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"River restoration integrated actions to reduce river Zero nitrate input to Venice Lagoon"

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INDEX

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Abstract

The contamination of surface- and ground waters by nitrates is still one of the major factors determining the readily-usable quantity of water resource available within Europe, despite the Directive 676 of 1991. Since there appears to be an urgent requirement for action to control the nitrate concentration of freshwaters, there is a need to utilize existing knowledge in the development of management strategies to reduce the risk of such pollution impacts on the environment.

The Consorzio di Bonifica Dese Sile is located within the pumped drainage landscape of the Venice Lagoon. The Consorzio was involved in a big project aimed at developing a catchment strategy to reduce nutrient loads entering the Venice Lagoon from its rivers. To achieve this goal, the Consorzio planned a major river restoration project for the Zero River, which drains into the lagoon.

The main restoration actions carried out regarded: banks widening, increase of aquatic vegetation on river terraces, creation of lateral and inflow wetland (ponds and lakes) and creation of wooded riparian area irrigated by river water.

Within this project a pilot experimental system was built along the Zero River, to evaluate in particular the buffering efficiency of the wooded areas on non-point pollution sources of nitrogen.

On the experimental site, represented by a newly-established riparian woodland, the hydrology of the woodland is totally regulated through a series of pumps which irrigate the woodland with water coming from Zero River, through a series of parallel ditches (irrigation and drainage ditches).

The results of this study provided interesting suggestions for improving the management of buffer zones.

Introduction

1.1 Reclamation History

in Italy

Reclamation is a continuous task making urban areas and agricultural lands, which without hydraulic interventions would naturally be unhealthy and unusable due to persistent flooding, usable to the community.

Water reclamation in Italy was begun by the Etruscans in Tuscany, the Greeks on the Ionic coasts, and Romans on the areas surrounding Roma and the Po Plain. The word "centuriazioni" was used by the Romans to indicate the large work required to reclaim wet areas. Because reclamation is meant to recover land over large areas, it always required the use of large human and economic resources. For this reason, the main reclamations works were developed during period of political and social stability, when such resources were more easily available.

Before XVI, Italy had almost 3 millions of hectares of wetland; today most of these lands have been reclaimed or drained for agricultural uses (Fig.1).

In the XVIII century reclamation works were already numerous on the Italian territory; in the XIX century the number of reclamations, which had so far been funded by religious orders and single land owners, reached a maximum because they started to be funded by financial groups. The recovery of wet and unhealthy land allowed expanding agriculture and eliminating malaria, which was widespread in the XIX century. The last peak in reclamation work occurred between 1920 and 1940: the Mussolini Law, in 1928, created a national reclamation plan, and transferred the responsibility of such actions to the Agriculture Ministry.

in Veneto Region

(Rewritten from Rosato & Stellin)

From the Roman period to the XVI century

Roman settlers, more than 2000 years ago, were the first to attempt the reclamation of wetlands, making large portion of the plain suitable for agricultural activity. The Romans divided the territory in "centuriations" characterized by the square shape of the plots (Fig.2) that were assigned to war veterans.

After the Roman Empire, due to the numerous and reoccurring barbaric invasion, no significant effort was made to protect or maintain the water management interventions, and as a consequence the territory became progressively wooded and wetlands reformed again. Around the second half of the XI century religious orders, mainly Benedictine monks, resumed the land reclamation work so the Plain was again suitable for agriculture and settlement. In those times it was difficult for one individual land owner to deal with flood risks, therefore they organized the Consortia.

During the Republic of Venice

In the XVI century the republic of Venice started its expansion to the mainland for two reasons:

1) to defend Venice by deviating the main rivers to avoid silting of the lagoon and a decrease in water salinity;

2) to ensure the food self-sufficiency, using corn (just arrived from the Americas).

The Republic considered reclamation to be "of public benefit" and not only useful for private landowners so two Authorities were set up: first the Water Authority with the goal of water safety, and later the Uncultivated Soil Authority with the goal of reclamation and irrigation.

From then on, projects were carried out and managed by private individuals or by Consortia and the Republic gave or denied the permission to carry out the projects.

At the very beginning, the main goal of the land owners Consortia was to keep the water under control by embankment and similar work, rather than food self-sufficiency.

From Venice until the proclamation of Law 215 of 15th of February 1933
The Reclamation Consortia were an important and unique institution of the Venice Republic. With the fall of the Republic in 1797, a period of great uncertainty regarding the nature and power of the Reclamation Consortia began.
This situation changed radically during the period between the two World Wars when a significant support grew in all Italy for an increase in agricultural production by reclaiming lands which were still flooded, and by increasing irrigation.
The article 59 of the special law of the Royal Decree n. 215 of 15th of February 1933, entrusts to the Consortia the power to impose levies to the owners of properties included in the territory of competence of each Consortium. According to article 11 of the same Law, such levies must be quantified and shared between the members of the Consortium in proportion to the benefits gained by the reclamation work.
Consortia also took a new role, represented by hydraulic safety for urban areas (Fig. 3) as well. In fact cities and towns began spreading faster and faster into rural areas so the reclamation Consortia dealt with a territory which included cultivated lands, urban settlements and non-agricultural production as well.

