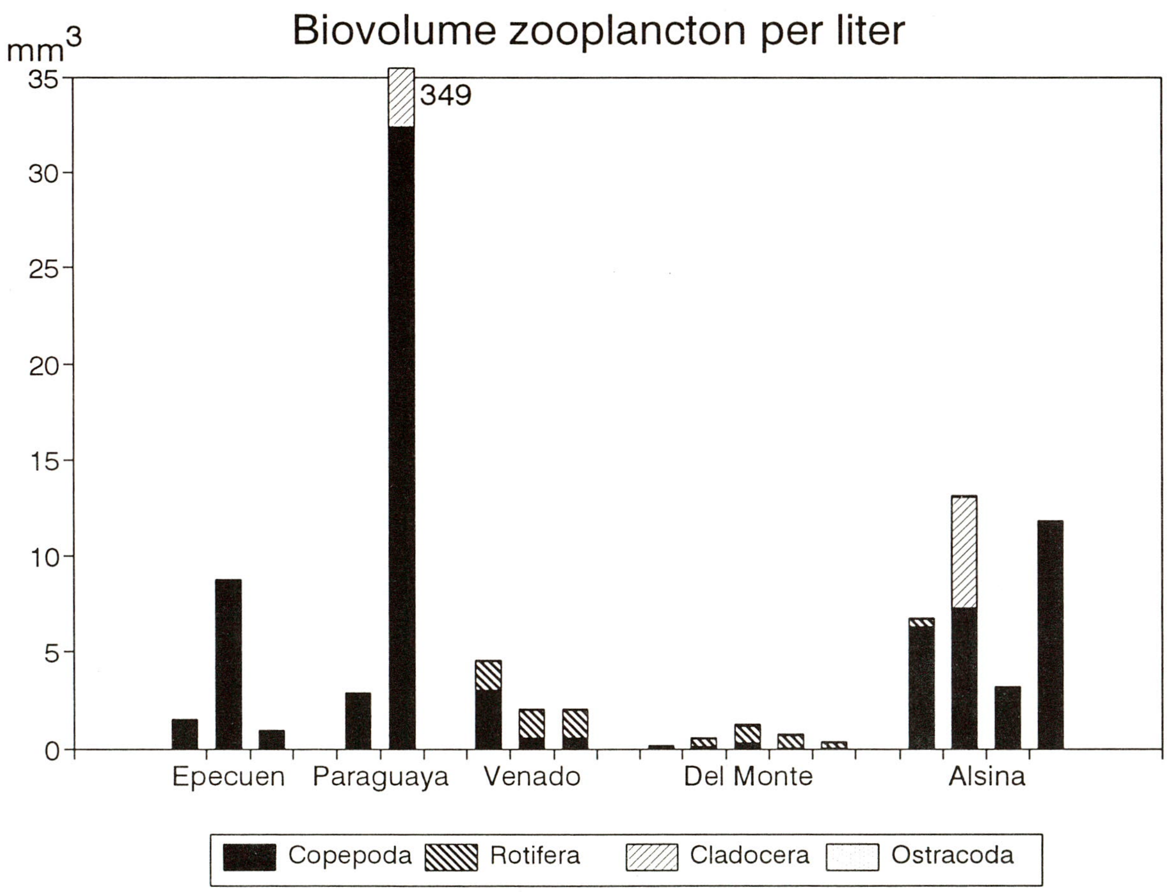


Fig. 12 Biovolume of zooplankton at the inshore area of five different lagoons as measured 7-9 November 1993.

vegetation
Submersed and floating waterplants were not abundant. Some species were identified in shallow areas in rather low densities. *Enteromorpha* sp. was present in all lagoons, but Cochico and Alsina. *Eleocharis* was found along the shores of Paraguaya, Venado and Del Monte. In Del Monte and Alsina inundated shallows were rich in *Myriophyllum* spp. All lakes but Epecuen had

Under normal conditions each type of lagoon has its own characteristics. The more fresh water systems may have extensive reedbeds (*Phragmites australis*), rushes (*Juncus* spp) along their shores. The brackish lagoons are bordered by a halophilic vegetation comprising of *Scirpus californicus*, *Eleocharis* spp. and *Carex* spp. Grazing by cattle may influence the extension of the vegetation.

benthic fauna

No information about benthic fauna is available. The results of the study on the feeding of pejerrey indicate however that at least in Del Monte there may be a rich benthic fauna community with among others ostracods and amphipods (Lopez et al. 1993). The inshore sampling of water indicated locally high densities of Amphipoda, Chironomidae, Hemiptera and Gastropoda which is in accordance with the eutrophic state.

fish

In 1993 Lopez et al. have carried out an extensive study on the fish population consisting of 18 species. In this report the main conclusions are summarized.

In species diversity there is a gradient from the east to the west: in Alsina and Cochico the species diversity is about twice as high as in Del Monte and Venado; in Epecuen only one species has been identified (fig. 13, based on table 5 of Lopez et al. 1993).

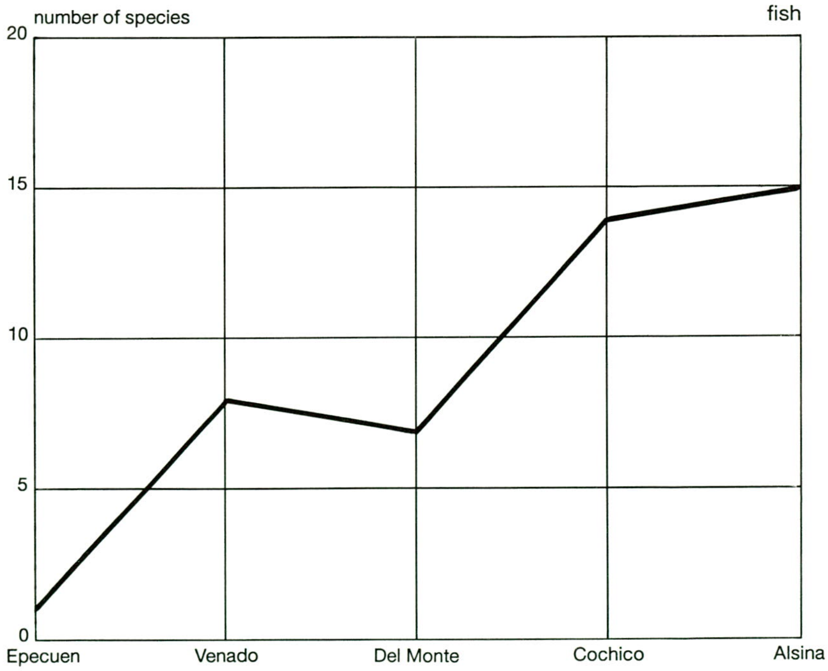


Fig. 13 Number of species of fish recorded during field surveys in 1993 for five different lagoons. Data refer to table 5 in Lopez et al. 1993.

