Life Sellustra Project: Planning and implementation of integrated methods for the restoration of the catchment in Val Sellustra

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Life Sellustra Project: Planning and implementation of integrated methods for the restoration of the catchment in Val Sellustra

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Abstract. The "Sellustra Life" project is one of the 19 Italian projects financed in 2001 through the "Life Environment Program". The proponent end-beneficiary of this project is the Municipality of Dozza (a town in central Italy) with the scientific collaboration of CIRF (Italian Center for River Restoration). The project appeals to the Public Administrations and offers an example of application of innovative systems at low environmental impact for the control of pollution sources and for the requalification of river environments and rural landscape. The objective of the project consists in planning and steering public and private works oriented to manage the sources of pollutants that flow in the Sellustra stream and to improve the environmental value of its banks and of the rural landscape. The purpose is to join productive activities (included farming) with environmental safeguard and sustainable development. The planting of buffer strips, to improve the landscape and to reduce pollution, will not be funded directly by Life project but will be encouraged by farmers-oriented activities that will be carried out. Other actions directly financed by the project regard the building of constructed wetland and some bioengineering works. Another objective of the project is not to demonstrate the validity of the single techniques but to highlight the opportunities of using these integrated techniques for solving different problems (pollution, environment degradation, simplification of landscape). This project wants to produce a useful "model" for planning remediation projects following a bottom-up strategy that can be reproduced in other geographical areas.

Keywords. River restoration – Buffer strips – Bioengineering – Constructed wetland.

Le Projet Life Sellustra : Planification et mise en œuvre des méthodes intégrées pour la réhabilitation du bassin hydrographique dans la région de Val Sellustra

Résumé. *Le projet "Sellustra Life" est l'un des 19 projets italiens financés en 2001 par le Programme "Life Environment". Le bénéficiaire final et porteur de ce projet est la municipalité de Dozza (une petite ville en Italie centrale) qui a pu compter sur la collaboration scientifique du CIRF (Centre Italien pour la Réhabilitation des Rivières). Ce projet s'adresse aux administrations publiques et représente un exemple de l'application de systèmes innovants à faible impact environnemental pour la lutte contre les sources de pollution et la réhabilitation des environnements des rivières et du paysage rural. L'objectif de ce projet est donc de planifier et orienter les travaux publics et privés pour la gestion des sources de polluants qui sont déversés dans le cours du Sellustra et de promouvoir la valorisation environnementale de ses berges et du paysage rural. Les activités productives (y compris l'agriculture) seront couplées à la protection de l'environnement et au développement durable. La création de zones tampons pour améliorer le paysage et réduire la pollution ne sera pas soutenue directement par le projet Life, mais elle sera encouragée par des activités en faveur des exploitants qui les réaliseront. D'autres actions financées directement par le projet concernent les zones humides artificielles et les travaux de bioingénierie. Par ailleurs, le projet vise non seulement à démontrer la validité de chaque technique, mais surtout à mettre en évidence les opportunités qu'offrent ces techniques intégrées pour faire face à de nombreux problèmes (pollution, dégradation de l'environnement, simplification du paysage). Enfin, un "modèle" sera proposé pour contribuer à élaborer des projets d'intervention basés sur une stratégie ascendante qui pourrait être reproduite dans d'autres régions géographiques.*

Mots-clés. *Réhabilitation des rivières – Zones tampons – Bioingénierie – Zones humides artificielles*

I – Introduction

The general methodological objective of the project "Planning and implementing integrated methods for the environmental restoration of the Val Sellustra basin" was to demonstrate the effectiveness of a new approach to the management and restoration of catchment areas based on orchestration between citizens and public organisations. From ideation up through implementation, the project strategy was intended to:

– highlight the role that a small municipal administration can assume in promoting initiatives regarding river restoration with respect to superordinate bodies;

– emphasise the importance of starting with in-depth planning at the basin level involving all parties interested in the territory to ensure the design and subsequent implementation of focused and effective measures;

– favour cultural growth and sharing of environmental subjects at local and regional level;

– successfully implement pilot measures that could act as flywheels in spreading the use of low environmental impact techniques throughout the Sellustra basin as well as in other environments.

