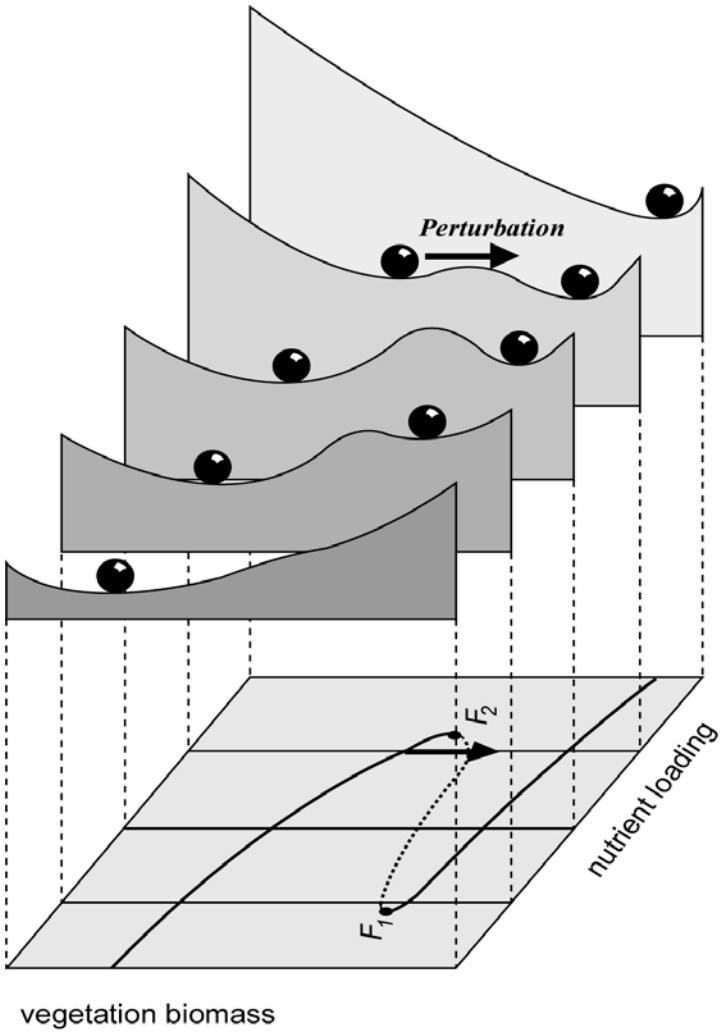
BALANCING AT THE TIPPING POINT: LAGUNA DEL DIARIO AND THE MECHANICAL HARVESTING OF SUBMERGED PLANTS

Mazzeo N, Iglesias C, Inda H, García-Rodríguez F, Lotter AF, Goyenola G, Teixiera de Mello F, Vanderstukken M, Garay A, Pacheco JP, Vianna M, Fosalba C, García S, Lopes Figueira R, Michaelovitch de Mahiques M, Bracco R, Stutz S & E Jeppesen

CURE
Centro Universitario de la Región Este



Shallow lakes are amongst the most analyzed examples of systems with alternatives states, the causal and buffer mechanisms involved are very well understood

Laguna del Diario. Spring 2006

The proliferation of submerged plants (as a consequence of eutrophication) has both positive and negative effects on water quality and ecosystem services

The latter one is a serious problem when the whole water surface remains completely covered by plant biomass. In such cases, plant removal could be a desirable strategy

Laguna del Diario. Autumn 2009

Is it possible to partially remove the submerged plants without adverse consequences (avoiding a critical transition to a turbid state dominated by cyanobacteria)?

34°54´09.06´´S
56°00´25.60´´W
Uruguay, South America

Basin
Area: 23.2 km2
Perimeter: 24.3 km
Slope: 5.0%
Two main tributaries

Shallow reservoir
Area (including wetland zones): 165 ha
Water area without emergent plants: 55 ha
Mean depth: 1.5 m

Isolated from the ocean since the second half of XX century (definitively since 1970)

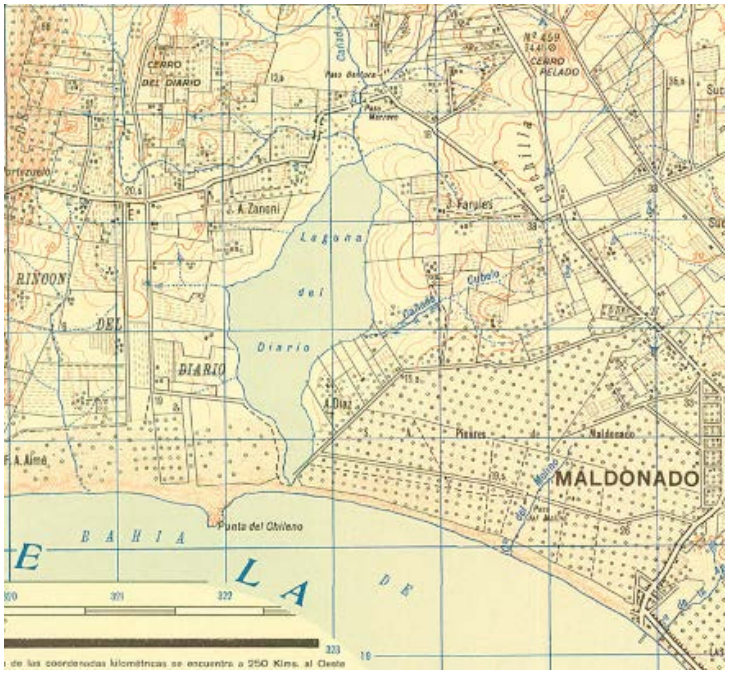
Eutrophic ecosystem dominated by submerged plants since 2003

The players

MAIN QUESTIONS?	APPROACH
Is Laguna del Diario under an eutrophication process?	Paleolimnological and limnological evidence
Which are the main changes in the submerged plant coverage and composition during 2000 decade?	Spatial distribution and PVI estimation according to Canfield et al (1984)
What are the main effects of submerged plants harvest?	Whole-lake unreplicated experiment
How resilient is the biomass plant removal?	Mesocosm and lab experiments
Is it possible a positive role of the stakeholders and policymaker during the design and implementation of aquatic plant control program?	Socio-economic experiment and network analysis

Is Laguna del Diario under an eutrophication process?