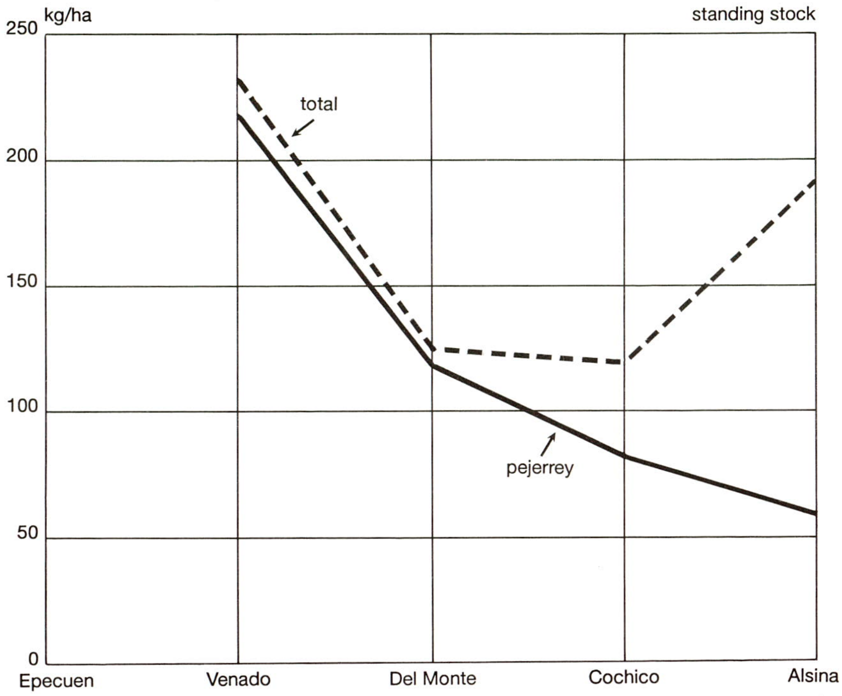


Fig. 14 Biomass of fish in five different lagoons based on field surveys in 1993 (Lopez et al. 1993). The proportion of "Pejerrey" Odontesthes bonariensis is also shown.

In Venado and Del Monte "Pejerrey" (*Odontesthes bonariensis, Atherinidae*) with more than 90% of the total biomass is by far the most dominant species. In Cochico Pejerrey forms about 65% of the total biomass, while in Alsina this is only 30% (fig. 14). Worth mentioning is the colonization of Alsina by Carp (*Cyprinus carpio*). In Laguna Chascomús in the Salado basin Carp forms already a threat for the natural fish population.
The highest biomass of fish has been found in Venado (231 kg/ha). The total biomass in Alsina is about 15% lower and in Cochico and Del Monte about 50% (fig. 14). Pejerrey has the highest biomass in Venado and the lowest in Cochico; Alsina and Del Monte are similar in this respect. Compared to the biomass found in Laguna Chascomús (31 kg/ha) the standing stock of fish in the Lagunas Encadenadas is high.

The present condition of fish in Alsina, Del Monte and Venado is good. The head-index shows, however, that in the past only in Alsina growth was good (Lopez et al. 1993); in Del Monte and Venado growth has been moderate.

In Cochico the present condition as well as growth in the past is relatively poor. Because fish is almost absent in Epecuen no further study has been carried out there.

Till a length of about 200-220 mm Pejerrey feeds mainly on zooplankton. In particular in Del Monte and to a lesser extend in Venado also benthic fauna and vegetation are part of the diet. Bigger fish are mainly piscivorous and may feed on other Pejerrey.

The presence of Pejerrey larvae in the zooplankton samples indicates good conditions for reproduction (Lopez et al. 1993). Pejerrey spawns by preference in inundated areas on helophytes and other plants (Iwaskiw, pers. comm.). Probably larvae and young fish grow up in vegetated area, where they have better protection against predation.
In the mouth of the Aroyo Pigue in Epecuen many young fish have been observed during the field study. This gives support to the idea that this brackish area forms a special habitat within the laguna.

conclusions

The Lagunas Encadenadas can be divided into three different ecological types, mainly based on differences in salinity. From the east to the west there is a tendency towards a decreasing diversity (plants, invertebrates, fish and to some extent also birds). Biodiversity is by far the lowest in Epecuen. However, the productivity (fish, bird density) seems to be highest in the brackish lagoons and lowest in Epecuen. Alsina and Cochico are intermediate in this respect. Venado, Del Monte and to a lesser extent Cochico are comparable. Epecuen has its very own characteristics. Alsina and in some aspects Cochico resemble other lagoons in the province of Buenos Aires.

Within the individual lagoons three different ecological zones are present: the periodically inundated zone, the upper layer of the open water and deep open water (fig. 15). Especially the periodically inundated zone is essential with respect to vegetation development, reproduction of fish and feeding of birds. The upper layer of the open water is important for fish eating birds. The deep water is essential for survival of fish. The mouth of the inflowing rivers forms a special habitat within the salt and brackish lagoons.

Eutrophication is a problem in all lagoons, but quantification of the different nutrient loads is not possible yet.

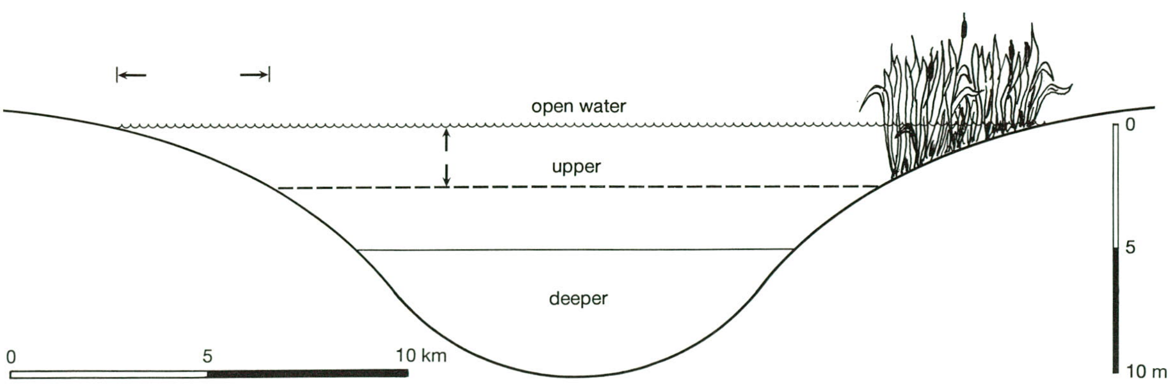


Fig. 15 Schematical cross section of a laguna with the different ecological zones.

