

The Waterharmonica in Costa Brava: Empuriabrava and Aiguamolls Natural Park

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Consorci de la Costa Brava

Photo: White water
crowfoot (*Ranunculus
aquatilis* L.) grown on
reclaimed water produced
by the Empuriabrava
constructed wetland facility
which is used to restore
wet meadows in the Parc
Natural dels Aiguamolls de
l'Empordà, April 2007

**Workshop “The value of the Waterharmonica for Waternet”
Amsterdam, 24 April 2009**

You already know why I'm here



The Dutch vs the Catalan experiences

- Same ideas, different approaches, similar results

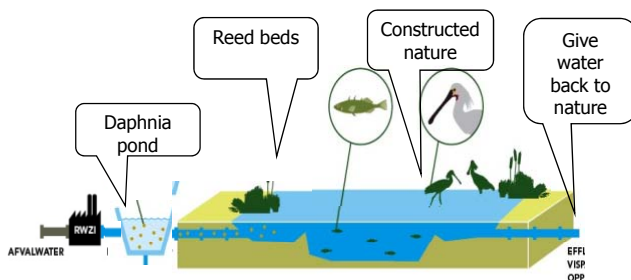


Dutch experiences



Catalan experiences

It's all about food chains

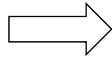


By courtesy of Ruud Kampf - <http://www.waterharmonica.nl>



It's about life

It's about providing time and space for the dissipation of chemical energy into biomass = to allow **LIFE** to develop



Sense of events in the Empuriabrava wetland system



Choices to make

Reclaimed water produces biomass – which one to grow?



Golf course turf, Sta. Cristina d'Aro, June 2005



Corn, Sta. Cristina d'Aro, June 2005

Constructed wetlands, Empuriabrava, May 2005



Or



Reclaimed water in the Tossa Creek, June 2005

Empuriabrava constructed wetlands as a recreation of a natural wetland



Some of Ruud's pictures taken at the Empuriabrava constructed wetland...









Porzana parva in flight





Environmental problems in Mediterranean aquatic ecosystems

- Generally, under severe stress due to:
 - Decrease in natural flows:
 - Increase in demand (agricultural and golf course irrigation, drinking water demand)
 - Periodic droughts
 - Urban (usually treated) and industrial wastewater discharges
 - Diffuse pollution (urban, agricultural, farming)
- EU Water Framework Directive: requires good ecological status in natural water bodies. A demand impossible to fulfill in the case of Mediterranean aquatic ecosystems?
- The situation of smaller ecosystems is sometimes dramatic



Boadella reservoir,
october 1998



Pond in l'Albera
mountains,
january 2007



Ter river near its mouth in
Torroella de Montgrí, january
2008 (left) and march 2009
(right)

Reclaimed water potential for aquatic ecosystem restoration or recreation

- Urban supply is a non-consumptive activity: availability of water is limited, but the volumes are predictable and relatively constant over time.
- If there are no toxic discharges, original quality can be restored to a great extent.
- It can be used for restoration of ecosystems affected either by drought and/or pollution and for recreation of vanishing habitats (i.e., wetlands)



Water produced by the Blanes reclamation plant (N/DN + Title-22) and used for the recharge of the lower river Tordera aquifer by percolation, 7 July 2005

Summary of quality in 2007

(Percentile 90 of the annual set of data):

SS = 2.4 mg/L (319 samples)
 Turbidity = 2.2 UNT (324 samples)
 Total nitrogen = 9.2 mg N/L (140 samples)
 Total phosphorus = 1.8 mg P/L (141 samples)
E. coli < 1 cfu/100 mL (116 samples)

Secondary effluent from the Empuriabrava WWTP after biological filtration in *Daphnia* ponds, 10 July 2007



Main idea

To develop food webs from the nutrients dissolved in treated water to produce high-value biomass



Papers presented in the 1st Annual Meeting of the Society of Wetland Scientists – Europe, "Integrating our approaches to Wetland Science", Bangor, Wales, UK. January 5th-7th 2006.