1939

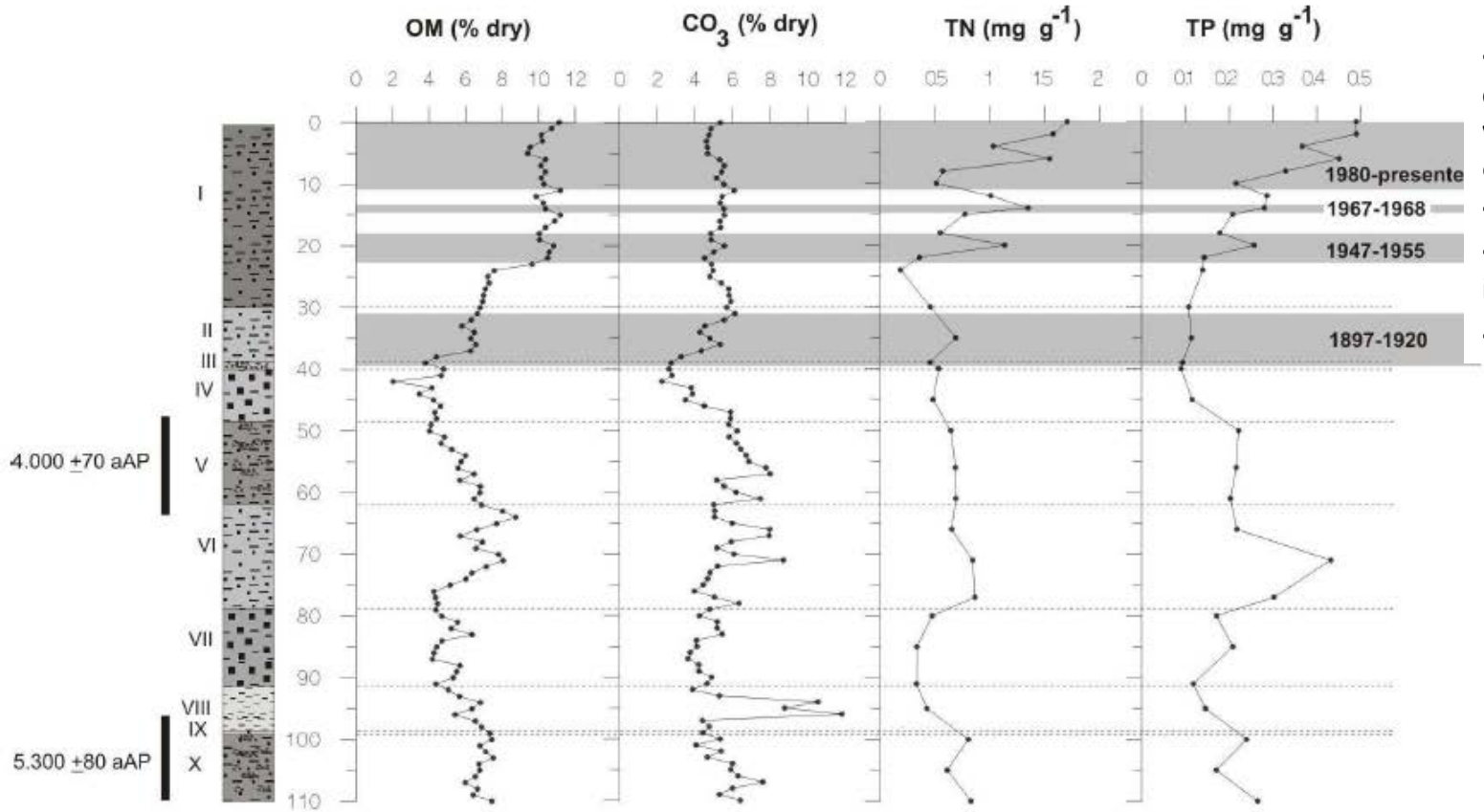


Open water area

1966= 165 ha

2001= 56 ha

2005= 55 ha

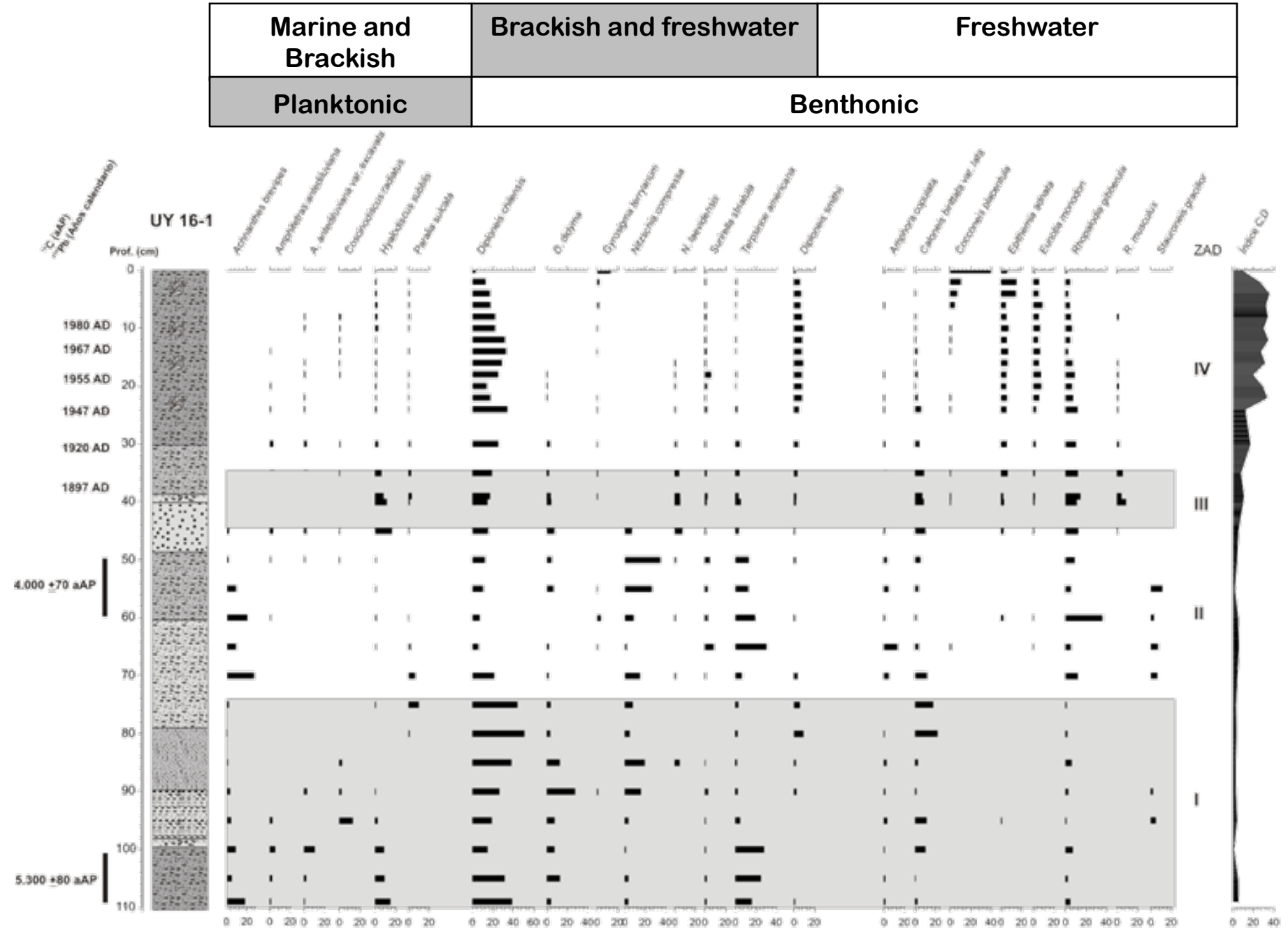


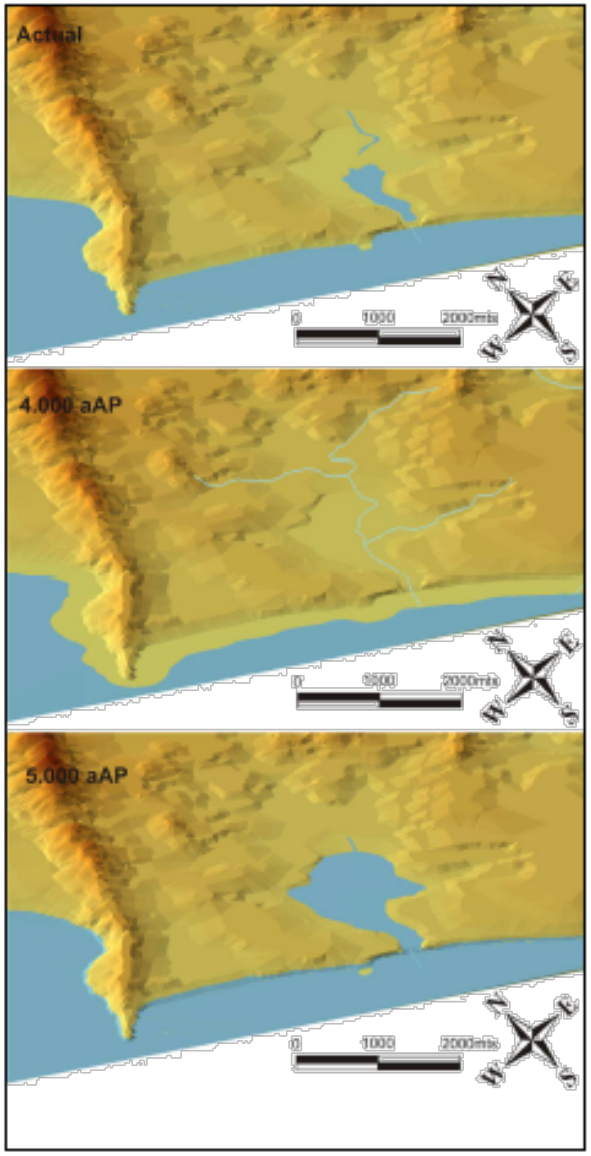
+ Urban development without sewage effluent treatment

+ Drinking water supply

+Route 10 and ocean isolation

+Forestation 1800 ha


Marine and Brackish
Brackish and freshwater
Freshwater
Planktonic
Benthonic
UY 16-1
Prof. (cm)
1980 AD
1967 AD
1955 AD
1947 AD
1920 AD
1897 AD
4.000 ±70 aAP
5.300 ±80 aAP
Achnanthes brevipes
Amphipleura sigmoidea
A. anastomosans var. excavata
Cocconeis placentula
Hyalodiscus subtilis
Paralia sulcata
Diploneis chilensis
D. didyma
Gyrosigma tenuirostrum
Nitzschia compressa
N. levidensis
Surirella striatula
Terpsinoe americana
Diploneis smithii
Amphora copulata
Caloneis bacillum var. las
Cocconeis dalmatica
Eunotia arcus
Eunotia monodon
Rhopalodia gibberula
R. musculus
Stauroneis phoenicer
ZAD
Indice C/D
IV
III
II
I

