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# Community based approach towards water quality restoration and pollution prevention of the Flores Creek (Uruguay)

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## Abstract

The micro-river basin of the Flores Creek is an important source of aquifer recharge, which is the drinking water supply of the mid-sized town of Libertad in Southwestern Uruguay as well as the irrigation source of the surrounding rural area. However, it is strongly contaminated by municipal wastewater and dairy sewage.

To mitigate this issue, an integrated river basin project based on technical and community approaches was initiated in 2008, raising awareness of the problems to relevant stakeholders and identifying the practically possible solutions.

So far, some of the implemented measures are:

- a) Design and construction of a constructed wetland for one of the larger dairy farms,
- b) Active participation of the local rural school children in the water quality/level monitoring,
- c) Integration of the data into the GIS based SWAT model (first time use in Uruguay) that will allow the prediction of the improvement of water quality and quantity following better management practices
- d) Increased monitoring of the water quality, the flow volume, the biodiversity and the water absorption capacity of the characteristic soils.

Therefore, the initial foundation for a successful IRBM has been laid, some relevant changes have occurred (such as the CW) and future steps to be taken are being addressed (such as the cleanup of the municipal sewage treatment facility).

## Keywords

water quality; constructed wetlands; SWAT; dairy farms; Santa Lucia River.

## INTRODUCTION

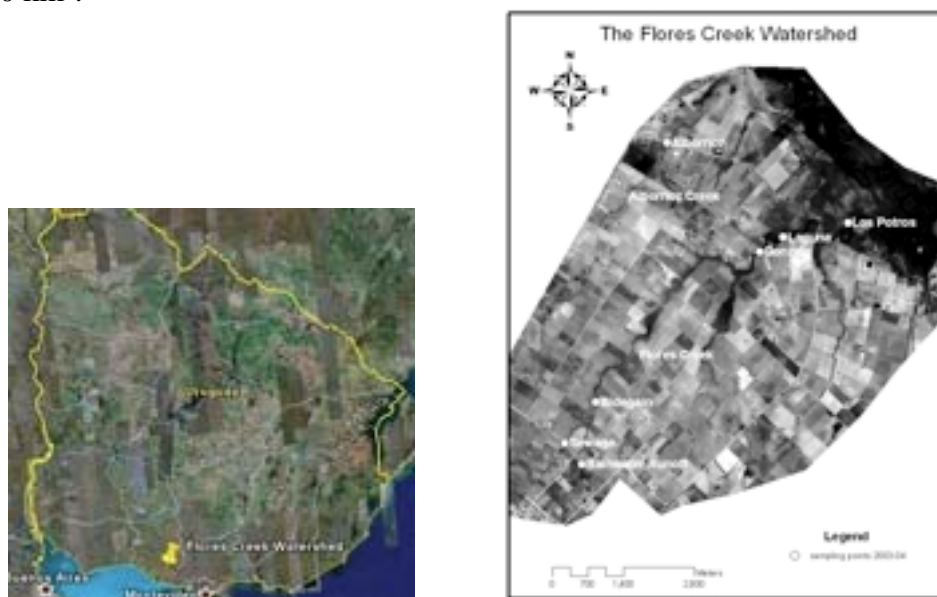
### General Background

Uruguay is one of the smaller countries in South America covering an area of 176.000 km<sup>2</sup> and a population of approximately 3 million people. It has a temperate climate where temperatures vary between 6.5 and 30.9 °C and where the annual precipitations reaches up to 1000 mm of about 90 days of rain a year, being the months between January and March the ones with the most amount of rainfall (RLA 2005). Uruguay is fortunate to have relatively large amounts of surface and subsurface waters. Sadly, drastic changes in land use, such as augmented herd sizes and the implementation of artificial pastures that go hand in hand with the uncontrolled use of chemical fertilizers and pesticides and increased irrigation activities as well as the lack of proper

sewage disposal systems of dairy farms, have provoked severe deteriorations of aquatic environments.