The Sellustra Life project was intended to demonstrate that local authorities, due to their greater and more direct knowledge of the territory and its social elements, are in some cases better able to develop participatory processes to allow objectives and intervention methods to be shared with interested parties.

In this way, by understanding the needs of the territory and transferring them to the decision-making process (bottom-up strategy), local authorities can become promoters of a more consistent and farsighted policy than typical command and control policies (top-down strategy). The project strategy transpired from the fact that, although the beneficiary of the planned activities was autonomous from the onset, meetings, internal conventions and debates with institutions were promoted in order to present the initiative and stimulate new partnerships, thereby increasing the possibilities of interventions on the Sellustra basin or favouring the reproduction of the experience in different situations.

The aim of the project was also to demonstrate, through the improvement of the ecological conditions of the Sellustra river, the effectiveness of the integrated application of low-impact techniques such as bioengineering and constructed wetlands. More specifically, the measures planned as part of the Sellustra Life project were aimed at:

– improving water quality in terms of nonpoint (nitrates from agriculture) and point (outflow discharges from the sewer system) source pollution;

– resolving problems regarding bank erosion through low-impact measures and eliminating or reducing the effects of the intense use of artificial elements in the channel;

– Increasing biodiversity and improving the landscape by restoring the riparian vegetation and recreating habitats, refuges for the fauna and ecological corridors.

II – Methods

1. The measures implemented - The constructed wetland.

The system implemented is a horizontal subsurface flow (SFS-h) system. The waste passes through a gravel bed located on an impermeable basin in which vegetation is planted, and the plants provide the oxygen required for the biological process of nitrification and degradation of the organic matter.

From a functional standpoint, this type of system provides greater purification efficacy per unit area than free water systems. Since the wastewater level is lower than the surface of the gravel bed, the surface of the wetland remains dry and accessible for maintenance activities, which, moreover, are minimal. Furthermore, the absence of wastewater exposure limits nuisances such as odours or insects.

Dimensioning of the purification system was based on the characteristics of the influent and the established purification objectives, using the most diffused seizing equation available in the international scientific literature to forecast the performance of the system.

The sewage system intercepted, which was previously attached to the Sellustra pumping station, collects wastewater for a total of approximately 120 population equivalents (p.e.). The system implemented provides for primary sewage treatment in Imhoff septic tanks, to treat the gross suspended solids and avoid clogging phenomena at the wetland inlet.

The Imhoff system effluent is divided inside a sump pit and routed to 2 rectangular constructed wetland cells each with a surface area of 180 m (12 m long and 15 m wide), positioned parallel to one another. The layout of the system was chosen for reasons regarding the area morphology, to allow better inclusion in the landscape, as well as for its functionality (Figure 1).

Figure 1. The constructed wetland realized near Sellustra stream.

It allows a better distribution of influents, provides a larger crossing area and prevents clogging. In addition, maintenance can be carried out on one of the cells without interrupting the system operation.

The beds of the cells are lined in non-woven fabric made of type 250 g/m2 mineral fibre, which, being biodegradable, is of moderate environmental impact as compared to other alternatives. A continuous layer of natural, easily obtainable sand was placed on top of the non-woven fabric in order to achieve a 1% slope and to provide mechanical protection of the geomembrane from puncture.

To avoid any contact of wastewater with groundwater, black, high-density polyethylene geomembrane (2 mm thick) was used, which offers high mechanical, chemical and physical resistance while having, in this case as well, moderate environmental impact as compared to other alternatives. It also provided considerable ease in shaping during positioning.

The inlet and outlet pipes are polyethylene, easily installable, highly resistant to chemicals and electrolytes and have surfaces that prevent scale build-up. In addition, they adapt well to irregularities in the terrain and, due to their smooth surfaces, provide higher flow rates than traditional piping.

The location of the wetland allows the wastewater flow occur by gravity, avoiding the use of pumps that requires energy. The drainage system is made of perforated polyethylene piping that enables flows to be drawn from the bottom of the cells, prevents the infiltration of coarse materials and allows backwashing.