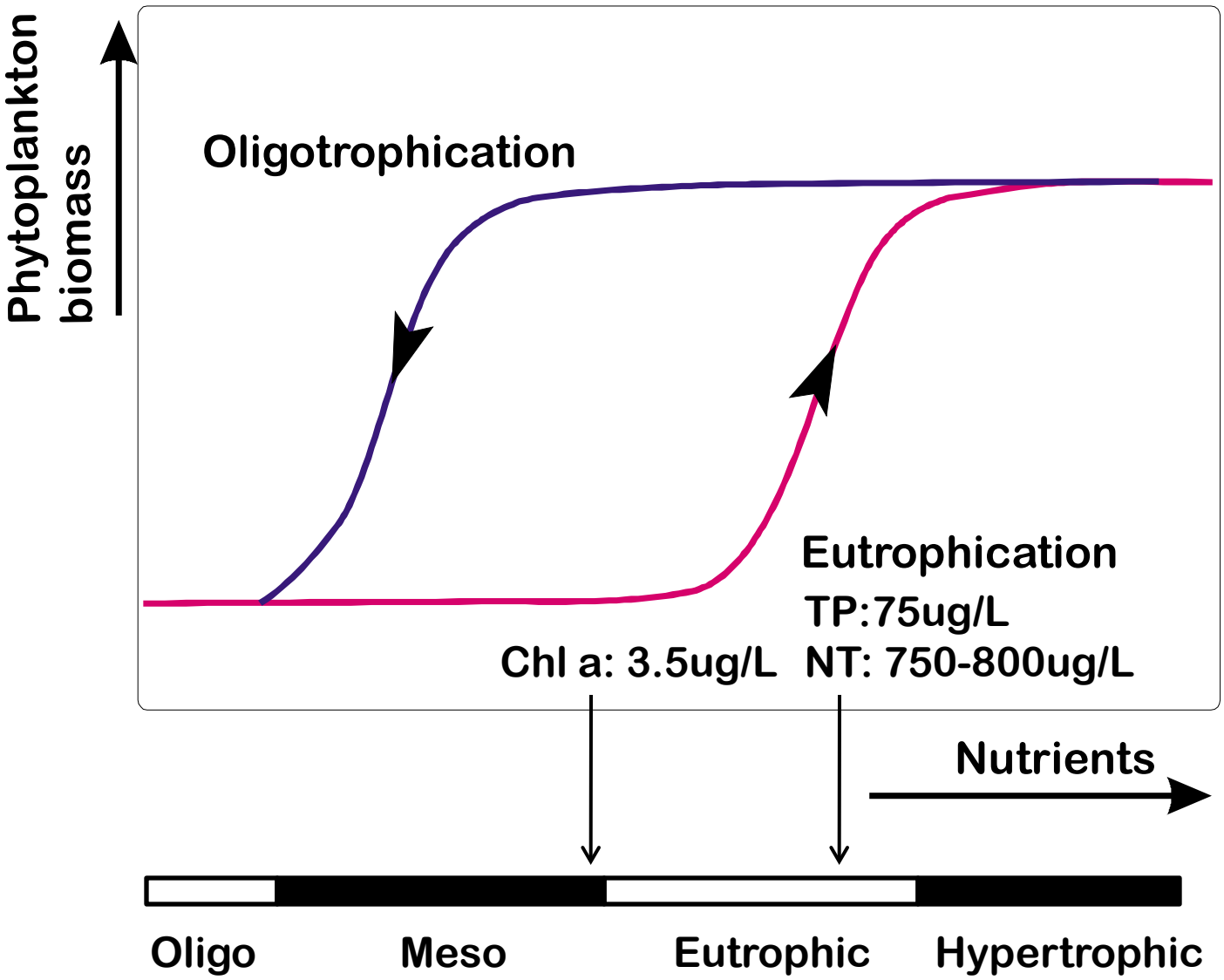


Laguna del Diario was a stream with a drainage occlusion by the coastal dune system during the Holocene

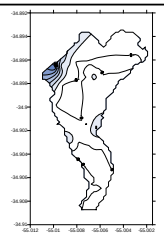
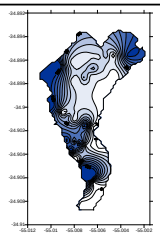
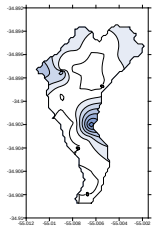
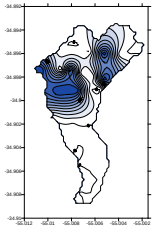
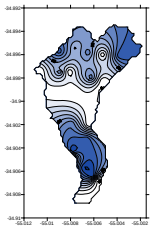
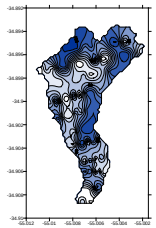
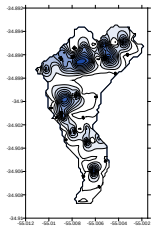
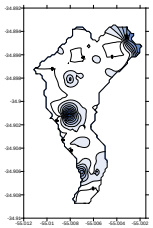
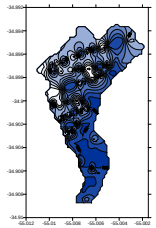
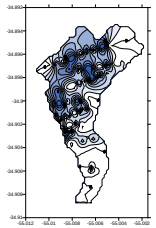
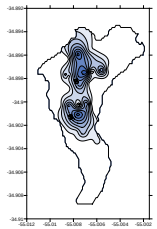
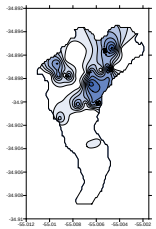
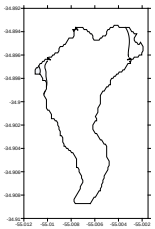
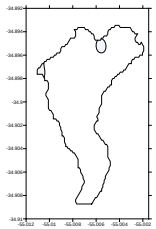
Laguna del Diario is under an accelerated eutrophication process, which started by 1900 with Pinus forestry activities

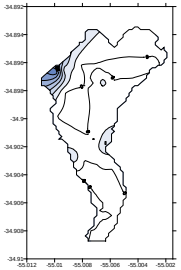
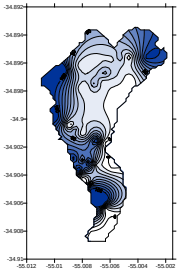
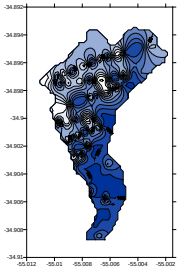
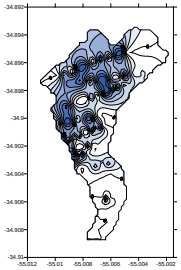
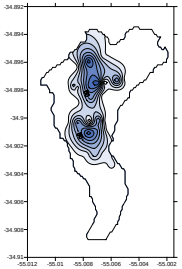
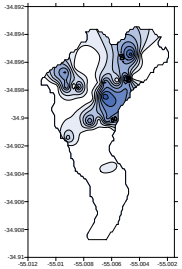
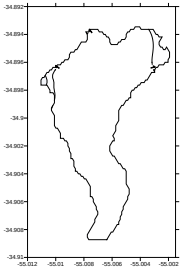
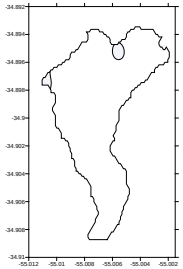
This human perturbation and the construction of the highway (completed in 1970) led an increased of water retention time and modified the brackish conditions

The tourism development, during the last 40 years, without adequate water sewage treatments could explain the tendencies observed at the top (10 cm)


Phytoplankton biomass
Oligotrophication
Eutrophication
TP:75ug/L
Chl a: 3.5ug/L
NT: 750-800ug/L
Nutrients
Oligo
Meso
Eutrophic
Hypertrophic

Which are the main changes in the submerged plant coverage and composition during 2000 decade?

	Myriophyllum quitense	*Potamogeton illinoensis*	*Potamogeton pusillus*	*Egeria densa*
01/2003				
12/2004				
03/2006				
08/2006				
harvest				
07/2007				

	Myriophyllum quitense	*Potamogeton illinoensis*	*Potamogeton pusillus*	*Egeria densa*
01/2003				
08/2006				
07/2007				

2006-2007

2008-2011

The initial purpose of the mechanic harvest was to control M. quitense, preserve and facilitate the expansion of P. illinoensis. An adaptive management plan was implemented. The harvest activities started on December 23th (2006).