The dairy sector (3600 dairy farms) plays an important economic role in Uruguay and a trend of increased milk production and thus, the number of cows in milking and sewage, has been occurring for the past decade (from 600000 cows in 1980 to more than 750000 in 2008, MGAP 2009) as is common to other parts of the world as shown by Martinez *et al.* 2009. The main challenges for the implementation of sewage treatment facilities for the milking parlor effluents lie within the costs of construction and the lack of direct benefit from this investment for the farmers. No economic incentives either by the government or the industries are being offered so far, although a clear link between eutrophication of surface and subsurface waterways and improper sewage disposal has been detected by the Ministry of Environmental Affairs (DINAMA) in a small scale study, where 5 out of 37 surveyed farms complied with national standards (Conaprole, DINAMA, 2007).

The Flores Creek watershed is a typical example of the ones found within the dairy belt and is situated in the Southwestern part of Uruguay within the department of San José, 60 km north of Uruguay's capital Montevideo (see figure 1). It drains into the Río San José which flows into the Río Santa Lucía which itself ends up in the Río de la Plata and the Atlantic Ocean. The Flores Creek has two small tributaries the Cañada Clara and the Cañada Fea and its watershed comprises ca. 80 km<sup>2</sup>.



**Figure 1: Location of the Flores Creek in South Western Uruguay (see pin) (Google Earth) and sampling locations within the Flores Creek Watershed (produced through ArcView 3.1).**

Moreover, this creek is to become part of the Santa Lucia Wetlands National Park (HSL 2009), where water and ecosystem quality will become a priority (Figure 2), and where the downstream portion of the Flores Creek would enter into both the core zone (Zona 1) as well as the buffer zone (Zona 2).

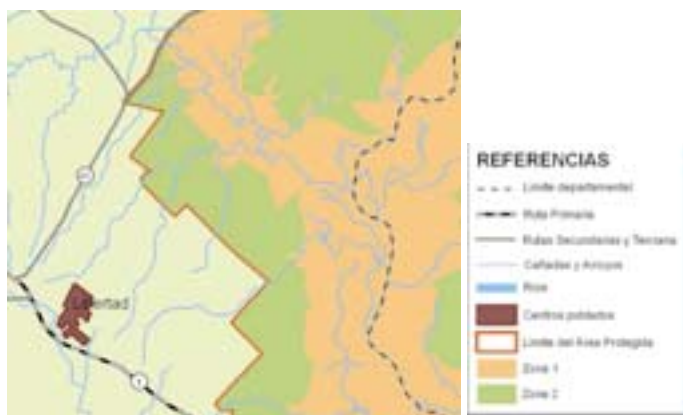


Figure 2: Map of the geographical zonation of the future National Park (Flores Creek area only) (HSL 2009)

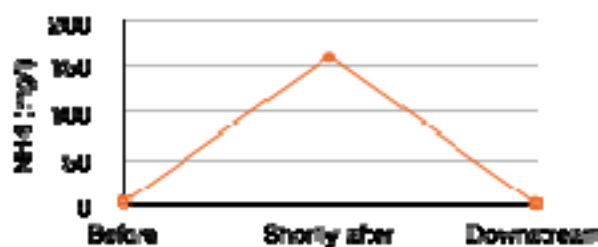
#### Water quality and ecosystem problems

Through water quality sampling since 2003 we have been able to show the detrimental effects of the outflow of

- the primary sewage treatment facility of the city of Libertad and
- the raw sewage discharge of several dairy farms,

on the water quality, leaving the upstream portion entirely anoxic (see figure 3) (Avellan 2004) and rendering some stretches of the tributaries not suitable for aquatic life.

