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BIOSYSTEMS ENGINEERING TECHNIQUES FOR HABITAT RESTORATION IN PROTECTED AREAS

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SUMMARY

A rural landscape is the final result of the mutual interaction among several natural ecosystems with the artificial intervention of the Man, who transformed the rural land, joining the agricultural production needed for human life with the control and care of extra-urban territory. A rural landscape includes the physical elements of landforms, the hydrological components and transitory elements such as lighting and weather conditions, strictly connected with living elements of land cover including indigenous vegetation, flora and fauna, as well as their possible spontaneous way of organization into different ecosystems. Human elements include different forms of land use, buildings and other rural constructions, who play a central role in determining the formal and substantial characteristics of the extra-urban landscape, influencing the agricultural environment and the visual perception of its landscape. Combining both their physical origins and the cultural overlay of human presence, often created over millennia, a rural landscape reflects a living synthesis of people and place that is vital to local and national identity, helping to define the self-image of the people who inhabit it, and a sense of place that differentiates one region from others.

The diffusion of intensive agriculture, together with the expansion of urban areas and consequent enlargement of the anthropic activities onto the rural landscape, determined a general loss in wetland areas all over the World. Because of the high rate of wetland loss over the last century, it has become routine to mitigate these losses by designing and executing specific targeted technical interventions, i.e., building or restoring existing constructions able to create local micro-environment favourable for some amphibian and reptile species, restoring existing wetlands or constructing new artificial ones, etc. Several studies have demonstrated anyway the difficulty of replicating natural habitats when attempting to create suitable habitat for these species.

In the present paper, the final results of an international Project – named: "ARUPA", financed by the EU LIFE+ Programme – aimed to guarantee the survival and increase in the population of some species of amphibians and reptiles in a protected area, are reported. The actions of the project were taken in the natural protected area surrounding the City of Matera (one of the UNESCO site of the Basilicata Region – Southern Italy) that is an EU Community Interest Site and Special Protection Zone as well. During this Project, some biosystems engineering techniques were employed, through specific constructions for the conservation and re-inclusion of some endangered species. Among these constructions, some dry-stone walls were built or restored, as well as some artificial ponds were realized. Their engineering design and construction aspects, which would contribute to the preservation of the local rural landscape, are here reported and discussed.

Keywords: Rural landscape; biosystems engineering; dry-stone walls; temporary ponds.

INTRODUCTION

A rural landscape includes the physical elements of landforms, water bodies and other morphological components, as well as living elements of land cover, including indigenous vegetation. Some transitory elements, such as lighting and weather conditions, would play a significant role as well. In this natural context, human elements are also often present, including different forms of land use, buildings and structures, *etc*. Combining both their physical origins and the cultural overlay of human presence, often created over millennia, a rural landscape reflects a living synthesis of people and place that is vital to local and national identity. The character of a landscape helps to define the self-image of the people who inhabit it and a sense of place that differentiates one region from other regions.

A rural landscape may be considered, far from being a mere passive expression of a visual component, as the result of the active interactions among several ***natural*** systems, in some cases connected to form different ecosystems. A landscape is therefore the final result of the interaction of the territory, including its own characteristics – geological, morphological, hydrological, *etc.* – with living organisms, *i.e.*: flora, fauna, *etc.* This interaction has been usually shaped by the ***artificial*** intervention of the Man, who transformed the agricultural land, joining the agricultural production needed for human nutrition with the control and care of extra-urban territory. All these aspects should be taken into the highest consideration during the landscape planning process [Dal Sasso & Caliandro, 2010; Picuno P., 2012].

Within this historic role played by humans, rural constructions play a fundamental role in determining the formal and substantial characteristics of the extra urban landscape, influencing the agricultural environment and the visual perception of its landscape [Hernández et al., 2004; Picuno et al., 2011; Tortora et al., 2015]. Some rural constructions, however, in addition to performing their primary role of support to agricultural production, may also play a proactive role in supporting suitable conditions for the persistence of some natural species that live in the extra-urban environment. In this paper, an example of effective implementation of biosystems engineering techniques, through the construction of specific elements able to support the resettlement of some amphibian and reptile endangered species in one protected area in Southern Italy, are reported.

BIOSYSTEMS ENGINEERING TECHNIQUES FOR HABITAT RESTORATION

Some of the interventions made by humans for populating and benefit the extra-urban land have been those aimed to delimit the country estate boundaries through dry-stone walls [Picuno P., 2015]. These interventions, aimed to physically demarcate boundary limits, avoiding forensic disputes, have at the same time deeply characterize the landscape, since they did not only constitute an evident construction clearly marking the territory, having at the same time realized, at micro-scale, a fertile environment in which some amphibian and reptiles species would grow, thanks to the local different soil humidity. These special conditions, mostly in sunny areas – as those located in Mediterranean Europe, *e.g.*, Southern Italy – that in summer suffer for being hot and dry, have allowed the survival of species that, otherwise, would have probably not survived [Picuno P., 2016].