1.2 Reclamation/drainage Consortia

The traditional role of the Consortia is today set in a wider social framework of environmental protection, for habitats strongly influenced by human activities.
Their duties are:

- protect and manage with updated knowledge the heritage of public reclamation and irrigation works;
- guarantee the hydraulic safety of the territory by preventing flooding;
- protect the natural resources, regulate old water licenses for different and competing uses, ensure suitable water for irrigation, and reduce water pollution.

In order to carry out these functions, the Consortia take part in urban and territorial planning and in water resources management.
The Consortia are public bodies, managed by Consortia members, which coordinate public and private works associated with drainage, irrigation, flood control, protection of soil, water and environment. Having completed the drainage and irrigation networks, Consortia today are mainly engaged in the maintenance and renovation of their works. Consortia are increasingly more involved in environmental activities and according to recent national laws, the Consortia contribute to the realization of actions aimed to environmental protection, water restoration (also for irrigation uses), renaturalization and phytodepuration of watercourses.
The members of Consortia are, compulsorily, all the owners (farmers and non-farmers) of lands and buildings situated within the Consortia districts. The districts are established referring to river basin and may cover both rural and urbanised areas.
The Consortia are controlled by the Regions, which follow national guidelines issued by the State through national laws (e.g. the general law about Consortia, issued in 1933). In Italy there are 160 Drainage and Irrigation Consortia covering an area of 15.000.000 hectares (50% of the Italian total surface).

Number of irrigated hectares	3,300,000
Total length of irrigation and drainage canals	181,312 km
Total length of dikes	9,233 km
Number of dams and weirs for full lamination	22,839
Number of water pumping systems	754
Number of water-lifting systems for irrigation	1301
Total drainage hectares:	7,000,000

Hectares under mechanical pumping	1,200,000
Private contributions (by farmers and non farmers) to the Italian Consortia in 2005: 466.000 euro.	
Approximately 8,000 people work in the Consortia.	

1.3 Venice Lagoon Basin

One of the main reclaimed areas is located in North-Eastern Italy. A large portion of the catchment of Venice lagoon lies within this area (Fig.4).
Venice Lagoon has a drainage basin of roughly 1850 Km^2, it includes all the lands with a superficial water network draining into the lagoon. The surface watercourses network is represented by natural channels and drainage canals managed by the various Consortia. Surface water reach the Lagoon from 27 input points, with 1000 $x10^6$ m^3 mean annual volume drained into the lagoon, and 30 m^3/sec mean annual discharge.
Soil in the southern part of the drainage basin is typically gravel-sand, with coarse granulometry which creates good draining conditions. Soil in the central part of the basin is mainly silt, with coarse granulometry in the elevated areas, and fine granulometry in the plains. Clayey soil is present near the Lagoon, which cause a strong reduction in water drainage. The territory included in the drainage basin is mostly used for agriculture (77%), and to a lesser extent for urban, industrial and touristic uses.

Dese Sile Consortium

The Dese Sile Reclamation Consortium continues the work of previous Consortia which were already active in the Venetian and Napoleonic Eras.
The consortium's territory (Fig.5) has an extension of 43,464 ha, located mainly in the province of Venice. Its territory (Comprensorio) is crossed by the Zero, Dese and Marzenego Rivers, which drain into Venice's lagoon, and manages a network of more that 600 km of canals and waterways.

Eutrophication of the Lagoon

Venice Lagoon is a wide, shallow coastal basin extending for about 50 km along the north-western coast of the Adriatic Sea. The lagoon has been substantially modified by human activities over the last century through the artificial control of the hydraulic dynamics of the lagoon, including the construction of channels to facilitate navigation.
Over the past decades nutrient loads delivered to the Venice Lagoon have attracted considerable concern. The local government (Regional Authority) established in 1995 a series of targets to reduce the level of nitrogen and phosphorous entering the Lagoon. The aim of the targets was to establish eutrophication protection measures as well as to improve the overall quality of the water entering the lagoon.
The Dese Sile Consortium, that manages three key-rivers contributing 40% of the freshwater flowing into the Lagoon, was involved in a large project aimed at developing a catchment-scale strategy to reduce nutrient loads into the Lagoon.
In particular, for two of the main rives managed by the Dese Sile Consortium (which developed the project) Dese and Zero (tributary to the former) rivers, the following values of nutrient loads reduction were established:

Catchment	**Ntot reduction (tons/year)**	**Ptot reduction (tons/year)**
Dese and Zero Rivers	150	40

The value of 150 tons/year of Ntot represent a reduction of 12% of the total loads of the Zero and Dese rivers (1271.4 tons/year), whereas for Ptot a reduction of 17% (229.1 tons/year) is the target.
To achieve these results, the Consortium planned a major river restoration project for the Zero river. The project was one of the first series of actions undertaken by this drainage authority in order to meet these results.

