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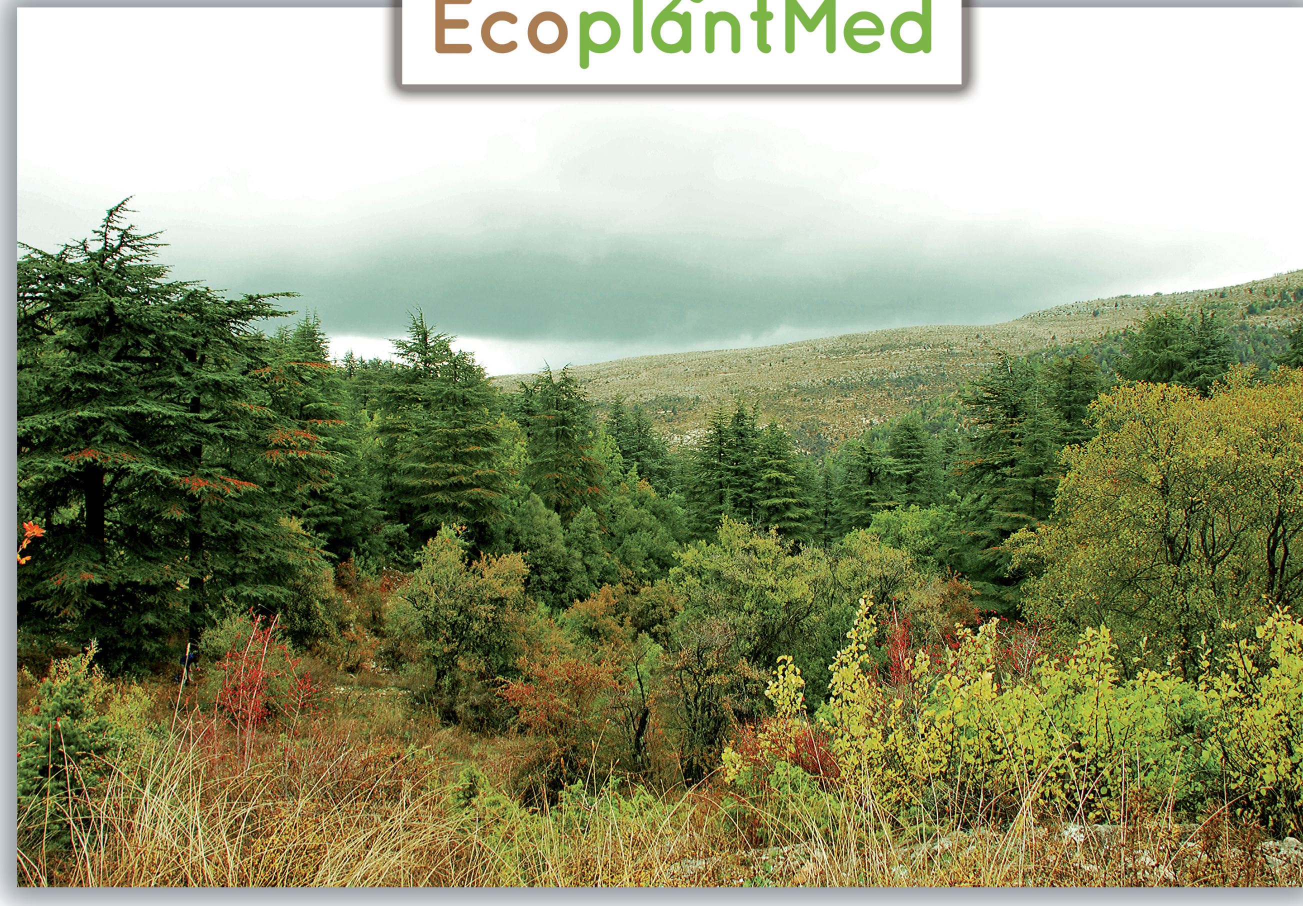

