Relevant Plant Recovery Programmes. Conservation Management of Plant Micro-Reserves and Ecological Restoration

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I. Introduction

The purpose of the creation and maintenance of PMRs is not just mere passive conservation of unique plant species and their habitats, but active conservation through actions tailored to the specific needs of each taxon. In the most extreme case, some PMR can be declared only to ensure the passive conservation of a given species, with monitoring of populations –census, demographic studies, etc.– as the only intervention. But this is probably an exception to the general rule. By contrast, most species whose physical protection is ensured through PMR are threatened plants that need direct intervention on the population or the surrounding environment, or other unique species –endemic, rare– with which there is little management experience. In this instance, PMR play the role of plots in which management techniques can be tested, with a view to fine-tuning protocols in situ for a variety of situations.

In most cases, the PMRs have been proposed for the protection and development of species specific conservation actions, so that the management of these areas must revolve around the maintenance and improvement of their populations. This requires an intervention on the species or habitat, the intensity of which should be properly planned. The range of activities that can be carried out is ample, and often requires planning beforehand. Basically, the models that can be applied are:

- Site specific Planning: Management plan of a given PMR, which regulates all activities and scheduled to be developed. It may consist of a synthesis of guidelines, as it is being done in the PMR network of Valencia, or more detailed and complex programs, such as those established for PRM created in Crete or Cyprus.
- Local Implementation schedules for species or habitats: consisting in the adaptation and implementation in a PMR of the guidelines of a conservation plan for a particular species or habitat

In an ideal situation, even if the PMR has a management plan, its provisions on a particular threatened species must be in accordance with its recovery plan, which in turn must have been prepared in agreement with technical regulations or rules in force for each territory. Several introductory works, such as Laguna (2004, 2005a and b) or Laguna *et al*. (2001) stress the need for a fine correlation between management plans of PRM and recovery programs for such taxa. However, there might not be a recovery plan for the species. Additionally, in some situations the PMR can shelter a substantial proportion of the population of a threatened species, so that the management plan of the PMR can play the role of the recovery plan for that particular taxon.

II. The Contribution of *Ex Situ* Activities

Regardless of a certain amount of office work –collection of scientific and technical information, drafting of management plans or adjustment of recovery plans, regulatory process, etc.– the purpose of the action often involves *in situ* management work on the species and/or habitat as well as *ex situ* activities. In the case of the most endangered species, it is necessary to ensure the conservation of the species reproductive material through accessions in gene-banks or living plant collections and the fine-tuning of germination protocols and plant production in specialized nurseries. Although this text does not elaborate these activities in detail, we recommend reading some basic work for the conservation and *ex situ* management of wild species intended for reintroduction in genetic reserves (PMRs, nature reserves, etc.) such as Hernández-Bermejo *et al*. (1990), Iriondo & Perez-Garcia (1999), Bacchetta *et al*. (2006, 2008) and Smith *et al*. (2003). Data on germination and other *ex situ* activities with species with which conservation work has been carried out in PMR can be found, among others, in the works of Herranz *et al*. (2002) in Castilla-La Mancha (Spain), Fournaraki & Thanos (2004) and Fournaraki *et al*. (2007) in Crete (Greece), or type *et al*. (2006), Ferrer *et al*. (2012) and Escribá *et al.* (2006) and Laguna (2007) in Valencia (Spain).

III. Census and Monitoring

Conservation of threatened species and detailed monitoring of biodiversity changes in PMR in the long-term requires regular collection of populational data of the species within each plot. For techniques and examples regarding these issues, in addition to what has been explained in the chapter on research within PMR in this book, the synthetic works of Iriondo *et al*. (2008, 2009) should be consulted as well as other works on demographic studies of endangered species through population viability analysis (Morris *et al*., 2002; Morris & Doak, 2002). A good number of the examples cited by Iriondo *et al*. (2009) for Spanish plants correspond to species included in PMRs in Castilla-La Mancha and Valencia, or whose inclusion in the network is planned when other regions adopt this legal protection figure. With regard to sampling of protected species within PMR, when they are not subject to detailed demographic studies, a census can be made every few years. Navarro *et al*. (2010) suggest a sampling method consisting of a census of the species using 'buffers' of 1-2 m around each point of data collection established with GPS in the field. This technique is recommended for PMR networks with a large number of protected sites, while the detailed demographic studies are optimal for extreme cases of highly endangered species, or for intensively monitored PMR networks.