Changes in  $\text{NH}_4$  Conc. b/o of Dairy Farm Sewage July 2008



Changes in Dissolved Oxygen Concentrations along the Flores Creek

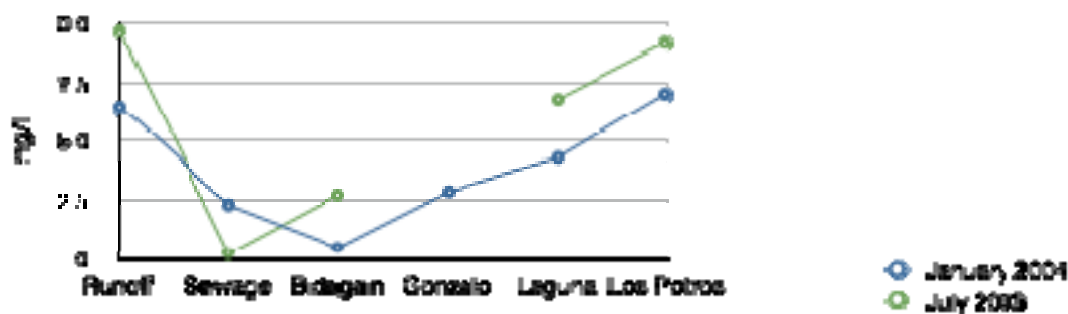


Figure 3: Influence of untreated dairy farm sewage on the ammonium concentration of the Canada Clara (July 2008) and Dissolved Oxygen concentrations along the Flores Creek in 2003 and 2004

We also clearly showed a link between sewage effluent pollution in the Flores Creek and species diversity (see figure 4), being the least polluted sites the more biodiverse ones (from Avellan 2004).

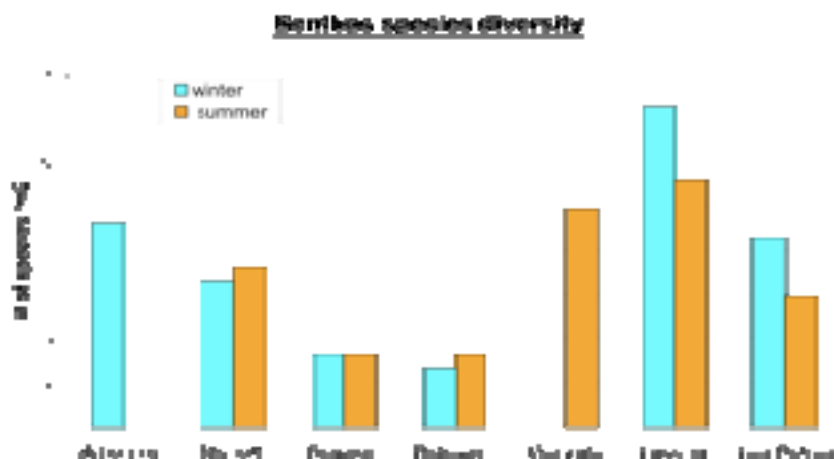


Figure 4: Benthos species diversity of samples taken in July 2003 (winter) and January 2004 (summer)

Moreover, the creek is an important recharge element for the aquifer since the infiltration rates through the surrounding limestone soil is slow and the aquifer is largely rainwater fed (RLA 2005). High nitrogen rates have already been confirmed in the aquifer (RLA 2005) and correlate strongly with anthropogenic pollution sources.

Wetlands are known to be the most prone sites for aquifer recharge and therefore need special attention, such as a 20 ha *Typha sp.* wetland between the Bidegain and the Gonzalo site (see figure 5) that might be largely responsible for the enhanced water quality at the latter site.



Figure 5: Part of the *Typha* wetland at about 1/3 of the creek.

## MATERIALS & METHODS

### Research and community based problem identification and solution finding

Following APHA standard procedures, we have been studying the water and ecosystem quality of the Flores Creek since 2003/2004 (for detailed description see Avellan 2004).

Further, several reports about the water quality of the region exist, such as the work on the Ragoon Aquifer and the ongoing study of the Santa Lucia River Basin by the Ministry of Environmental Affairs (RLA 2005, JICA 2008), in which part of the diagnostic of the water and ecosystem quality has been based.

From November 2007 onwards, we actively searched for the interaction with potential interest groups. First, we invited all the dairy farmers of the creek for a meeting where their main con-

cerns in view of the environmental degradation were addressed and potential solutions they had thought of, heard of or implemented, were discussed.