Mechanical harvest between spring and summer: MH

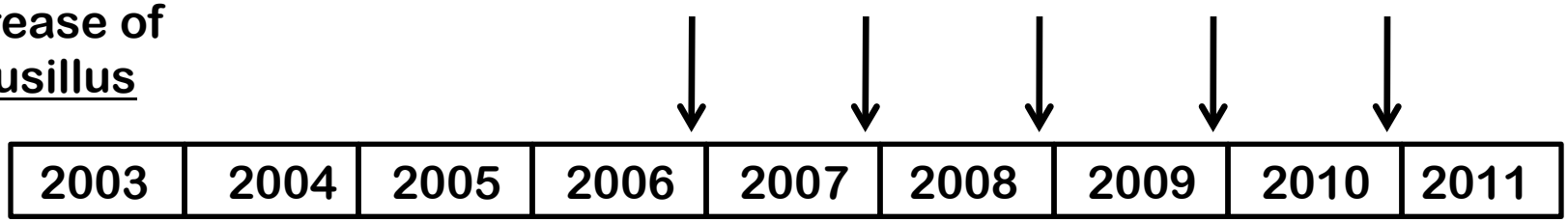
M. quitense

M. quitense
P. illinoensis

P. pusillus

E. densa

Drastic coverage increase of P. pusillus



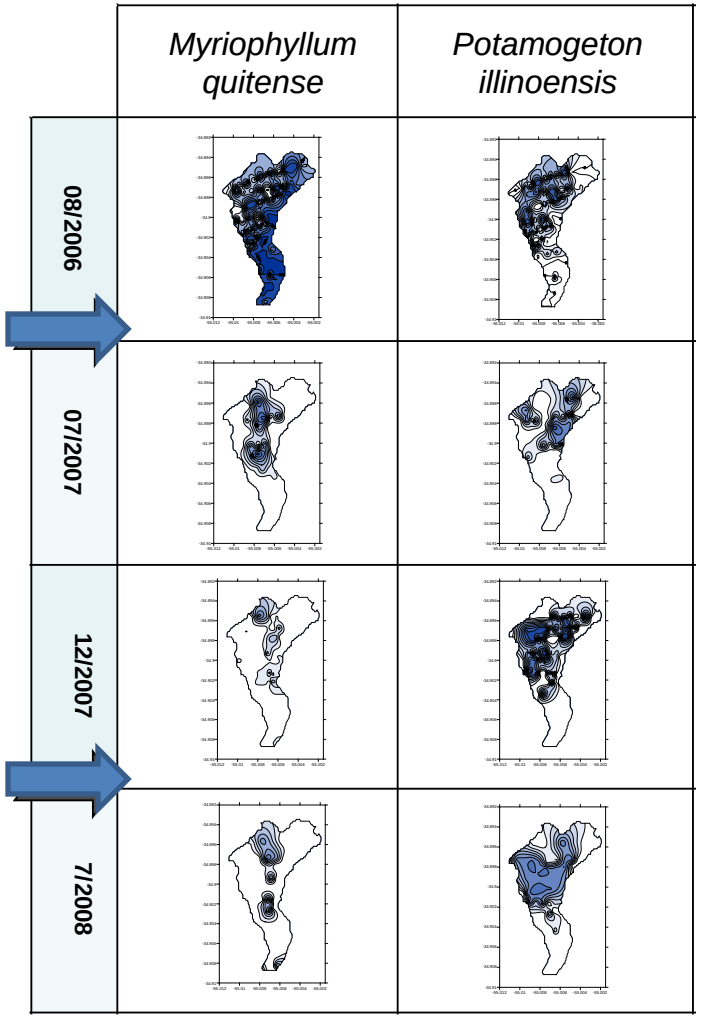
Replacement sequence of P. pusillus by M. quitense and P. illinoensis

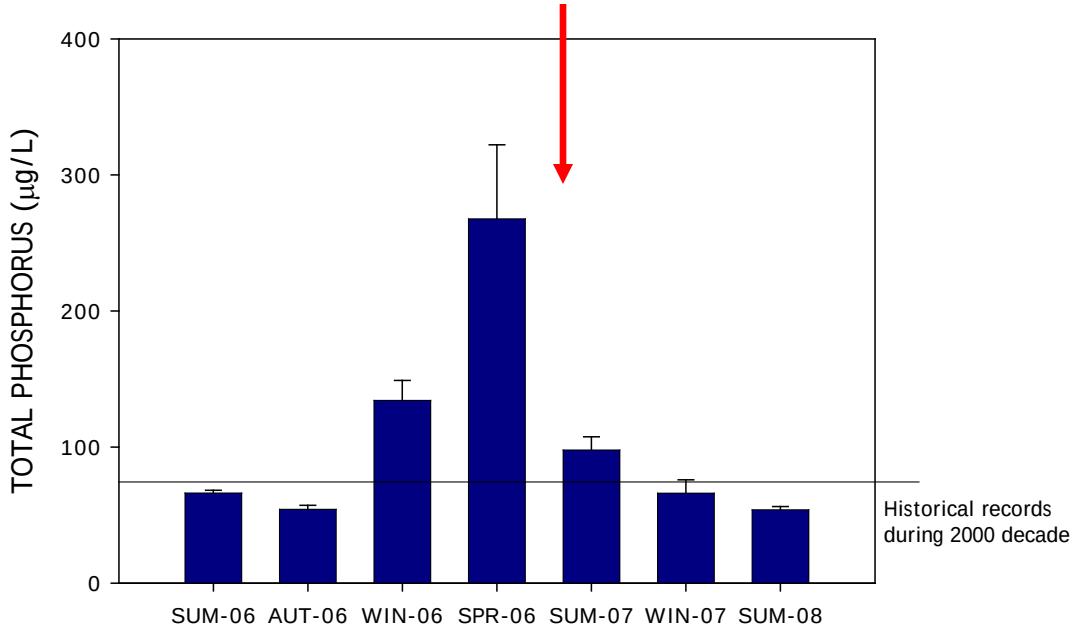
Succession (facilitation)

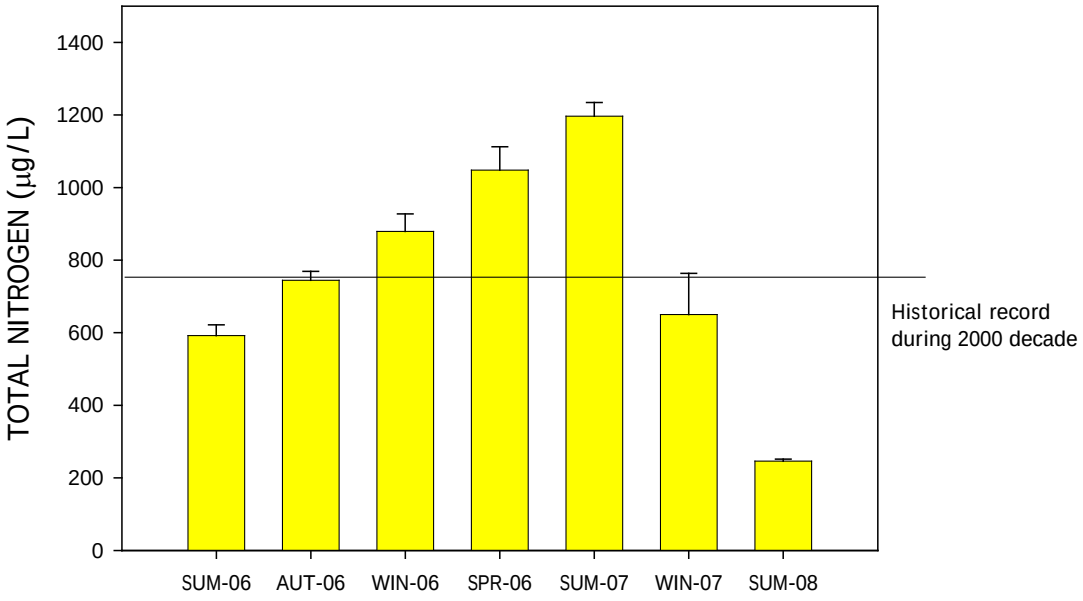
M. quitense disappear and was substituted by P. pusillus

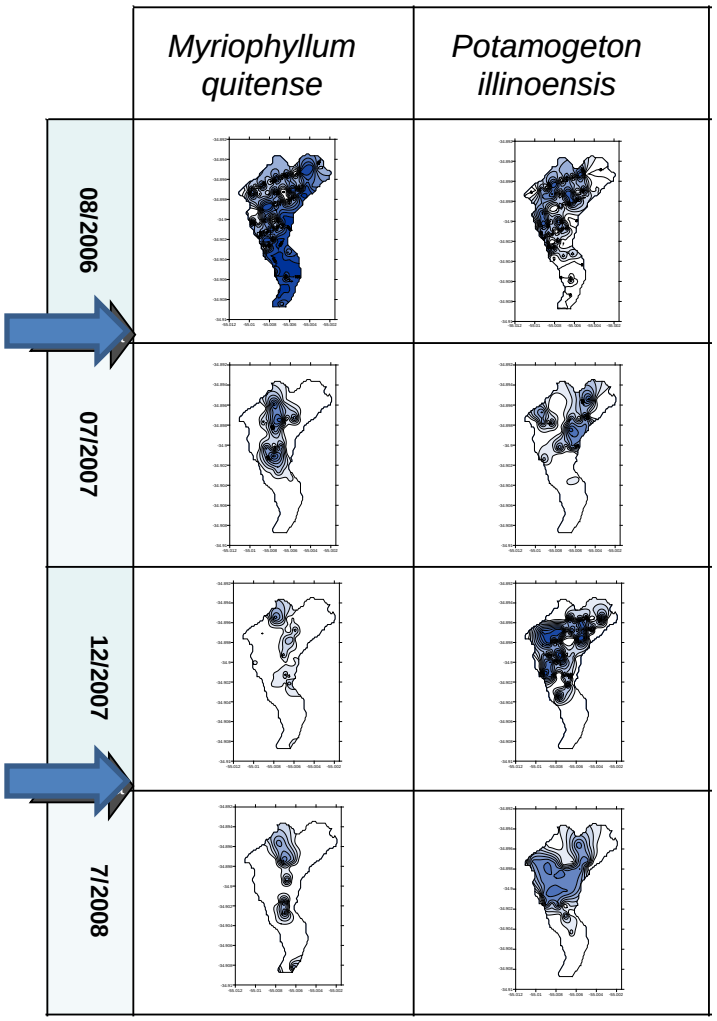
PVI of Potamogeton illinoensis and Egeria densa achieved 100%