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Bridging nature and human priorities in ecological rehabilitation projects - a show case from Mediterranean environment - Qattine, Lebanon

J. Fenianos[1, 4], C. Khater[2], J. Viglione[3], D. Brouillet[4]
[1]*ASE - SARL - Jdeideh - Lebanon.*
[2]*Center for Remote Sensing - National Council for Scientific Research Lebanon. Bir Hassan - BP 11-8281 Riad El Solh, Beirut - Lebanon.*
[3]*EcoMed - Tour Méditerranée - 65, av. Jules Cantini - 13298 MARSEILLE cedex 20 - France.*
[4]*University Paul Valéry, Laboratoire Epsylon, Montpellier, 34199 - France.*

Abstract
The rehabilitation of quarries is an environmental issue where different parameters should be taken into consideration. In reality, few approaches are put in practice and many are yet to be discovered. When proposing new approaches and techniques, we often face psychological resistance from stakeholders mainly due to their prejudgemental perceptions. This paper showcases the development of an ecological rehabilitation scheme on the basis of a baseline assessment and an ecological screening. This leads to the suggestion of a concept called "Across the Wild Rocks" while land owner's perception was rather directed towards the classical scenario of terracing and orchards plantation. This paper presents the analytical methodology and describes the rehabilitation concept converging between a hierarchical organization of priorities. We conclude by saying that relying on social sciences to increase cognitive flexibility might lead to a better acceptance of new techniques while reducing psychological resistance.

Key words: cognitive flexibility, ecological rehabilitation, Lebanon, psychological resistance, quarries.

Introduction

Out of the several pathways a site could follow during a self or assisted regeneration, Ecological Rehabilitation is "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SER primer, 2004).

Ecological Rehabilitation emphasizes the reparation of ecosystem processes, productivity and services, with no particular focus on the re-establishment of the pre-existing biotic integrity in terms of species composition and community structure.

The term "reclamation", as commonly used in the context of mined lands in North America and the UK, has an even broader application than "rehabilitation". The main objectives of reclamation include the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to what, within the regional context, is considered to be a useful purpose. Revegetation, which is normally a component of land reclamation, may entail the establishment of only one or few species. Reclamation projects that are more ecologically based can qualify as rehabilitation or even restoration (SER primer, 2004).

Are these orientations incompatible? Can ecological concerns be reconciled with socioeconomic priorities? Could a more "natural" site reallocation or a more "human oriented" restoration be envisaged? These questions are becoming increasingly strategic in highly urbanized Mediterranean environments where co-evolution of man and nature render it difficult to give priority to either one at the exclusion of the other (Di Castri, 1982).

Quarrying is an ancient economic practice, dating as far back as the Stone Age, as stone was required for the creation of tools such as knives and hammers, as well as for construction purposes. However, extraction evolved from small scale activities to present-day industrial quarrying, which is essential for urban development, road construction, and raw construction material (Legwaila *et al*., 2015). Exploitation therefore takes place on a significantly larger scale and, although quarrying is a necessary economic activity for social and urban development, it can have profound impacts on the environment (Martin *et al*., 2002; Khater & Martin, 2007; Darwish *et al*., 2010; CNRS-L/AFDC/IUCN/Holcim, 2013).

Quarrying operations have multiple negative consequences as they impact and alter ecosystems and disturb hydrogeological and hydrological regimes (Khawlie *et al*., 1999; Shaban *et al*., 2007; Darwish *et al*., 2010). Moreover, they can significantly change the substratum, impact landscape integrity, destroy natural habitats, interrupt natural succession, disrupt fundamental ecological relationships, and in certain cases, alter genetic resources (Bradshaw, 1997; El-Fadel *et al*., 2000; ESCWA, 2001; Khater, 2004; Stehouwer *et al*., 2006; Jomaa *et al*., 2008).

