

***THE SUDDEN LOSS OF A RAMSAR WETLAND SITE IN SOUTHERN CHILE: EMIGRATION AND MORTALITY OF BLACK-NECKED SWANS, DECREASE IN AREAL EXTENSION OF THE WATERWEED EGERIA DENSA AND HABITAT DETERIORATION***



**Eduardo Jaramillo  
Instituto de Zoología  
Universidad Austral de Chile  
Valdivia, CHILE**

# Introducing Chile

- long and narrow country
- 4,200 Km from North to South,  
18 – 55°S
- on average, 140 Km from East  
to West

The wetland of río Cruces “Carlos Anwandter Natural Sanctuary” (the Sanctuary), is located ca. 40°S



**This site had been recorded as the main reproductive site of the black necked swan (*Cygnus melancorrhypus*) in the Neotropic area of South America, one of the reasons blamed by the Chilean Government when it requested its inclusion on the RAMSAR Convention, apart from the high diversity of waterbirds and aquatic plants in the Sanctuary**





# The Sanctuary

*Location: north of Valdivia, ca. 160000 people*

*Origen: earthquake and tsunami (May 1960)  
due to sinking of agricultural lands*

*Area: 4877 hectares*

*Approximate length: 25 Km*

*Approximate width: 2 Km*

**Valdivia**

Image © 2005 EarthSat  
Image © 2005 DigitalGlobe

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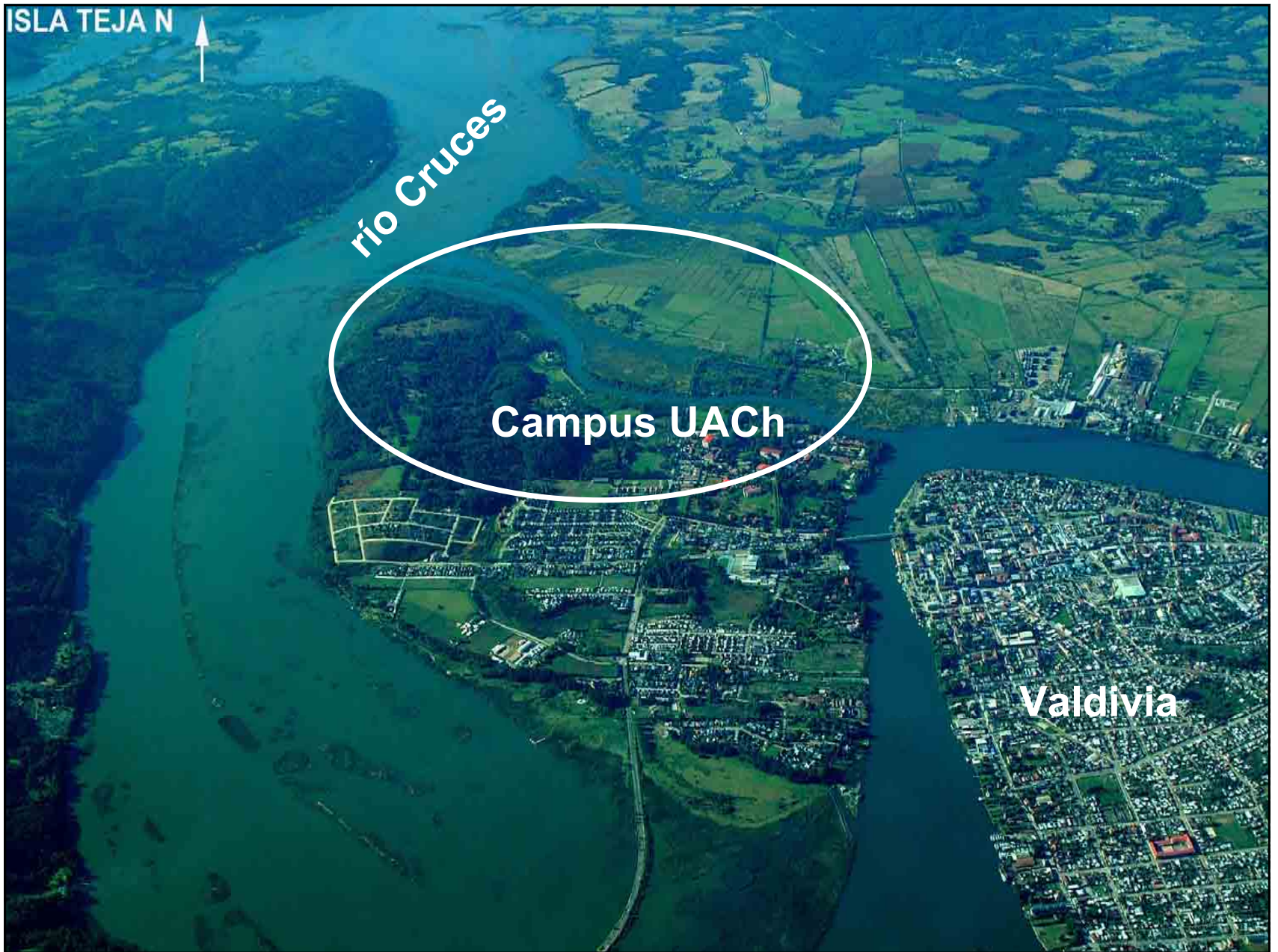
ISLA TEJA N



río Cruces

Campus UACH

Valdivia

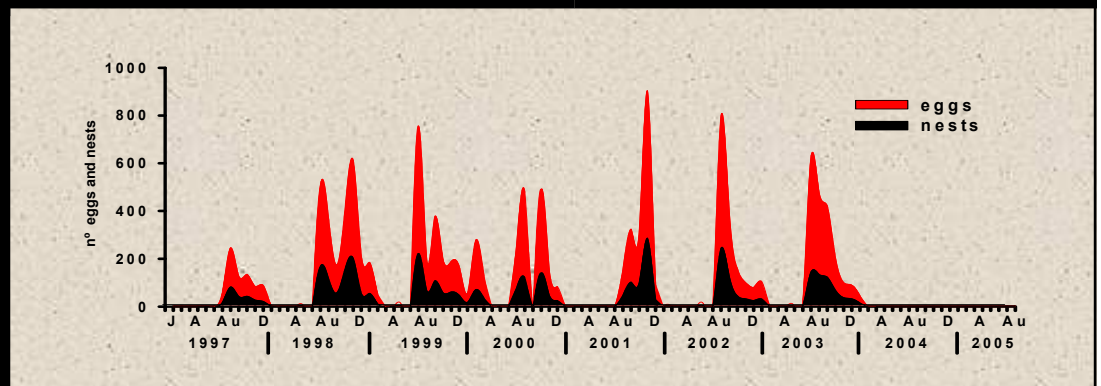


# The environmental changes





# The warning signals were first given by the black necked swans during late autumn – winter 2004



Demise of the aquatic macrophyte *Egeria densa* ("Luchecillo"), the primary food of swans and other herbivorous birds

29 1 2005

lost of plant cover





# Arrival of brown waters to Valdivia coming down from the Sanctuary: spring 2004



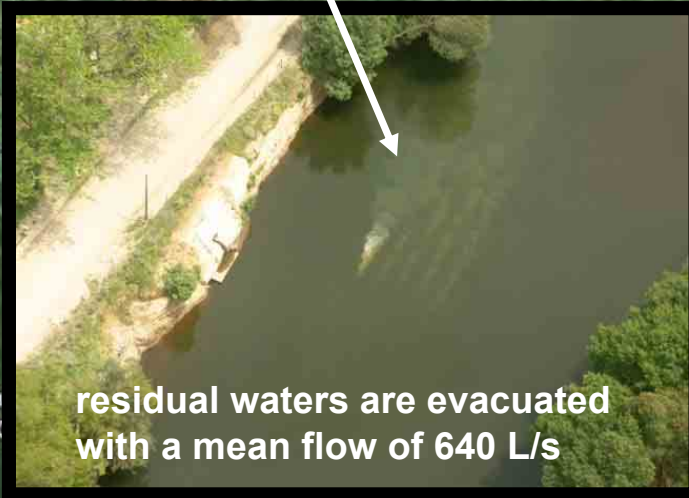


From the beginning, citizens pointed towards CELULOSA VALDIVIA (CELCO), a 1,000,000 tons/year pulp plant, as the ultimate cause of the environmental changes