Fig. 1 After Holland, Italy is the country with the most wide reclamation area (colored in red).

Fig 2 Example of Romans "centuriations" characterized by the square shape of the plots

Fig 3 The first reclamation projects for the lower Dese Sile area date back to 1882. The actual work, however, would be carried out only starting from 1926-27.

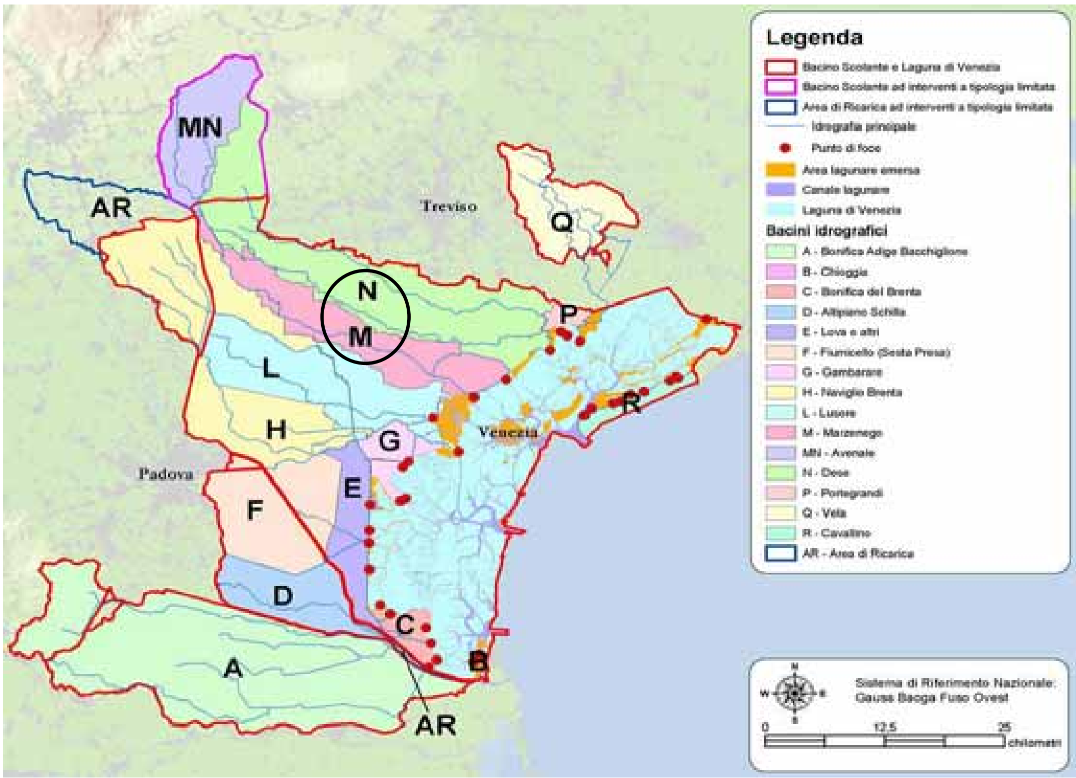


Fig.4 - The Drainage Basin of Venice Lagoon divided in sub-basins. The Consortium Dese Sile is highlight with a black ring.

2 The project

The last 11 km of the river Zero (Fig. 5) before it flows into the river Dese, was scheduled to be re-engineered as part of the long-term flood defence works along the Zero. The river banks along this section are below the 13,50 m threshold required and therefore are liable to fail as a flood defence structure when both high flows within the river and high tides occur. Since this work was planned, the Consortium saw this as an opportunity to develop a new channel section that could increase the ecological value of the river as well as increase the nutrient retention capacity of the riverine environment. Paralleling these developments was a need to limit saline water intrusion within the 11 km section and thereby allow freshwater to dominate a greater length of the river. In doing this, freshwater could be made available to agricultural lands for irrigation as well as for habitat creation.

2.1 Creation of key habitat

In order to reach the project aims, the Consorzio di Bonifica Dese Sile identified a series of natural key habitats (Fig. 6) to create or to restore:

1. **freshwater lake "Lago Pojan":**
this is a riverine lake, with the same function of an instream wetland, with an approximate surface of 2 ha, and 4 m depth.

