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Relict species and the challenges for conservation: the emblematic case of *Zelkova sicula* Di Pasquale, Garfi et Quézel and the efforts to save it from extinction

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ABSTRACT The foreseen rapid climate changes are thought to represent a major threat for many plant species. Owing to that, in the Mediterranean Basin, one the most important area worldwide for biodiversity, a number of taxa are at risk of extinction, especially the endemics and the rarest ones. Within them a particular significance is recognised to the pre-glacial relicts, that are rather conspicuous in the area and represent a valuable heritage for their biogeographical relevance and evolutionary history. *Zelkova sicula* is one of the most prominent plants within this flora. To date, it is a very rare species, and due to a number of threatening factors it is on the brink of extinction. In the present paper, we discuss the main topics related to its conservation criticalities and the ongoing integrated strategies to save it from extinction. Particular emphasis is addressed to assisted colonisation, a "last resort" conservation approach consisting in the establishment of pilot-planting out of the species native range.

KEY WORDS Assisted colonisation; clonality; Life+ EC programme; Sicily; threatened plants

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INTRODUCTION

In the Mediterranean area a number of rare and threatened island plants have been recently the object of a campaign of awareness for their conservation (Montmollin & Strahm, 2005). The campaign was promoted by IUCN in order to mobilize conservation practitioners, decision makers and the general public to take actions needed to save from extinction the most endangered species. Among the fifty species considered, as much as ten were selected from Sicily and the surrounding islets, so highlighting the notable significance of this region as a major biodiversity hotspot within the whole Mediterranen Basin (Quézel & Médail, 2003).

According to the IUCN Red List Categories and Criteria (IUCN, 2001), nine out of the ten Sicilian species therein included are quoted as Critically Endangered (CR) mainly due to their extremely restricted area and/or the low number of surviving individuals. *Zelkova sicula* Di Pasquale, Garfì et Quézel is one of the most renowned and prominent taxa owed to both its biogeographical relevance and evolutionary history.

First described as a new species to the science in 1991 (Di Pasquale et al., 1992), *Z. sicula* is a glacial relict tree, taking part in the conspicuous contingent of Sicilian relicts plants - e.g. *Abies nebrodensis* (Lojac.) Mattei, *Bupleurum dianthifolium* Guss., *Cytisus aeolicus* Guss. ex Lindl., *Erica* *sicula* Guss., *Petagnaea gussonei* (Sprengel) Rauschert, *Pseudoscabiosa limonifolia* (Vahl) Devesa, *Thymus nitidus* (Guss.) Jalas, etc. - that notably contribute to the world evolutionary inheritance, and remarkably significant for conservation of plant diversity (Petit et al., 2005).

In the present paper we outline an overview about the special meaning of biodiversity in insular environments, with some remarks on relict species and their vulnerability particularly in the Mediterranean. Within this issue, the case of *Z. sicula*, as an outstanding representative of a relict and most threatened flora, will be discussed especially with respect to the main topics related to its conservation criticalities and the ongoing strategies to take it away from the brink of extinction.

BIODIVERSITY, RELICT SPECIES AND THREATS IN INSULAR ENVIRONMENTS

Biodiversity hotspots: the preponderance of insular environments and their vulnerability

Conservation International identified 34 priority zones for conservation. These hotspots are concerning only 2.3% of earth's area but gather more than 50% of plant and 45% of animal species of the planet. They all are threatened by human activities. For the most part, these hotspots are made, totally or partially, of islands and archipelagos, such as New Zealand, East Melanesia, Polynesia, Micronesia, Japan, Philippines, Indonesia, Sri Lanka, Madagascar and Indian Ocean islands, Caribbean islands, Mediterranean Basin islands, etc..

Insular species are witnesses of a unique evolutionary history. The endemism rate in insular environments is much higher than in continents. For example, the Hawaiian archipelago counts 90% of endemic species, whereas 50% of vascular plants are endemic to Mauritius and 93% to Madagascar, which contains as much as 8000 endemics. Given these endemism rates, insular biodiversity represents a very important part of world biodiversity, which has no link with the small area covered by these islands.

