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 (secondary effluents, raw wastewaters, combined-sewer overflows) and industrial wastewater discharges
  - Diffuse pollution (nutrients, pesticides) from agricultural and farming activities
- EU Water Framework Directive: requires a good ecological status of natural water bodies. A demand impossible to fulfill in the case of Mediterranean aquatic ecosystems?
- Example: Ter river and the supply to the Barcelona metropolitan area:
  - Diversion of 6.7 m$^3$/s = 210 million m$^3$/y (avg. 2005)
  - Minimum desirable flow at the mouth (Catalan Water Agency –ACA- ecological flows plan, DOGC 4685 of 27/7/2006): 4.4 m$^3$/s
  - Flow imposed by drought conditions in 2005: 0.3 m$^3$/s (ACA’s decree).
- The situation of smaller ecosystems is sometimes dramatic
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).

Summary of quality in 2006
(Percentile 90 of the annual set of data):
- Total nitrogen = 9.8 mg N/l (150 samples)
- Total phosphorus = 2.4 mg P/l (149 samples)
- E. coli = 4 cfu/100 ml (120 samples)

Main idea

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

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


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?
What kind of biomass can be produced?

- Constructed wetlands, Empuriabrava, May 2005
- Reclaimed water in the Tossa Creek, June 2005
- Golf course turf, Sta. Cristina d’Aro, June 2005
- Corn, Sta. Cristina d’Aro, June 2005

Food chain approach

By courtesy of Ruud Kampf - http://www.waterharmonica.nl
Reclaimed water quality

- Influenced both by kind of biological and reclamation treatments

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<tr>
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<td>Volume treated in 2006, m³</td>
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(c) The “Title-22” treatment is composed by coagulation, flocculation, sedimentation, filtration and disinfection. In the case of Blanes, phosphorus is removed by chemical precipitation.
Reclaimed water quality

- Influenced both by kind of biological and reclamation treatments

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| Volume treated in 2006, m³ | 661,000 | 263,000 | 962,000 | 3,155,000 |

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Main criteria for reclamation through natural systems and environmental reuse

- 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 produce water that doesn't pose an oxygen demand in the receiving water body.
- Ammonia stimutales growth of phytoplankton and leads to oxygen imbalances and loss of biodiversity (high biomass of very few species)
- Nitrified effluents are suitable to be further polished in natural systems such as constructed wetlands if environmental reuse is intended
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 coliforms)
- 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

Phosphorus removal

- Differently than in the case of nitrogen, no harmful incidence on the ecosystem is observed (i.e., no development of cyanobacterial populations due to the low N/P ratio, but chlorophyta)
- However, it is desirable, for the lower risk of eutrophication of the receiving water body
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 (Jan-Aug 2007): 2.9 log removal of FC between secondary clarifier and outlet of the constructed wetland (2.1 log in Daphnia ponds).
- Though not a primary goal of the reclamation treatment (constructed wetland’s mostly aimed at nutrient reduction), removal of faecal microorganisms is close to the values achieved by more conventional techniques.

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 iberia), 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

- 2000-2006: 73 % of the treated wastewater treated through the wetland system and recycled for environmental purposes (660,000 m³/year out of 910,000 m³/year ⇒ not discharged to the Muga river).

- 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 73% of the nitrogen in 2005 (approx. 7,000 kg N) and 83% in 2006 (5,542 kg N)
  - Estimations of soluble P removal at 69% in 2005, approx. 2,300 kg P, and 70% in 2006, approx. 1,400 kg P. More accurate evaluations with total P needed.
Empuriabrava constructed wetlands as a recreation of a natural wetland

The *Parc de Sa Riera*, Tossa de Mar (I)

- Former uncontrolled landfill of construction materials turned into a park thanks to the availability of reclaimed water
- Streamflow augmentation in the local Tossa Creek through percolation in the park’s wetland. Avoids total dessication in summer and provides minimal but highly valuable flows that sustain the ecological function.
- New projects for the improvement of the ecological condition of the stream also based on the use of reclaimed water.
The *Parc de Sa Riera*, Tossa de Mar (II)

- Visited by celebrities!

Prof. Takashi Asano visiting the Park de Sa Riera and Tossa Creek in June 12, 2007. Flows due to artificial recharge from the pond of the park.

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**Improvement of water resources management in the Ridaura basin**

- Small basin and small aquifer that until 1993 was the only supply of a large touristic area. Dry river bed almost continuously for decades—except after heavy rains—.
- Water transfer from Ter river for drinking water supply (7 million m$^3$/y) and supply of reclaimed water for irrigation (agricultural, golf course) have decreased groundwater extractions and allowed natural flows in the Ridaura river between 6 to 9 months/year.
- Extraordinary recovery of the macroinvertebrate indexes of ecological quality
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).

Thank you for your attention!

Special acknowledgments to Anna Huguet, Joan Colom, Marc Carré, Jordi Muñoz, Silvia Quintana, Maribel Marín & Estel Dalmau (EMACBSA), Eduard Marquès (Mosquito Control Service of the Roses Bay), Jordi Couso (Municipality of Tossa de Mar) and Jordi Sala (environmental consultant)

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