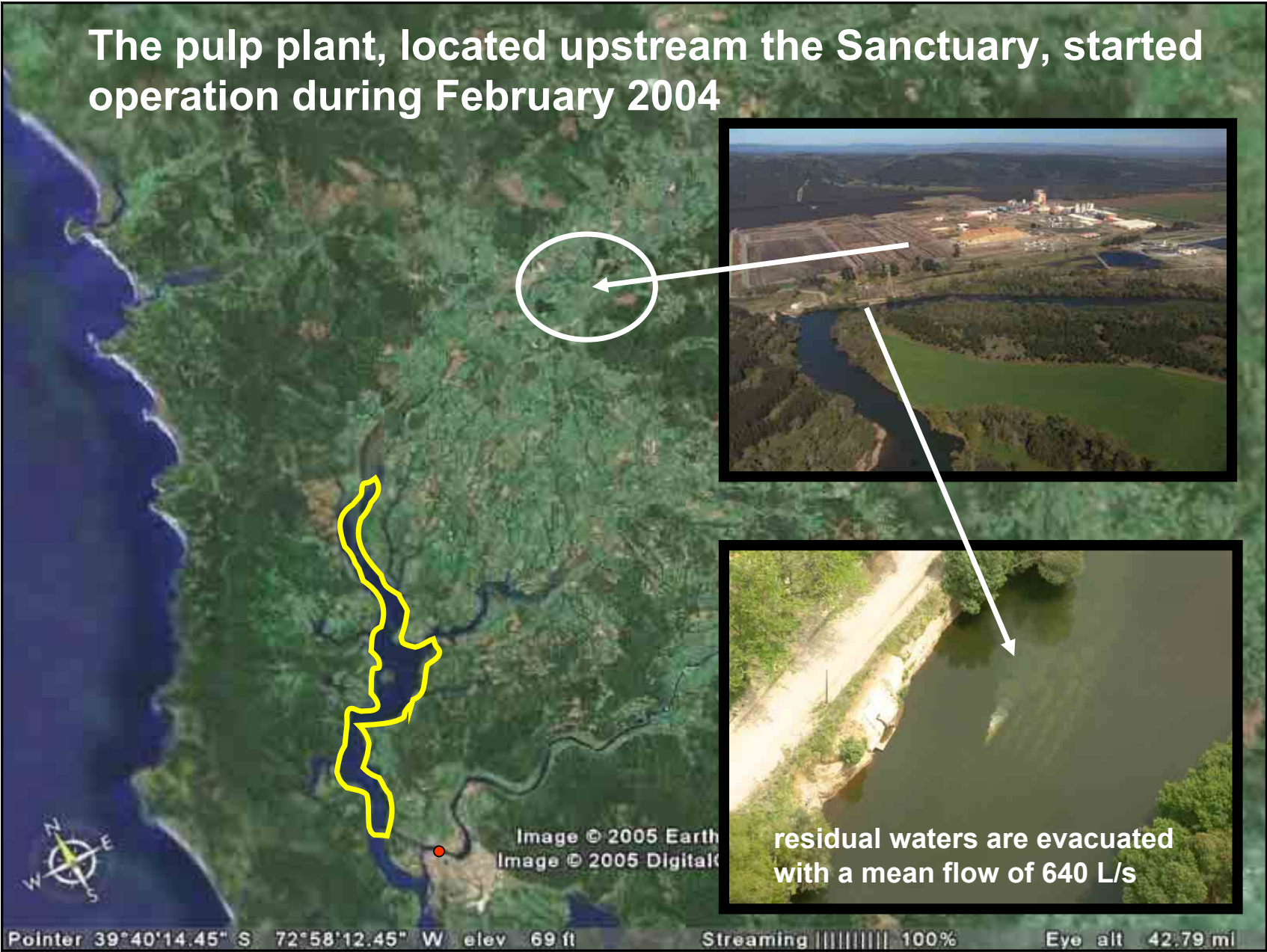




The pulp plant, located upstream the Sanctuary, started operation during February 2004



residual waters are evacuated with a mean flow of 640 L/s





**During November 2004, CONAMA (Comisión Nacional del Medio Ambiente) commissioned a study to Universidad Austral de Chile, to find out the reasons of the environmental changes mentioned earlier**

**The study period: November 2004 – April 2005**

**Number of hypotheses tested: 15**

**11 11 2004**



# SOME OF THE HYPOTHESIS TESTED:

## Problem 1

Mortality and migration of swans

## Hypothesis 1

Mortality of swans is due to infecto-contagious diseases

## Studies

Inoculation of swan tissues (liver, kidneys, brain, heart and lungs) into SPF chicken eggs

## Conclusion

The hypothesis is **rejected**: no pathologic alterations were detected (e.g. embrionic enanism, bleding of embryos or damage in corio-alantoid membranes)



“SPF” (Specific Free Pathogen) chicken eggs

# Problem 1

Mortality and migration of swans

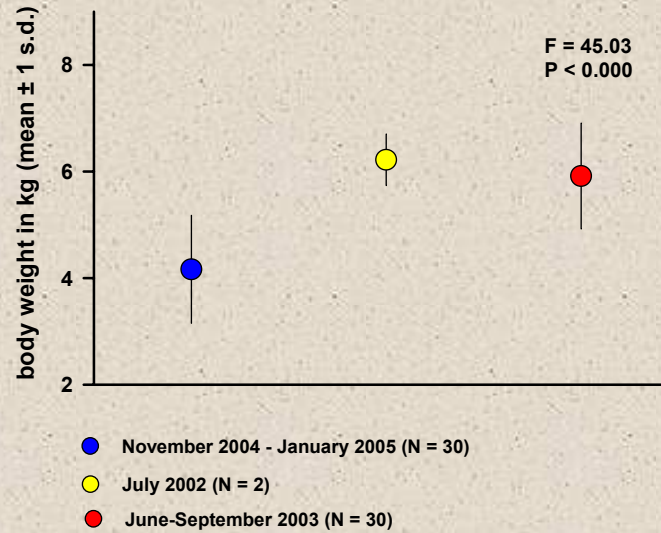


# Hypothesis 2

Mortality and migration of swans is related to demise of *Egeria densa*

# Studies

Visual analyses of dead animals and stomachs and interannual comparisons of body weights



# Conclusion

The hypothesis is accepted: the body weight of swans was nearly 2 kilos lower than in previous years, there is almost no fat on the body and no rest of plants were observed in the stomach, just sediments





# Problem 1

Mortality and migration of swans

# Hypothesis 3

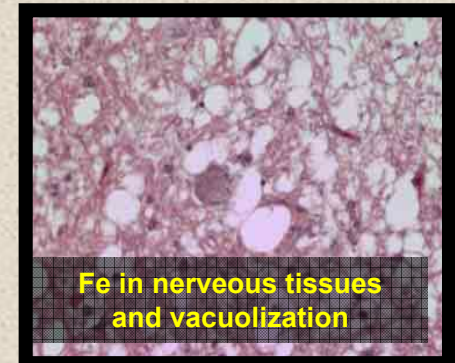
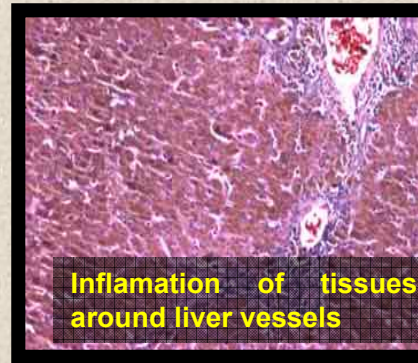
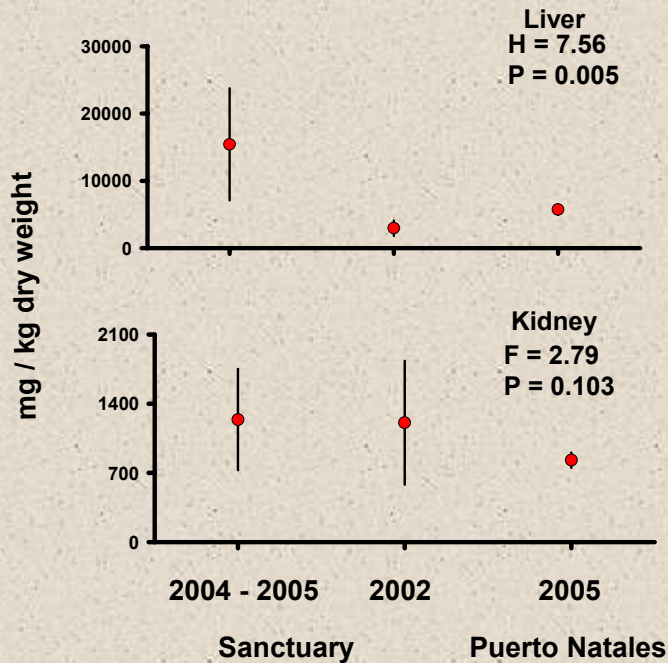
Mortality of swans is due to accumulation of chemicals in their bodies

# Studies

Analyses of concentrations of heavy metals and organic compounds in liver and kidneys

# Conclusion

**The hypothesis is accepted:** even when the primary cause of death was emaciation, high concentration of heavy metals (Fe, Mn), resulted in structural damages of body tissues.



## Problem 2

Demise of *Egeria densa* in the Sanctuary

## Hypothesis 1

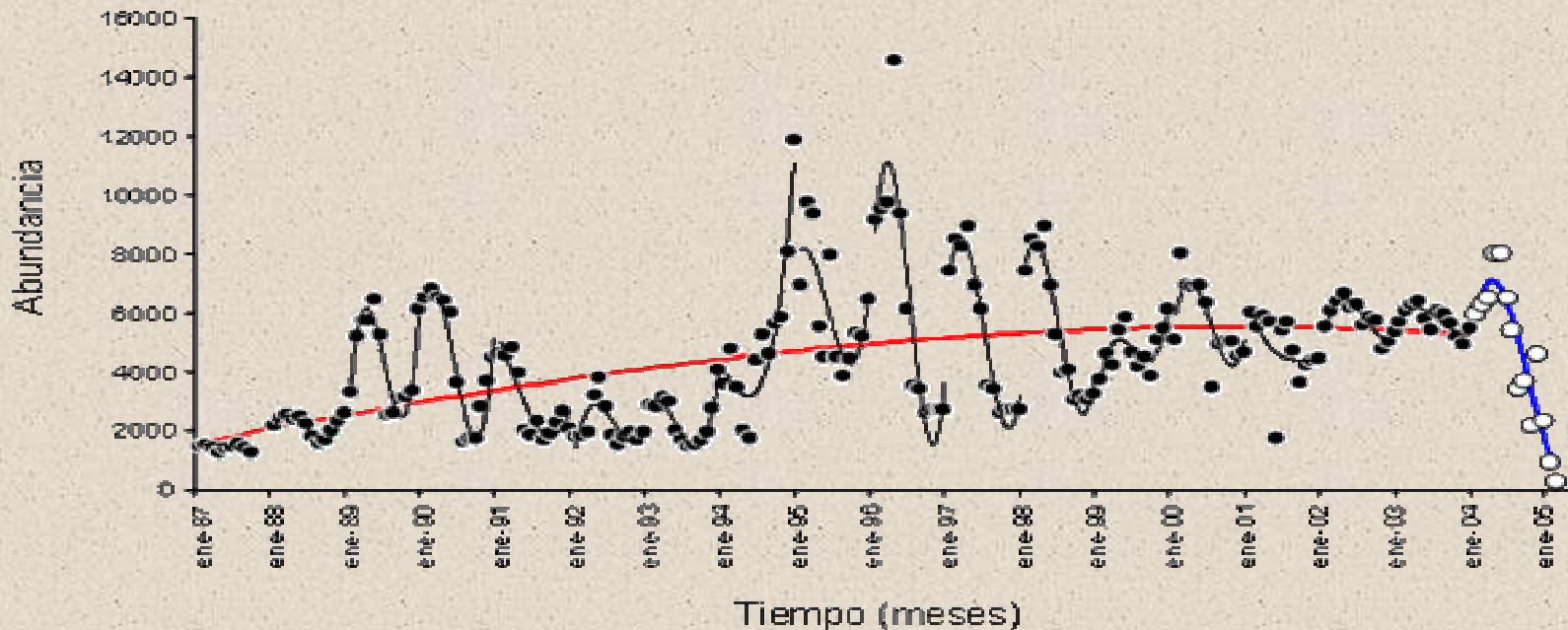
Demise of *Egeria* is due to overforaging, resulting from increase of swans during last years