4.2. Productivity and biodiversity related to fluctuations in salinity and waterlevel

The ecology of the Lagunas Encadenadas is strongly linked to changes in waterlevel and salinity. Both seasonal as annual fluctuations are very important for biodiversity and productivity of the system. Although the entire lagoons as well as specific zones may show great fluctuations in time, the three ecological types and three ecological zones are always present in the lagoon system.

The lagoons in the pampa area resemble to some extent the prairie potholes in the USA and some European wetlands, e.g. the Oostvaardersplassen in the Netherlands (van der Valk & Welling, 1988; RWS directie Flevoland, 1994). In these shallow lagoons seasonal and annual changes in waterlevel are known to be the "engine" of the ecosystem. In the Lagunas Encadenadas analogical processes may be valid.

Besides seasonal fluctuations long term annual fluctuations in waterlevel and salinity occur in the Lagunas Encadenadas as caused by series of dry or wet years. Both seasonal and long term annual fluctuations seem very important for the ecology of the system. Seasonal fluctuations are essential for survival of helophytes in the inundated zone (germination of seeds), spawning of fish (e.g. Pejerrey) and feeding and breeding of birds. In short: seasonal fluctuations determine the presence of the inundated zone and its ecological importance. Furthermore a fluctuating waterlevel prevents the shoreline from erosion.

Long term (cyclic) changes of dry and wet years in systems like the Lagunas Encadenadas are the keystone factor in the regeneration of the system. Periodic changes in waterlevel cause a pattern of so called cyclic succession (fig. 16). Diversity and productivity of vegetation, fish and birds "explode" when a series of dry years is followed by wet years.

The same pattern may be valid for cyclic fluctuations in salinity. After a series of dry years in some lagoons salinity can rise considerably. This causes a shift towards communities with a high tolerance for salt. Depending on the salinity, biodiversity may go down. The salinity decreases after a series of wet years. This can cause a strong increase in the production of organisms

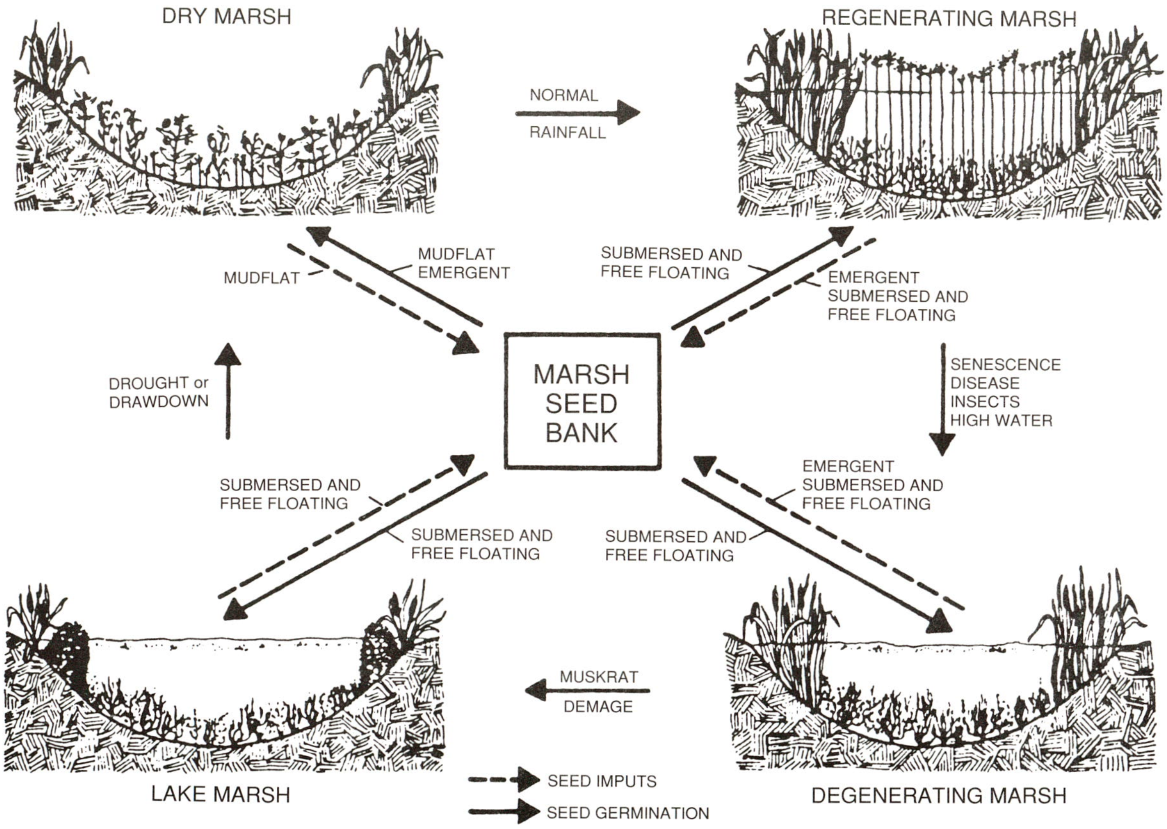


Fig. 16 Cyclic phases of dry and wet periods affecting the vegetation. Animals depending on the vegetation (herbivores) play an important role in this cycle, others (e.g. fish eaters) are closely linked to the different ecological states. From van der Valk (1978).

When the wet years persist diversity and productivity go down gradually as the system gets older. A series of dry years is essential for the regeneration of the helophyte zone and its ecological importance for amphibians, fish and birds. The rate of regeneration of the helophyte zone depends largely upon the hydraulic conditions in spring on the grounds recently fallen dry; a "muddy or marshy" environment is necessary for germination of seeds and survival of seedlings of helophytes.

adapted to fluctuations in salinity like Pejerrey (Iwaskiw, pers.comm.). This is reinforced because of the increase in surface and volume as well as quality of the inundated zone that occurs at the same time. The yield by commercial fisheries recorded in the past also showed large fluctuations which might have been associated with these cyclic patterns (fig. 17).