2. **freshwater pond with the gate "Nodo Carmason"**
one of the objectives of the project was to reduce the length of saline water intrusion within the Zero river thus enabling water to be abstracted from the river for agricultural purposes. To achieve this a gate was built 3.2 km upstream from the confluence of the Zero and Dese rivers. The height of the gate can be regulated in order to prevent tidal water to flow upstream, but at the same time to permit the discharge of freshwater to the tidal section of the river. The final effect of the gate is the creation of a 6.7 km long section of freshwater that behaves like a pond characterized by near static water height and slow moving water from the majority of the time.
(see also the figures in the summary tables).

3. **terrace in freshwater section**
Within the freshwater section of the Lower River Zero, the proposal is to have a *Phragmites* thicket of 1.5 m minimum width to limit bank erosion and to facilitate nutrient retention. These functions maybe limited but the conservation and ecological value of this community will be significant for the invertebrate communities and fisheries interest.

4. **a series of rainwater- and groundwater-fed shallow lakes, called "Cave Cavalli"**
created in an area previously used for the extraction of clay. The lakes are 1-4 meters deep, with a water surface of over 30 ha. Some of the River Zero water passes through the quarry and utilises the potential nutrient retention capacity of the lakes before entering into another series of drainage ditches which ultimately discharge into the Dese river.

5. **wetland next the tidal gate**
Within the proposal for the Zero river, provision has been made for a small wetland to be created next the Zero tidal gate. The main function of the wetland is to allow ecological continuity from the tidal river to the freshwater section. The wetland will consist of a sedimentation pool followed by 0.7 ha of Phragmites thicket. This system will receive the river

low flows and act as small but significant filter for freshwater before it passes into the tidal section.
(see also the figures in the summary tables).

6. Riparian woodland

An extensive area of land which is historically setter than the fields runs parallel to the lower River Zero. This is due to the fact that the river water surface is higher than the agricultural land surface for much of the river length. A cultivated area of about 30 ha was converted in a forested buffer strip, irrigated with freshwater from the Zero river, so that the wet woodland could operate similarly to a natural riparian woodlands.
(for details see the attached paper).

7. Saline wetland

The Zero river downstream from the tidal gate will be subject to the largest degree of engineering work in order to increase the flood defence value of the banks. Nonetheless, there are still opportunities enhance the ecological value of the tidal river. The proposal is to allow a minimum of 6 m of *Phragmites* to colonise the river banks and help minimise the erosion of the new banks from tidal wash and the effects of boats passing along the river. In addition to provide bank erosion control, the *Phragmites/Scirpus* vegetation complex can help nutrient erosion.

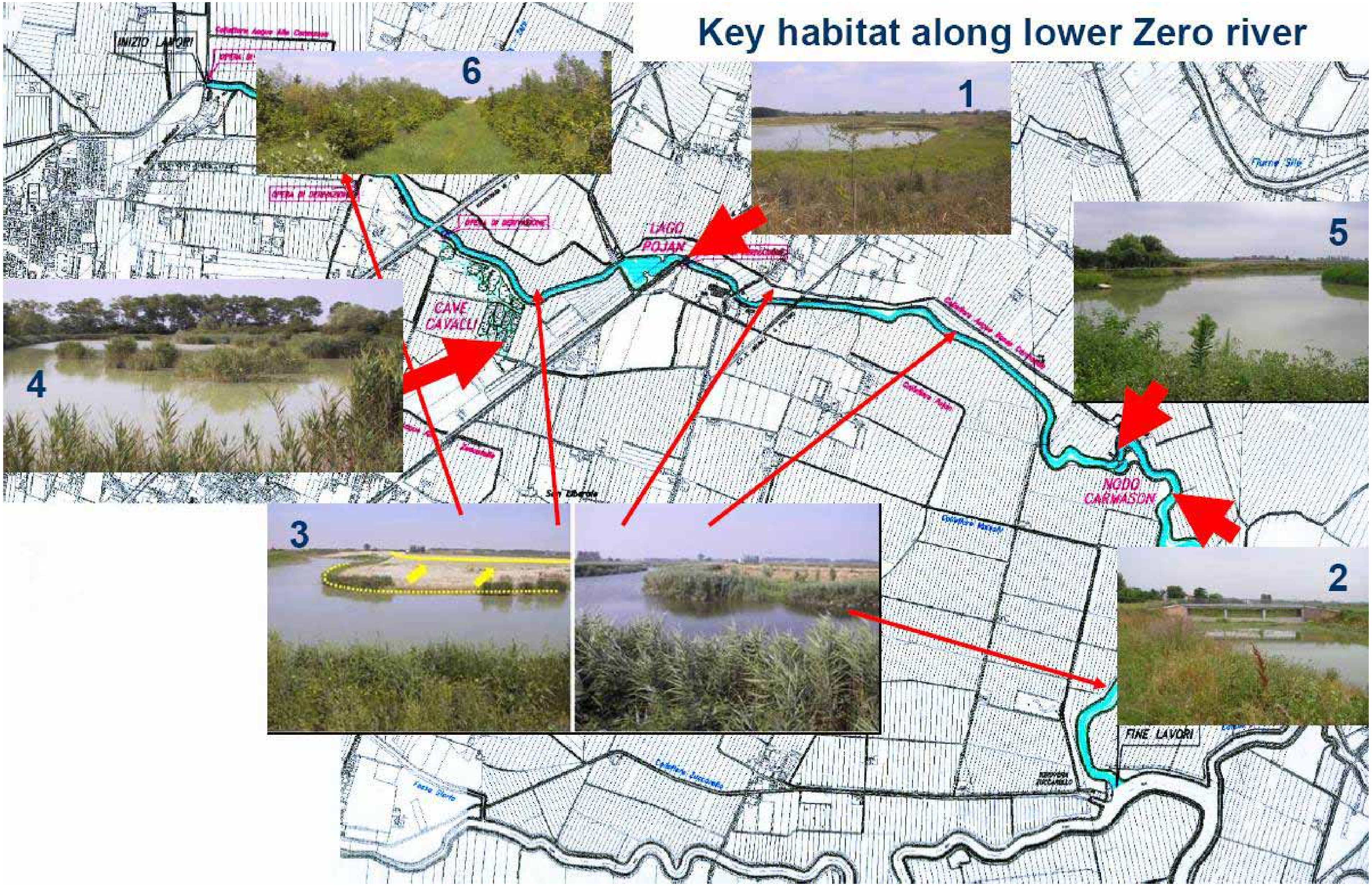
Figures below:

Figure 5- the area managed by Consorzio di Bonifica Dese Sile and the tract of the Zero river interested by the restoration project

Figure 6 - location of the key habitat: 1) the riverine lake "Lago Pojan"; 2) freshwater pond with the gate "Nodo Carmason"; 3) Terrace in freshwater section 4) a series of rainwater- and groundwater- fed shallow lakes, called "Cave Cavalli"; 5) wetland next the tidal gate 6) riparian woodland.

Consorzio di Bonifica Dese Sile

Key habitat along lower Zero river



2.2 Effects in term of nutrient reduction

In order to allow the estimate of nutrient retention capacity of different geometries and hydrodynamic conditions of the buffer zones, the nutrients mass balance was investigated for each habitat (research conducted by Quest Environmental) with the commercial numerical model STELLATM 5.0, which has been tested and widely used in this kind of investigation. The assessment of the global effects of the reduction of pollutants loads requires to distinguish between the different habitat typologies and define a detailed model which includes an accurate evaluation of hydraulic characteristics such as the mean system inflow, the total nutrient load, the mean residence time and the total hydraulic capacity, and which applies the appropriate exchange kinetics such as, for nitrates, the time constants of mineralization of biomasses, denitrification, and more (see, for an accurate use of these kinds of models: Ambio, Special Edition: Wetlands as Nitrogen Traps, 23(6), 320-386, (1994)). Once the model (or the set of submodels regarding the different buffer areas) has been built, by using meteorological, hydrological and nutrient concentration data it was possible to estimate (Table 1) the nutrient reduction for each habitat on a daily or yearly scale (a nutrient retention effect is assigned not only to the action of the natural buffer strips, but also to irrigation)[1].

Table 1 – Results of the simulation of N and P reduction which can result from the restoration of the lower course of the Zero River.

Table 6:
Statistical summary of all simulations (33) of the Lower River Zero Nitrogen Model (Tons N per annum)

Tons N / annum	Mean	Std. Dev.	Std. Error	Minimum	Maximum	Notes
TKN input (est)	113.311	14.591	2.540	87.276	151.088	
Total NO3-N input	186.982	24.078	4.191	144.020	249.320	
TKN Retention	**12.425**	**0.480**	**0.084**	**11.262**	**13.333**	
Total NO3-N Retention	**31.745**	**1.236**	**0.215**	**23.995**	**35.010**	
TKN to Lagoon	100.886	14.291	2.488	76.015	138.336	
Total NO3-N to Lagoon	155.237	23.234	4.044	113.082	216.876	

Tons N / annum	Mean	Std. Dev.	Std. Error	Minimum	Maximum	Notes (area)
Zero Lake NO3N	0.997	0.097	0.017	0.745	1.159	2 ha.
Zero Ponded Water NO3N	7.583	0.750	0.131	5.639	8.811	15.5 ha.
Zero Phrag. Terrace NO3N	0.741	0.000	0.000	0.741	0.742	3.5 ha.
Cava Cavalier NO3N	1.383	0.072	0.012	1.243	1.624	7.5 ha.
Riparian Woodland NO3N	18.678	0.686	0.119	16.961	20.111	60 ha.
Irrigation Water NO3N	0.443	0.177	0.031	0.167	1.054	220 ha.
Pump / Gate Wetland NO3N	0.349	0.026	0.005	0.289	0.379	0.7 ha.
Saline Phrag. Terrace NO3N	1.571	0.180	0.031	1.127	1.920	5 ha.
Cava Cavalier TKN	0.838	0.043	0.008	0.753	0.984	7.5 ha.
Riparian Woodland TKN	11.319	0.416	0.072	10.278	12.187	60 ha.
Irrigation Water TKN	0.268	0.107	0.019	0.101	0.639	220 ha.