Corresponding author: Carla Khater. *Center for Remote Sensing - National Council for Scientific Research Lebanon. Bir Hassan - BP 11-8281 Riad El Solh, Beirut - Lebanon; e-mail: ckhater@cnrs.edu.lb*

Also, as mechanical excavation leads to the creation of cliffs, platforms, and embankments, natural regeneration is often slow and uneven (Khater *et al*., 2003; Darwish *et al*., 2010). Other consequences include increases in dust emission, traffic due to transportation to and from the quarry site, noise pollution and aesthetic disfiguration. All of these impacts are aggravated by the fact that, in most countries, quarries are generally abandoned and left without rehabilitation after their completion, leading to increased surface runoff, decreased natural recharge, and seawater intrusion into coastal karst aquifers (El Moujabber *et al*., 2006).

Located on the eastern shores of the Mediterranean Sea, Lebanon is a country with a surface area of 10,452 Km^2. Characterized by high landscape and geomorphological complexities (Thompson, 2005), Lebanon has witnessed a succession of 17 geological formations, spanning from the Jurassic to the Quaternary age (Dubertret, 1955). Its rich biodiversity comprises 2,486 identified animal species and 2,600 plant species, of which 92 are endemics (CBD, 2004).

However, due to its relatively small size, Lebanon has limited natural resources, including water and soil, and has been subject to pressures from human activities since ancient times (Darwish *et al*., 2010; Khater *et al*., 2012). Decades of uncontrolled exploitation of mineral resources have resulted in more than 710 quarries across the country (Handassah, 1996), a number that has been estimated at 1,300 by Darwish *et al*. (2010) and 1,800 by the Green Party in 2010 (http://greenpartylebanon.org/). Most of these quarries have been abandoned and have left a mosaic of scars throughout the Lebanese landscape, impacting human safety, natural resources, and ecosystems' functions (ECODIT, 2001; Khater *et al*., 2003; ELARD, 2007; Saad *et al*., 2007). Given the lack of integrated land use planning, quarry expansion, which predominantly took place during the rapid urban expansion of the 1990s, did not occur according to land suitability (Khawlie *et al*., 1999; Khawlie, 2000; Faour *et al*., 2005).

According to Darwish *et al*. (2010), this uncontrolled expansion has led to the destruction of 738 ha of grasslands, 676 ha of arable lands, and 137 ha of forested area. Furthermore, over 23 percent of quarry expansion took place on the already scarce agricultural lands, leading to 629 to 1,367 ha of pasture land and 219 to 895 ha of arable land impacted by excavation. However, no landscape has been affected more than rocky lands, with up to 217,000 ha destroyed.

The Lebanese quarry legislation, decree 8803/2002, dictates mandatory quarry rehabilitation. Yet, no guidelines accompany this decree, rendering this legislation ineffective (Nadim Mroueh –Head of the Natural Resource Department at the Ministry of the Environment, oral communication, 2015). Moreover, each quarry permit, upon issuance, is accompanied by the need to dedicate a financial reserve of 134,000 USD for rehabilitation purposes.

However, in Lebanon there are numerous barriers to rehabilitation, including political corruption as well as ecological, economic, financial, and social obstacles. One of the key obstacles is the lack of proper law enforcement, complicated by the large number of various stakeholders involved (MoE, 2007; Saad *et al*., 2007). In light of these legal constraints, rehabilitation and/or reclamation efforts in Lebanon, whether after or during the exploitation phase, systematically consist of terracing and planting (fruit trees and/or forest species).

These practices are generally implemented with a minimal budget aiming to free the financial reserve (134,000 USD), with a low financial investment and inexistent monitoring efforts. They are carried out with little or no consideration for the biodiversity and ecological dynamics of the site (Fig. 1).

Natural dynamics, even when slow, often result in the presence of a wide variety of plant and/or animal species in a degraded site.