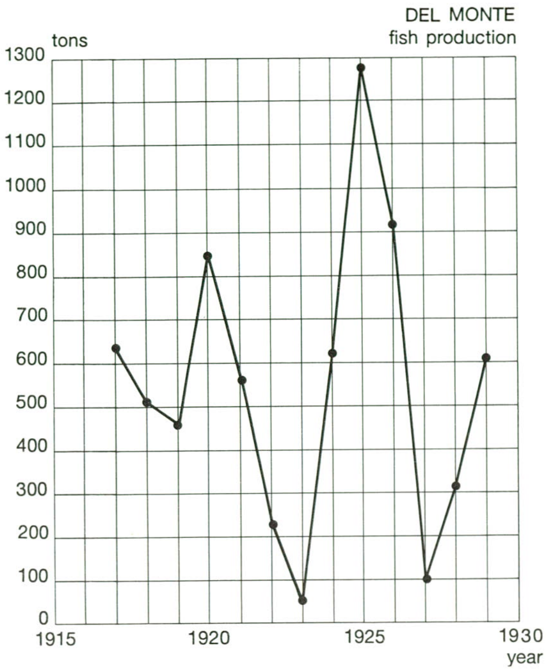


Fig. 17 Periodical changes in annual catch by commercial fisheries at Laguna Del Monte. Data from Grau (1930).

Besides fluctuations in time, there are also spatial fluctuations in salinity. Simulation of the hydrology of the lagoons show that during wet years the fresh and brackish character moves to the western lagoons, whereas in dry years a shift occurs to the eastern lagoons (Delft Hydraulics, 1993). Yet there is always a gradient of saline, brackish and freshwater lagoons. This is supported by the most recent data and by the available historic data (Lopez et al., 1993; Grau 1930; Anonymous 1970, 1979, 1984, 1988).

4.3. The lagunas Encadenadas as part of the wet Pampa system

The Lagunas Encadenadas form a chain of important wetlands and function in periods of drought as a wet island of survival for birds and other organisms of the surrounding Pampa area

Being the upstream part of the rivers Vallimanca and Salado with a total catchment area of ca 12 million ha, the Lagunas Encadenadas are part of a much wider wetland system. This comprises a riverine system of temporarily inundated meadows, permanent or temporal ponds and marshes. During wet years this flooded area may consist of some 2.5-3 million ha as judged from an aerial survey on 12 November 1993 (1300 km of transects covered). Compared to this huge size the 60,000 ha of water that forms the system of Lagunas Encadenadas during wet years may seem small.

Yet these lagoons have a special ecological importance. They form a chain of lakes with a typical gradient in salinity from fresh water to saline, which gives them their special character. Moreover in dry periods the lagoons are one of the few permanent waterbodies in the western part of the pampas, which make them important areas of survival of various organisms typical of the system. Birds for instance may well breed scattered over the pampa during periods of high water tables (own obs.), but retreat to the lagoons at times of drought (Padin, pers.comm.). At those periods the Lagunas Encadenadas are important strongholds in the area. But also in wet years, as 1993, for birds the lagoons form a wetland of international importance (Chapter 4.1.; INTERMEZZO 2).

5. Ecological impact of the flood control alternatives

5.1. Ecological premises

For the productivity and biodiversity of the lagoons it is recommended to stay as close as possible to the natural fluctuations in waterlevel and salinity and to maintain the connection between rivers and lagoons

From the conclusions about the ecological functioning of the Lagunas Encadenadas the following ecological premises can be derived:

- nivellation of the gradient of salt, brackish and freshwater lagoons would reduce their special characteristics and would suppress biodiversity in the overall system
- reduction of the seasonal waterlevel fluctuations would affect the inundated zone and its ecological importance; in addition to that erosion would be enhanced
- a reduction of the long term annual natural fluctuations of the waterlevel would reduce the biodiversity and productivity of the lagoons
- connection of lagoons may lead to the nivellation of biodiversity but depending on the specific case also the stabilisation of certain biological values
- diversion of the inflow of the streams would affect the fluctuations in waterlevel and salinity; moreover the ecological link between lagoon and stream would be broken and the special habitat at the mouth of the streams would be lost

5.2. Ecological impact of the flood control alternatives

From an ecological point of view the alternative with a flexible "canal collector" from Aroyo Pigué to Venado or Del Monte and pumping between (Venado), Del Monte, Cochico and Alsina is preferred. Del Monte and Cochico may be connected

maximum and minimum waterlevels[2]
Because of safety and infrastructure maximum waterlevels have to be chosen. In Epecuen it could be of interest to bring the waterlevel down to the level in the period before the wet years (93 m above sea level). The main objective is to restore the extreme high salinity that is said to be of therapeutical importance. Minimum levels are desired in Del Monte and Cochico because of recreational purposes. The desired minimum level for Del Monte is 103 m, for Cochico 104 m.
Because of the ecological importance of fluctuations of the waterlevel maximum levels should be chosen as high as possible, and minimum levels as low as possible (table 2). The desired minimum levels for recreation correspond with the ecological acceptable minimum levels, so there seems no contradictionary interest in this respect. From a historical point of view an initial waterlevel of 93 m with the corresponding salinity in Epecuen is correct. But one should be aware of the consequences to bring the level down this far. According to the model runs in the worst case it would take up to 30 years (case 5a) to reach this level.

Stagnant levels are ecologically far less desirable. The choice for minimum levels implies also import of water from upstream areas to downstream areas. This can have a disturbing effect on the dynamics of naturally occurring waterlevels as well as on salinity. It is also related to the hydraulic measures in the upstream areas, which in detail cannot be judged by now. Furthermore it opens the possibilities for Carp to migrate to other lagoons, where it can compete with the original fish population.

Along with the choice for maximum and minimum levels it is essential that between these levels natural fluctuations occur; fluctuations that can occur without human interference. The maximum and minimum levels should not be considered as fixed target values, but as limits. Measures as to assure flood control or water supply should only be taken when the maximum or minimum waterlevels are exceeded. When the minimum waterlevel falls below the threshold, supply of water in winter time is the least disturbing in ecological respect.