[1] Later on the Consorzio Dese Sile coordinated the activity of "Revision of the models and methods used for the calculation of nitrogen and phosphorus reduction" conducted by IRIDRA S.r.l which partly confirmed the modeled values, and partly enhanced the estimation power.

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Table 8:
Statistical summary of all simulations (33) of the Lower River Zero Phosphorus Model (Tons P per annum)

Tons P / annum	Mean	Std. Dev.	Std. Error	Minimum	Maximum	Notes
TOP input (est)	7.418	0.658	0.115	6.199	8.796	
Total PO4-N input	7.146	0.634	0.110	5.972	8.474	
TOP Retention	**0.999**	**0.052**	**0.009**	**0.949**	**1.192**	
Total PO4-P Retention	**2.300**	**0.095**	**0.017**	**2.027**	**2.468**	
TOP to Lagoon	6.419	0.642	0.112	5.185	7.842	
Total PO4-P to Lagoon	4.846	0.661	0.115	3.524	6.066	

Tons P / annum	Mean	Std. Dev.	Std. Error	Minimum	Maximum	Notes (area)
Zero Lake PO4P	0.119	0.012	0.002	0.089	0.138	2 ha.
Zero Ponded Water PO4P	0.903	0.089	0.016	0.671	1.049	15.5 ha.
Zero Phrag. Terrace PO4P	0.088	0.001	0.000	0.083	0.088	**3.5 ha.**
Cava Cavalier PO4P	0.086	0.003	0.001	0.079	0.094	**7.5 ha.**
Riparian Woodland PO4P	0.800	0.019	0.003	0.777	0.843	60 ha.
Irrigation Water PO4P	0.076	0.040	0.007	0.050	0.227	220 ha.
Pump / Gate Wetland PO4P	0.041	0.003	0.001	0.034	0.045	0.7 ha.
Saline Phrag. Terrace PO4P	0.187	0.021	0.004	0.134	0.229	5 ha.
Cava Cavalier TOP	0.089	0.003	0.001	0.082	0.097	**7.5 ha.**
Riparian Woodland TOP	0.831	0.020	0.003	0.807	0.875	60 ha.
Irrigation Water TOP	0.079	0.041	0.007	0.052	0.235	220 ha.

As regards nitrogen, the mean value of N-NO_3 introduced in the system (obtained from several simulations conducted for years with different meteorological conditions) was 187 tons/year with a total reduction ability for the entire system of 31.7 tons/year (17%).
According to the model, the most efficient buffer system is represented by a 60 ha forested buffer strip (30 ha of which have been developed so far) which should remove 186 tons/year of N-NO_3 (59% of the total reduction). Total reduction of Ntot (NO_3-N+TKN) is estimated in 44.17 tons/year, i.e. 22% more than the amount of Ntot introduced into the system. Therefore, even for Ntot the most efficient buffer system is represented by the forested buffer strip with an estimated reduction of 30 tons/year of Ntot.
Values obtained from modeling are, at least for forested buffer strips, similar to those measured during the monitoring campaign conducted in the years following the model implementation (see Appendix), which assessed a real reduction ability (for 15 m wide buffer strips) of about 75 Kg/ha of N-NO_3 and thus (for the 30 ha of strip developed so far) of 2250 tons/year of N-NO_3 removed instead of the 9.3 tons/year (for 30 ha) forecasted by the model. As shown by experimentation, the "potential" buffer ability of these areas (with higher nitrogen loads) is definitely higher: the initial overestimate given by the model is mainly due to the partial reduction of the irrigation volumes which flow through the system, and to a lower concentration of nitrogen in the water of Zero River than the one forecasted initially.

2.3 Other results

The project Zero, although directed to the reduction of nutrient loads to the Lagoon , contributed to gain other objectives, such as:

- Reduction of hydraulic risk, as a consequence of the widening of sections of the river;
- Improvement of the nature value, due to the high naturality of the restored habitats, which have became important humid ecosystems, considering also the simple environmental structure in which they are included;
- Improvement of the multiple uses of banks and adjacent areas and of their landscape value.

<table>
<tr><td>Box n.</td><td>Type of activity</td><td rowspan="3"></td></tr>
<tr><td>01</td><td>Environmental restoration of an embanked river</td></tr>
<tr><td colspan="2">Environmental restoration of the lower course of the Zero River for the control and reduction of the nutrient input to Venice Lagoon (1999 – 2004)</td></tr>
</table>

Objectives

- Reduction of nitrogen and phosphorus loads into Venice Lagoon.
- Reduction of the hydraulic risk (by facilitating water infiltration, reducing surficial runoff and increasing the total stored volumes)
- Increase of the nature value of the river (biodiversity).
- Improvement of the multiple uses of banks and adjacent areas.