Furthermore, if the restoration/rehabilitation plan does not account for this rich biodiversity, whether naturally or potentially present on site, richness might in turn be reduced.

This paper deals with the case study of an abandoned quarry located in Qattine, Keserwan – Lebanon (Fig. 2) and argues that it is possible to design a rehabilitation plan based on the ecological attributes of a site and building on the existing and potential biodiversity while serving human aspiration for future use of the site and acknowledging the ecological, economic, financial, and social challenges. As the site falls on private property the political interference has a minimal impact in this case.

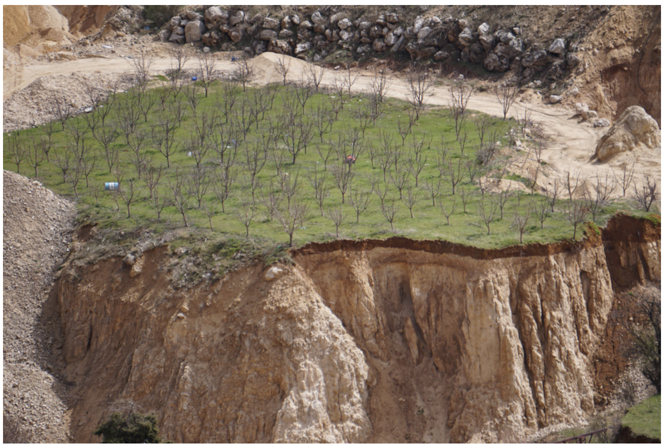

Fig. 1 - Amez, Lebanon - example of common rehabilitation practices in Lebanon, where abandoned quarry sites are used for agriculture.

Fig. 2 - Aerial view of the Qattine quarry.

Fig. 3 - Triptych Approach for integrated rehabilitation planning (Khater, 2015).

Study area

The Qattine quarry is located at 740 m a.s.l. (Latitude 34°1'37.82"N; Longitude 35°42'31.95"E) in a meso-Mediterranean zone characterized by vegetation dominated by *Quercus calliprinos*, and its main understorey species on limestone substrates (Mouterde, 1966; Abi Saleh & Safi, 1988; Khouzami *et al*., 1996). The mean annual temperature is 18 C and mean annual rainfall is 1000-1100 mm (Khawlie *et al*., 1999). Abandoned since 1980, more than 35 years of slow, timid natural processes have mainly resulted in an increased erosion and have exacerbated degradation. The quarry extends over an approximate area of 2.5 ha and is composed of hard, well-bedded to massive dolomite and dolomite limestone of the Kimmerdjian Formation (C6) of the Upper Jurassic. This formation is characterized by intensive fracture systems.

Materials and Methods

Although rehabilitation is often needed, techniques may vary depending on the local context, financial means, timeframe, as well as resources available. When proposing a rehabilitation concept and approach, several factors must therefore be taken into consideration. This methodology followed a Triptych Approach (Fig. 3) to ensure that the concept is ecologically sound, socially acceptable and technically feasible.

In order to increase the chances of success and reduce negative externalities, the concept also took into consideration the following parameters: legally fit, builds on community vision, and serve well-being, as described in (Fig. 4).

The concept for rehabilitation was derived from the methodological scheme detailed in Fig. 5 hereafter.

The baseline assessment (Fig. 5) covers ecological screening, biodiversity assessment, and geology, hydrology and topographic mapping of the site and its direct surroundings. It enables us to identify the sites' potentialities in order to overcome its challenges.