Subsequent to this first meeting, we started to address the public agencies to sense their interest for the matters of integrated catchment management and water pollution at the rural-urban interface.

Several other meetings that were open to all public followed, in which the proposed solutions were presented, explained and discussed and the importance of the natural riverine habitats were underlined.

In coordination with the farmers and the other involved interest groups the following actions to undertake were distinguished:

- innovative and sustainable solution for the dairy farm waste waters → Constructed wetlands
- integration of the locals → environmental education with the school children
- use of IT tools to aid in the visualization of the problems and model future scenarios → use of SWAT

Monitoring of the process to show the changes in the water quality were requested to justify the implementation of the solutions and to potentially pinpoint other sources of pollution.

## RESULTS & DISCUSSION

### Community based problem identification

The farmers identified soil erosion, water quality and invasive exotic species as well as useful and easy solutions for their sewage treatment facilities as their main concerns.

With the public agencies three working agreements were signed.

1. One with the local municipality (Intendencia de San Jose) in particular the hygiene section, who have committed to ongoing water quality monitoring of the creek as well as to exercise pressure on the local water company to enhance the municipal sewage treatment facility. Further, it is likely that the Intendencia will lend their heavy machinery to the farmers for the construction of further constructed wetlands for the dairy farm effluent and set up a plan for the regular maintenance of the systems.
2. The Ministry for Agriculture, especially the Water and Soil section and their laboratory, is performing water analyses on a regular basis to test if the water quality complies with irrigation standards and are also testing the soil humidity and water absorption capacity of the surrounding soils.
3. The Universidad de la Republica is undertaking studies on macro-invertebrates in the creek to see how the species composition has changed in the past 5 years and to monitor further changes which may arise due to the implementation of measures that shall enhance the water quality.

### Proposed integrated solutions

#### *Constructed wetland for one of the larger dairy farms*

The Bidegain family is one of the six mid sized dairy farms of the Flores Creek catchment (there are also 4 small farms) and has traditionally milked cows for the past 100 years here. In their dairy parlor they milk approx. 200 cows twice a day and use roughly 16 m<sup>2</sup> of freshwater a day for washing the cows and rinsing the parlor. About ten years ago they had constructed a double lagoon system as a means of treating the waste water before it entered the Cañada Clara, a tributary to the Flores Creek. However, this system had filled up recently due to the lack of maintenance and they therefore decided to build a new system.

Using an online calculation tool developed by local civil engineers and agronomists we were able to calculate the dimensions needed for a sediment trap as well as a double lagoon system (MGAP PPR 2009).

Following this, we designed a free water surface constructed wetland of 736 m<sup>2</sup> planted with *Scirpus americanus* (see figure 6) (according to methods proposed in Kadlec & Knight, 1996).



Figure 6: Images of the construction of the wetland and the vegetated areas.

To optimize future constructed wetlands we undertook root oxygen loss laboratory experiments with four plant species (*Typha latifolia*, *Phragmites australis*, *Cortaderia selloiana*, *Juncus acutus*), which were carried out at UNESCO-IHE, The Netherlands, sponsored by the UNESCO Keizo Obuchi Research Fellowship. These experiments showed increased oxygen release into the water column of two native species, *C. selloiana* and *J. acutus* (Figure 7).

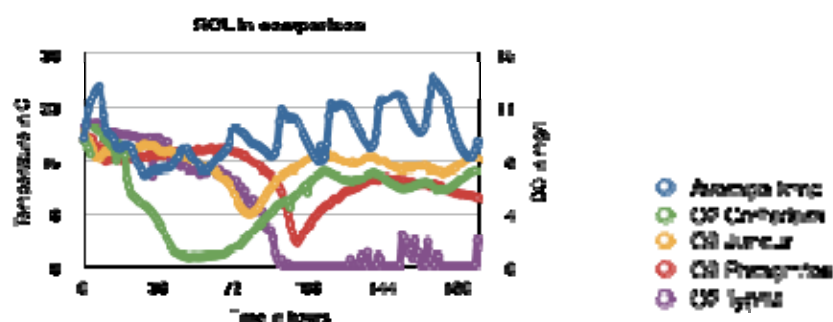


Figure 7: Changes in Dissolved Oxygen Concentration in artificial sewage water according to the used plant