## Studies

Analyses of interannual variability in population abundances of swans

## Conclusion

**The hypothesis is rejected:** during 2004, the swann abundances were lower than in other years when no decrease in canopy of *Egeria* was observed





## Problem 2

Demise of *Egeria densa* in the Sanctuary

## Hypothesis 3

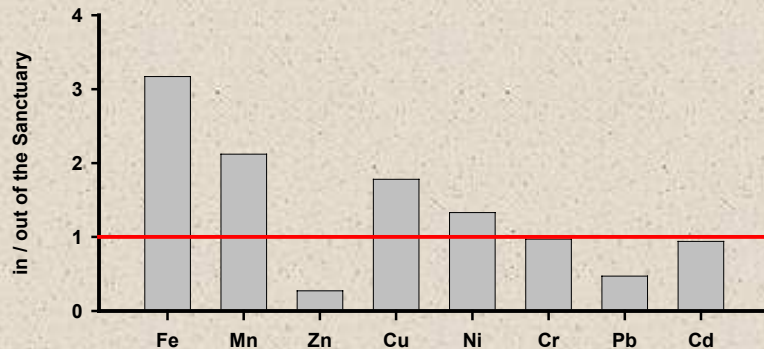
The demise of *Egeria* was the result of toxic accumulation in the plant tissues

## Studies

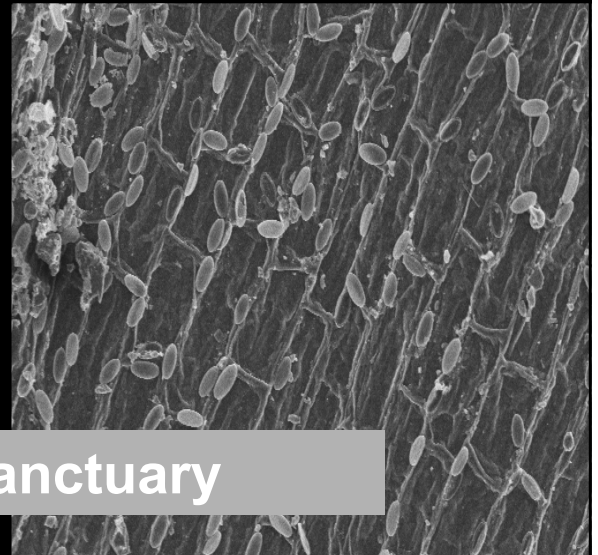
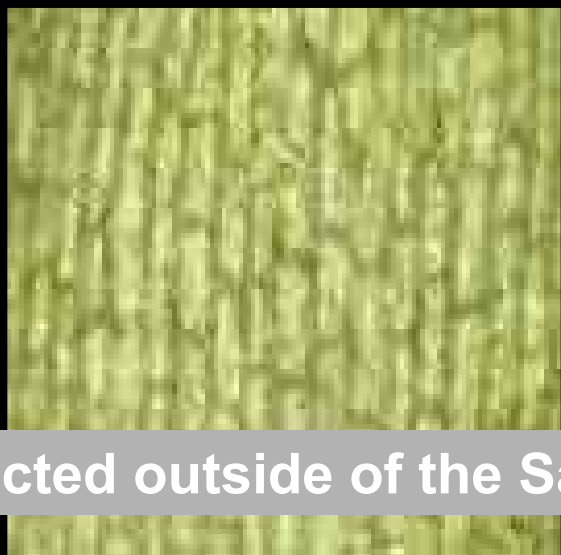
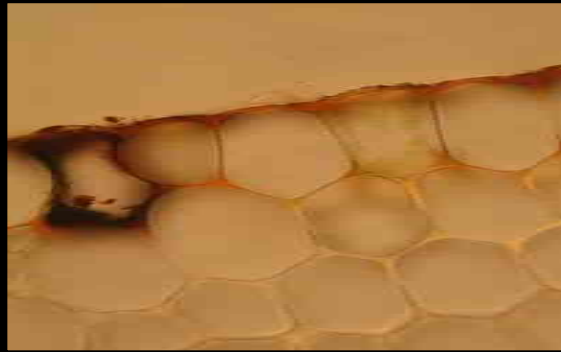
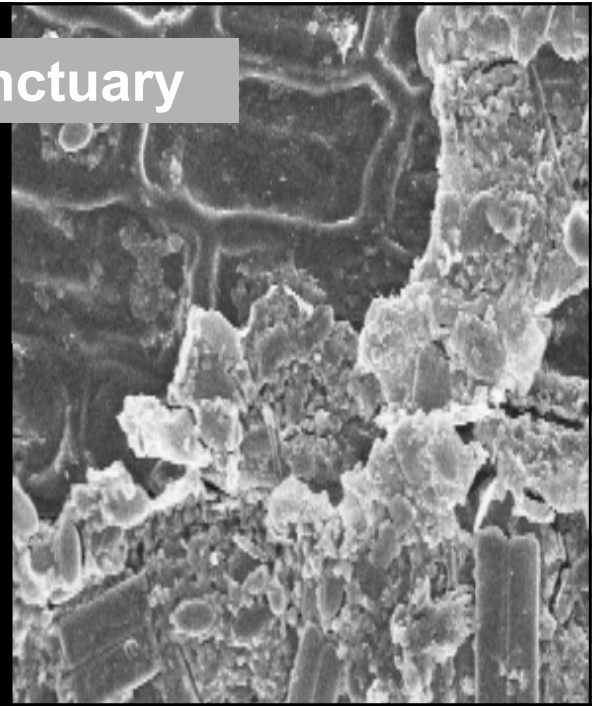
Analyses of heavy metals and POC contents, in plants from the Sanctuary and outside sites and laboratory experiments to test the effect of different concentrations of Cu, Mn and Fe salts on the survival of plants collected from healthy sites

## Conclusion

**The hypothesis is accepted:** concentrations of some heavy metals such as Fe, Mn and Cu were higher in tissue plants collected from the Sanctuary as compared with healthy plants collected from nearby sites, and results of laboratory experiments showed that salts of Fe and Cu affect survival of healthy plants



plants collected from the Sanctuary



plants collected outside of the Sanctuary



## Problem 3

Water and sediment quality

## Hipotesis 1

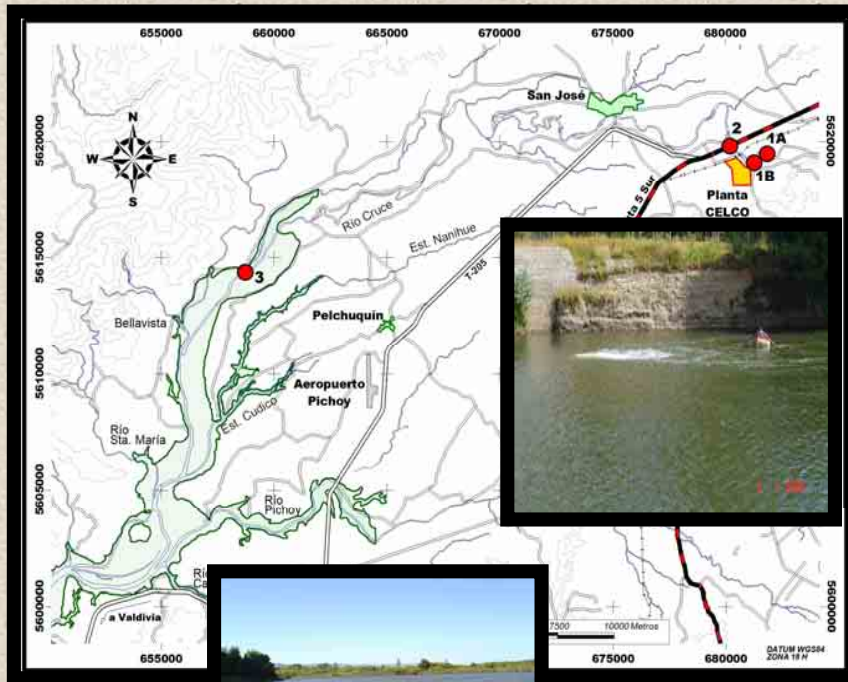
There is an important load of chemical in waters and sediments

## Studies

Physico-chemical analyses of water and sediments and analyses of results of monitoring programs of sewage treatment plants and that of the pulp plant

## Conclusion

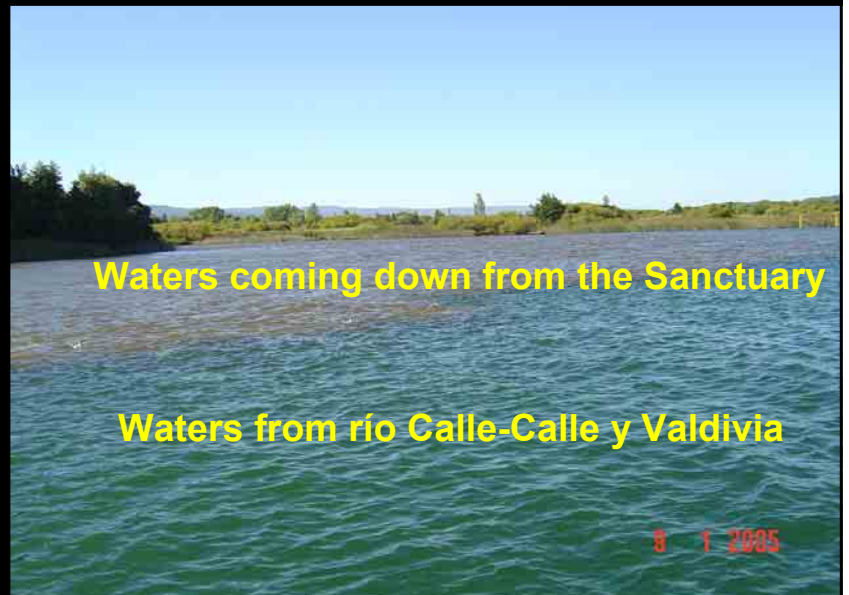
**The hypothesis is accepted:** the values of several physico-chemical variables increased significantly with time and others were significantly higher in waters and sediments of the Sanctuary.