The cells were filled with round gravel with an average diameter of 8/10 mm, which was thoroughly washed and deposited in a layer of 80 cm average thickness. A level of porosity was chosen that would ensure good hydraulic conductivity, efficient removal by sedimentation and adequate support for the development of bacterial biofilms and macrophyte communities.

The species of plants used are *Phragmites australis*, which have a high capacity for survival in extreme environmental conditions and a good tolerance to influent concentrations. They are proven to be efficient, are readily and economically available and have more extensive root systems than other macrophytes. Plant density is approximately 4 plants/m2.

Lastly, an embankment was placed around the wetland with a height of 0.33 m, a width of 0.5 m and a slope of approximately 45°. Turfgrass was placed on the banks and protected with a geonet made of jute in order to mitigate the impact of the geomembrane, to allow a layer of terrain to be blocked, to protect the banks from erosion and to prevent soil runoff during heavy rains. Discharge of the effluent into the receiving body of water occurs after passage through a control sump where the water level is adjusted and samples are taken.

2. The measures implemented - Bioengineering measures

The objectives of the bioengineering measures implemented as part of the project included:

– restore natural conditions of the aquatic ecosystem;

– enhancing the landscape and ecological quality of the riparian vegetation strips;

– reducing the transport of fine sediment in the channel.

In selecting areas to act on, situations were identified that were representative of the overall conditions of the river. In this way, generalised implementation methods could be outlined, in keeping with the “pilot” character of the project. The general approach of the project aimed at reducing the restoration works to the minimum, trying to increase the natural enhancement capacity of the river itself. Despite its general state of degradation, the channel of the Sellustra presents a varied morphology useful for a rich river ecosystem. Even some areas of the riparian formations are of significant interest, with isolated specimens of arboreal species such as willow trees and poplars.

A generalised reprofiling of the banks would have led to the loss of these elements and impoverished the channel by making it monotonous. It was therefore decided to act on areas that showed true signs of instability or where the introduction of artificial elements into the channel was particularly accentuated. For measures regarding vegetation restoration, an effort was made to enhance the existing vegetation as much as possible by removing only invasive arboreal vegetation and replanting where coverage had become exceedingly sparse. The site was identified downstream from the bridge in Via Sellustra, near a pig-breeding farm.

The naturalness of the channel had been particularly damaged in this tract as a result of erosion-halting measures that had been implemented over time. In addition to the discontinuity caused by the bridge foundation, which created a weir approximately 1 metre high, the river bed is covered with a slab of reinforced concrete, also almost a metre high. The banks are protected with mesh gabions filled with rock that, if removed, would have excessively upset the equilibrium that has been established over time. The remaining banks showed excessive sloping and the presence of numerous points of active erosion. The vegetation along the banks was considerably degraded with an abundance of Robinia. The measures implemented had two distinct goals:

– reducing the artificial elements in the upstream part of the channel;

– finding more stable physical and ecological conditions for the banks along the remaining tracts.

The discontinuity created by the weir under the bridge was resolved by constructing a ramp out of rocks partially tied with steel cables, at a 10% slope. Above the cemented area, which would have been too difficult to remove and excessively risky for the area overall stability, a number of weirs were constructed using stones tied with steel cables or beams anchored to the concrete underneath. In the portion of the channel downstream from the curve, the banks were reprofiled to provide a more stable slope. In the few bank sections where riprofiling was not required only restoration of the vegetation was carried out.

The reprofiled bank was protected from erosion at the toe by horizontal or vertical live palisades and, in the lower 2 m portion, with turfgrass protected with a geonet made of jute. Small, deep-rooted, shrubby plant species were planted in the area of the bank above the protected turfgrass in the following proportions: Euonymus europaeus 20%, Cornus sanguinea 30%, Rosa sempervirens 15%, Sambucus nigra 20%, Ligustrum vulgare 15%. In the area near the river edge, Ulmus minor and Fraxinus oxycarpa varieties, ranging from 1.5 to 2.0 m in height, were planted with their rootballs.