IV. Species Conservation

The basics of conservation programs of wild plants and their realization through recovery plans can be considered sufficiently summarized in synthetic approaches such as Wyse-Jackson & Akeroyd (1994) or more developed treaties such as that of Maxted *et al*. (1997). Preservation techniques have been summarized and developed by Kell *et al*. (2008), and much of it is presented in **Table 17.1**.

In the case of representative PMR networks whose goal is to preserve select samples of the plant diversity of a region, it is likely that part of the PMR may not require actions aimed at conserving the species, and that mere passive habitat preservation may be enough to ensure their conservation. Since a share of the Valencian PMR network is designed for this purpose, some of the plots are sufficiently protected by signage –see specific chapter in this book– and regular monitoring, either by official staff or through voluntary agreements with conservation NGOs, etc. However, the most common case in the design of PMRs is that they contain one or more threatened species. In these cases educational signage is often put in place -see specific section in this book on these type of activities – as has been done in all areas where PMRs have been established physically – Valencia, Crete, Cyprus, Castilla-La Mancha, etc.

Most PMR are proposed and declared for the conservation of one or a few species, usually threatened. Once the causal factor or factors responsible for population decline and the threatened status of the species have been pinpointed or inferred, the development of a conservation program or its inclusion in the management guidelines of the PMR should be considered. In order to increase the status or functionally improve the population of the endangered species management of the species itself (i.e. reinforcement, reintroduction if considered extinct, etc.) and of the species that interact with it might be required (competition, mutualistic interactions, etc.), or even management of the whole habitat. The diversity of causal factors that can influence plant conserva-

Table 17.1 Indicative table of problems and solutions for the management of endangered species, as well as complementary or reinforcement accessions.

Problem	Basic solution	Reinforcement
Trampling, physical damage to the plant	Limit access	Indicative or educational boards
Harvesting	Limit access, intensive monitoring	Indicative or educational signage, Contact sectors exerting pressure on the species (collectors, horticulturalists)
Lack of genetic diversity or other genetic issues	Population reinforcement or creation of new populations with genetic criteria (with ex-situ genetic improvement if necessary)	Establishment of new close populations/creation of bridge-population to favour ecological connection
Low seed set	Improvement of natural pollinators or artificial pollination	Contact sectors exerting pressure on the species (farmers using pesticides in the area)
Lack of recruitment owing to juvenile plant predation	Control of predatory pressure, support irrigations, limitation of access to ungulates	Contact sectors exerting pressure on the species (farmers, hunters that favour particular game species)
Decline in plant numbers or fitness due to plagues or illness	Biological or integrated control of causal agents	Contact farm sector, particularly if plagues may come from host-crops nearby
Displacement by competitive species	Thinning of vegetation or selective removal of competitors	Contact land managers (forest, landscape managers…)
Displacement by invasive species	Removal and control of invasive species	Contact sectors exerting pressure (horticulture, urban gardening authorities of nearby areas, interurban road managers, etc.)
Constantly low number of individuals	Population reinforcements	Apply one of the former

tion status is so large that it is impossible to establish rules for feasible solutions. Only general guiding principles can be recommended. The practical application of these or other solutions may depend on biological issues inherent to the species, the convenience to use a particular technique in relation to sociology and local idiosyncrasies, or even issues that exceed the capacity of the managers of the species (i.e. need for legal changes). For example, the presence of low levels of pollination and subsequent poor seed production due to the rarefaction of an insect pollinator affected by the excessive use of insecticides in peripheral areas can be addressed by specific regulations to limit the use of biocides, but if that limitation cannot be implemented or can only be addressed in the long term, artificial pollination can be a temporary alternative, as shown in the work currently being done in the PMR sheltering *Ophrys kotschyi* in Mitsero (Cyprus). Some solutions for complex cases involving a combination of threats such as in some plant species like *Medicago citrina*, *Silene hifacensis* or *Frangula alnus* subsp. *baetica* in Valencia have recently been synthesized in the work of Laguna (2011), Ferrer *et al*. (2011a and in press) and Laguna *et al*. (2011).