the brown colour waters



9 1 2005

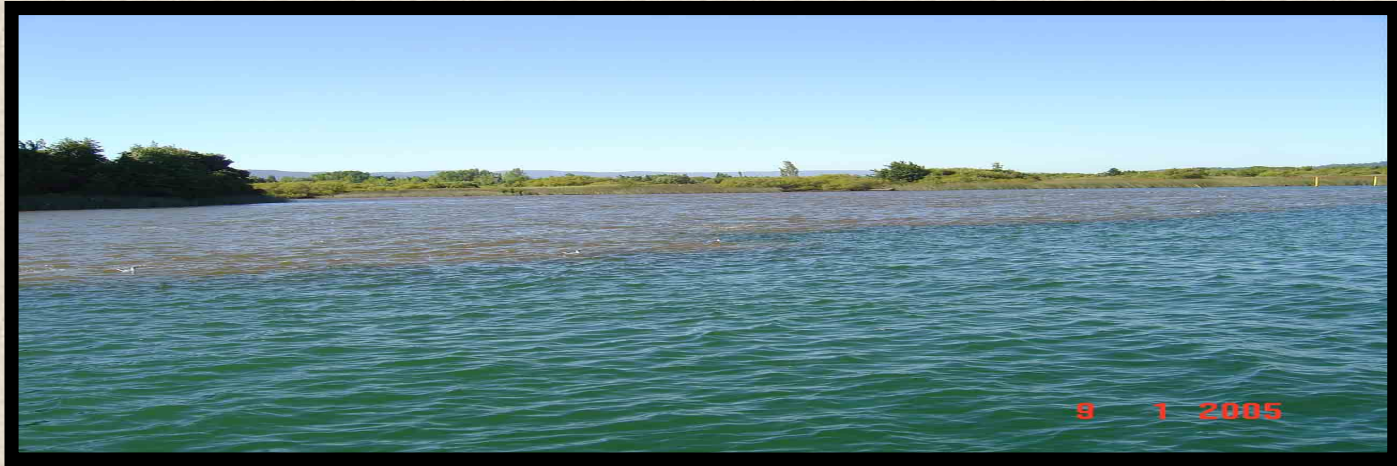


Waters coming down from the Sanctuary

Waters from río Calle-Calle y Valdivia

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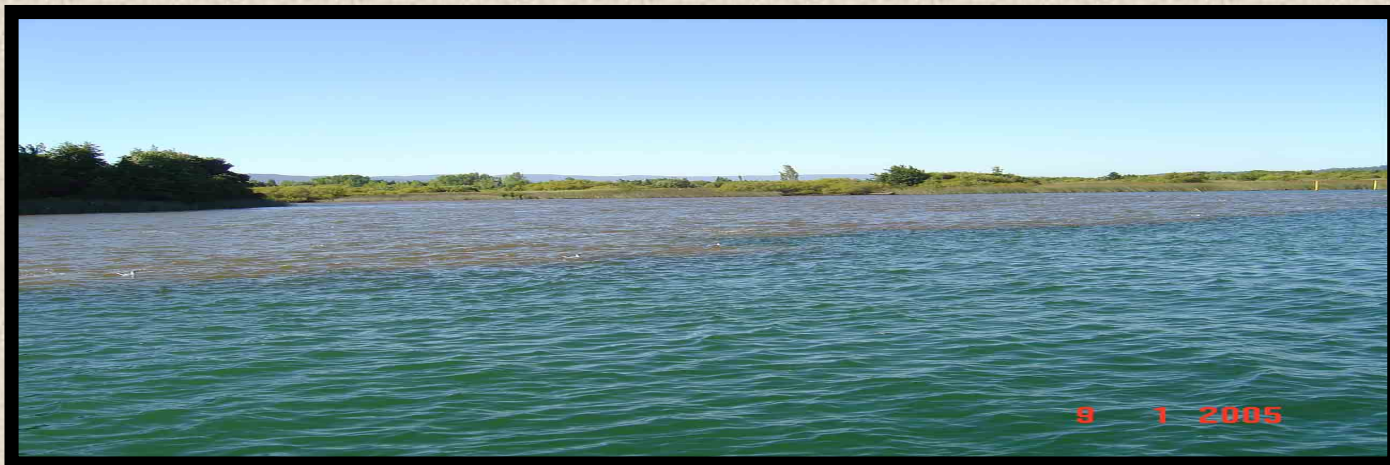




**brown colour waters**

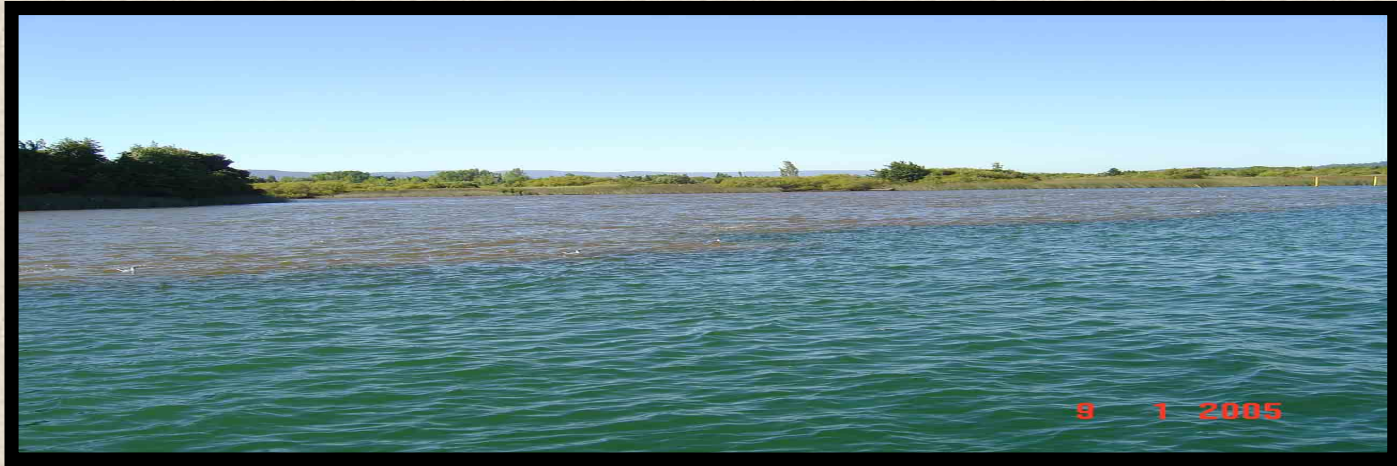
**waters without brown colour**

	<b>bcw</b>	<b>wwbc</b>	<b>bcw/wwbc</b>
<b>°C</b>	<b>20.93</b>	<b>19.81</b>	<b>1.06</b>
<b>pH</b>	<b>7.02</b>	<b>7.12</b>	<b>0.99</b>
<b>Conductivity (μS/cm)</b>	<b>372.53</b>	<b>247.14</b>	<b>1.51</b>
<b>N (mg/L)</b>	<b>0.117</b>	<b>0.084</b>	<b>1.39</b>
<b>P (mg/L)</b>	<b>0.042</b>	<b>0.016</b>	<b>2.64</b>
<b>SS (mg/L)</b>	<b>13.82</b>	<b>2.71</b>	<b>5.10</b>
<b>DS (mg/L)</b>	<b>265.88</b>	<b>92.75</b>	<b>2.87</b>



		<b>brown colour waters bcw</b>	<b>waters without brown colour wwbc</b>	<b>bcw/wwbc</b>
<b>dissolved Fe</b>	<b>29/12/04</b>	<b>0.033 mg/L</b>	<b>0.007 mg/L</b>	<b>4.71</b>
	<b>15/01/05</b>	<b>0.400 mg/L</b>	<b>0.079 mg/L</b>	<b>5.06</b>
<b>dissolved Mn</b>	<b>29/12/04</b>	<b>0.010 mg/L</b>	<b>0.001 mg/L</b>	<b>10.00</b>
	<b>15/01/05</b>	<b>0.113 mg/L</b>	<b>0.009 mg/L</b>	<b>12.56</b>



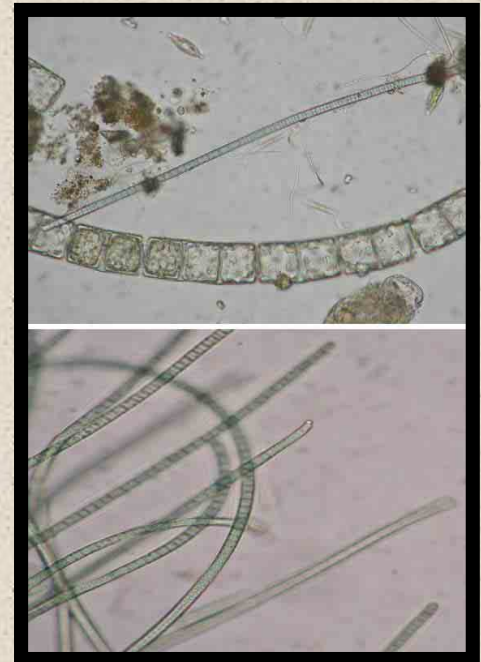


## Fitoplancton

**brown colour waters      bcw      103 275,776 cel/L**

**waters without brown  
colour      wwbc      18 080 203 cel/L**

**5.75**



## Problem 4

Origen of changes in water and sediment quality

## Hypothesis 4

Due to the high flow and diversity of chemicals in its effluent, the operation of CELCO has changed the water quality of the river

## Studies

Analyses of monitoring programs of CELCO and the own data from UACH

## Conclusion

**The hypothesis is accepted:** water quality of the river changes significantly downstream the location of the effluent of CELCO and that quality has changed after the pulp plant started to operate