Reverse succession and a new succession trajectory conditioned by MH


Myriophyllum quitense
Potamogeton illinoensis
08/2006
07/2007
12/2007
7/2008


TOTAL PHOSPHORUS (µg/L)
400
300
200
100
0
SUM-06
AUT-06
WIN-06
SPR-06
SUM-07
WIN-07
SUM-08
Historical records during 2000 decade


TOTAL NITROGEN (µg/L)
1400
1200
1000
800
600
400
200
0
SUM-06
AUT-06
WIN-06
SPR-06
SUM-07
WIN-07
SUM-08
Historical record during 2000 decade


Myriophyllum quitense
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08/2006
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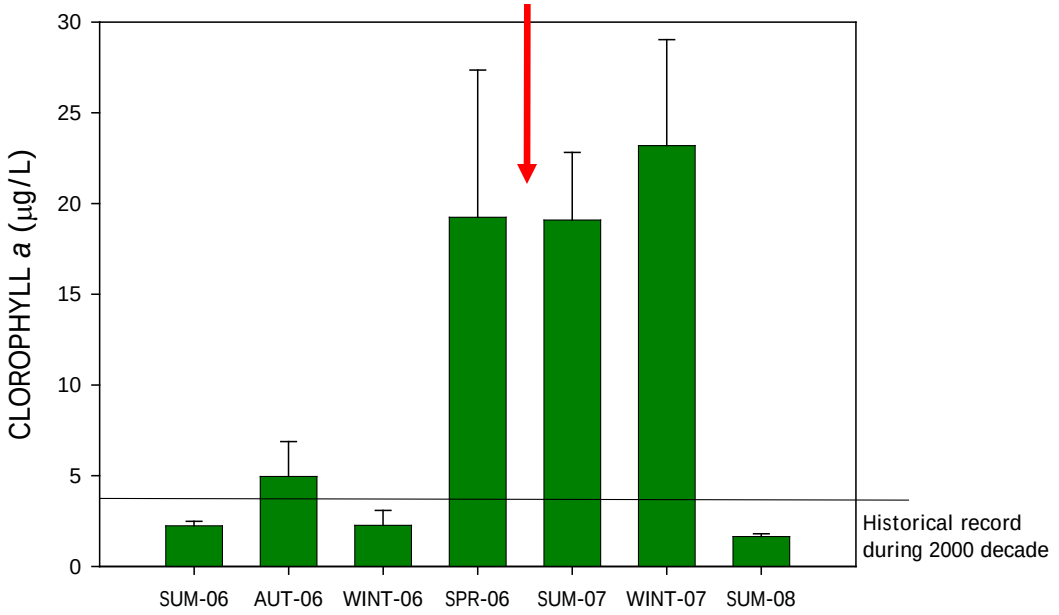
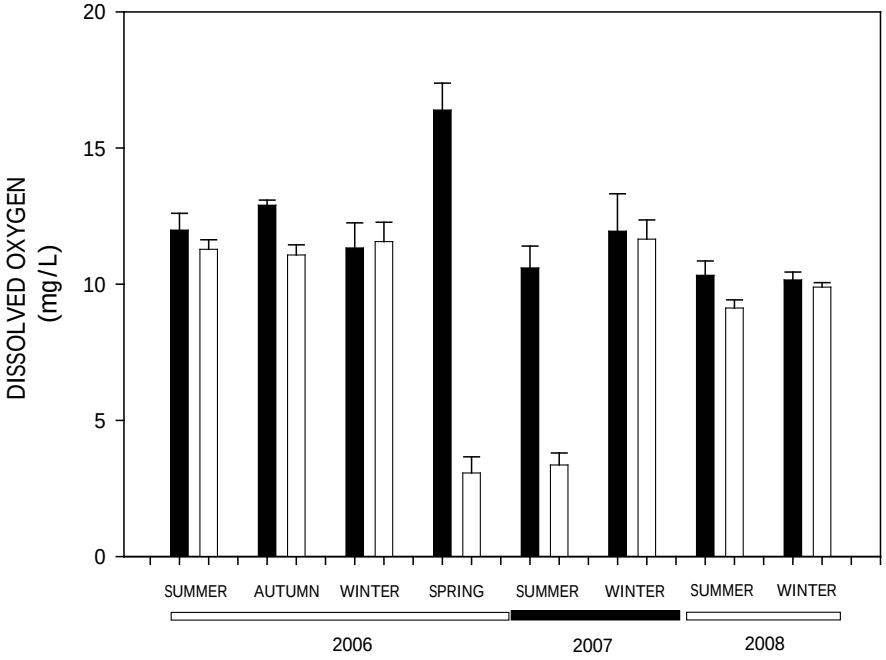
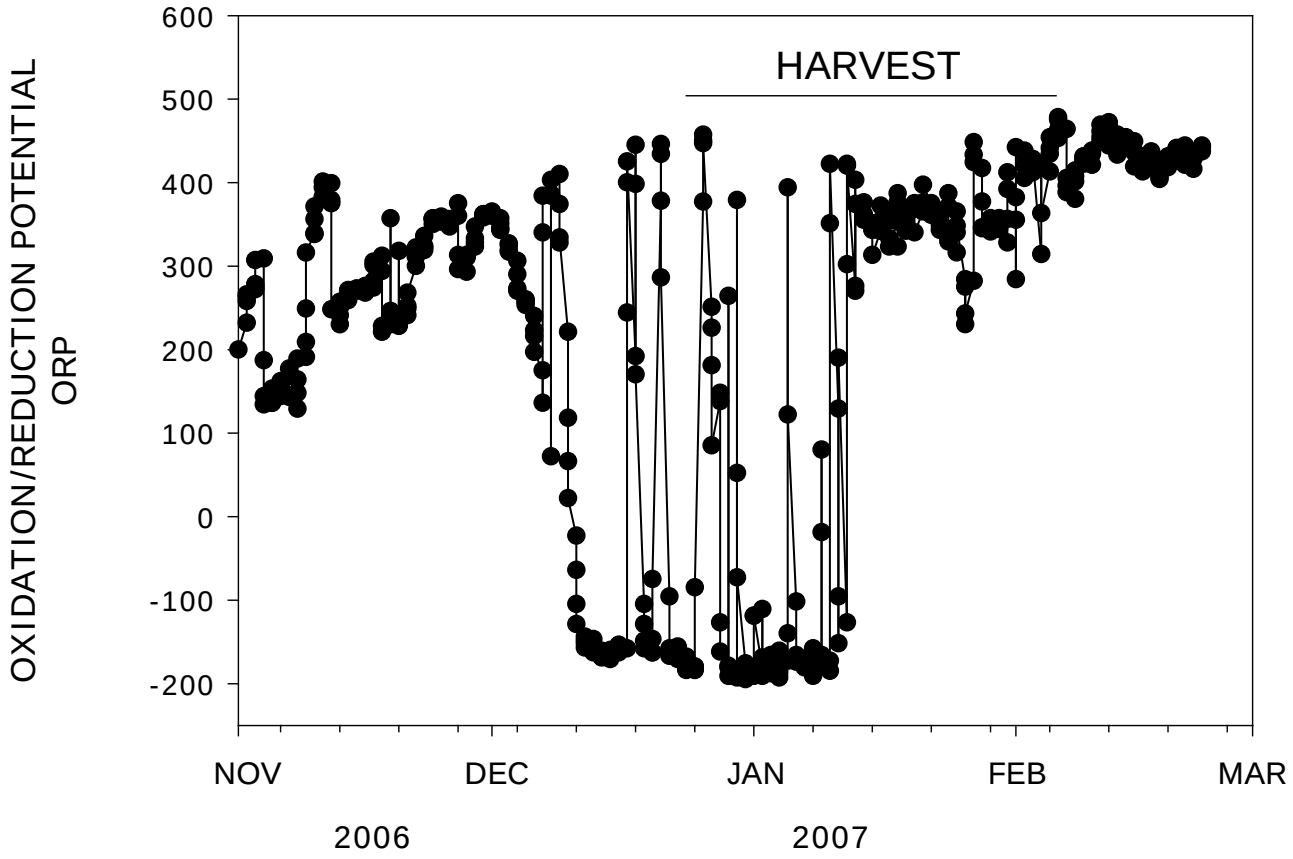
7/2008


CLOROPHYLL a (µg/L)
30
25
20
15
10
5
0
SUM-06
AUT-06
WINT-06
SPR-06
SUM-07
WINT-07
SUM-08
Historical record during 2000 decade