The second level comprises the varied typology of practical applications for each of the technical solutions provided. Once a solution has been chosen or designed, it can be reached by using different materials, at varying intensities, deadlines, etc. and this may influence decisively the result of the action to be performed. For example, population reinforcement, reintroduction or establishment of new populations, the goal of which is the introduction of new specimens which did not exist or whose numbers were too low, can be achieved by sowing seeds, planting newly produced specimens or trans-locating individuals from another area, and in all cases it may be necessary to develop a specific protocol. In our opinion, the best way to achieve this is as part of a work-in-process to establish the optimal restoration protocol for the species, involving conducting different experiments (i.e. how deep should seeds be sown or plantings planted, what is the most appropriate age for seedlings to be planted, how far should individuals be planted from one another, what kind of protective devices should be put in place to prevent predation of plants, is it necessary to water newly introduced plants and how often, etc.) rather than attempting to establish more 'idealistic' goals which can only be attained in the long term, such as of saving this species from extinction (Laguna *et al*., 2003a). It is preferable to develop a battery of small, localized experimental actions, before attempting to carry out a major work, i.e. reinforcement with a large number of plants, whose success cannot be adequately guaranteed. Overall meta-analytic type assessments show that moderate success can be expected for works dealing with reintroduction projects or other forms of population reinforcement (e.g. Godefroid *et al*., 2011) carried out by sowing or planting.

Generally speaking, there is still a reduced exchange of results on these activities, and many of those that have been obtained worldwide over the past decades have not been published in technical or scientific journals that allow their assessment; some of those obtained in the framework of the Valencian PMR network are listed in **Table 17.2**. The review by Kell *et al*. (2008) compiles abundant technical literature for each specific action to be developed (thinning of vegetation, fences, etc.) but it is important to note that the results of the same technique can be contradictory depending on the particular species, type of habitat, etc., and that all too often results are not published so that their effectiveness remains undetermined. For instance, the experimental exclusion of herbivores by means of fences to protect populations of *Limonium dufourii* in the PMR 'Marsh dels Moros' or *Marsilea strigosa* in the PMR 'Lavajo de Arriba', both in

Table 17.2 Some examples of conservation works on singular species within the PMR network of the Valencian region, with published results (E: English; S: Spanish; F: French).

Species	Addressed problems	Published in
Silene hifacensis Rouy	Reinforcement and new populations in a rupicolous environment	Laguna *et al*. 2011 (E)
Medicago citrina (Font Quer) Greuter	Reintroduction/Restoration of populations affected by plagues	Laguna, 2011 (E); Fabregat & Laguna, 2013 (E); Laguna & Jiménez, 1995 (S)
Gypsophila struthium L. subsp. *struthium*	Erosion in gypsum outcrops	Ferrer *et al*., 2011b (F)
Teucrium lepicephalum Pau	Negative effect of former reforestations, erosion on gypsum outcrops	Ferrer *et al*., 2010 (S); Ferrer *et al*., 2007 (F)
Limonium mansanetianum M.B. Crespo & Lledó	Erosion on gypsum outcrops	Ferrer *et al*., 2009 (S)

Valencia, lead to the conclusion that the technique is not appropriate, because although they restrict access of large herbivores that can harm species, fencing (**Fig. 17.1**) also greatly limits access to the plots of other smaller herbivores that exert control over competing plants -*Halimione portulacoides* and various grasses, respectively- that eventually have displaced those intended to protect. On the contrary, ungulate exclusion fences at the PMR 'Avakas Gorge' in Cyprus to protect *Centaurea akamantis* plantations in cliff crowns have provided satisfactory results so far.

An emerging issue to be evaluated in the design and implementation of adaptive conservation programs in PMRs is the presence of hidden or difficult to detect causes acting against a particular species, as well as those derived from specific problems associated with small populations of endangered plants (see Ballou *et al*., 1995). These factors are especially important when, in the framework of the management of a PMR, the reintroduction of locally extinct species is intended, as it is often the case that the cause of extinction is not sufficiently known and may have not disappeared at the time when the reintroduction is carried out (see indications in Falk *et al*., 1996). It is likely that problems of recruitment, survival of seedlings, etc.. that have often been attributed to inbreeding or the existence of genetic bottlenecks, actually are the result of hidden or difficult to evaluate causes (e.g. a need for either mycorrhization or association with bacterial symbionts, some effect of root pests, etc.). In a recent communica-

Figure 17.1
Small, experimental fenced plot to monitor the effects of herbivores on the population of *Marsilea strigosa* Willd. in the PMR 'Lavajo de Arriba' (Sinarcas, Valencian Community) (photo: E. Laguna).

tion on conservation works of the Valencian endemic *Lupinus mariae-josephae* in the PMR Lloma Coca it became evident that the options to strengthen or create new populations for this species are strongly determined by the bacterial nodulation with *Bradyrhizobium* strains, without which development of plants is not very vigorous and does not result in seed yield sufficient to ensure adequate population turnover rate (Navarro *et al*., 2013).