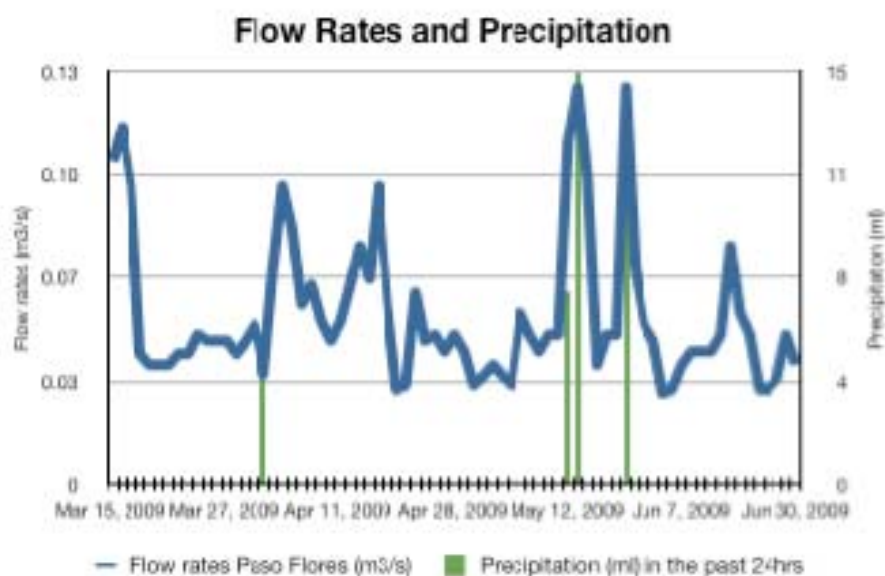
#### *Active participation of the local rural school children in the water quality/level monitoring*

Within the watershed there is one school with children ages 4-14. Several environmental education lessons have been taught here (by myself and others, Figure 8) and they now form part of the World Water Monitoring Day Campaign from WEF and IWA, where a donation of water quality sampling kits has been obtained.



**Figure 8: Left: Workshop on waste management with the children of 3rd grade of a school in Libertad in co-work with REDES- Friends of the Earth; Right: Water quality monitoring with the rural school children using the donated kits of the WWMD campaign**

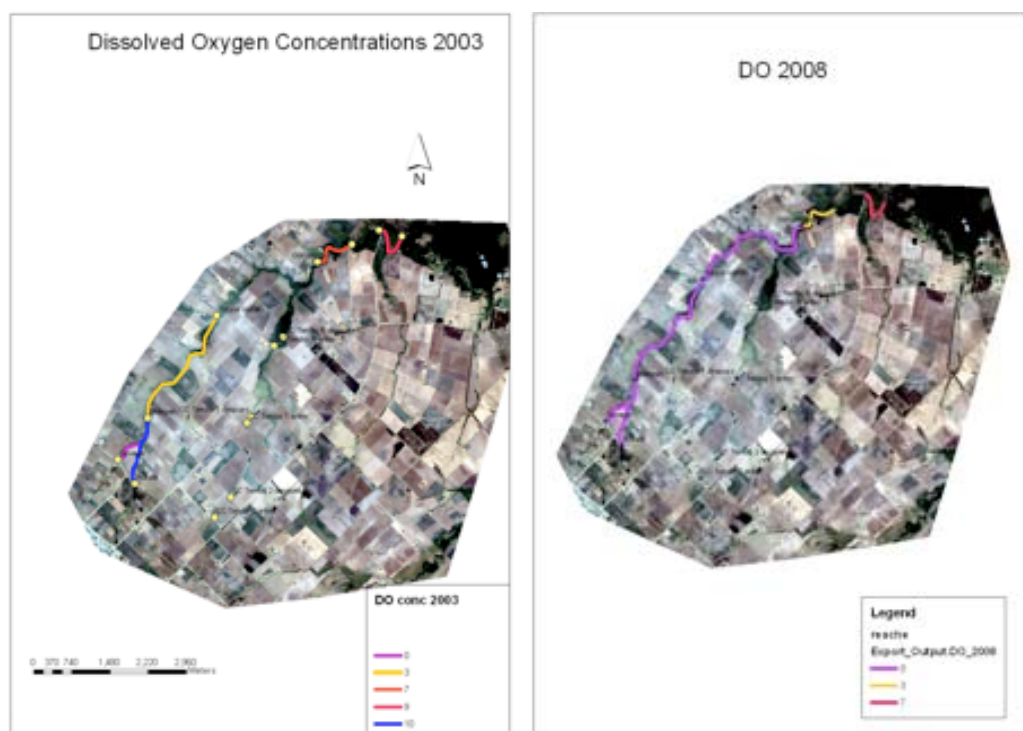
Further, three of the children pass over the Flores Creek (Paso Flores) every day on their way to school and have been in charge of taking daily water level measurements with a graduated stick. Thus we have been able to obtain the fluctuation of the water level since the March 2009 (Figure 9) showing an average flow rate of  $0.05 \text{ m}^3 \text{ s}^{-1}$ .