Available in <http://www.waterharmonica.nl/posters/bangor.htm>

L. Sala, T. Claassen, R. Kampf, J. Sala, D. Boix, H. van der Geest: *Trophic webs from discharges: Nature enhancement through the Waterharmonica concept* (new version in this conference, poster SC18)

R. Kampf, H. van der Geest, T. Claassen, and L. Sala: *Sludge particles as food source for Daphnia*.

See also poster SC19, R. Kampf, L. Sala, H. van der Geest, A. Romaní, J. Comas, T. Claassen, S. Gerbens and R. Neef: *Biological filtration of treated waste water by Daphnia: An alternative for technical filtration, or an addition?*

Main criteria for reclamation through natural systems and environmental reuse

- According to our empirical observations:
 - Change of paradigm in wastewater treatment: classical limits of 25 mg/l BOD and 35 mg/l SS not useful anymore.
 - Need of nitrification (+ denitrification, if possible) to create no oxygen demand in the receiving water body.
 - Ammonia stimulates growth of phytoplankton and leads to oxygen imbalances and loss of biodiversity (high biomass of very few species) + duckweed growth
 - Nitrified effluents are suitable to be further polished in natural systems such as constructed wetlands if environmental reuse is intended



Effect of ammonia: growth of phytoplankton



Effect of nitrate: growth of hydrophyta and filamentous algae

Benefits of nitrification

- Water remains clear in the constructed wetland
- Allows the development of dense populations of cladocera (i.e. *Daphnia* spp.), filamentous algae and hydrophyta (*Zannichelia palustris*, *Najas minor* in Empuriabrava) that keep on improving water quality (reduction of SS, turbidity and faecal indicator microorganisms)
- Denitrification is an almost spontaneous process, except in winter, due to the low water temperatures
- Development of food webs from the nutrients still dissolved in the water
- No oxygen depletion



Impressive *Daphnia* populations!

Phosphorus removal

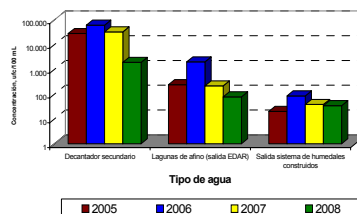
- Desirable due to the lower risk of eutrophication
- Differently than in the case of nitrogen:
 - Lower removal efficiencies in the wetland: no aerial portion of the P cycle and intense phosphatase activity in sediment's biofilm – P brought back to the water column. Gemma Vidal's Master Work at UdG - http://www.ccbgi.org/docs/recerca_aplicada/projecte_sac-_master_gv-08.pdf
 - Possible increasing trend with years
 - Despite the low N/P ratio, no cyanobacterial development observed.
- At the Aiguamolls de l'Empordà, nitrogen, not phosphorus, is the limiting nutrient, but still a greater care would be required in the future.



Disinfection

- Natural disinfection provided by environmental conditions and by filtering organisms (i.e., cladocera)
- Real performance may be hindered by animal contributions (wildfowl, grazing animals, etc.)
- Empuriabrava (2007): 2.6 log removal of *E.coli* between secondary clarifier and outlet of the constructed wetland (1.7 log in *Daphnia* ponds). In 2008, 1.8 log and 1.4 log, respectively.
- Removal of faecal microorganisms is close to the values achieved by more conventional technologies.

CONCENTRACIONES DE COLIFORMES FECALES (2005, 2006 Y 2007) Y *E. COLI* (2008) EN LAS INSTALACIONES DE TRATAMIENTO DE AGUAS RESIDUALES DE EMPURIABRAVA. MEDIAS GEOMÉTRICAS.



By courtesy of Georgina Mila

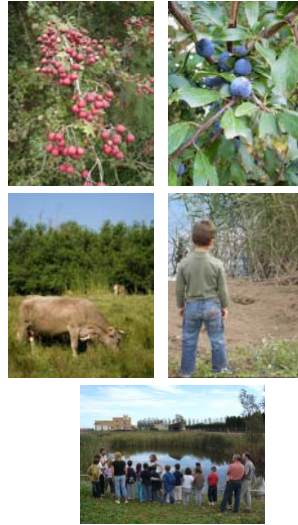
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Additional opportunities offered by artificial systems for environmental enhancement

- Biodiversity enhancement:
 - Create diversity of environments (ponds with different depths, bushes with berries, wet meadows)
 - Control of water levels
 - Design of specific areas for the protection and/or breeding of species threatened by habitat loss -fartet (*Lebias iberà*), European pond turtle (*Emys orbicularis*), etc.