DISSOLVED OXYGEN (mg/L)
20
15
10
5
0
SUMMER
AUTUMN
WINTER
SPRING
SUMMER
WINTER
SUMMER
WINTER
2006
2007
2008

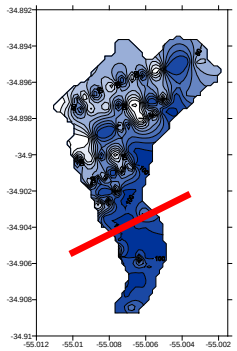
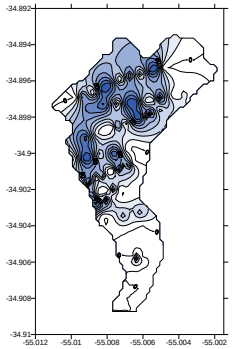
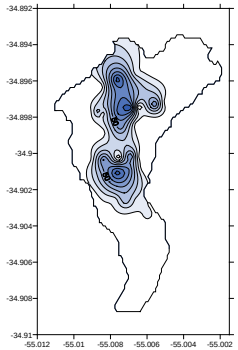
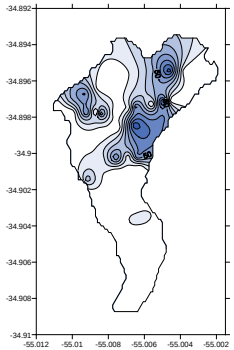

OXIDATION/REDUCTION POTENTIAL
ORP
600
500
400
300
200
100
0
-100
-200
HARVEST
NOV
DEC
JAN
FEB
MAR
2006
2007

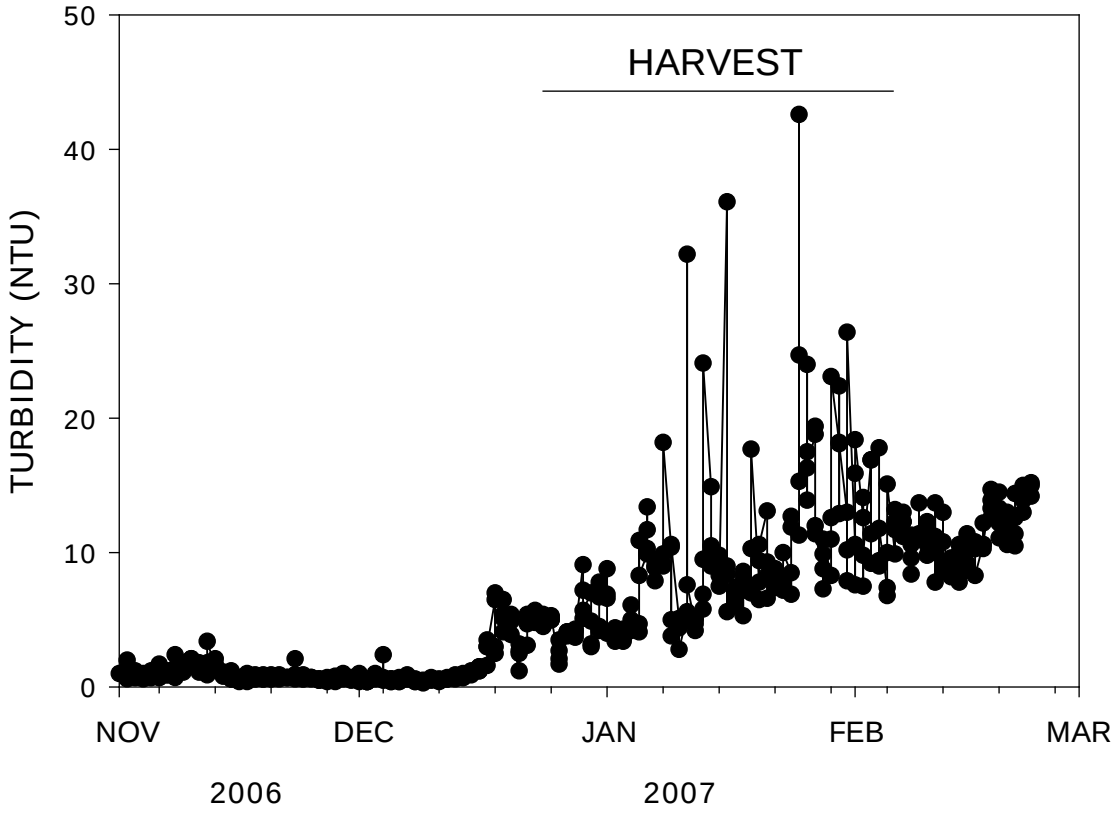
The harvest process improved very quickly the oxygen deficit at the bottom

It is interesting to point out the gap in temporal changes between nutrient levels and phytoplankton biomass

The risk of transition to a turbid state is very high in this ecosystem

How resilient is the submerged plant removal?

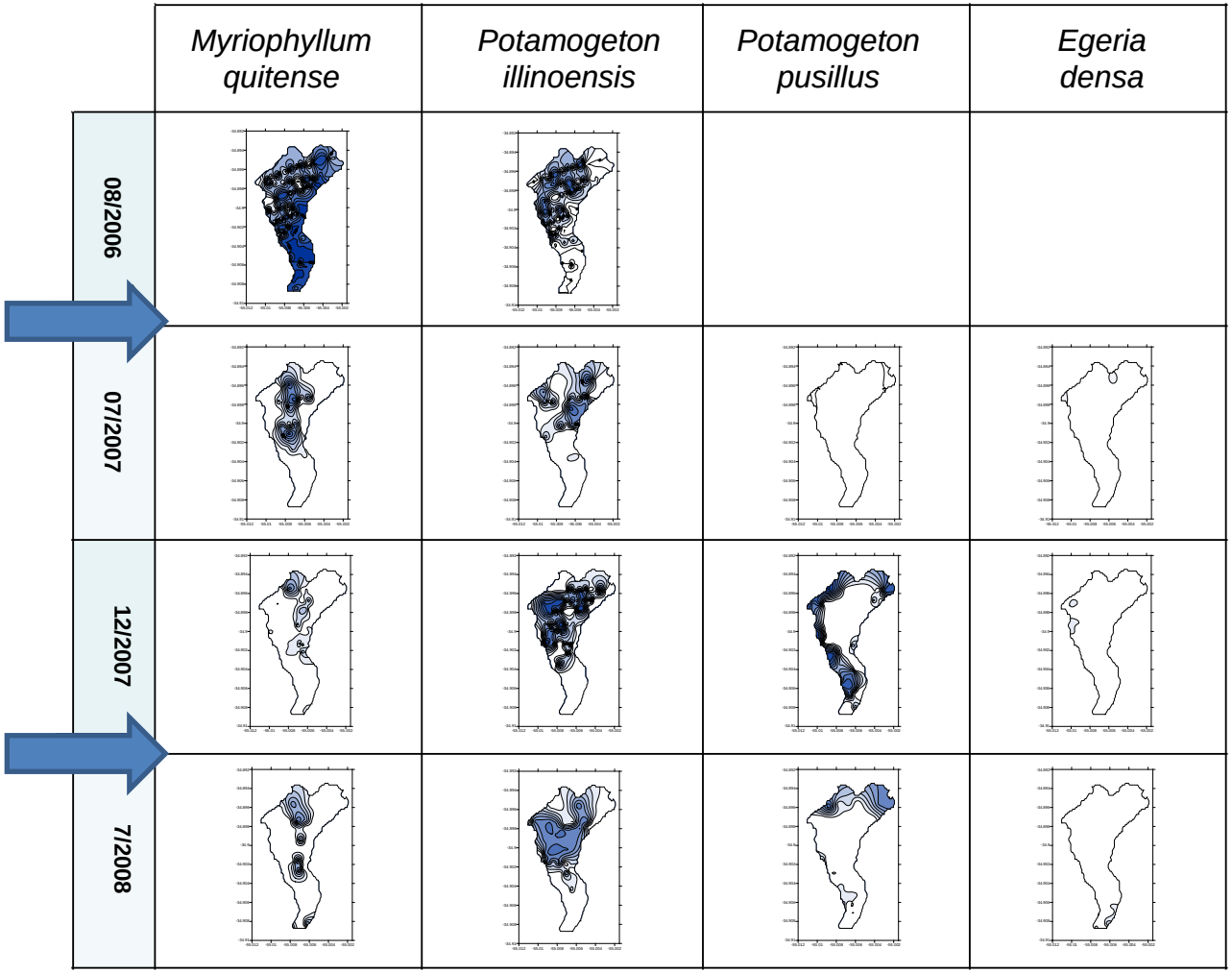
	Myriophyllum quitense	*Potamogeton illinoensis*
08/2006		
07/2007		

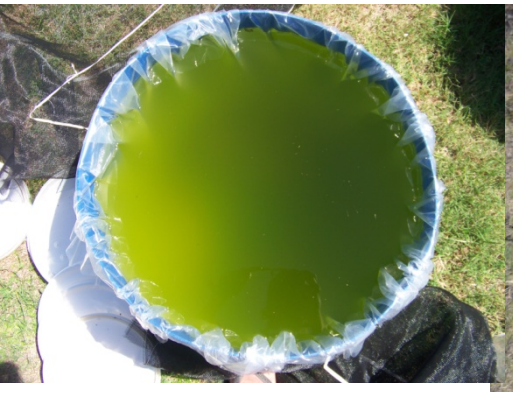


Mechanical harvesting led to a reduction in water transparency because of sediment resuspension and to the increase of the algal biomass