2 maximum and minimum levels are defined as levels that should not be exceeded

Table 2 *Maximum and minimum (desired and ecologically acceptable) levels (m).*

Laguna	maximum*	minimum (desired)	minimum** (ecologically acceptable)
Alsina	112		(109)
Cochico	106.5	104	(104)
Del Monte	106	103	(103)
Venado	106		(102)
Epecuen	99	<93	(93)

* latest information from IATASA

** derived from morphometrics of the lagoons and C_0-alternative (Delft Hydraulics, 1993)

() not strictly minimum, by preference lower

pumping from one laguna to another

Pumping water from one laguna to another is part of the suggested flood control alternatives (intermezzo 1). The difference in salinity between Epecuen and the other lagoons is much higher than the differences between the other adjacent lagoons. Especially under wet conditions the gradient in salinity from Venado to Alsina is rather gradual. Pumping of salt water from Epecuen to Venado and the other lagoons causes a sharp rise in salinity there and nivellates the gradients in the lagoon system and should therefore be avoided. Pumping between the other lagoons has just a small influence on the natural fluctuations and gradients, as long as only is pumped when the maximum waterlevels are exceeded.

open connections between the lagoons

Some flood control alternatives imply open connections between Venado, Del Monte and Cochico or between Cochico and Del Monte only (intermezzo 1). Although the ecology of these lagoons resembles each other in certain aspects, connection of these lagoons is not without effects. Open connections reduce the minimum and maximum waterlevels of the different lagoons to the most critical (Del Monte), cause a slight reduction of the seasonal waterlevel fluctuations and nivellate the salt gradients between the connected lagoons, especially under dry conditions. However, these effects of the connection of Del Monte and Cochico are not considered too serious. In the past these lagoons have been connected in some periods (Grau 1930). A positive effect of connection of Del Monte and Cochico is the enlargement of the living and breeding area for Pejerrey and other species of fish. The effects of connecting Venado to Del Monte and Cochico have to be considered more serious. Connection means here more reduction of the dynamics in waterlevel fluctuations and the reduction of the overall gradient in salinity of the entire system.

canal collector

Inflowing river water can be diverted from the lagoons by means of a canal collector (intermezzo 1). The canal collector as proposed in the hydraulic alternatives diverts continuously river water from the lagoons. This has an considerable effect on the waterlevel fluctuations and salinity. Also it cuts off the ecosystem of the laguna from that of the river and makes the transitional habitat in the mouth of the river disappear. The same effects, but to a lesser extent, occur when only part of the inflowing water is diverted. In this way a canal collector has to be judged harmful for the ecology of the lagoons.

If the canal collector is only used to bring the waterlevel down to the desired maximum level and after that the river would flow under normal conditions into its own laguna, it can be considered an acceptable solution. Only when a canal collector is used to bring down the waterlevel in Epecuen to 93 m, this would take up to 30 years of continuous diversion. In practice this would mean a permanent diversion.

Another point is the question from where to where a canal collector should be built. Two points are important here: the impact on groundwater currents and on the hydrology of the receiving laguna. In theory the canal collector could cut through groundwater currents and could drain the surrounding area. Therefore it should be constructed as far north as possible and should be not longer and deeper than necessary (Maiola, pers. comm.). This pleads for a canal collector from A.Pigué to Venado or (longer) to Del Monte. Diverting water from the A.Pigué to Venado reduces the minimum and maximum salinity of this laguna considerably (1.6 - 8.3 gCl^-/l instead of 2.3 - 18.3 gCl^-/l according to case 5a), yet it stays within the range of a brackish lake. Diverting continuously riverwater from the A.Pigue and A.Venado to Del Monte may change Venado from a brackish laguna into a hypersaline laguna (>20 g Cl^-/l). These high salinity levels will bring down diversity and productivity in Venado to the (low) level of Epecuen. This pleads for a canal collector between A.Pigué and Venado and pumps between Venado and Del Monte.

The negative effects of a canal collector between A.Pigué and Del Monte however may be anticipated. The canal collector should be constructed in such way that water is diverted to Venado as long as the maximum level in Venado is not exceeded. When the maximum water level in Venado threatens to be exceeded, then water should be diverted to Del Monte. In this scenario pumps between Venado and Del Monte are not needed.

presa in A.Pigué

The possibility of the construction of a dam in the A.Pigue is in discussion. The so formed storage basin ("presa") should be as large as to comprise some 25 hm^3 of water, being the amount of water not entering Epecuen during times of superfluous discharge (1 m^3/sec, 50 % reduction). This water could be used during spring for complementary irrigation. The collecting basin should be emptied each year to assure its safety action. This option has not been worked out yet.

A storage basin differs from a retention basin. The main purpose of a retention basin is the retention of flood peaks. It should be seen in combination with a canal collector. In this case the capacity of the canal collector can be smaller than without retention basin. As long as the operation rules are the same as those of a canal collector, the ecological impact is the same. Costs will make the main difference.

A storage basin is a multipurpose basin: the purposes are floodcontrol and watersupply for agriculture. The water in the basin has to be used for complementary irrigation.

Because of the absence of a canal and because other lagoons are not influenced by the diversion of river water the option of a storage basin might be promising with respect to the ecology of the lagoons. Premise is that the ecological impact on Epecuen is comparable with that of a canal collector. Therefore it is recommended to work out this option more in detail.

6. Conclusions and recommendations

conclusions

Confronting the ecological directives with the flood control alternatives leads towards the following conclusions:

- Maximum levels should be chosen as high as possible, and minimum levels not or as low as possible (table 2)
- Between maximum and minimum waterlevels natural fluctuations should be accepted
- Pumping between Epecuen and Venado should be avoided. Pumping between the other lagoons has ecologically little effect
- A canal collector should function only if the maximum waterlevel is about to be exceeded. A canal collector from A.Pigué to Venado has ecologically the least impact
- A canal collector to Del Monte has the same ecological impact as a canal collector to Venado, when under normal conditions water is diverted to Venado. Only when the maximum level in Venado is exceeded water can be diverted to Del Monte so no pumps are needed between Venado and Del Monte
- An open connection between Del Monte and Cochico has ecologically little effect. For Cochico the situation even may improve. An open connection between Venado, Del Monte and Cochico has negative ecological effects for Venado and the system as a whole, by reducing the typical gradients and dynamics
- A storage basin in A.Pigué could be a promising option with respect to the ecology of the lagoons

The alternatives that correspond with these conclusions are shown in fig 18.