A similar effect is that one connected to the diffusion of temporary ponds - also referred to as vernal pools, ephemeral wetlands, or various combinations thereof - within the rural land. The diffusion of intensive agriculture, together with the expansion of urban areas and consequent enlargement of the anthropic activities onto the rural landscape, determined a general loss in wetland areas all over the World. Because of the high rate of wetland loss over the last century, it has become routine to mitigate for these losses by restoring existing wetlands or constructing new artificial ones. Several studies [Brown et al., 2012; Drayer and Richter, 2016] however, have demonstrated the difficulty of replicating natural habitats when attempting to mitigate or create habitat for amphibians. Identification and quantification of specific characteristics that differ between natural and constructed wetlands are important information for land managers and policy-makers, for an improvement of current constructed habitats and for the success of future amphibian enhancement projects.

The inclusion of the Mediterranean temporary ponds as a priority habitat for conservation in the Habitats Directive (EC-EDG, 1992) highlights the importance of these ecosystems and the necessity to conserve them. Mediterranean temporary ponds constitute one type of temporary pond and are considered a priority habitat type in Europe. According to the Interpretation Manual of European Union Habitats, these are very shallow temporary ponds (a few centimetres deep), which exist only in winter or late spring. According to the Ramsar Convention, temporary ponds are usually small (< 10 ha) and shallow wetlands which are characterized by alternating of flooded and dry phases, and whose hydrology is largely autonomous. They occupy depressions, often endorheic, which are flooded for a sufficiently long period to allow the development of hydromorphic soils and wetland-dependent aquatic or amphibious vegetation and fauna communities. However, equally importantly, temporary ponds dry out for long enough periods to prevent the development of the more widespread plant and animal communities characteristic of more permanent wetlands. One of the main characteristics of temporary ponds is their isolation. If they were connected to more permanent habitats, this would probably cause the colonization of species typical of permanent habitats and the disappearance of those typical of temporary habitats due to competition and predation [Pérez-Bilbao et al., 2015].

Petranka and Holbrook [2006] have given prescriptive measures for the spatial configuration of pools at the landscape scale. These Authors urged restoration ecologists who are designing creation or restoration projects to consider whether natural pools are patchy (clustered, allowing free flow from pool to pool within a single amphibian population) or distant (suggesting a meta-population structure with limited interaction among pools). Calhoun et al. [2014] noted that one needs to think about particular species to assess whether pools are “patchy” or “distant.” Since, for example, permanent created pools did not support wood frogs and marbled salamanders, those species remained restricted to natural, ephemeral pools. According with Brown et al. [2012], for most amphibians with complex life cycles, standing or slow-moving water is necessary for the egg and tadpole development stages. The establishment of several wetlands in close proximity to one another is typically optimal for long-term persistence. Thus, careful consideration of the placement of wetlands within the surrounding landscape is necessary. Petranka and Holbrook [2006] indicated also that a “patchy population” wetland complex design, characterized by large variability in wetland size, hydro-period, and spatial proximity, was better than a meta-population design. Several studies indicated that upland habitat composition was important for connectivity among wetlands. Wetland creation and restoration may be effective for enhancing amphibian abundance and diversity, and thus may be a valuable tool for mitigating amphibian population declines [Brown et al., 2012].

Comparing amphibian communities of shallow and deep constructed wetlands to natural wetlands, so as to identify which wetland characteristics affect species communities, Drayer and Richter [2016] reported that constructed wetlands did not sufficiently replicate natural wetlands with respect to the amphibian community. Bellakal et al. [2014] concluded that smaller lakes are more favourable than the larger ones, in relation with a shore effect proportionally higher due to vegetation. These artificial wetlands increase the number of suitable habitats for pond-spawning species (frogs, toads), provide good compensation for the reduction of natural wetlands and may be adopted by managers as a new function (species conservation) for hill lakes. Denton & Richter [2013], considering that wetlands built for mitigation often do not replicate lost natural wetlands in structure or ecological processes, underscored the need for monitoring constructed wetlands to assess ecological condition.