Site visits were conducted in July 2014, February

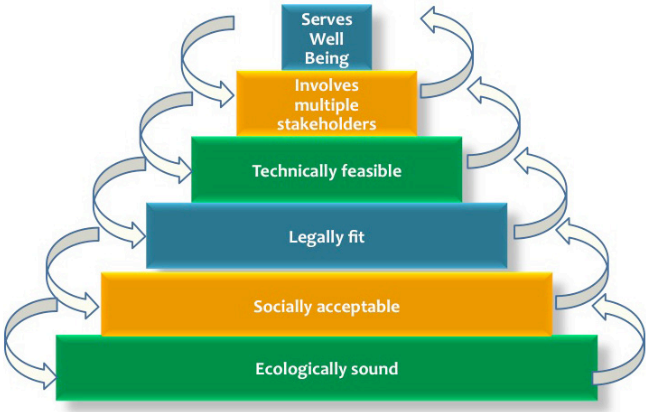

Fig. 4 - Hierarchical perception for optimal rehabilitation (Khater, 2015).

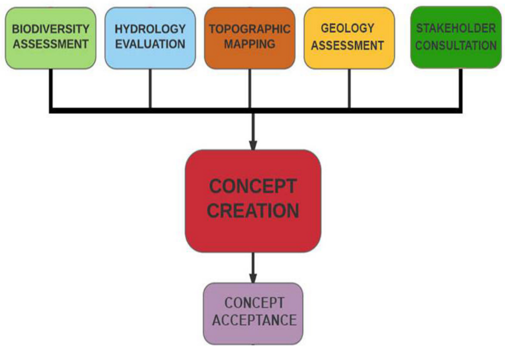

Fig. 5 - Methodological scheme resuming the baseline assessment towards the development of the rehabilitation concept (Khater, 2015)

2015, and April 2015 bringing together experts from various fields. Ecological screening involved an ecologist, a botanist, a herpetologist and an ornithologist. Surveys dedicated to biodiversity were conducted during the Spring season, which is the best calendar period for biodiversity studies given that it is the main flowering season and the time when most of the local biodiversity is active, reproducing, and therefore visible.

The adopted approach focused on the conservation status of the natural habitats and highlighted the important ecological functionalities of each biological group.

The geological stability assessment was viewed from structural and stratigraphic perspectives. The following site characteristics were investigated:

Exposure Setting (Excavation aspect, Cutting angle, Aspects of mass movement); Lithological Characteristics (Rock formation and type, Permeability, Porosity); Structures (Fault system, Fissuring systems for fractures, joints and crushing zones); Rock inclination (Dip; Karsitfication); Stratigraphy (Bed thickness, Hardness; Strata homogeneity); and Stability Assessment.

Hydgrological modelling was performed on the basis of a 10 cm resolution digital elevation model (DEM) to favour the correct presentation of the drainage patterns. Accordingly, the estimation of the amount of overflow of water was performed by simulating a hypothetical design storm by a 2D hydrological watershed model HEC-HMS over the site subbasin.

Topographic survey was performed using a UAV platform equipped with a high resolution calibrated camera and a high accuracy GPS/IMU system. Differential GPS points were surveyed on the ground (approximately 4 points). Data was downloaded from the UAV data memory and further checked for image quality and errors. Consequently, data was imported into a customized photogrammetric workflow process along with additional auxiliary on board GPS/IMU data.

The stakeholder consultation was restricted to the Committee of Private Land Owners with whom several meetings were conducted to discuss the site attributes, challenges and rehabilitation objectives.

Results

Baseline assessment and ecological screening guided the identification of the site's attributes and challenges (Tab. 1).

From an excavation point of view, the geological evaluation confirmed the presence of two subunits on the site: 1. the old one (lower) with vertical cut exposure, at foot slope; and 2. a more recent one (upper), excavated on the fault mirror with inclined exposure.

The quarry is situated in a tectonic zone, as slickensides (crushing walls/fault mirrors) are well pronounced.

The ecological screening revealed the hidden biodiversity of the site.