Planetary insular environments are particularly fragile. Since the sixteenth century and European expansion, the impact of human activities (agriculture, urbanisation, introduction of invasive species, etc.) has caused a lot of damages on insular biodiversity. Currently, islands figure amongst the most threatened territories on the earth. In this way, 2017 out of over 7000 plant species of the Caribbean hotspot are threatened or even disappeared. Similarly, among 3334 Polynesian and Micronesian species, 926 are currently threatened (Brooks et al., 2002). The recession of natural insular habitats is even more informative. The original forest which covered Mauritius currently represents just 5% of the total area of the island. In Madagascar, human occupation led to a diminution of 90% of the original forest in only 200 years.

Peculiarity and viability of the Mediterranean Basin flora

The five biggest Mediterranean biomes, i.e. Mediterranean Basin, California, Mediterranean Chile, South Africa and Southwest Australia, count 50, 48, 50, 68 and 75% of endemic species respectively (Médail & Quézel, 1997). With 5000 islands and small islets, the Mediterranean Basin is one of the biggest insular sets in the world. There are more than 25000 superior plants according to Quézel (1985) and about 30000 species and subspecies according to Greuter (1991).

This biodiversity is primarily due to the particular climatic conditions, habitat heterogeneity and different origins of the flora, which can be divided into three main biogeographic groups (Quézel 1985, 1995): a native species group, a southern affinity species group and a non-Mediterranean Holarctic-Eurasiatic group.

In addition, geological, palaeogeographical and historical factors have helped to create highly diverse environments and the insular mountain or isolated edaphic systems generally appear to be major endemic centres (Gómez-Campo et al., 1984). Comparing the vascular flora of each of the above mentioned Mediterranean biomes, the circum-Mediterranean one shows the highest taxonomic richness although the degree of endemism varies from 50% (Quézel, 1985) to 59% (Greuter, 1991).

Relict species and insularity in the Mediterranean

Regarding young islands, the isolation, the poor number of pioneer elements, the presence of unoccupied ecological niches and a natural selection lower than in the continent are major ways of speciation. More insular refuges are likened to arks protecting their biota from extinction during hostile events (Terborgh, 1992).

In the Mediterranean, small islets have served as natural laboratories of plant evolution while large islands have contributed to the conservation of middle Tertiary flora with a high degree of endemism (Greuter, 1995). In this context, the high rate of endemism results from the very complicated natural (i.e. tectonic, geologic and climatic) history since the middle Tertiary (Quézel, 1985; 1995). Due to the moderate direct impact of the Quaternary glaciations, especially the Würm (Debrandt-Passard, 1986), several zones have acted as refuges (Hewitt, 1999; 2000). Thus, more favourable thermal conditions and plenty of conservative microhabitats (cliffs, nunataks, etc.) have helped to preserve numerous elements from a Tertiary palaeoflora (Médail & Verlaque, 1997).

Accordingly, we can distinguish two kinds of endemics: palaeo-endemics, i.e. ancient vestiges of taxa that were once widespread, and neo-endemics, that have evolved only recently. The presence of paleo-endemic trees is also remarkable, particularly on larger islands, and includes fir species *Abies nebrodensis* and *A. cepholonica* Loudon in Sicily and Cephalonia respectively, *Zelkova sicula* in Sicily and *Z. abelicea* (Lam.) Boiss. in Crete, *Quercus alnifolia* Poech and *Cedrus brevifolia* (Hook.f.) A.Henry in Cyprus (Barbero et al., 1995).

Relict plants, especially trees, as having been able to survive impressive environmental changes over millions of years, are of great concern for their valuable contribution in improving understanding of past and recent biogeographical and evolutionary processes (Kozlowski et al., 2011). Moreover, in the frame of forecasted climate changes, some elements could have a role in the future establishment of novel ecosystems with new species combinations, thanks to their aptitude in niching strategy, as reported for several relict taxa in the forests of Georgia (Transcaucasia) (Denk et al., 2001). On the other side, human-induced future climate scenarios could reveal quite catastrophic for many of these elements, acting as the “last nail in the coffin for ancient plants” (Connor, 2009). Hence, any effort should be made to improve the perspective of their conservation.

Mediterranean plants and conservation issues

Conservation strategies represent a crucial issue in the Mediterranean biome because this area, which represents only 2% of the world’s surface, houses 20% of the world’s total floristic richness (Médail & Quézel, 1997). Many of these Mediterranean insular species are currently threatened.

Despite the long history of botany in the Mediterranean, there is a lack of species distribution and abundance maps which hinders effective conservation and management of local botanical heritage. The assessment of the Mediterranean Islands Flora (Delanoë et al., 1996) suggests that a significant proportion of the islands flora is under threat.