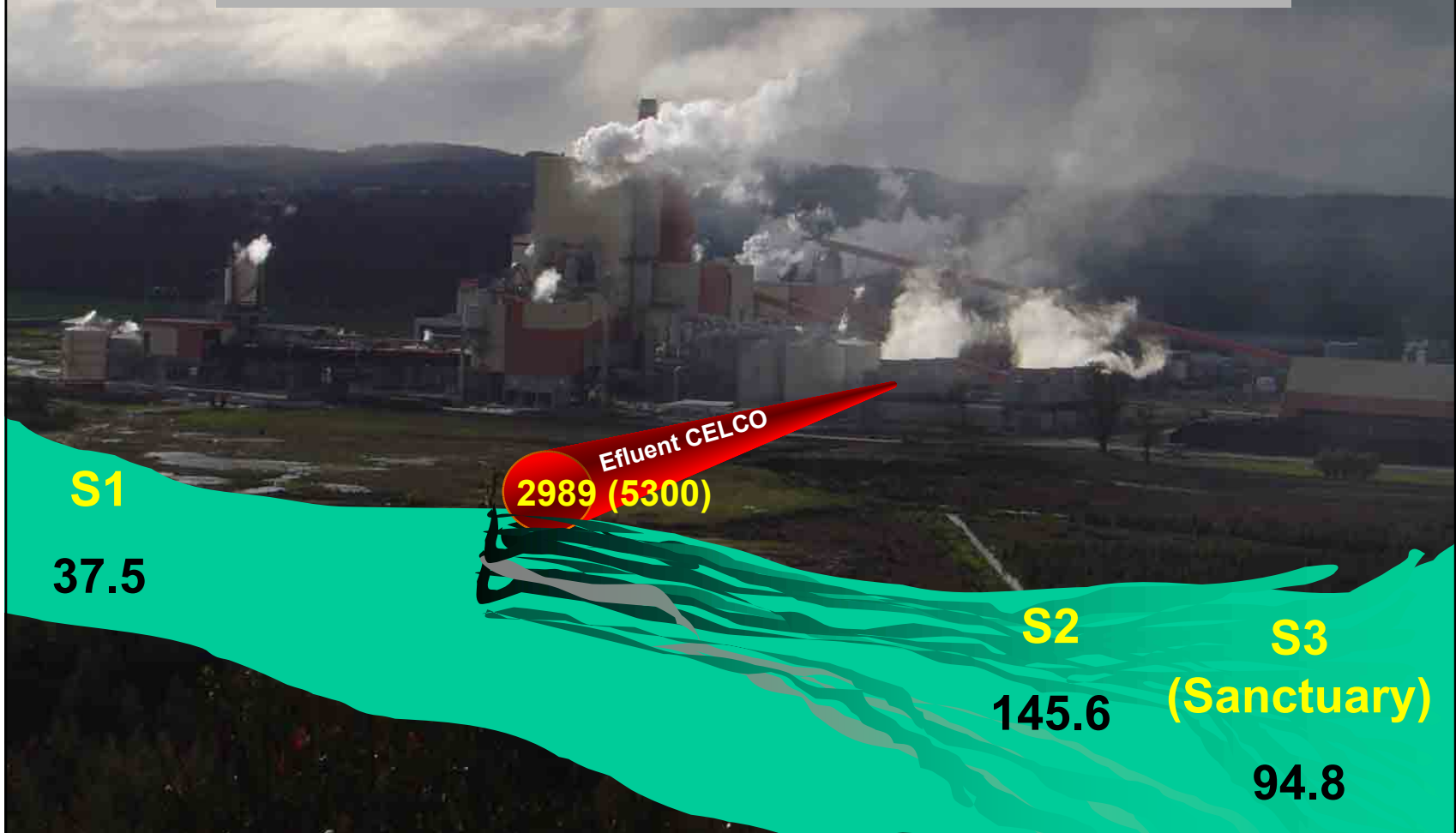




An aerial photograph of a river delta system, showing a wide river branching into numerous smaller channels and distributaries. The landscape is a mix of green forested areas and brownish-yellow fields. The text "CHANGES IN SPATIAL SCALE" is overlaid in the center in a bold, white, sans-serif font.

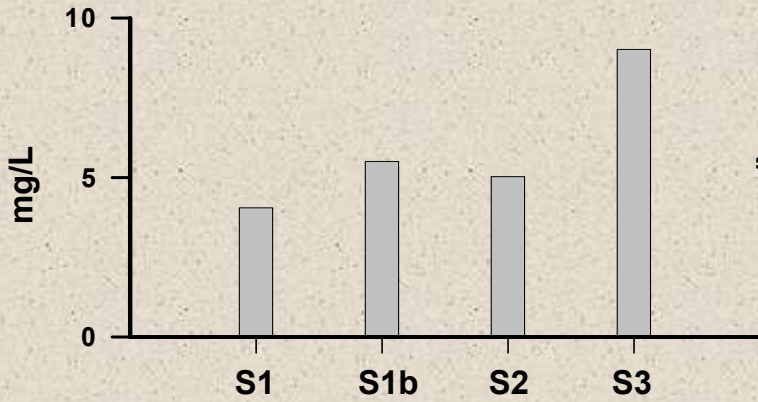
# CHANGES IN SPATIAL SCALE

# Conductivity of water, Dec. 2004 ( $\mu\text{S}/\text{cm}$ )

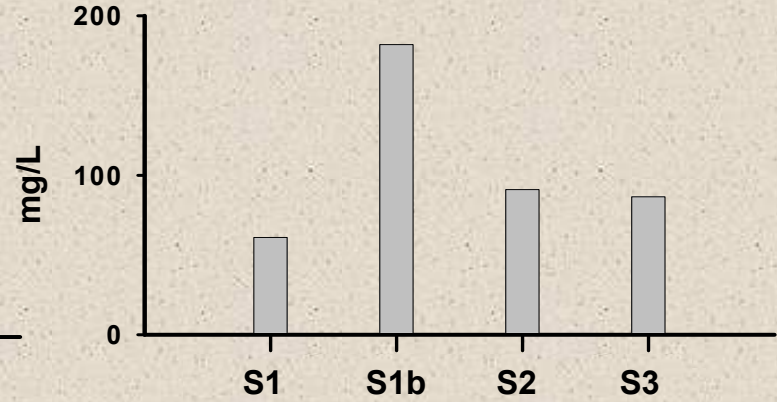






total suspended solids (mg/L)



total dissolved solids (mg/L)



 % organic fraction

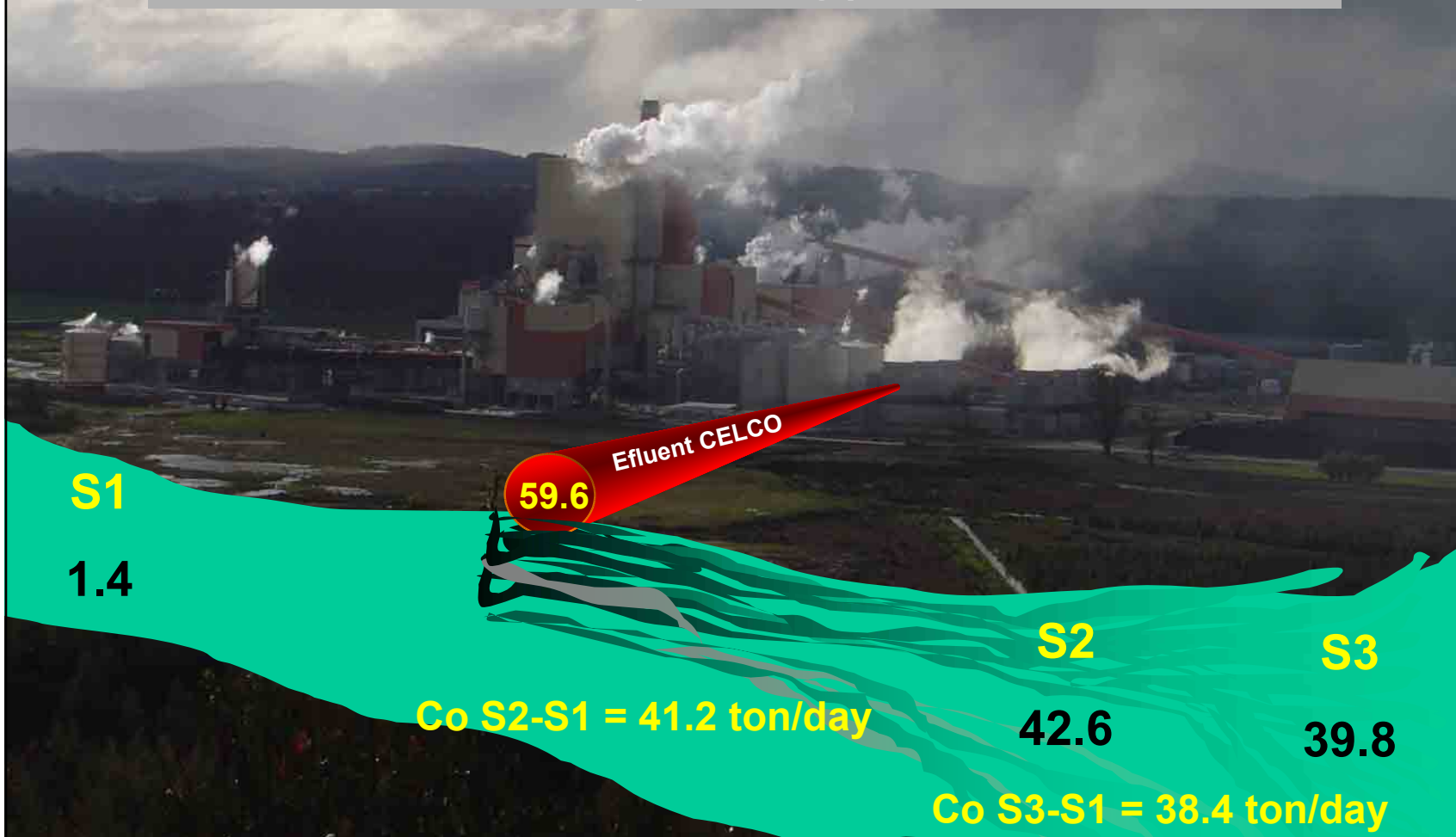
 % inorganic fraction

# Concentrations of dissolved Sulphate, Dec. 2004 (mg/L)



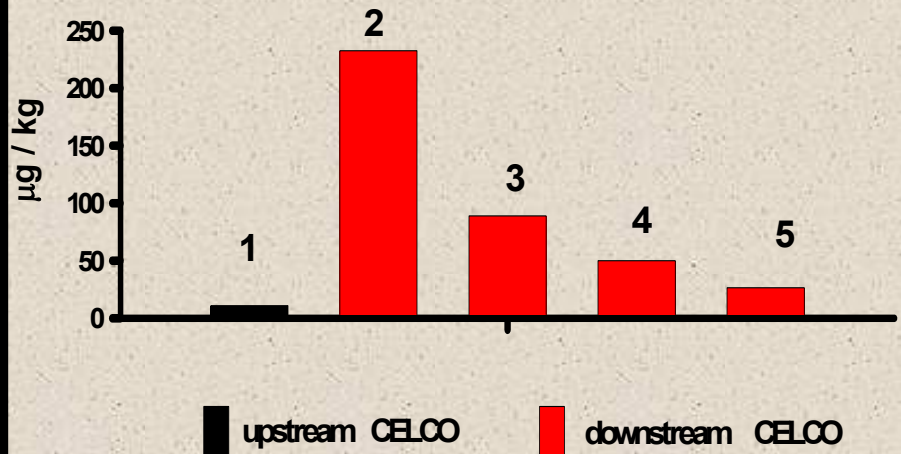


# Loads of dissolved Sulphate, Dec. 2004 (ton/day)





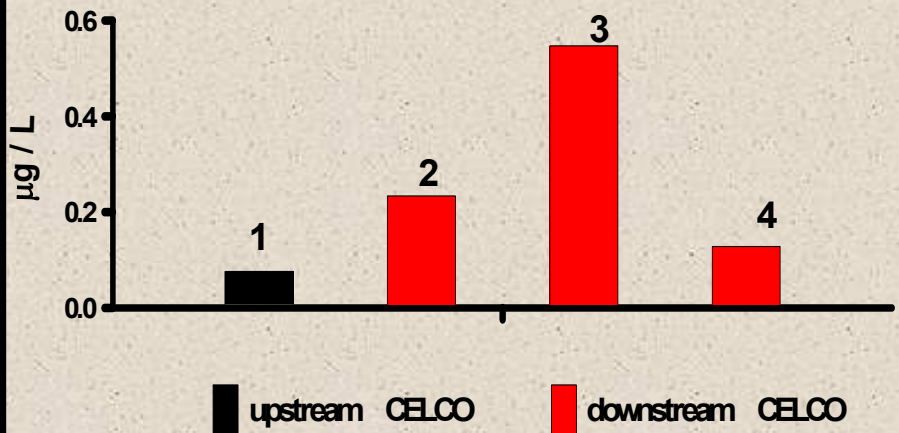
### Adsorbable Organic Halides (AOX) in sediments; 23 November 2004