It includes a number of plant species such as wild orchids *Ophrys episcopalis* and *Anacamptis coriophora* subsp. *fragrans*, insects and arthropods such as *Archon apollinus* (butterfly) and *Scorpio maurus*, as well as a high diversity of reptiles including *Testudo terrestris*, *Rhynchocalamus melanocephalus*, *Platyceps collaris*, *Dolichophis jugularis*, *Phoenicolacerta laevis*, *Laudakia stellio*, *Ophisops elegans*, a *Pseudopus apodus*, and several saxicolous birds such as *Monticola solitarius*, *Apus apus*, and swallow passerines birds in addition to one species of bat *Myotis capaccini* were also spotted on site.

Hydrology and topographic surveys provided the base maps that were used to develop the site concept. They guided the location of the plantation pattern to grant higher probability of self-sustainability in view of the natural drainage.

Meetings with stakeholders allowed to identify that initial stakeholder’s perception for the site meets the traditional common rehabilitation practices consisting of removing the fallen rocks and using them to build terraces, adding agricultural soil and planting some apple trees as shown in the reconstructed scenario (Fig. 6).

The “Across the Wild Rocks” rehabilitation concept (Fig. 7) presented in this paper was inspired from the story of the site and the observation of existing and potential biodiversity.

As reported by locals “It was on a Sunday night, 40 years ago when the inhabitants woke up to a huge sound. Every one thought it was a bomb and only in the mountain did they notice the big landslide thinking it was probably coming from an over dose of dynamite. Since then, the owner stopped the exploitation of the quarry. The actual owner of the site had wished to erase the scars and build apple orchards instead”.

In front of such a huge scar, and discovering the mini biodiversity spots it shelters, the “Across the Wild

Tab. 1 - Challenges, Attributes, and Rehabilitation Objectives.

Challenges	Attributes
Instability of the land	Proximity to the major town Ghazir
Presence of rock falls	Willingness of the land owners to collaborate
Water runoff	The relatively long period of natural dynamics (more than 35 years) which favoured local diversity and richness
Fault mirror and subsequent footwall have considerably limited the establishment of natural vegetation	Site’s easy accessibility
The limits of ecosystem's resilience have been exceeded due to the absence of soil and vegetation cover	The ecological continuities with neighbouring ecosystems
The cost for rehabilitation should be shared among landowners	Quarry is located on private land and thus less political interference
Rehabilitation objectives	
To take the best advantage of such attributes to implement adequate rehabilitation plans	
To increase biodiversity	
To attract people to the site and create an outdoor venue for recreational activities	
To shed light on the impacts of destructive human activities	

Rocks" concept emphasizes the scar and guides people to give the opportunity for those mini gardens to grow into larger gardens where nature could not find its way before.

The concept acknowledges and preserves existing ecological attributes and suggests a new approach in an overall perspective to reallocate the site while restoring it as closely to its pre-existing natural state as possible. This is based on the idea that if the site becomes a future destination for "nature escapade" and education purposes, a combination of engineering intervention methods can be applied while prioritizing the human dimension.

The concept is designed in such a way as to blend in the surrounding geomorphology and scenic landscape, while diversifying landforms to host a greater number of animals and plants (Fig. 8).

Promoting visitors' access to the site will serve two major purposes: providing a recreational spot for locals and visitors and transmitting educational messages on the importance of ecological processes and spontaneous biodiversity, as well as the impacts of quarrying. Furthermore, it challenges the unfounded idea that quarries represent a harsh environment, a scar that should be erased. "Across the Wild Rocks" emphasises the scar as it leads visitors via a stone stairway across biodiversity spots where interventions consist of highlighting the existing natural gardens and promoting their development by adding seeds or planting native species. A variety of adapted native species is suggested, including *Viburnum tinus*, *Cyclamen persicum*, *Spartium junceum*, *Teucrium pollium*, *Salvia triloba*, *Callycotome villosa*, *Myrtus communis*, *Sarcopoterium spinosum*, *Cercis siliquastrum*, *Quercus calliprinos*, *Capparis spinosa*, *Pinus brutia*, *Ceratonia siliqua*, *Nerium oleander* (Appendix I).