Such effects propagated to the rest of the system because the reservoir main axis is oriented in the direction of the predominant winds

The factor that played a key role for avoiding a critical transition was the fast re-colonization of P. pusillus, probably from the seed bank





No macrophytes

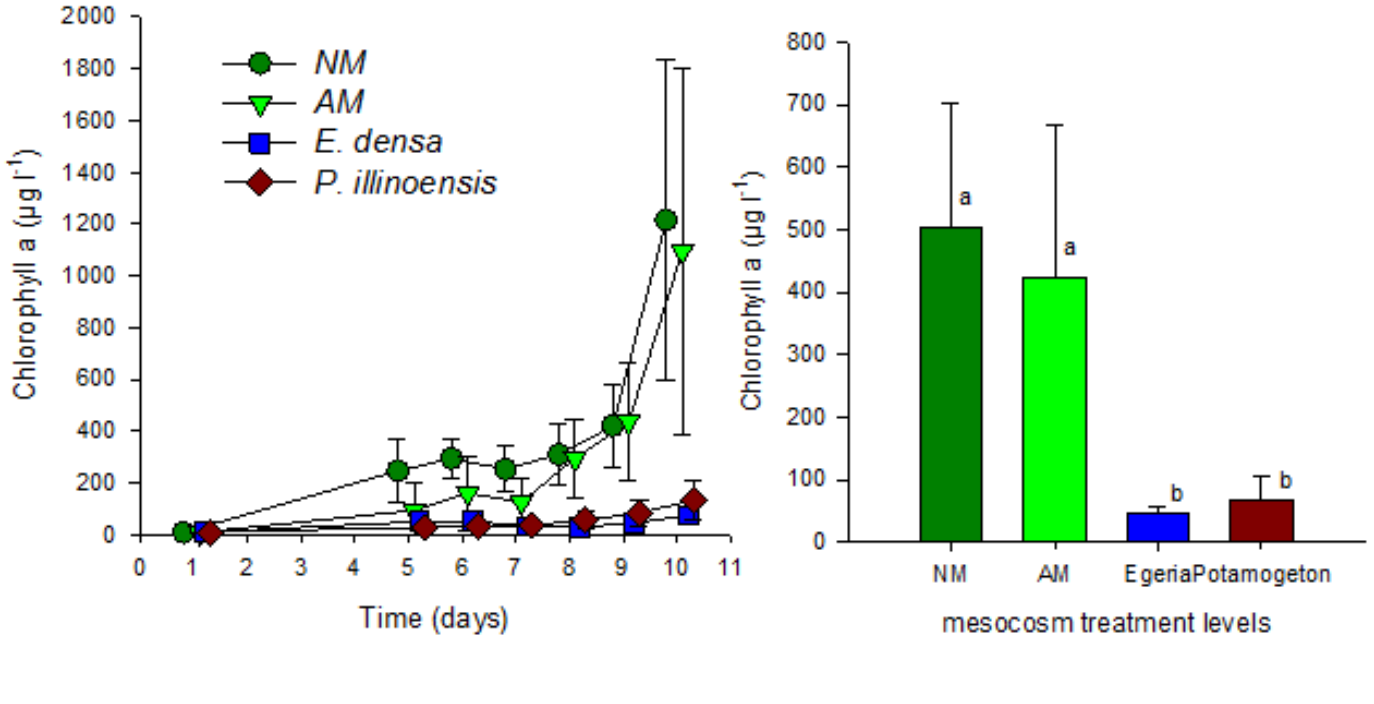
Artificial plants

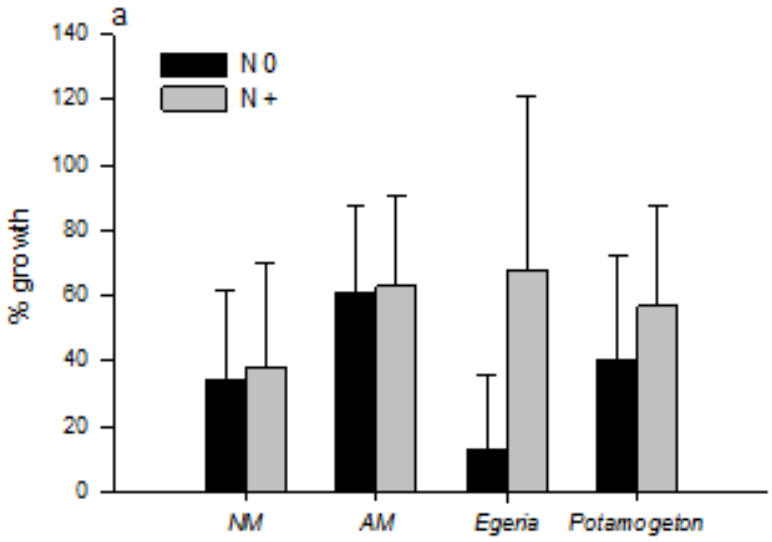
E. densa

P. illinoensis

Maarten Vanderstukken Ph.D Thesis

No macrophytes | Artificial plants | E. densa | P. illinoensis




a
140
120
100
80
60
40
20
0
% growth
N 0
N +
NM
AM
Egeria
Potamogeton

Positive factors that stabilize the clear water state

+ The capacity of *P. illinoensis* to synthesize alellopathic compounds

+ These compounds may also contribute to the absence of other submerged plants in the *P. illinoensis* beds

+ The important *Egeria densa* nutrient competition capacity

Negative factor

+ The zooplankton community was dominated by micro-filterers (rotifers and nauplii)

Positive factor

+ In terms of biomass, the facultative piscivores constitute the highest percentage of the community, with values from 62% to 82% (open water and aquatic plant bed respectively)

Why the zooplankton structure do not reflect the excellent conditions of PVI percentage and fish structure?