**Adsorbable Organic Halides (AOX) in water;  
3-7 January 2005**



An aerial photograph of a river delta system, showing a wide river branching into numerous smaller channels and distributaries. The landscape is a mix of green forested areas and brownish-yellow fields. The text "CHANGES IN TIME SCALE" is overlaid in the center of the image in a bold, white, sans-serif font.

# CHANGES IN TIME SCALE



# B A C I

S2 (downstream or impacted station)

effluent

S1 (upstream or control station)

Mean of dif. S1-S2

BEFORE

---

12 ( $\pm 2$ ) - n = 10

12 ( $\pm 2$ ) - n = 10

---



Mean of dif. S1-S2

AFTER

¿ is there any impact ?

---

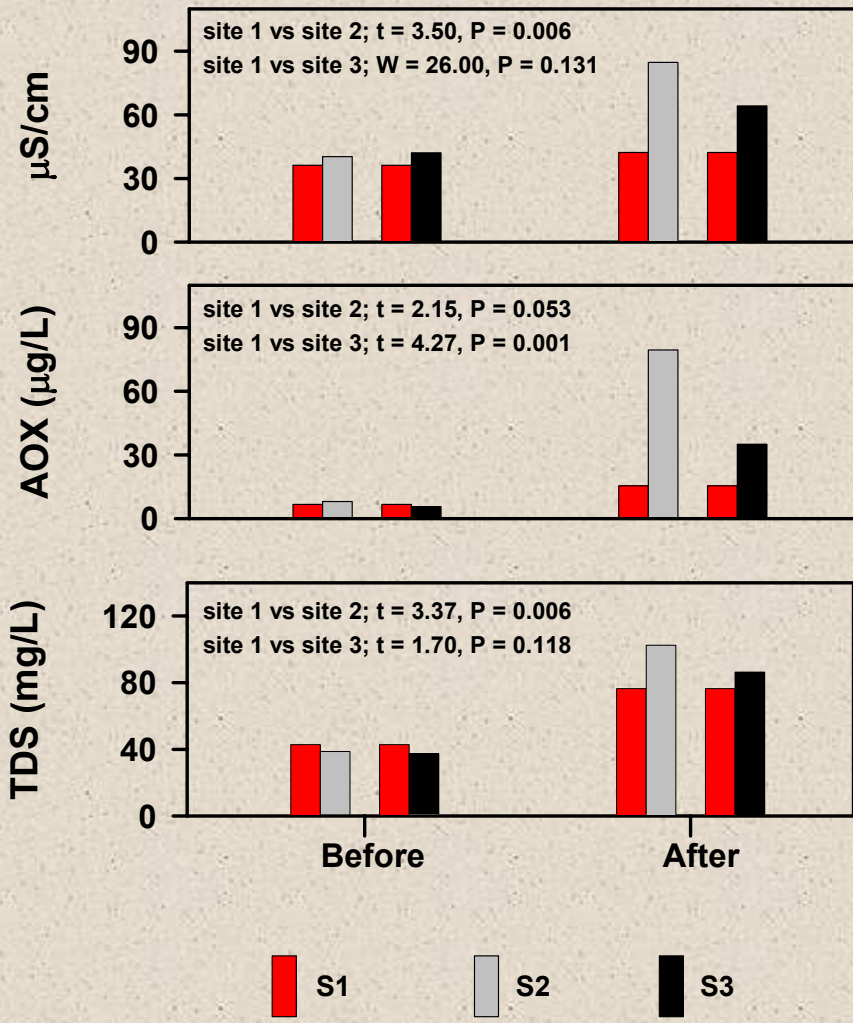
14 ( $\pm 2$ ) - n = 6

NO

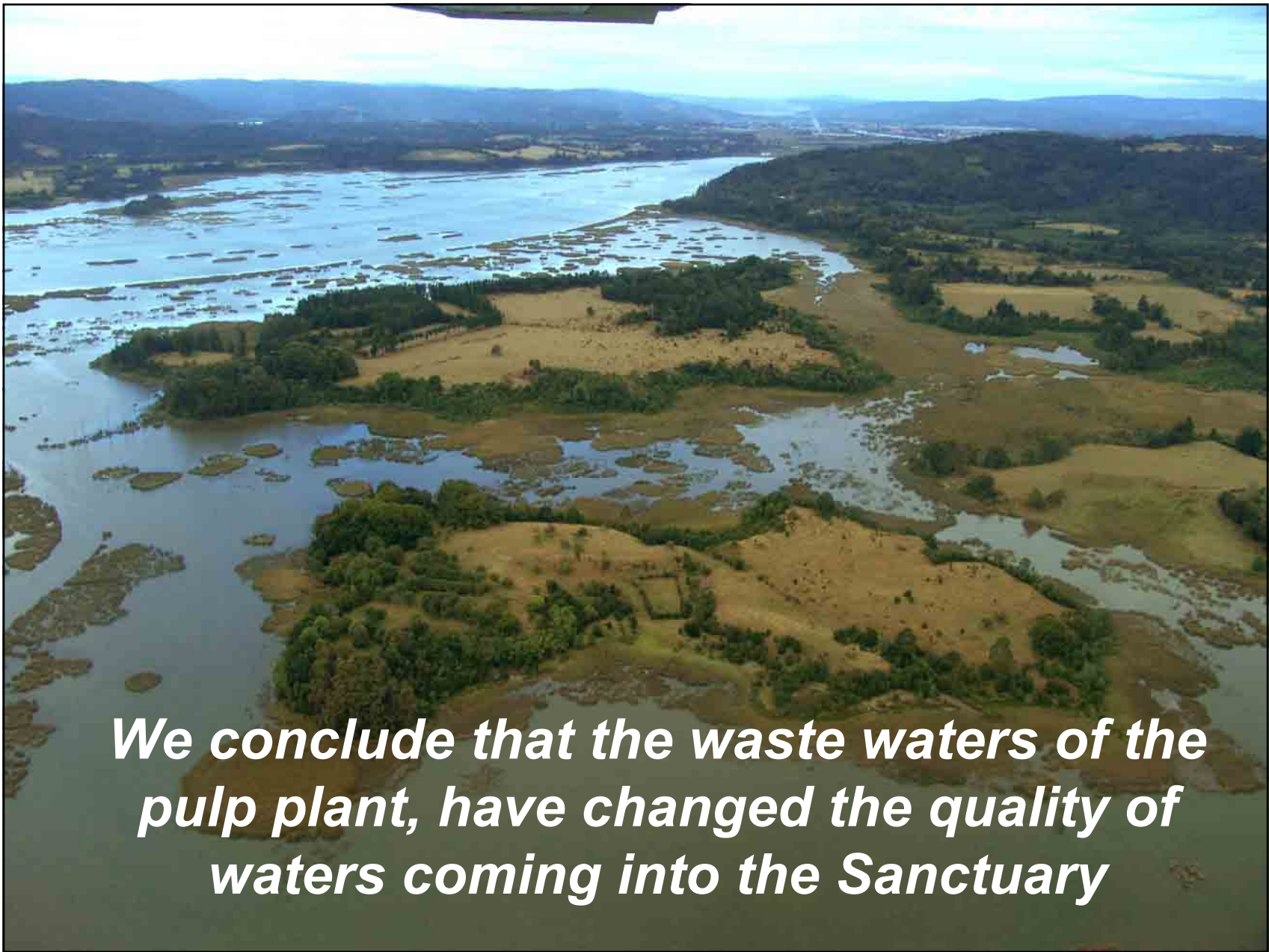
20 ( $\pm 2$ ) - n = 6

YES

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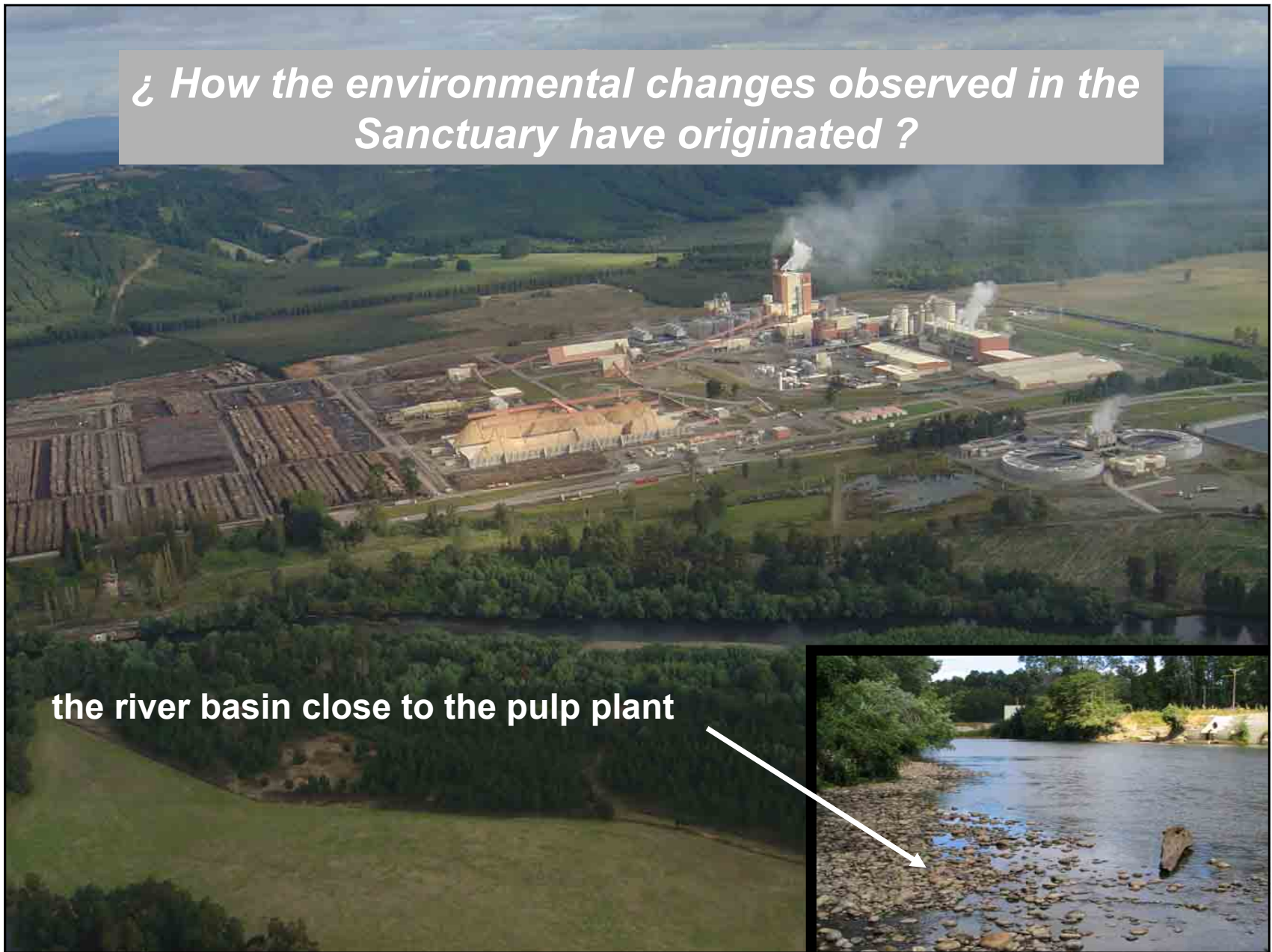






***We conclude that the waste waters of the pulp plant, have changed the quality of waters coming into the Sanctuary***

*¿ How the environmental changes observed in the Sanctuary have originated ?*



**the river basin close to the pulp plant**



*circa* 10 km downstream the pulp plant