Fig. 6 - Reconstructed scenario of classical rehabilitation in terraces and orchards plantation as expressed by the site's owners.

Fig. 7 - 'Across the Wild Rocks' rehabilitation concept - developed for the Qattine quarry as a meeting point between ecological priorities and future human use.

Site erosion will be prevented by encouraging the establishment of stabilizing species with adequate root systems. While these species might not be intended for advanced stages of succession, they will support plants as part of the resilience dynamic of the future ecosystem. Finally, certain ligneous species would be planted in scattered patterns to initiate bush like formations and to accelerate natural dynamics by attracting fauna on the medium-term. However, it must be noted that the long-term stabilization of the site will significantly depend on the stabilization of the substrate, emphasizing the importance of a multidisciplinary approach. Furthermore, monitoring will be a key step towards the success of the process, serving as a strict and constant control measure of potentially invasive species which might hinder or compromise natural regeneration processes. Pioneer plants will be included in the planning in order to limit soil erosion and ensure the transition to future stages.

Keeping in mind the availability of species and the accessibility of the areas to be planted, a palette of adapted native species will be selected, with preference given to low maintenance species to ensure lasting sustainability. The fault mirror will be scratched and spread with seeds to initiate natural dynamics. Rock walls shall bare some 60x60 cm holes filled with soil and planted with local species and smaller holes to facilitate bird nesting and bat frequentation on site. Finally, to facilitate access, a network of stairs will be traced and built with the rocks removed by the stabilization process.

The implementation process will start with the stabilization of the rocks to ensure the safety of the site, which will allow proceeding to the second main step, namely the delineation of the micro-gardens with respect to biodiversity richness and ecological connectivity.

These will serve as the cornerstones of the rehabilitation process, followed by infrastructure works meant to define the future locations of the various micro-gardens.

Water runoff will be reoriented to reduce erosion and erosion processes will be used during the preparation phase to fill the future micro-gardens pockets, in order to benefit from the local soil which will enclose local seeds.

Fig. 8 - Close ups views on the enclosed natural gardens conceived to enhance existing biodiversity and promote natural dynamics.

The pockets will be drilled in different sizes and different locations across the quarry face, which will allow the site to host wildlife again.

The pockets on the mirror fault will be a few centimetres wider and their cavity would be filled with soil containing seeds collected from the site's surroundings.

Discussion and Conclusion

The ecological rehabilitation objectives listed in Tab. 1 were derived from the initial site assessment and from the main ecological restoration principles (Tab. 2).

The "Across the Wild Rocks" concept was developed to build on site attributes and to overcome its challenges (listed in Tab. 1). The baseline assessment and the ecological screening guided the creation of the concept in view of the hierarchical perception presented in Fig. 4. In particular, it has enabled us to:

- Address main ecological concerns especially when aiming to maintain and restore ecological functionalities on site and reinforcing major ecological connectivity, respect local vegetation dynamics and maintain/improve the shelter capacity of the site.
- Respect local social frame as it considers the local values and traditions in terms of family gathering and recreational venue.
- Answer the legal constraints especially in terms of landownership.
- Implement a technically feasible scheme with a realistic projection building on existing physical attributes with minimal external additional input and earth movement.
- Suggest a phased implementation in view of financial availability of funds for the execution.

However, when it comes to building on community vision, and in this case stakeholder's/owner's perception, both the suggestion ("Across the Wild Rocks" concept) and the expectation (owner's vision) did not meet.

Obstacles to effective ecological rehabilitation, enabling proper consideration of ecological priorities, can vary from conceptual, technical, political, to financial.

Technical obstacles can include a lack of human resources or skills, lack of the biological material needed, the fact that nature and societies have different timeframes, and absence of law enforcement. These might also include concerns about whether the technical capacities to rehabilitate exist and what approach would be most effective. It must be noted that access to funds are always one of the major drivers in a rehabilitation concept. In turn, technical barriers often increase conceptual ones due to several limiting factors. Political interference in this case is minimal as the land falls on private property. In most cases finances can be major limitations to proper rehabilitation, as the financial resources and funding sources required might not always be available.