CASCADING EFFECTS OF PREDATORS IN TEMPERATE AND SUBTROPICAL SHALLOW LAKES

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PhD Thesis 2010

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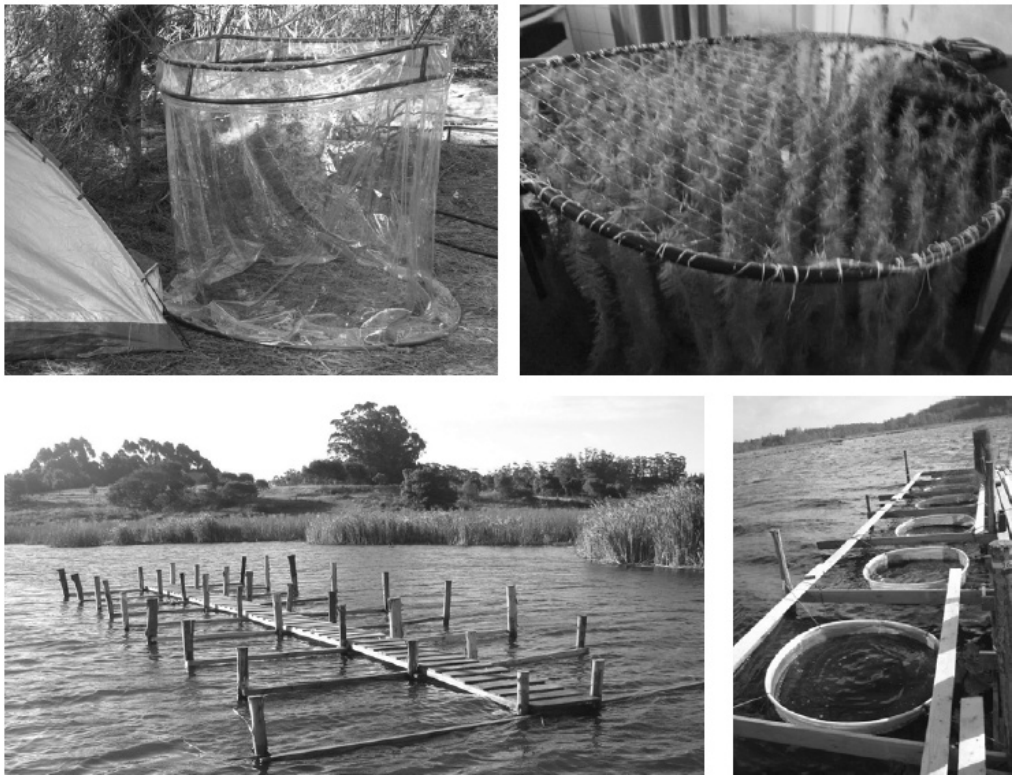
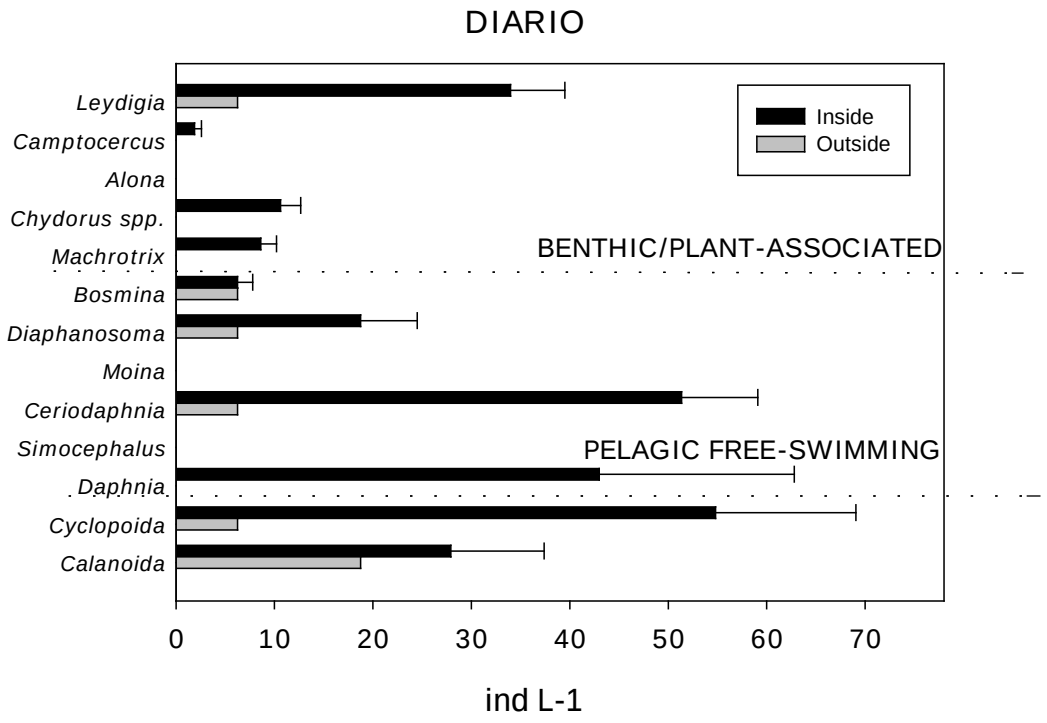
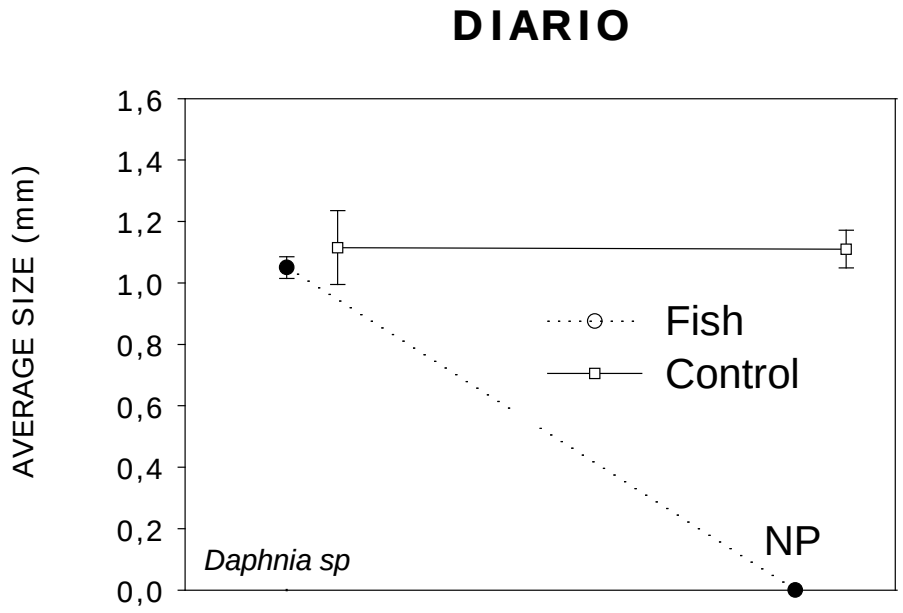


Table 2. Fish and macroinvertebrate predator species and numbers added to the mesocosms in the treatments F: Planktivorous fish; F+INV: Planktivorous fish + macroinvertebrates, and INV: Omnivorous macroinvertebrates. In both the F and F+INV treatments two fish species were added (final densities, as ind. m^{-2}, are given in parenthesis). Densities of predators were taken from literature: *Teixeira de Mello et al. 2009; +Liboriussen et al. 2005; ¤ Wilhelm and Schindler 1999.

		Fish sp. 1	**Fish sp. 2**	**Macroinvertebrates**
Subtropical	Name	*Cnesterodon decemmaculatus*	*Jenynsia multidentata*	*Palaemonetes argentinus*
	Density	50 (42)*	40 (33)*	120 (100)*
Temperate	Name	*Gasterosteus aculeatus*	*Perca fluviatilis*	*Gammarus lacustris*
	Density	12 (10)+	6 (5)*	240 (200)¤

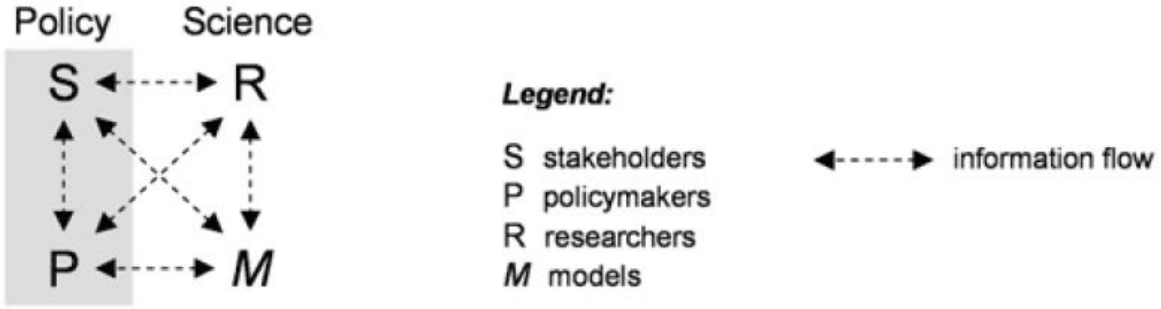

DIARIO
Leydigia
Camptocercus
Alona
Chydorus spp.
Machrotrix
Bosmina
Diaphanosoma
Moina
Ceriodaphnia
Simocephalus
Daphnia
Cyclopoida
Calanoida
Inside
Outside
BENTHIC/PLANT-ASSOCIATED
PELAGIC FREE-SWIMMING
0
10
20
30
40
50
60
70
ind L-1


DIARIO
AVERAGE SIZE (mm)
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Fish
Control
NP
Daphnia sp

The submerged plant control the phytoplankton biomass mainly by competition and allelophatic mechanisms, the refuge capacity is very limited by the abundance of shrimps and small omnivorous-planktivorous fish

Is it possible a positive role of the stakeholders and policymaker during the design and implementation of aquatic plant control program?

Yes, but depends on the structure of the actors networks and several critical attributes:



The critical attributes of Laguna del Diario network are:

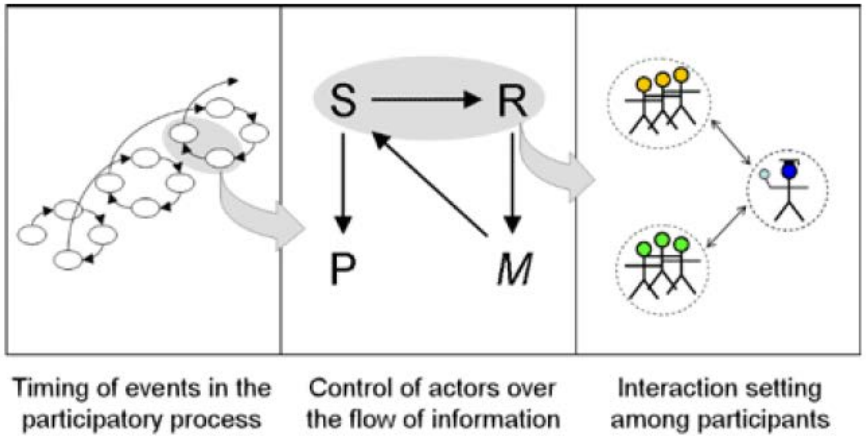
+ Mode of participation collegiate: different actors work together as colleagues or partners, ownership and responsibility are equally distributed among the partners, and decisions are made by agreement and consensus among all actors

+ Open and flexible epistemic network

+ Different strategies of learning

+ All the actors find an adequate space to meet and foster learning

+ Fostering of trust through leadership



In general, critical transitions determine more complex networks with an increase of the model use (aquatic plant biomass removal) control by the Science and more collaborative or collegiate participation

Gunderson, L. H., S. R. Carpenter, C. Folke, P. Olsson, and G. D. Peterson. 2006. Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. *Ecology and Society* **11** (1): 16. [online] URL:http://www.ecologyandsociety.org/vol11/iss1/art16/

Insight, part of a Special Feature on Exploring Resilience in Social-Ecological Systems

Water RATs (Resilience, Adaptability, and Transformability) in Lake and Wetland Social-Ecological Systems

Lance H. Gunderson[1], *Steve R. Carpenter*[2], *Carl Folke*[3], *Per Olsson*[4], and *Garry Peterson*[5]

Thank you