The Empuriabrava constructed wetland system

- In operation since 1998 beside the Empuriabrava WWTP. Project funded by EU Cohesion Funds (80%) and CCB (20%):
 - Constructed wetland: 3 treatment cells of 0,8 ha each + shallow lagoon of 4,5 ha (total, approx. 7 ha).
 - Pumping station and 2 km pipeline to deliver reclaimed water to the Parc Natural dels Aiguamolls de l'Empordà (PNAE).
 - Pedestrian bridge on the Muga river to connect urban area of Empuriabrava with PNAE.

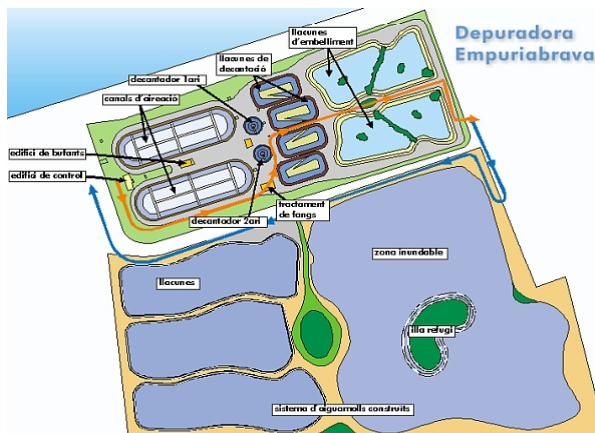


Goals of the project

- To supply water in the 18-ha manmade Cortalet lagoon to avoid its summer dessication and/or to restore wet meadows in the surrounding area.
- To reduce discharges in the nearby Muga river
- To avoid the eutrophication that reclaimed water could cause if nutrients were not removed.
- To help with the preservation of the local habitats and their specific flora and fauna



Diagram of the facilities



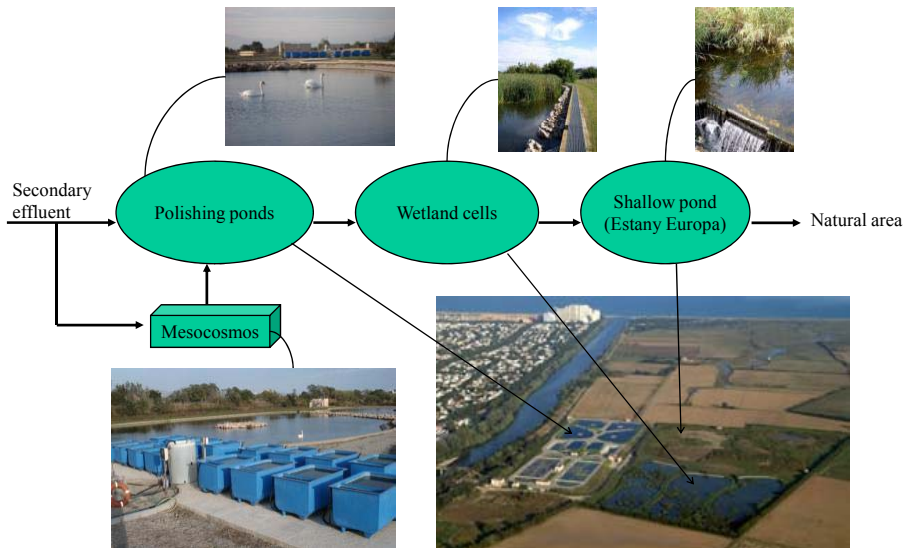
Operation of the system

- 2000-2008: Average of 78 % of the treated wastewater treated through the wetland system and recycled for environmental purposes (737.000 m³/year out of 940.000 m³/year ⇒ not discharged to the Muga river). Since 2007, almost all the flow is reused thanks to the new third biological reactor.
- Performance:
 - Evaluated according to the removal of total inorganic nitrogen (TIN)
 - Nutrient loads (concentration x flow) calculated for both system inlet and outlet
 - Removal of 85% of the TIN in 2008 (approx. 6,300 kg N)
 - Estimations of P removal show greater annual variability; in 2008, 47% of total phosphorus (approx. 2,700 kg P).