Pre- Activity conditions

During the planning phase, the nutrient load to Venice Lagoon was estimated as 230 tons/year of total nitrogen, and 13 tons/year of total phosphorus. The river did not have any oxbows, nor trees within the riverbanks. The surrounding territory was at high hydraulic risk due to the reduced storage capacity. The banks and adjacent areas were devoid of structures allowing for multiple uses of the watercourse.

Conducted activities

Channel recalibration with creation of oxbows and increase in stored volumes.

Edges of various shape and size were constructed along the 10 km long river reach; they hosted emerging macrophytes and trees. Were feasible, small emerged islands were left within the channel. The stored volumes of the selected reach of the Zero River were enhanced trough the creation of the Pojan Lake wetland, which covers 2.5 ha.

Construction of a support structure

A water support structure was built near Carmason hydrovore; the structure allows reducing the water flow, increasing the water-vegetation contact surface, and control saltwater intrusion.

Use of quarry lakes outside the riverbank for phytodepuration

The agreement between the Dese-Sile Drainage Consortium, the Marcon (VE) municipality, and a private quarry, states that once the clay extraction form Gaggio quarries will be completed, part of them (for a total surface of 13 ha) will be flooded with water from the Zero river. In the same areas, following the riverbanks, several hygrophilic trees were planted, for a total surface of 5 ha. This action will reduce the nitrogen loads to the Zero River, acting on both surface water and subsurface runoff.

Construction of a tree buffer strip.

Near the pilot farm Diana, a property of "Veneto Agricoltura", a 30 ha forested buffer strip was planted for timber production. The buffer strip is irrigated for 10 months/year with water for the Zero River. A water quality monitoring station, installed for this project, allows evaluating the efficiency of the trees in reducing all nitrogen compounds. A tree strip of purely nature value, covering a surface of 4 ha, was planted between the buffer strip and the riverbank.

Improvement of multiple uses of the areas.

After the completion of the above-described work, a 6 km long bike path along the Zero River banks and below the Dese River and Santa Maria Canal banks was built in cooperation with Marcon and Quarto d'Altino (VE) municipalities. An accessible nature trail for the disabled was built inside Gaggio Quarries. The trail will be soon completed by an accessible bird watching tower.

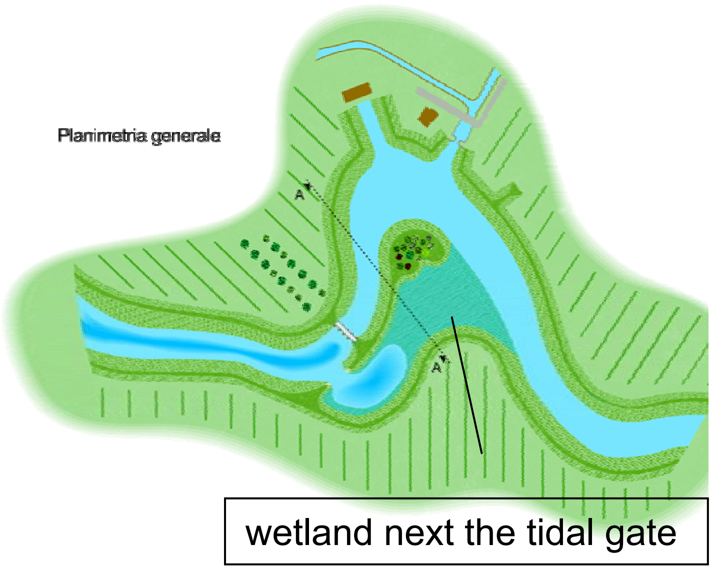
Assessment of the project effectiveness

Data collected at the water quality monitoring station within the forested buffer strip showed a total nitrogen reduction of 23% in 2000 (2-3 years old plants), 63% in 2002, and 71% in 2003-2005. Likewise, the percentage of nitric nitrogen reduction increased from 39% in 2000 to 88% in 2003-2005.

Cost of the project

7,230,396.59 €

Zero river - NODO CARMASON



<table>
<tr><th>Box n.</th><th>Type of activity</th><td rowspan="3"></td></tr>
<tr><td>02</td><td>Environmental restoration of cement-covered canals.</td></tr>
<tr><td colspan="2">Environmental restoration of Venice mainland watercourses (2002 – 2004).
Pagana Canal.</td></tr>
</table>

Objectives

- Reduction of nitrogen and phosphorus loads into Venice Lagoon.
- Reduction of the hydraulic risk (by facilitating water infiltration, reducing surficial runoff and increasing the total stored volumes)
- Increase of the nature value of the river (biodiversity).
- Increase of the landscape value of the watercourses.