Finally, Calhoun et al. [2014] resumed the existing literature about vernal pools, giving advice and general recommendations to practitioners gleaned from the literature. These Authors recommended that practitioners consider the complex ecology of pool ecosystems and the historical and current distribution of pools and other wetlands in their local context before designing pool mitigation projects. Vernal pools provide the core breeding habitat for reptiles and amphibians (*e.g.*, frogs, salamanders, *etc.*), but they are often inadequately protected because of their small size and ephemeral nature. Creation usually occurs as part of a proactive program to augment or diversify habitat by building new pools. Most natural vernal pools have shallow littoral zones available with gradual slopes to the centre, which has been linked to greater species richness compared to constructed wetlands. Natural wetlands to have significantly lower slope (measured as depth at 1 m from shore - mean = 9.1±0.8 cm) than constructed wetlands (15.4±1.6 cm). Steep, abrupt slopes may cause access problems for salamanders and may limit the growth of vegetation. Additionally, shallow areas can be important for predator avoidance, thermoregulation of amphibians for growth and to decrease the occurrence of diseases. Optimal slopes vary from pool to pool depending on typical levels of winter and fall rains.

MATERIALS AND METHODS

The Project ARUPA (*Azioni urgenti per la salvaguardia degli anfibi e rettili della Gravina di Matera - Urgent actions for the safeguard of reptiles and amphibians in the "Gravina di Matera" river*) was financed by the LIFE+ Programme of the European Union in the year 2008 (Contract number: LIFE08NAT/IT/000372). Aim of this Project was to guarantee the survival and increase in the population of some species of amphibians and reptiles in the Special Protection Area (SPA) IT9220135 of this location (www.arupalife.eu). The Project actions were taken along the "Gravina" torrent, flowing close to the City of Matera (Southern Italy), one of the most important key site for the following species: Zamenis situla, Triturus carnifex, Triturus vulgaris, Bombina pachypus.

The Project site is important also at the European level because the abovementioned species populations can be found elsewhere in the Mediterranean area. At the regional level (as far as two Italian regions are concerned, *i.e.*, Apulia and Basilicata), the site is a strategic area for the conservation of *Elaphe quatuorlineata*. While the City of Matera is an UNESCO site, the "Gravina" of Matera is one of the most spectacular rocky landscapes of Italy, witnessing the ancient relationship between man and nature. The whole surrounding territory is characterized by a soft rock, formed by deep furrows that form cliffs, caves, ravines used by the man who has lived since prehistoric times. The deep canyons that separate the plateau are the most common landscape element in the protected area. Of great suggestion, the Gravina of Matera - a huge limestone groove that crosses the park, with its twenty kilometers in length - constitutes an human, natural and environmental heritage of inestimable value. A seemingly desolate land but that hides the natural and historical riches of exceptional value. The Gravina of Matera from 1995 is included in the SIC site (Site of Community Interest) and SPA (Special Protection Area) "Gravine di Matera" included in the "Natura 2000 Network", *i.e.* the network of natural and semi-natural areas of Europe, born with the objective to contribute to the safeguard of the biodiversity of the habitats, the flora and the wild fauna. Currently, the Gravina torrent is affected by an unacceptably high level of pollution, which has reduced, if not cancelled, the presence of faunal and floral components in close contact with water.

In order to preserve the disappearance of amphibians and reptiles and to mitigate the threat factors, the ARUPA Project has put in place initiatives to ensure the survival of populations through renaturalization of the watercourse, reforestation, creation of forest nurseries and farms for the multiplications of the endangered species of amphibians, reptiles, as well as some works specifically designed basing on biosystems engineering criteria, *i.e.*: restoration of dry stone walls and realization of some temporary ponds/vernal pools. These biosystems engineering techniques were designed on the basis of a general survey of the whole area and the relevant implementation of all key parameters within a Geographical Information System (GIS), specifically aimed to the definition and design of the Project works. On this basis, the following works were realized:

- Construction of about 2,000 meters of drystone walls around the most threatened areas
  (Reference habitat: 92A0 *Salix alba* and *Populus alba galleries*)
  (Reference species: *Zamenis situla, Elaphe quatuorlineata, Testudo hermanni*)
- Restoration of some small wetlands – temporary ponds
  (Reference species: *Bombina pachypus, Hyla intermedia e Triturus carnifex, Triturus italicus* (*Lissotriton italicus*), *Elaphe quatuorlineata*)
- Realization of some grounded water storage tanks/vernal pools
  (Reference species: *Triturus carnifex, Triturus italicus (Lissotriton italicus), Bombina variegata*.)

RESULTS AND DISCUSSION

Construction of drystone walls around the most threatened areas

The dry-stone walls were constructed with the aim to:

- create new refuge and trophic habitats for many species of invertebrates and small vertebrates, especially for the endangered amphibian and reptile species;
- support the realization of better soil moisture conditions;
- promote a traditional artefact suitably integrating within the surrounding landscape, able to improve the creation of ecological corridors as well;
- increase the margin effect, expanding the ecotonal bands.