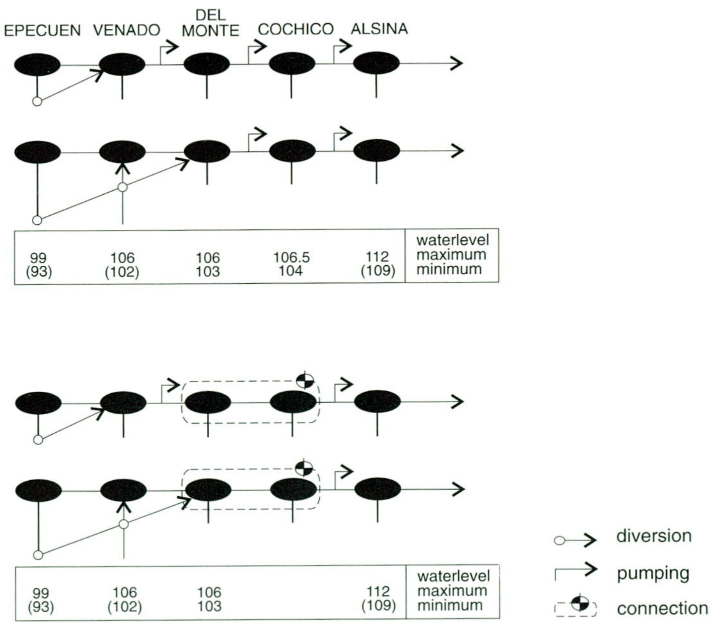


Fig.18 Alternatives for flood control that have the least ecological impact in case a solution with a canal collector has been chosen.

recommendations

The ecological impact assessment of the masterplan for the Lagunas Encadenadas is mainly based on preliminary results of the different flood control alternatives. The ecological effects of bringing water to the lagoons in order to maintain a minimum level could only be estimated very globally because concrete hydraulic information was not available at the time of the mission. Depending on the chance that wet or dry periods will occur, watersupply can perhaps become of more importance in the future than flood control. In the final masterplan IATASA will try to asses the probability of the occurrence of wet and dry periods and the consequences for the watermanagement. If watersupply turns out to become of great importance, a more detailed ecological impact assessment is desired.

The same counts if the final results of the hydraulic evaluation of the flood control alternatives turn out to differ strongly from the preliminary results.

In relation with the actual situation (case 0), from an ecological point of view the possibility just reinforcing the dikes seems worthwhile to be analyzed in the policy analysis of the masterplan. In the preliminary evaluation, however, this option is considered not realistic, because there is no local support for this alternative. By means of a hydraulic simulation of a storage basin upstream the A.Pigué the effectiveness for floodcontrol should be evaluated properly.

In order to improve the water quality it is recommended to quantify the nutrient balance of the lagoons. Based on this analysis a plan can be worked out to diminish the eutrophication of the lagoons. Part of this plan can be purification of the water through the biological activity of helophytes. Either at the inlets of the streams or along the shores these vegetations should be promoted.

In order to balance the different forms of use by man that will be made in future of the total system it is recommended to destinate certain areas as nature reserves which may become integrated into the total plans for development of the area. Further investigations about the natural values is necessary. Nothing is known about the winter ecology of the lake system. Especially for birds the area has great potential as a wintering site. It is therefore recommended to have an integrated aerial count in July 1994 in order to make a full comparison possible with other wetlands in Argentina and the rest of latin America.

The final decision making about the plans should be accompanied by monitoring research in order to judge the effects of the various measures.

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APPENDIX 1

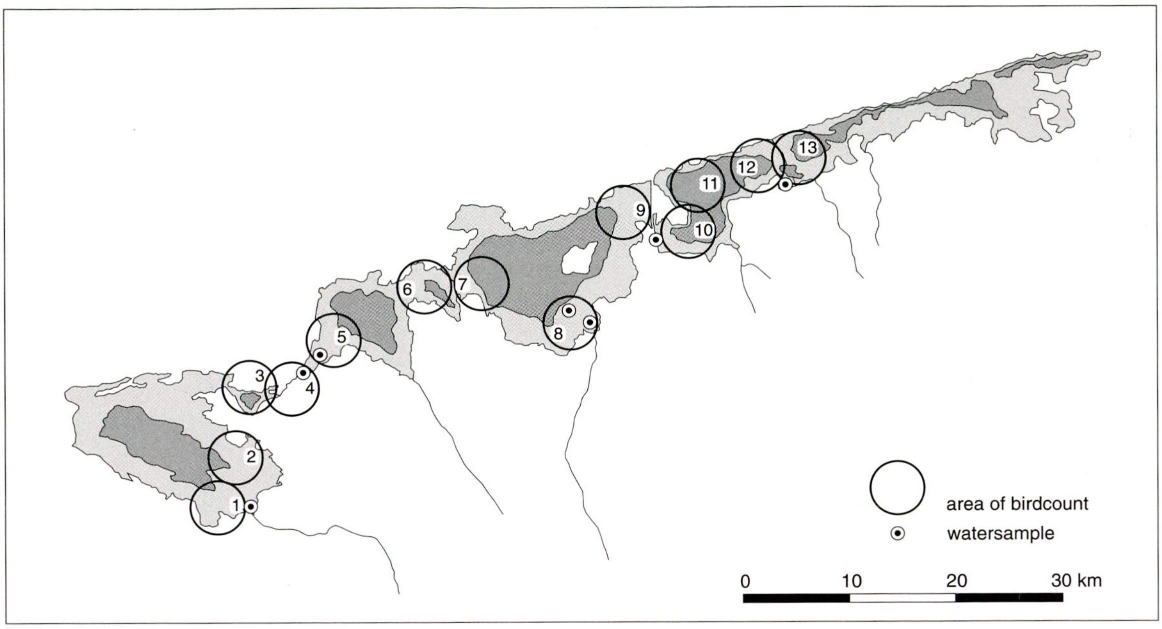
Set up of the field study

During the field visit the shore area of the different lagoons was visited. Birds were identified and counted with the use of binoculars and a 20-45 * telescope. The areas where birds were counted are shown in the figure of this appendix.

birds
An integral bird count of the larger species was conducted at 12 November 1993. Visibility was excellent (15 kms) and there was little wind (3 Beaufort). During an eight hours flight with a Cessna 182, flying at an altitude of 1000 feet and 80 knots the entire shoreline of all lagoons was covered. The area was divided in 30 stretches of about equal shore length. The presence of shore vegetation (helophytes, presence of inundated meadows) was recorded simultaneously using an index. This ranged from 0 (no records) to 5 (entire shore with emergent vegetation and extensive inundated areas. The same was done for the aquatic vegetation which could be identified from the air. Here also a five points scaling procedure was used ranging from 0 (no aquatic vegetation) to 5 (80-100 %) coverage of stretch.
The stretch flown was from La Plata - Coronel Suarez - Lagunas Encadenadas - Tandil - La Plata.

water quality
We took samples of water from different parts of the lagoons and some streams entering these lagoons. Water samples were stored as cool as possible in 250 ml plastic bottles which were kept in the dark. Samples were analyzed at Oranjewoud laboratories at Lelystad.
Zooplankton was collected in the near shore area using a 200 * 10^{-6} m mesh sampling net. Ten times five litres of water were taken per sample. The samples were preserved with formaldehyde.

bottom samples
At two places bottom samples were taken, both in recent sedimentation areas of the streams A. Pigué and A. Guamini. The samples were taken under water with the aid of a core sampler. Five cores were mixed and in total 1 litre of soil was taken per sample. Chemical analyses were performed at Tauw laboratories. The results of the samples are presented in Appendix 3.