Finally, it should be acknowledged that some of the activities that have been carried out are particularly complex. As an example, Draper *et al*. (2006a) proposed the establishment of a PMR in Portugal for the endangered plant *Narcissus cavanillesii* protected by the Habitats Directive. The technique of translocation included removal of soil and rock fragments containing the species to be placed on a future safe site, as the former location of the plant is now within the flooded area of the new Alqueva reservoir, and this would certainly result in the complete disappearance of the species in Portugal (Draper *et al*., 2006b).

V. Habitat Conservation and Ecological Restoration.

The above-mentioned guidelines for species are suitable for habitats too, applying similar techniques when they are threatened in the entirety of their original floristic composition; in fact, some of the causal factors of threat formerly indicated for some species, (**Table 17.1**), such as trampling, predation by ungulates, expansion of invasive alien species, etc., often simultaneously affect most species within a given PMR, and not only the main species undergoing protection or management. Problems that are usually not regarded as risk factors for threatened species, such as soil erosion, coastal erosion, recurring forest fires, etc. must be considered as well. Although exceptionally some species may derive benefit from some of these processes (e.g. endemic pyrophytic plants in the case of fire) often these factors entail significant risks for the plants whose conservation is intended, and their amendment will require the involvement of multidisciplinary teams –i.e. civil engineers, foresters, hydraulic engineers– and high economic input. Again, the review by Kell et *al.* (2008) provides a wide range of works that can be consulted for each of the main technical solutions, but at the heart of these there is the general philosophy of ecological restoration.

The contribution of technical solutions to the prevention and restoration of damaged ecosystems requires an understanding of habitats as fine-tuned as possible, including a detailed characterization of its main components (see Laguna *et al*., 2003a). In the case of the first PMR networks, such as the one in the Valencian Community, numerous habitat conservation actions have been carried out (Laguna *et al*., 20003b), but as a rule of thumb they consisted of works aimed at benefiting one or a few species, except for wetland restoration (Sebastian *et al*., 2008), where it is relatively easy to work with many species simultaneously. However, the Valencian PMR statement as well as their management plans often include generic preventive actions common to many PMRs, such as reduction of the fuel load in the surroundings of relict forest vegetation (e.g. yew tree or linden forests, etc.) which is highly vulnerable to wildfires.

The goal of ecological restoration, the foundations of which date back to the 70s and 80s, is to restore, at any time, appropriate balance in ecosystems through the maintenance of interspecific relationships by means of a combination of techniques –such as plantations (**Fig. 17.2**), structural reinforcements, etc.– (Young, 2000). As in the case of species, the combination of technical problems and techniques is extremely varied and, at most, we can only recommend a set of studies ranging from general treaties that address the fundamentals and results of ecological restoration (Jordan *et al*., 1987; Cairns Jr., 1995; Gilbert & Anderson, 1998; Nash & Burch, 2001; Nicolau *et al*., 2003; Sutherland & Hill, 1995) and some case studies (including Hammitt & Cole, 1998; Munshower, 1994; Saunders *et al*., 1993), as well as some comprehensive manuals that tackle most restoration needs and even include 'primers' or 'toolkits' to be developed (Gilbert & Anderson, 1998; FWS-NOAAFS, 1996; Parker, 1995; Perrow & Davy, 2002; SER, 2004). As it is often the case, the starting point is the existence of an altered state where natural restoration reaches a changing balance that deviates from the classical concepts of primary succession (Walker & del Moral, 2003) and that points to the need of using adaptive techniques of habitat management (Salafsky *et al*., 2001). In the PMR network of Valencia, numerous examples have been addressed and have been summarized by Laguna *et al*. (2003a). These include preventive enclosures, structures to redirect visits and access, elevated roads to avoid traffic on PMRs (**Fig. 17.3**), sowing and planting of structural species that favour optimal future habitat for the threatened species, etc. Several of the areas proposed for housing PMRs in Minorca have undergone restoration works such as dry stone walls (**Fig. 17.4**), which in turn support a rich microhabitat of mosses and ferns in the relict forest of *Laurus nobilis* of S'Algendar ravine, or the re-colonisation of vegetation as a result of soil de-compaction and planting of native species in various enclaves of a PMR proposed for the site of Ets Alocs,