areas where fine particles settle due to lower water velocity



**The Sanctuary: water velocity decreases, biological traps increase and tidal waves coming from the estuarine area downstream operates**





# PHYSICO-CHEMICAL TREATMENT OF WASTEWATER IN THE PULP PLANT

PRECIPITATION OF PARTICLES



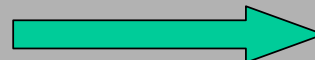
SLUDGE



LANDFILL

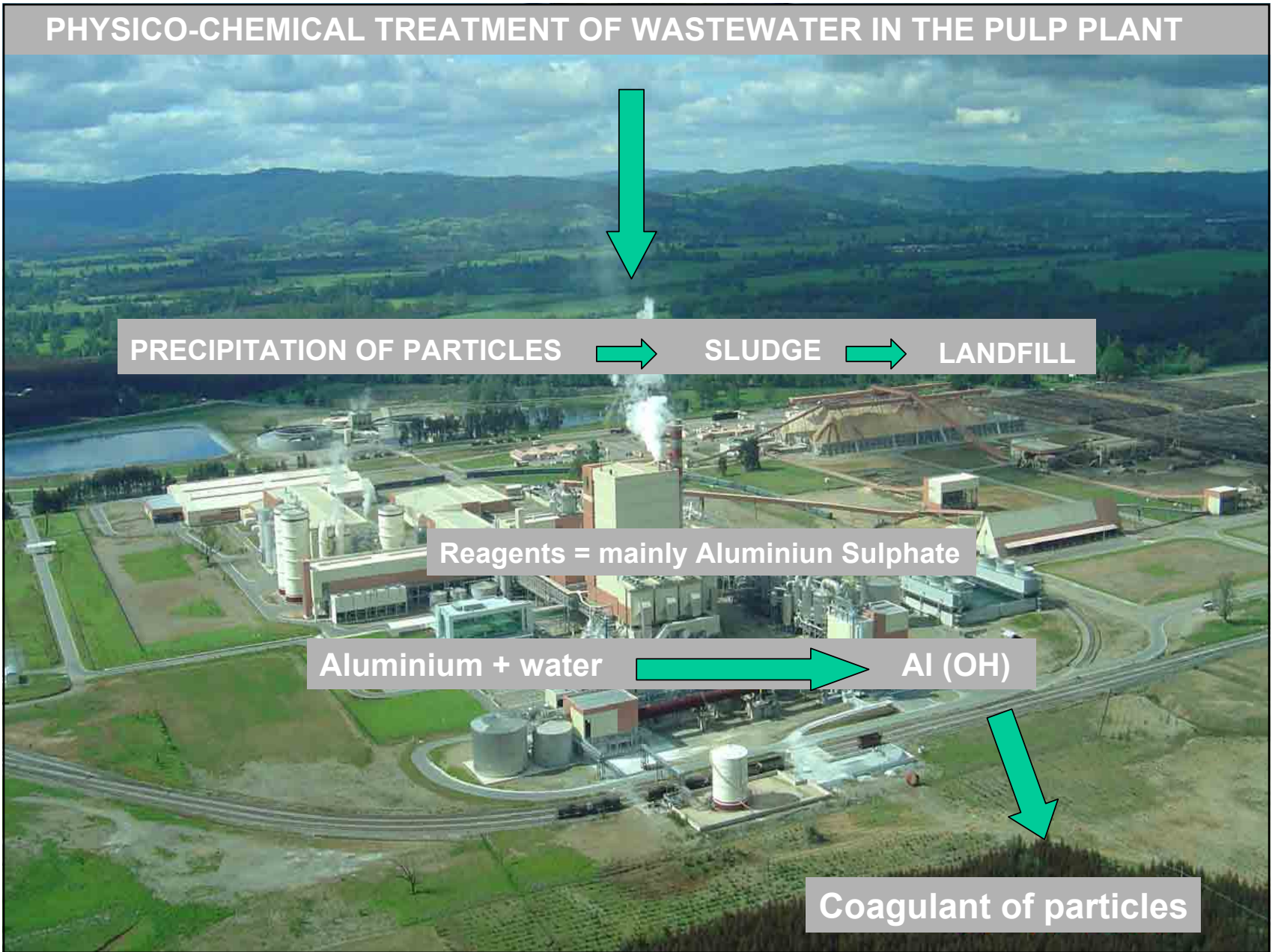
Reagents = mainly Aluminium Sulphate

Aluminium + water

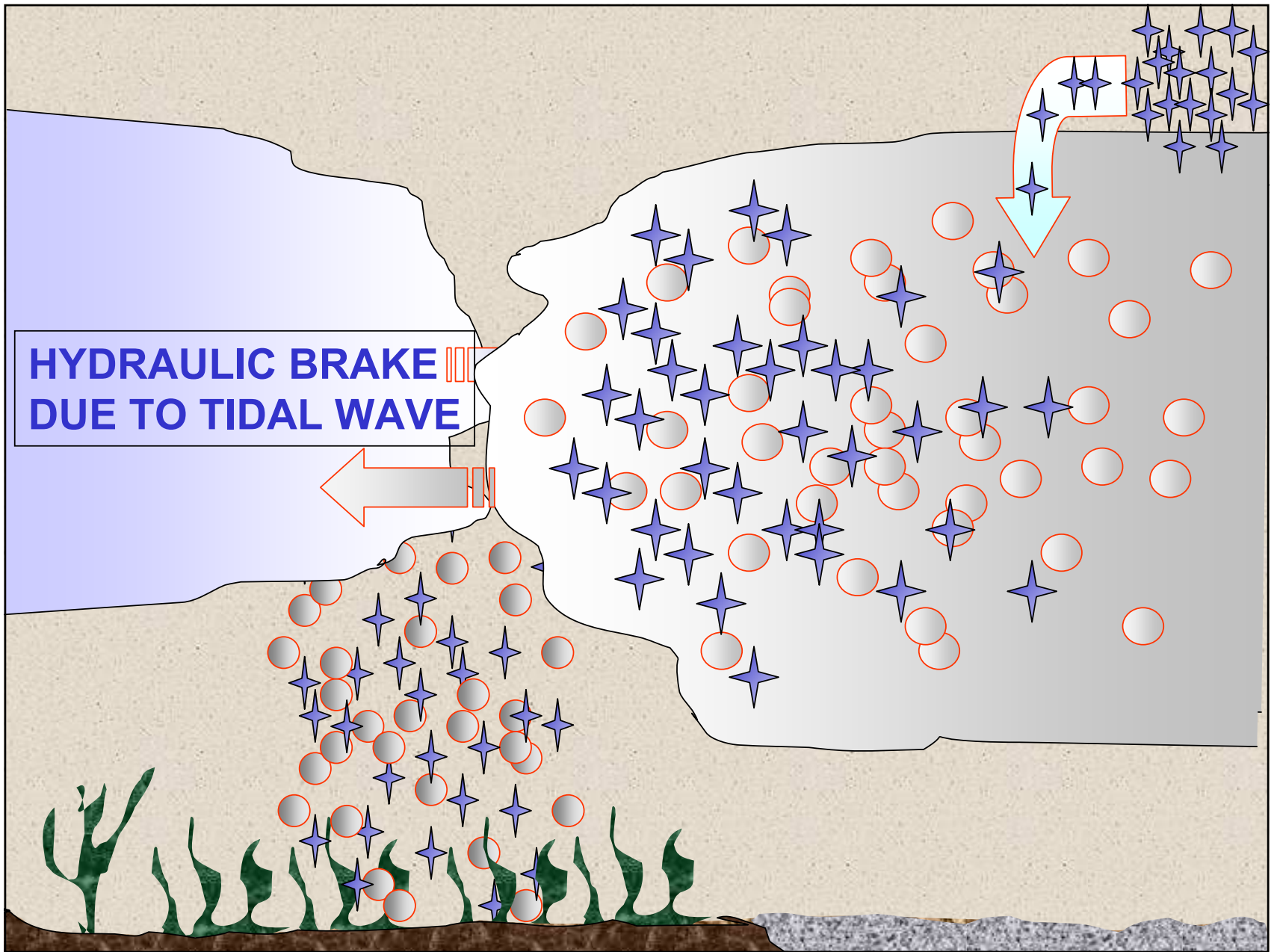


Al (OH)

Coagulant of particles







**HYDRAULIC BRAKE  
DUE TO TIDAL WAVE**

## *¿ WHY ALL THIS HAPPENED ?*

- The pulp mill is located upstream a wetland with tidal influence.
- The wetland is not a river, but an estuary; thus, tidal influence affects water velocity and consequently, deposition of particles.
- The residual coagulant (Aluminium Sulphate) entering to the wetland, induces physico-chemical reactions favouring the precipitation of flocs with high concentrations of heavy metals such as Fe, Mn and Al.
- High loads of chemicals such as Sulphates, Chlorines and heavy metals, affect aquatic macrophytes.