Bird counting areas from ashore (circles) and points where water- and zooplankton samples were taken.

APPENDIX 2

List of birds

List of bird species encountered in the area of Lagunas Encadenadas. Numbers indicate total count during aerial investigation at 12 November 1993. A short characterization of habitat and abundance is given. Also data about breeding are indicated.

Rhea americana Greater Rhea Nandu	Up to 8 birds with young, NW of Laguna la Paraguaya
Rhynchotes rufescens Red w. Tinamou Colorada	Scattered breeder in fields south of Epecuen and Venado
Nothura maculosa Spotted Tinamou Inambu Commun	Common breeder in fields all over the region
Podiceps dominicus Least Grebe Macacito Gris	Two birds 7 November 1993 at inundated meadows west of Guamini
Podiceps rolland White Tufted grebe Maca Commun	Common breeder in freshwater areas with aquatic vegetation
Podiceps occipitalis Silvery Grebe Maca Plateado	Regular breeder in freshwater areas with aquatic vegetation
Podilymbus podiceps Pied-billed Grebe Maca Pico Grueso	Regular breeder in brackish and freshwater lagoons
Podiceps major Great Grebe Huala	Widely distributed breeder and summer visitor of lagoons
Phalacrocorax olivaceus Neotropical Cormorant Bigua	Common summer visitor to all lagoons. Total count 15,800
Ardea cocoi White-necked Heron Garza Mora	Regularly distributed along shores with helophytes. Some breed at Alsina (10-15 p)
Syrigma sibilatrix Whistling Heron Chiflon	Some observations in densely vegetated areas around Alsina
Casmerodius albus Great Egret Garza Blanca	Breeds with 50 p at Alsina, 80 p at Inchauspe, total count 1120 along shores
Egretta thula Snowy Egret Garcita Blanca	Breeds with 15 p at Alsina, 100 p at Inchauspe, total count 2442 along shores
Bubulcus ibis Cattle Egret Garcita Bueyera	Common with cattle on somewhat drier soils. Total count 405
Botaurus pinnatus Pinnated Bittern Mirasol Grande	Scattered along shores with extensive helophytes. May breed at Inchauspe
Butorides striatus Striated Heron Garcita Azulada	Scattered along shores with helophytes

Nycticorax nycticorax Black-crowned Night-Heron Garza Bruja	Regular distributed, mostly imm.
Euxenura maguari Maguari Stork Ciguena Americana	Few observations around Laguna Inchauspe and Alsina
Phimosus infuscatus Bare-faced Ibis Cuervillo Pico-Marfil	Widely distributed at the somewhat drier fields in the region
Plegadis chihi White-faced Ibis Cuervillo de Canada	Very common in wet meadows Total count 2840
Ajaia ajaja Roseate Spoonbill Espatula Rosada	Scattered in freshwater lagoons Total count 50
Phoenicopterus chilensis Chilean Flamingo Flamenco Austral	Flocks in brackish lagoons Total count 254
Chauna torquata Southern Screamer Chaja	Some observations around Alsina and Inchauspe
Dendrocygna bicolor Fulvous Tree Duck Siriri Colorado	Widely distributed in wet meadows, scattered breeder
Dendrocygna viduata White-faced Tree Duck Siriri Pampa	Common in wet meadows and marshes, breeder and visitors
Coscoroba coscoroba Coscoroba Swan Coscoroba	Breeds in small number along vegetated shores. Total count 2762, probably pre-moult
Cygnus melancoryphus Black-necked Swan Cisne Cuello Negro	Breeds in small number along vegetated shores. Total count 3850, probably pre-moult
Chloephaga picta Upland Goose Cauquen Comun	One observation Laguna la Paraguaya of a male bird 8 November 1993
Anas sibilatrix Southern Wigeon Pato overo	Common in areas with floating vegetation, also scattered breeder
Anas georgica Brown Pintail Pato Maicero	Widely distributed and very common, common breeder
Anas flavirostris Speckled teal Pato Barcino	Widely distributed and rather common, common breeder
Anas platalea Red Shoveler Pato Cuchara	Widely distributed and rather common, common breeder
Anas cyanoptera Cinnamon Teal Pato colorado	Widely distributed but scarce, in freshwater habitat. Scattered breeder
Anas bahamensis White-cheeked Pintail Pato Gargantilla	Widely distributed but scarce, in brackish and freshwater. Scarce breeder
Anas versicolor Silver Teal Pato Capuchino	Not very common and closely linked to freshwater habitat Scattered and scarce breeder

Netta peposaca Rosy-billed Pochard Pato Picazo	Not very common and closely linked to freshwater habitat
Heteronetta atricapilla Black-headed Duck Pato Cabeza negra	Few times observed, Alsina
Oxyura vittata Lake Duck Pato-ambulidor Chico	Widely distributed but not common. Scattered breeder
Elanus leucurus White-tailed Kite Milano Tijereta	Extensively managed pastures
Buteogallus uribitinga Great Black Hawk Aguila Negra	Two birds at Alsina, well south of normal distribution
Rostrhamis sociabilis Snail Kite Caracolero	Common in inundated meadow area
Circus buffoni Long-winged Harrier Gavilan Planeador	Scattered over entire area
Circus cinereus Cinereous Harrier Gavilan Ceniciento	Scarce at somewhat higher fields
Buteo magnirostris Roadside Hawk Taguato Commun	Very common
Harpyhaliaetus coronatus Crowned Eagle Aguila coronada	One observation Sierra de la Ventana
Polyborus plancus Crested Caracara Carancho Commun	Widely distributed but scarce
Milvago chimango Chimango Caracara Chimango	Very common, often in small flocks
Falco peregrinus Peregrine Falcon Halcon Peregrino	One observation, la Paraguaya
Falco sparverius American Kestrel Halconcito Commun	On higher fields, few records
Aramus guarauna Limpkin Carau	Widely distributed but mostly smaller flocks at higher fields
Fulica armillata Red-gartered Coot Gallareta Ligas Rojas	Rather common in vegetated areas, common breeder Alsina
Fulica leucoptera White-winged Coot Gallareta Chica	Very common in areas with floating vegetation. Total count 10557
Fulica rufifrons Red-fronted Coot Gallareta Escudete Rojo	Rather common in vegetated areas. Scattered breeder
Gallinula chloropus Few observations Alsina Common Gallinule Polla Negra	