**Figure 9: Daily flow rates of the Flores Creek at Paso Flores.**

#### *Integration of the data into the GIS based SWAT model*

The data has been included and integrated into GIS (ArcView and MapWindows) which is helping in the visualization of the problem zones (figure 10), both in space and time and will allow the prediction of the improvement of water quality and quantity following better management practices (such as constructed wetlands for dairy farm effluents). Figure 10 clearly shows the deterioration of the water quality in the basin and the strong influence that the insufficient sewage treatment facility at the headwaters has.



**Figure 10: Comparative images of dissolved oxygen concentrations in the Flores Creek Watershed that show the clear deterioration of the water quality in time and space.**

Moreover, preliminary intents to build the model (Soil and Water Assessment Tool SWAT) have been undertaken and the missing data has been identified as well as the sources to fill in the gaps. Thus within the coming months a full model should be built and ready to use, enabling us to predict changes in water quality and levels according to the management practices, the infiltration into the aquifer and the enhancement of the overall system. The Ministry of Agriculture, in particular, will use the outcome of the model to better allocate the irrigation quotas to the farmers and make them dynamic and in relation to rainfall, in order to not strain the ecological base flow of the creek in drought periods.

This model could further form the basis for future uses of SWAT in Uruguay, such as for the large Santa Lucia River Basin.

*Increased monitoring of the water quality, the flow volume, the biodiversity and the water absorption capacity of the characteristic soils*

Since 2008, through the working agreements with the public institutions water quality measurements and benthic species diversity as well as soil water absorption capacities monitoring were commenced. Thus a decrease in dissolved oxygen and an increase in nutrients was noted since the last measurements in 2003/2004 (see figure 11) which is due to the lack of maintenance of the municipal sewage treatment facility.

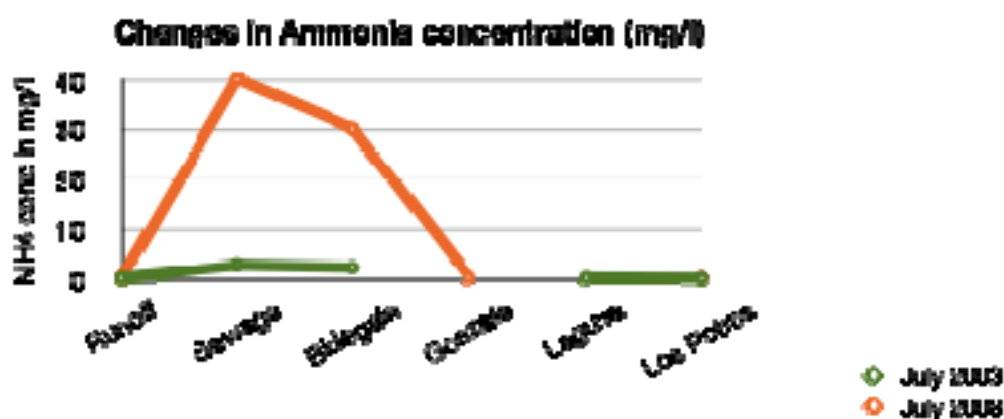


Figure 11: Increase in  $\text{NH}_4^+$  concentration in 2008 compared to the previous years.