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# Problem 5

Environmental health of the Sanctuary

# Hypothesis 1

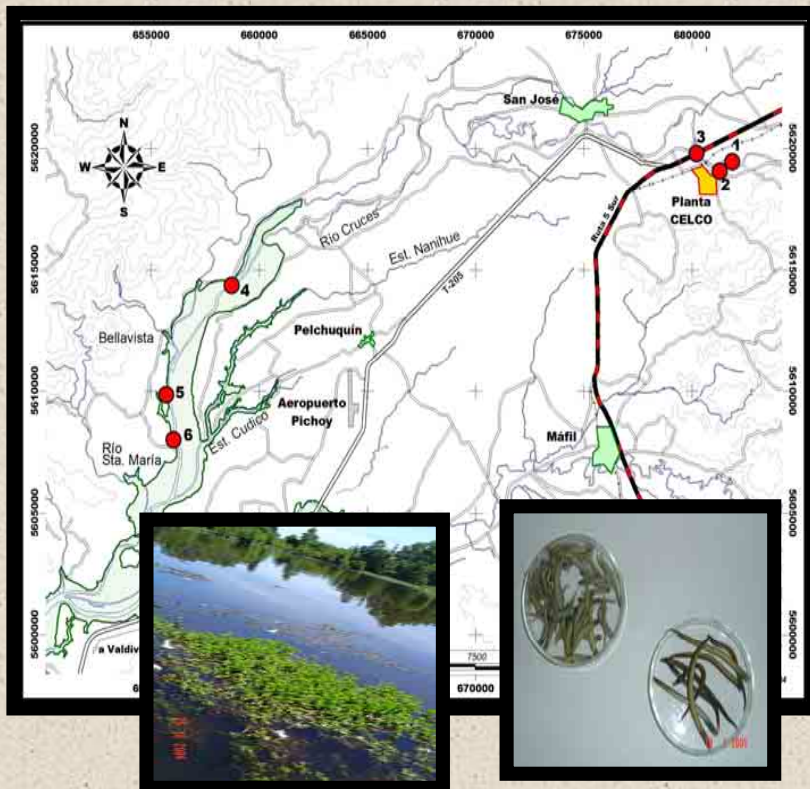
The environmental changes have affected other species apart from the swans

# Studies

Analyses of bird census, snapshot samplings of macroinvertebrates and fishes, studies of other aquatic plants apart from *Egeria* and comparison with historical data

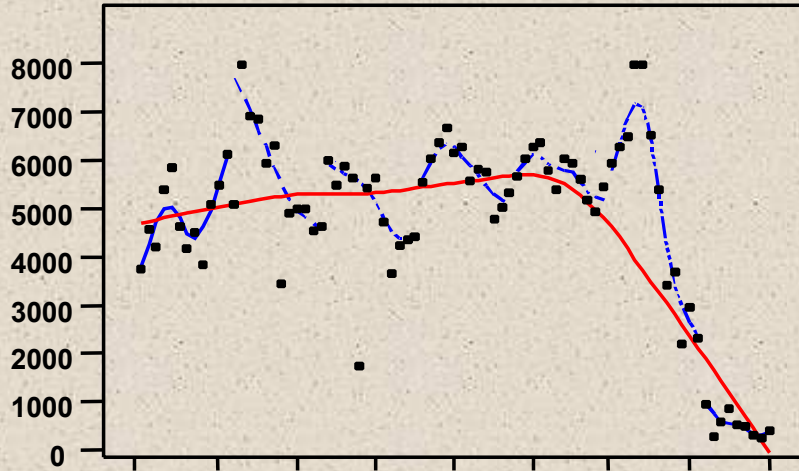
# Conclusion

The hypothesis is accepted only for some birds; for macroinvertebrates and fishes is rejected; however, no sublethal effects have been studied for the last organisms

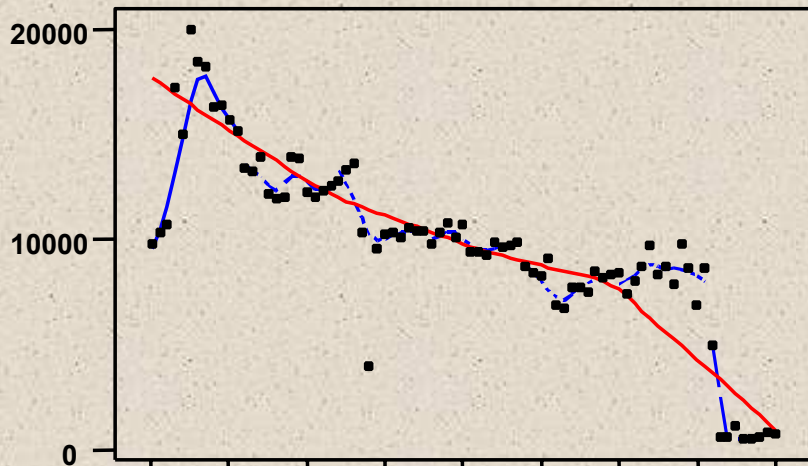




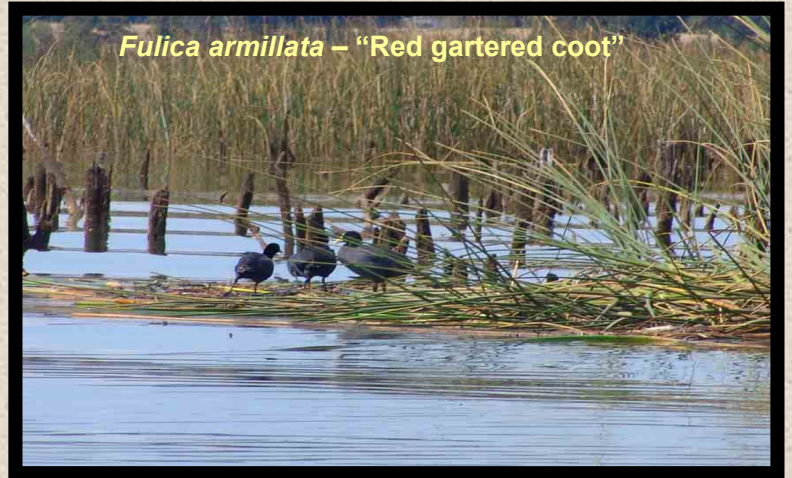
number of birds



*Cygnus melancoryphus* – “Black necked swan”

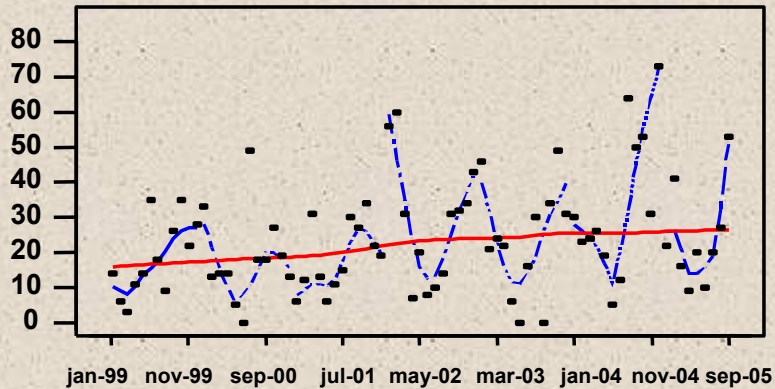
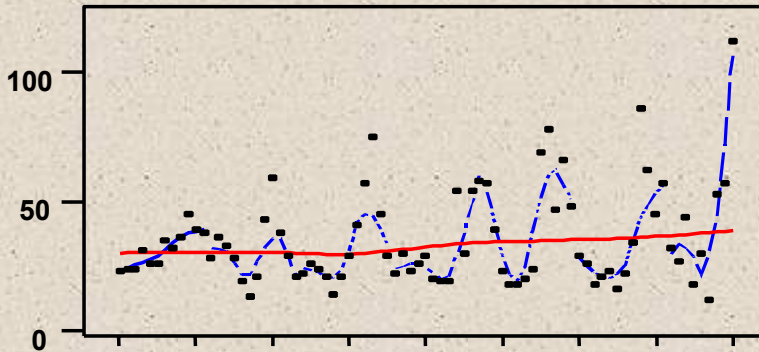
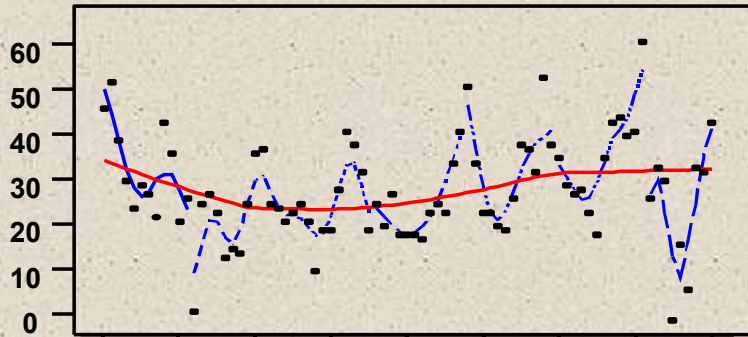


*Fulica armillata* – “Red gartered coot”



herbivorous birds

number of birds



*Ardea cocoi* - "White necked heron"



*Cosmerodius albus egretta* - "Great egret"



*Egretta thula thula* - "Snowy egret"

**piscivorous birds**