Hemantopus melanurus South American Stilt Tero real	Common along shores and inunda ted meadows. Common breeder
Vanellus chilensis Southern Lapwing Teru-Teru Commun	Very common and widely distributed breeder on pasture land and fields
Pluvialis dominica American Golden Plover Chorlo Dorado	Some flocks la Paraguaya
Tringa melanoleuca Greater Yellowlegs Pitotoi Grande	Scattered Laguna Alpataco, Venado
Tringa flavipes Lesser Yellowlegs Pitotoi Chico	Inundated meadows, common
Calidris melanotos Pectoral Sandpiper Playerito Escudado	Scattered Laguna Alpataco, Venado, la Paraguaya
Limosa haemastica Hudsonian Godwit Becasa de Mar	Few birds seen at Laguna la Paraguaya
Gallinago gallinago Common Snipe Becassina Commun	Widely distributed
Steganopus tricolor Wilson's Phalarope Falaropo Tricolor	225 birds counted la Paraguaya
Larus dominicanus Kelp Gull Gaviota Cocinera	Breeds at Laguna del Monte some 150 nests counted at islet Total count 850 birds
Larus cirrhocephalus Grey-hooded Gull Gaviota Capucho Gris	Scattered over brackish area
Larus maculipennis Brown-hooded Gull Gaviota Capucha Cafe	Scattered over entire area Breeds Alsina
Sterna trudeaui Snowy-crowned Tern Gaviotin Corona Blanca	Some birds seen along shores
Sterna hirundinacea South American tern Gaviotin Sudamericano	A single bird at Del Monte 8 November 1993
Columba picazuro Picazuro Pigeon Picazuro	Common in wooded areas
Columba maculosa Spot-winged Pigeon Paloma Manchada	Few observations in wooded and rural areas
Columba livia Rock Dove Paloma Casera	Common in rural areas
Zenaida auriculata Eared Dove Torcaza	Very common in rural areas
Columbina picui Picui Ground Dove Torcacita	Common in rural areas

Cyanoliseus patagonus Burrowing Parrot Loro Barranquero	Pasture land with scattered trees A. Pigue upstream area
Myopsitta monachus Monk Parakeet Cotorra	Few observations in cultivated areas
Dromococcyx phasianellus Guira Cuckoo Pirincho	Common in rural areas
Speotyto cunicularia Burrowing Owl Lechucita Pampa	Few observations between Epecuen and Venado
Asio flammeus Short-eared Owl Lechuzon Campestre	One observation, la Paraguaya
Colaptes campestris Field Flicker Carpintero Campestre	Near Epecuen in pasture area
Colaptes melanolaimes Golden-breasted Woodpecker Carpintero Real Commun	Near Epecuen one observation
Geositta cunicularia Common Miner Caminera Commun	Common in drier pampa area
Furnarius rufus Rufous Hornero Hornero Commun	Wooded area near Carhue
Phleocryptes melanops Wren-like Rushbird Junquero	Reed beds Alsina, breeds
Xolmis irupero White Monjita Monjita Blanca	Few observations rural areas
Hymenops perspillicata Spectacled Tyrant Pico de Plata	Widely distributed, bushes and extensively managed pastureland, along streams Lago Epecuen, Eucalyptus alley
Knipolegus aterrimus White-winged Black Tyrant Viudita Commun	
Serpophaga nigricans Sooty Tyrannulet Piojito Gris	A. Pigue, stream edge
Pitangus sulphuratus Great Kiskadee Benteveo Commun	Common in rural areas with trees
Muscivora tyrannus Fork-tailed Flycatcher Tijereta	Very widespread in fields with
Pyrocephalus rubinus Vermillion Flycatcher Churrinche	On higher soils Epecuen
Progne modesta Southern Martin Golondrina Negra	Common along shores of lagoons
Phaeoprogne tapera Brown-chested Martin Parda grande	Common along shores of lagoons

Tachycineta leucorrhoa White-rumped Swallow Golondrina Ceja Blanca	Fields south of Paraguaya
Passer domesticus House Sparrow Gorrion	In villages
Sicalis luteola Grassland Yellow Finch Misto	Very common breeder on higher soils
Zonotrichia capensis Rufous-collared Sparrow Chingolo	Widely distributed
Embernagra platensis Great Pampa Finch Verdon	Regularly seen on higher fields
Agelaius thilius Yellow-winged Blackbird Ala Amarilla	In marshy area, freshwater
Pseudoleistes virescens Brown-and-yellow Marshbird Dragon	Common in marshy areas
Sturnella loica Long-tailed Meadowlark Loica Commun	Upstream area of A. Pigue Sierra de la Ventana

APPENDIX 3

Quality of bottom samples from the mouth of A.Pigué and A.Guamini

COMPONENT		A. Guamini	A. Pigue
lutum < 2 µm	%	8.7	10.6
silt < 16 µm	%	14.5	21.9
fraction 63 m	%	37.7	52.4
calcium carbonate	%	2.5	6.5
elementary carbon	%	0.9	1.6
fraction > 2000 µm	%	0.0	0.0
EOX	mg Cl/kg	0.4	0.5
phenol	µg/kg	20	24
benzo(b)fluoranthene	mg/kg	<0.05	<0.05
benzo(k)fluoranthene	mg/kg	<0.05	<0.05
benzo(ghi)perylene	mg/kg	<0.05	<0.05
indenopyrene	mg/kg	<0.05	<0.05
fluoranthene	mg/kg	<0.10	<0.10
benzo(a)pyrene	mg/kg	<0.05	<0.05
dry matter (NEN 6620)	%	66.9	52.5
As	mg/kg	4.5	6
Cr	mg/kg	9	9
Cu	mg/kg	12	15
Hg	mg/kg	<0.1	<0.1
Pb	mg/kg	<10	<10
Zn	mg/kg	36	45
Cd	mg/kg	<1	<1
Ni	mg/kg	<1	<1