Conceptual challenges are various as the visions and needs of the various stakeholders may contradict each other. In this case they were mainly related to pre-judgemental ideas where what is first mobilized are the pre-existing concepts and traditional ideas.

In the global context of interplay between human and ecological disciplines and more specifically, the disciplines that investigate and aim to understand human cognitive mechanisms (both psychology and philosophy), as well as those focused on social interactive skills (involvement, animation, consultation, collaborative work, etc.), interdisciplinary approaches play a key role. Relying on social sciences might help overcome such obstacles in human behaviour.

This problematic challenge requires the mobilization of cognitive flexibility (i.e. the ability to deconstruct existing configurations to lead to the emergence of new configurations) in order to facilitate the adoption of ideas that are different than the ones pre-existing and deeply rooted in human minds (innovative measures and creative approaches).

It is therefore of great importance to find the typical areas of resistance of a group and try to work on them through cognitive flexibility exercises in order to lower the resistance and head towards acceptance.

Working on lowering the resistance and increasing the acceptance of a group in future research for rehabilitation purposes, building on an active human-based pedagogic approach and on project-based learning, will give the ecologists a greater chance of success when proposing untraditional ideas of rehabilitation. This must be coupled with an initial analysis of the cognitive sources of the local population and on cooperation with the promoters concerned by quarry rehabilitation, in order to identify the convergence and braking points of beliefs of the local communities.

Tab. 2 - Ecological Restoration Principles (AABR, 2013).

Ecosystems Principles	Human Systems Principles
• Incorporating biological and environmental spatial variation into the design	• Ensuring all stakeholders are fully aware of the full range of possible alternatives, opportunities, costs and benefits offered by restoration
• Allowing for linkages within the larger landscape	• Empowering all stakeholders
• Emphasizing process repair over structural replacement	• Involving relevant stakeholders in the definition of boundaries for restoration
• Allowing sufficient time for self-generating processes to resume	• Considering all forms of historical and current information, including scientific and indigenous and local knowledge, innovations and practices
• Treating the causes rather than the symptoms of degradation	• Providing short-term benefits leading to the acceptance of longer-term objectives
• Include monitoring protocols to allow for adaptive management	• Providing for the accrual of ecosystem goods and service
	• Striving towards economic viability

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Appendix I: Species List with Reference

Anacamptis coriophora subsp. *fragrans* (Pollini, 1811)
Archon apollinus (Herbst, 1789)
Callycotome villosa (Link, 1822)
Capparis spinosa (Linnaeus, 1753)
Ceratonia siliqua (Linnaeus, 1753)
Cercis siliquastrum (Linnaeus, 1753)
Cyclamen persicum (Miller, 1768)
Dolichophis jugularis (Linnaeus, 1758)
Myotis capaccinii (Bonaparte, 1837).
Myrtus communis (Linnaeus, 1753)
Nerium oleander (Linnaeus, 1753)
Ophisops elegans (Ménétries, 1832)
Ophrys episcopalis (Poiret, 1816)
Phoenicolacerta laevis (Gray, 1838)
Pinus brutia (Tenore, 1811)
Platyceps collaris (Müller, 1878)
Pseudopus apodus (Pallas, 1775)
Quercus calliprinos (Webb, 1838)
Rhynchocalamus melanocephalus (Jan, 1862)
Salvia triloba (Miller, 1768)
Sarcopoterium spinosum (Spach, 1846)
Scorpio maurus (Linnaeus, 1758)
Spartium junceum (Linnaeus, 1753)
Testudo terrestris (Forskål, 1775)
Teucrium pollium (Linnaeus, 1753)
Viburnum tinus (Linnaeus, 1753)