Figure 2. The slope built with stone blocks in order to smooth the drop under the bridge.

III – The measures implemented - The wooded buffer zones

Buffer zones are typically used as best management practices along lower-order streams for the enhancement of water quality, protection of fish and wildlife habitat, etc. To meet such diverse objectives, riparian zones remove sediment from overland flow, remove and sequester nutrients and other pollutants from overland and shallow subsurface flows, and provide habitat values in the form of streamside shading, generation of coarse and fine particulate matter, and food and cover for wildlife.

The control of nitrate pollution can be realized increasing the complexity of the landscape, not necessarily all over the catchment but in specific zones, especially within the river corridor. For this reason an important part of the project was the plantation of woody buffer strips near the Sellustra stream and its tributaries.

Plantation of the wooded buffer zones was not included in the Sellustra Life project as an initiative financed by the project itself, but as the result of the activity of territorial animation primarily directed at the farms bordering the river.

It was, in fact, decided to implement measures that were in synergy with the already existing possibilities of financing provided for by the structural funds of the Regional Rural Development Plan, with strategic objectives that included involving regional authorities in the project, making private parties directly responsible for and involving them in restoration of the catchment area and generating a flow of additional resources to the territory.

From an environmental standpoint, the buffer zones contributed to the attainment of objectives regarding the improvement of water and landscape quality as well as the containment of erosion along the banks. The information counter provided farms with the technical assistance necessary for planning the wooded hedges plantation and preparing applications for financing. A total of four buffer zones were planted during the Life project, three of which were financed by independent private initiatives and one of which was publicly financed.

IV – Results and discussion

1. Evaluation by monitoring activity

Evaluation is an extremely important step in the rehabilitation procedure. With no formal check on the success of a project, it is difficult to improve the techniques we use, because we don't even know if they need improving. The monitoring involved in evaluation means that damage, or flaws in the project, can be detected and fixed, where otherwise they may have gone unnoticed. Our evaluation approach dealing with natural and spatial variability is called BACI (Before-After/Control-Impact). This is an evaluation program with rehabilitation and control sites, with replicate samples taken through time.

Adoption of a basin-level approach imposes that the environmental monitoring activity not be limited to assessing water quality, but that it takes other important aspects into consideration as well, including the morphology of the channel, the structure and state of riparian vegetation and the functioning of selected ecological processes.

Each index used is associated with the specific environmental objectives of the project: EBI (Extended Biotic Index), chemical and bacteriological parameters (L.I.M.), SECA (Ecological State of the River), I.F.F. (Index of River Functionality), and Leaf packs. This last one is a method allowing the evaluation of the complex effect of different biochemical water parameters through the measure of decomposition rate of leaves inside water.

The improvement of water quality resulting from the implementation of the constructed wetland and buffer strips is measured using the EBI (Extended Biotic Index), macro indicators (L.I.M.) and Leaf packs. Enhancement of the quality of the landscape resulting from the naturalistic engineering measures and buffer strips is evaluated using I.F.F. (Index of River Functionality). The evaluation of the functioning of the fluvial ecosystem was performed using retention capacity and Leaf packs methods.

An integrated evaluation of the LIM and EBI data allows determination of the SECA. For the Sellustra stations, the worst results are those registered by the EBI. The chemical and bacteriological parameters (L.I.M.) have instantaneous values so they could not measure alterations either occasional or not directly caused by water quality. On the other hand, these alterations are well recorded by macroinvertebrate community.

For sure the river restoration realized is not yet adequate to improve water quality. In addition, the extraordinarily dry climatic conditions of the summer 2003 and some temporary and unknown urban and industrial wastes impacted water quality. All these natural and artificial unpredictable events hindered the normal performance of the monitoring activities, resulting in the delay of an entire data collection campaign. The post restoration monitoring shows only one improvement and some worsening of class SECA quality.