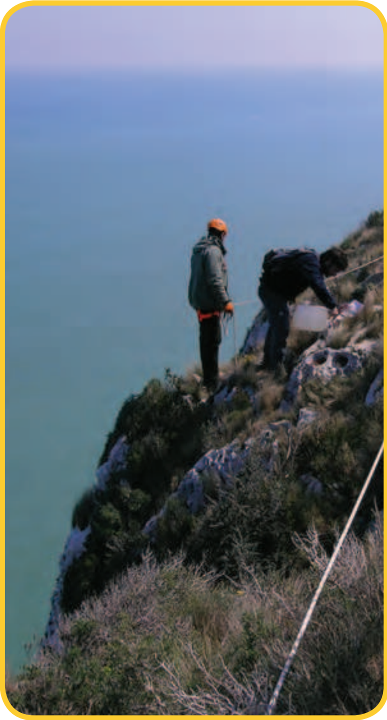

Figure 17.2
Planting and watering *Silene hifacensis* Rouy at the coastal cliffs crown in the PMR 'Cap de Sant Antoni' (Xàbia, Valencian Community) (photo: E. Laguna).

Figure 17.3
A wooden path crosses over the PMR 'Marjal dels Borrons' (Xeresa, Valencian Community) to allow the development of educational and recreative activities (photo: E. Laguna).

Figure 17.4
Traditional dry stone walls made close to the proposed PMR 'Ets Alocs' (Minorca, Balearic Islands) to avoid uncontrolled car parking near the riverine vegetation of *Vitex agnus-castus* (photo: E. Laguna).

which include among other interesting plant communities riparian thickets of *Vitex agnus-castus*. Pedestrian access redirection, which prevents the dispersal of visitors across PMRs has also been implemented in several PLANTNET-CY LIFE project areas in Cyprus.

A key element in the development of restoration projects is the choice of species when threatened plants and those providing support to the ecosystem structure must be combined. Ferrer (2007) –working in the Center for Forestry Research of the Generalitat Valenciana– has developed a methodology for the selection of species by combining 1) dominant structural plants, 2) threatened or rare species and 3) determinant taxa for ecosystem through its mutualistic or facilitative function. This selection procedure is called 'structural basis of the habitat' and is still undergoing trials. Similarly, another technique is being developed and tested in the Valencian PMR network consisting of the preliminary implementation of facilitator species of threatened plants, so that the latter naturally colonize new environments under restoration, following a 'stepping stone' model. This model is being applied to sites which shelter relict taxa of high mountain forest vegetation –*Taxus baccata*, ravines with *Tilio-Acerion* communities, etc.– by combining the plantation of structural slow dispersing species (e.g. *Quercus rotundifolia*, *Q. faginea*) with other wind-dispersed trees (*Fraxinus ornus*, *Acer granatense* etc.) and especially fruit bearing plants that attract and stabilize populations of thrushes and other forest birds, ultimately responsible for the establishment of *Taxus baccata*, *Sorbus aria*, *S. torminalis*, etc. (García-Martí *et al*., in press). A previous proposal to those dealt with so far is that of 'synaccessions' or seed samples with appropriate proportions of basic species required for restoring a particular habitat (Laguna *et al*., 2008).

Among the most important emerging issues that require the use of restoration techniques is combating invasive alien species, including the rehabilitation of the sites from where they are extracted, which must often be re-vegetated with native plants (see Myers & Bazely, 2003; Sandlung *et al*., 1999; Veitch & Clout, 2002). The presence of abundant invasive species in large areas of the European continent, and particularly in the Mediterranean, results in that many of the works that are carried out in PMR or their immediate surroundings, in order to prevent their invasion, deal with the same invasive species, such as *Carpobrotus edulis*, *Agave americana*, *Opuntia* spp., etc. For instance, thorough eradication of invasive species has been carried out in coastal PMRs of Minorca and Valencia, as well as in sites of botanical interest linked to heavily urbanized areas (**Fig. 17.5**).

Figure 17.5
Eradication of the invasive exotic *Opuntia ammophila* Small on the dunes bordering the PMR 'Marjal dels Moros B' (Sagunto, Valencian Community) (photo: J. E. Oltra).

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