Preliminary classification of benthos diversity into classes, within the samples taken in November 2008, confirms the trend revealed in previous years of a gradual increase in diversity downstream of the sewage effluent (Figure 12). This is true even if the sampling season were different, showing the highest species diversity in July 2003 - in winter - whereas the highest species diversity should be expected in spring (Sept-Nov). Further, in 2008 not even the characteristic *Tubifex sp.* worms were found at the sewage location.

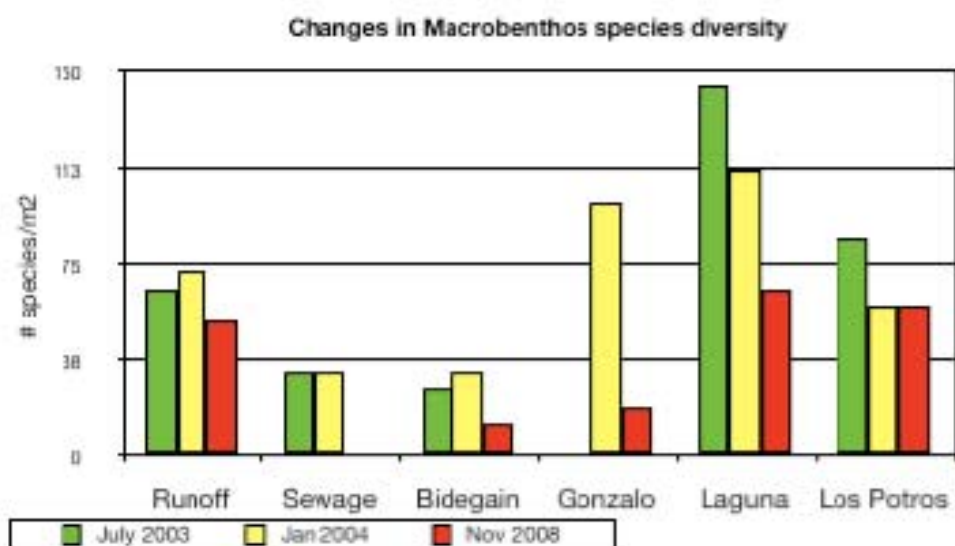


Figure 12: Benthos species diversity in the Flores Creek of samples taken in 2003/2004/2008

As oxygen depletion becomes less of a problem due to sewage input reduction, we expect an increase in species diversity in all sites which will be a clear sign of ecosystem rehabilitation and the justification of the initial investment in the sewage treatment facilities.

## CONCLUSIONS

This project is one of the first intents in Uruguay to apply integrated river basin management techniques in order to stop the pollution of the surface and subsurface waters and safeguard the livelihood of the affected rural and urban population. Starting on a sound scientific basis as well

as community based approaches, relevant problems, stakeholders and adequate solutions were identified and carried out. Validation of these processes is still occurring and will determine the efficiency of the applied measures.

Many problems still need to be tackled such as

1. the pollution caused by the insufficient municipal sewage treatment facility (a claim has already been entered to the Ministry of Environmental Affairs DINAMA in March 2009)
2. the pollution caused by other dairy farms - further CW are in planning
3. data collection (ongoing)
4. fine-tuning of the model - will be aided by the results of some of the studies such as the water absorption and moisture retention analysis
5. further integration of the community - such as the city schools

Nevertheless, the most important obstacle of gaining the trust of the involved parties has been overcome.

## ACKNOWLEDGEMENTS

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