Pre- Activity conditions

The constructions of structures for irrigation and reclamation lead to the use of reach with characteristics which would guarantee, at the same time, the minimum hindrance and the quick flow of water towards Venice Lagoon. The Pagana Canal was built with these purposes, but its entire bed (3.5 km) was covered with cement, and thus its contribution to the biodiversity of agricultural-forest habitats and to the reduction of N and P loads to Venice Lagoon was almost non-existent.

Conducted activities

Total removal of cement covers

The cement cover (240 cm wide on the bottom and 320 cm wide at the top, with 150 cm high side banks) was completely removed in a 1.5 km long reach.

Partial removal of cement covers

Near buildings the cement cover was left in place or only partially removed, creating a flooding area and banks with reduced slope.

Widening and diversification of the reaches

The new section of the Pagana Canal is variable in size, with long reaches 12 m large and larger size in the central section (15-70 m). The presence of wide banks with reduced slope allowed reducing erosion and increasing the number of vegetation species in the riparian area and, more in general, a larger water-vegetation contact zone. Morphological changes in the riverbed enhanced biological complexity thus increasing the buffering actions on nutrients, which enter the food-web of the wet biotopes.

Creation of ponds and wetlands

Ponds and wetlands of different depths were constructed at the joining with the main tributaries. The presence of wetlands along the watercourse allowed to further enhancing biodiversity with increases in water quality and the landscape and natural value of the area.

Assessment of the project effectiveness

Data on nitrogen and phosphorus loads reduction are not yet available.

Cost of the project

4,648,112.10 €

"Fossa Pagana"
ENVIRONMENTAL RESTORATION OF CEMENT-COVERED CANALS

March 2003

Septembere 2003

October 2003

September 2005

July 2005

"Fossa Pagana "
CREATION OF PONDS AND WETLANDS

May 2003

October 2003

September 2005

Box n.	Type of activity	
03	Environmental restoration of dismissed quarries.	
Environmental restoration along the low course of Draganziolo River to reduce the nutrient input to Venice Lagoon (2003 - 2005) **Noale Quarries**.		

Obiettivi

- Reduction of nitrogen and phosphorus loads into Venice Lagoon.
- Reduction of the hydraulic risk (by reducing surface runoff and increasing the total stored volumes)
- Increase of the nature value of the area (biodiversity).
- Improvement of the multiple uses of the quarry area.

Pre- Activity conditions

The area was designated as a site of Community Interest (SCI n°IT3250017 ex Cavasin Quarry in Noale Municipality). Before restoration, the area was characterized by a wide monospecific *Phragmites australis* thicket, which was filling up.

Conducted activities

Creation of a new watercourse inside the caves
A new watercourse was created at the thicket edges; it connects the quarry lakes and allows water to circulate before entering the Draganziolo Stream. The new watercourse meanders, runs on different elevation levels and has a size large enough to allow the residence time necessary for phytodepuration. The creation of a new habitat (slow-running water) contributes to the increase of biodiversity in the quarry territory.

Construction of three ponds along the new rivercourse
Three ponds were built along the new watercourse in order to slow the water flow, enhancing sediment retention and increasing the diversity of habitats with the creation of deep water areas. The three ponds are directly connected with the watercourse and the quarry lakes; a fourth pond was built disconnected by those waterbodies.

Construction of two river margin wetlands along Draganziolo Stream

Draganziolo Stream is a krenal stream which, although embanked, is still sinuous. The banks were moved in two Dreganziolo reaches bordering the quarry lakes in order to exploit two large curves and use them as flooding areas within the riverbanks.

Construction of support, water abstraction and restitution structures
A support structure was built in order to provide the elevation gradient which would allow water abstraction and restitution from the same watercourse. A bypass was necessary to prevent interruptions in the watercourse continuity. The support and the water abstraction and restitution structures were both built with the minimum possible visual impact. The whole system can be managed by a remote control.

Construction of three bird observation structures
Three wooden bird watching towers which hide the observer thus avoiding any disturbance to the birds were built in points of particular interest.

Assessment of the project effectiveness

Data on nitrogen and phosphorus loads reduction are not yet available. Simulations conducted during the planning phase estimated a 62% reduction in total nitrogen in the quarries (88 tons/year) and 55% of total phosphorus (8 tons/year). The area is used during floods as a lamination basin and thus contributes to the reduction of the hydraulic risk for Noale and the villages and towns downstream. The immission of water in the quarries and the restitution to Draganziolo Streams now occurs gradually, thanks to the regulation created by the structures built for the project. Noale municipality organizes guided tours for groups and schools.

Cost of the project

2,065,827.60 €

"NOALE QUARRIES "
Environmental restoration of dismissed quarries