Mesocosmos experiments in Empuriabrava

- Provide very interesting information about the performance of polishing ponds
- Allow experimentation – replicas
- Unique field for ecological engineering experimentation – dynamics of nutrients, microbiology, particles, bioaccumulation, trophic webs, etc.
- Comparison with full scale natural treatments in the vicinity and with technical reclamation treatments in the nearby area
- And... impressive results, specially in microbiology!

Empuriabrava scheme



From Colom *et al.*, 2009

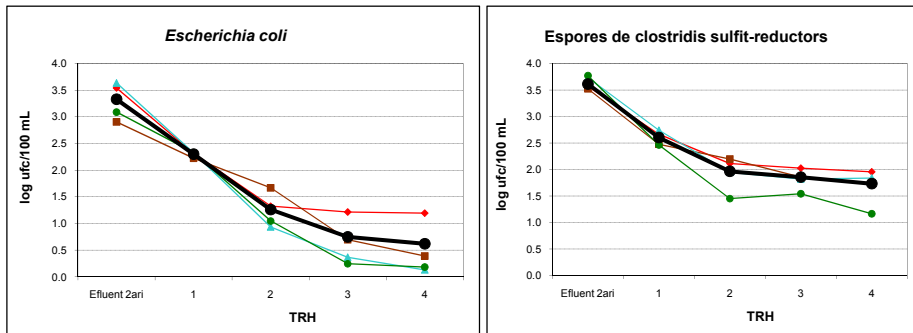
Results of the first year

Averages of the main parameters grouped according to the season of the year.
Removals and inactivations (Colom *et al.*, 2009)

	Fall - Winter			Spring - Summer		
	Concentration		Removal, % Inactiv., log	Concentration		Removal, % Inactiv., log
	Sec effl	TRH 4		Sec effl	TRH 4	
Physico-chemical parameters						
SS, mg/L	4.2	3.7	12	4.0	8.3	-108
Turbidity, NTU	1.8	2.3	-31	2.7	4.3	-60
Chl a, µg/L	1.6	6.1	73	4.7	12.1	61
Oxygen, mg/L	4.8	8.7	45	5.5	9.2	40
T254, %	75	74	-1	64	65	1
Total nitrogen, mg/L	5.6	2.7	53	5.5	3.2	42
Soluble P, mg/L	2.7	3.1	-15	4.9	3.3	32
Microbiological parameters						
<i>Escherichia coli</i> (a)	3.2	0.3	2.9	3.4	0.8	2.6
SRC spores (a, b)	3.6	1.8	1.8	3.6	1.7	1.9

(a) Units: log cfu/100 mL ; (b) Abreviation: SRC = sulphite-reducing clostridia

Microbiology graphs



Seasonal and annual geometric averages (july 2007 – june 2008)

From Colom *et al.*, 2009

The mesocosmos compared

Period	Escherichia coli			Spores of sulphite-reducing clostridia		
	Polishing ponds	Mesocosmos	Constructed wetlands	Polishing ponds	Mesocosmos	Constructed wetlands
Jul-Sep '07	1.1	2.3	2.4	-0.1	1.6	0.3
Oct-Dec '07	1.2	2.5	2.3	0.6	1.8	0.4
Jan-Mar '08	1.8	3.5	1.8	1.0	1.9	0.9
Apr-Jun '08	1.3	2.9	2.1	1.7	2.6	1.5
Annual average	1.3	2.7	2.2	0.6	1.9	0.6

From Colom *et al.*, 2009

Conclusions

- EU Water Framework Directive will demand policies aimed at achieving a good ecological status in natural water bodies.
- Reclaimed water is a resource that, under certain circumstances, can play a key role, specially in drought-prone areas such as the Mediterranean:
 - Either being used directly to recreate and restore aquatic ecosystems (i.e., Empuriabrava constructed wetland system and environmental reuse; Parc de Sa Riera and Tossa Creek, in Tossa de Mar)
 - Or when its supply will free volumes of high-quality waters to be preserved and used for ecological function (i.e., Ridaura river basin).
- Biological filtration is proving an interesting option for delivering back to nature water with a much better quality, specially in terms of a reduced microbiological pollution.

Thank you for your attention!



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Panoramic photo: Ruud Kampf (<http://www.waterharmonica.nl>)