While some existing – but often severely damaged – dry-stone walls were repaired, in the other cases, some brand new walls were included into the rural landscape, in areas planned on the basis of the results obtained through the implementation of the GIS. These new dry-stone walls were built *ex-novo*, on the basis of the traditional way in which these rural constructions were realized in the two neighbouring regions - Apulia and Basilicata - by using local limestone rocks trapped and blocked together without the use of any mortar (fig. 1), basing on a small foundation that was realized under each dry-stone wall, by digging the soil for 15-20 cm.

Figure 1 - Construction of a new dry-stone wall under the ARUPA Project.

The *ex-novo* built dry-stone walls were realized with a cross section having an isosceles trapezoidal shape (fig. 2), according with three different dimension sets (lower base/higher base/height of the trapezoid):

60/40/80 cm; b) 80/60/130 cm; c) 100/70/170 cm.

Figure 2 - Dry-stone wall constructed under the ARUPA Project.

The existing dry-stone walls were repaired adopting suitable technical adjustments, so as to better fit into the rural environment, by reducing the impact on the vegetation having developed in the margin and on the habitats of existing animals and plants that have consolidated over time, essential to maintain the multiple functions performed by the wall.

Restoration of small ponds

N. 3 small temporary ponds, for a total surface area of about 2 hectares, characterized by a variable water level, were realized in order to increase the availability of areas suitable for the target species (fig. 3). Each temporary pond was provided with a water supply channel and two weirs, for water loading and unloading.

For the creation of each temporary pond, the soil has been excavated to the depth of 40-50 cm, then adequately sealed on its bottom using a waterproof fabric sheet made of special bio-compatible material. Each pond was then delimited along its perimeter by a little embankment 50 cm height, made with the excavated soil, that was adequately shaped and compacted, topped with oblique side rails. The ditches feed the areas through small channels regulating the waters, which can be closed as soon as the water level of the ditches decreases and then maintain for as long as the flooded areas. Given the ability to fast colonization by native aquatic plants typical of the area, after completion of construction operations, a preliminary planting of a total area of 1 hectares of these species with rhizomes and seeds of local ecotypes found within the surrounding areas and from the Project vegetal nursery was finally realized as well.

Figure 3 – Small temporary pond constructed under the ARUPA Project.

Grounded water storage tanks/vernal pools

In the Project area there are several tanks / pools in the open air that were traditionally used for water supply and that, at present, given the socio-economic changes that have occurred within the agricultural sector, have largely lost their initial function. However, they retain an important role in the conservation of amphibians and reptiles in the area, which is largely devoid of surface water due to its karst nature. In analogy to what was already experimented in Italy under other LIFE+ projects, two reservoirs having an average depth of 1.5 m located in the centre of a land of irregular shape of about 1000 square meters, were realized. On the bottom of each basin, an underground tank at least 4 m deep with a flask shape (Fig. 4a) was incorporated. This type of tank, traditionally used for irrigation purposes, has proven its high ecological efficiency in permitting the survival of many species of amphibians during lean periods in which, while during winter the reservoir looks like a normal quagmire (fig. 4b), during summertime the tank (located in the lowest part) retains a sufficient amount of water to keep alive sufficient specimens of invertebrate amphibians. In relation to possible risks to humans and/or animals, suitable ladders for both security reasons and for inspection-monitoring were realized. The low depth of the collected water does not represent anyway a real danger neither for the man or the animals.

Figure 4 – Scheme of a traditional grounded water storage tank (a); Grounded water storage tank/vernal pool realized under the ARUPA Project (b).

CONCLUSIONS

Within the modern concept of landscape protection, the safeguard of each ecosystem included in the rural land plays a central role. With the aim to contribute to the protection of rural land – able to counterbalance the results of a wrongly planned expansion of urban areas, as well as an indiscriminate diffusion of intensive agriculture with an heavy environmental impact on the rural landscape - suitable actions mitigating these losses may be effectively implemented, through including in the rural landscape suitable elements able to protect natural components.

Biosystems engineering techniques have revealed a powerful tool for recreating suitable conditions for the survival and proliferation of endangered amphibian and reptile species that, mostly in very sensitive areas – like that one in which the EU LIFE+ Programme has financed the ARUPA Project – may support the sustainable development of the European Countries. The contribution that biosystems engineering may play in the protection of rural landscape - thanks to its powerful *know-how* deriving from its special mission to design constructions engineered to host biological productions, having no other comparable example in the wide epistemological sector of building construction – appears therefore fundamental. The birth, growth and development of living vegetal or animal organisms contained inside rural buildings raise indeed architectural and technical issues that are absolutely original, constituting an unique and unrepeatable technological model with no similar comparison in other building sectors. Biosystems engineering may play therefore a crucial role in supporting the extra-urban land planning, since rural constructions are strictly connected with the surrounding environment, due to the need of the farmer to live in close contact with animal husbandry and agricultural land, in harmony with the natural elements, joining the agricultural production with the control and care of extra-urban land.

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