Table 1. The S.E.C.A. values before-after/control-impact

PRE										
Sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**rio R.**	**rio S.**
L.I.M.	III	III	IV	II	III	IV	III	III	III	IV
I.B.E.	III	III	V	III	IV	IV	IV	IV	IV	V
S.E.C.A.	III	III	V	III	IV	IV	IV	IV	IV	V
POST										
Sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**rio R.**	**rio S.**
L.I.M.	III	III	IV	III	IV	IV	III	III	III	V
I.B.E.	III	III	IV	IV	III	V	IV	IV	V	V
S.E.C.A.	III	III	IV	IV	IV	V	IV	IV	V	V

Table 2. Comparison between daily rates (K) of decomposition before-after/control-impact

PRE	K(d-1)	95% I.C.	R2	p	g.l.
st. 2	0,020	0,015-0,026	0,774	< 0,0001	19
st. 3	0,024	0,017-0,032	0,745	< 0,0001	18
st. 4	0,017	0,011-0,023	0,744	< 0,0001	16
st. 6	0,021	0,017-0,024	0,933	< 0,0001	16
st. 8	0,028	0,016-0,040	0,745	< 0,0001	11
POST	**K(d-1)**	**95% I.C.**	**R2**	**p**	**g.l.**
st. 2	0,012	0,008-0,015	0,809	< 0,0001	14
st. 3	0,016	0,012-0,020	0,854	< 0,0001	14
st. 4	0,046	0,040-0,051	0,957	< 0,0001	15
st. 6	0,022	0,018-0,026	0,967	< 0,0001	13
st. 8	0,009	0,006-0,011	0,744	< 0,0001	17

The rate of decomposition of the leaves is surprisingly fast. The macroinvertebrate functional feeding group of shredders was limited, indicating that the fast rate of decomposition is attributable to the elevated concentrations of nitrogen and phosphorous. These concentrations are important in regulating the process of decomposition in that they cause an increase in the activity of hyphomycete fungi.

As regards the catchment area as a whole and the strong impact of nonpoint pollution on the Sellustra river, it appears that the first pilot buffer zone is insufficient for reducing the river strong nitrogen and phosphorus concentrations. More significant results would have been achieved if the project's aim, which entailed covering at least 75% of the banks with buffer zones, including near the drainage ditches in intensely cultivated areas or where manure spreading is practiced.

The naturalistic engineering measures have already begun to show some positive effects, both in terms of increased self-purifying capacity of the stream and, more important, as regards improved overall functioning of the ecosystem. These aspects can be effectively measured using the I.F.F. index. Although a period of at least two years will be required before the ecosystem reached stability and the results can be consolidated, initial analyses of the I.F.F. performed before and after the implementation of measures show significant improvements in all three reaches concerned. The promotion to a higher class is attributable to the improvement of vegetation conditions, better functioning of the banks and increased diversification of the channel morphology.

Table 3. Comparison between I.F.F. classes before-after/control-impact.

	sites	**3/A**		**3/B**		**4**	
	Banks	**L**	**R**	**L**	**R**	**L**	**R**
PRE	SCORE	82	39	69	74	132	156
	CQ	IV	V	IV	IV	III	III
	referring colours						
POST	SCORE	139	139	124	109	166	181
	CQ	III	III	III	III-IV	III	II-III
	referring colours						

V – Conclusions

The experience of the project "Sellustra life" cannot be considered concluded until actions carried out are completely developed, express definitively the foreseen environmental effects and these are measurable. Biological rate of growth of trees and shrubs must be respected and the requested time exceed the end of the project. Nevertheless, it is possible and appropriate to produce a first report into the results obtained by the work method adopted within the project:

– It contributed to developing the idea to treat locally wastewater and meteoric urban waters, adopting natural systems when possible, and return them as soon as possible to water course after cleaning

– It promoted the principles that the more natural the conditions of a river are, with a prosperous riparian vegetation, the safer and the more convenient its management is; and if important values are threatened it is better to adopt low-impact techniques.

– It showed a correct interpretation of the role of farmers as managers of the environment as established by common and national policies, especially suitably supported by financial subsides and also by information activities, training and technical assistance.

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