Crete, followed by the Balearics, has the highest percentage (11%) of plants endangered at a global level. The Maltese flora has the highest percentage (28%) of plants threatened at the local level reflecting the pressure on the island’s habitat. The publication of the IUCN Top 50 Mediterranean Island Plants (Montmollin & Strahm, 2005), albeit not an exhaustive check-list, has the merit to draw the general public’s attention to some of the most endangered plant species, stressing particular situations and conservation needs.

In the Mediterranean, the destruction of habitats due to a long and ancient human presence led to their extreme rarefaction and a drastic diminution of their populations. The low altitude zones are most affected, particularly coastal areas, rocky grasslands and damp ecosystems, but the risks now extend throughout all sectors due to the increase of human activities. As mentioned in Olivier et al. (1995), endemics regression in Mediterranean area is primarily due to the destruction of favourable habitats due to urban development, roads, etc. and by direct human impact (agricultural and forestry exploitations, wildfires, trampling). The biotic threats (concurrence of exotic species, competition with woody species), together with biological weakness (e.g. low reproductive efficiency, genetic erosion, ineffective dispersal) are traditionally considered less important, although recent research on plant conservation genetics acknowledges to the latter a much higher significance (Kramer & Havens, 2009).

To face with these major threats, numerous protective actions must be taken immediately through appropriate management of indigenous populations and scientific studies undertaken to analyze population viability. Among these native species, the relict species such as *Z. sicula* are priorities for conservation because they represent millions years of evolution.

ZELKOVA SICULA: FROM FOSSILS TO A LIVING PLANT

Until 1991 the genus *Zelkova* Spach was known to Sicily only through fossil records (Béguinot, 1929) and nobody before that time would have suspected the existence of living trees in the island. At present-day *Z. sicula* (Fig. 1) is a very rare species exclusive from South-Eastern Sicily, belonging to a genus which became extinct in the whole continental Europe during the Quaternary Glacial Age.

Up to very recent times the Sicilian species was known to consist worldwide of only a single population (hereinafter referred as ZS1) of about 250 trees, included in a small area less than 0.4 hectares within the Bosco Pisano, in the Iblei Mts. At the end of 2009 a second population (hereinafter ZS2) was unexpectedly discovered in the same mountainous massif (Fig. 2) (Garfì et al., 2011). As the former one, it includes a few hundreds stems, once again distributed over a limited area of about 0.5 hectares, in quite similar environmental conditions. In the conservation perspective, such extraordinary occurrence surely contributed to reduce the level of threat for this species, but at the moment it was not enough to allow a reduction of risk level adopting IUCN categories.

Figure 1. Branchlet of *Zelkova sicula*.

Included among the family of Ulmaceae, the genus *Zelkova* is currently represented by six species, whose worldwide distribution is quite fragmented: three taxa, *Z. serrata* (Thunb.) Makino, *Z. schneideriana* Handel-Mazzetti and *Z. sinica* C. K. Schneid., are widely spread in the lush forests of Eastern Asia, and one, *Z. carpinifolia* (Pall.) Dippel, is common in Transcaucasia, whereas the last two, *Z. sicula* and *Z. abelicea*, are narrow endemics to the Mediterranean islands of Sicily and Crete, respectively (Denk & Grimm, 2005).

In the ecological point of view, some differences may be outlined among all taxa. *Z. sicula* is the only species relatively able to face Mediterranean summer drought stress. It grows in the thermo-(-meso) Mediterranean bioclimate, within sclerophyllous sparse communities dominated by *Quercus suber* L., *Olea europaea* var. *sylvestris* (Miller) Brot and *Q. virgiliana* (Ten.) Ten.; its biogeographically closest relative *Z. abelicea* lives in areas with fresh microclimate and good water balance (N-facing slopes, small valleys, dolines), at elevations between 850 and 1,800 m a.s.l., within supra- and oro-Mediterranean mixed discontinuous woody stands with *Acer sempervirens* L., *Quercus coccifera* L. and occasionally *Cupressus sempervirens* L. (Barbero & Quézel, 1980; Egli, 1997). Finally, the four Asian species mostly thrive under a humid and warm-temperate climate, where rainfall usually exceeds 1000 mm/yr and can rise up to 2000-2500 mm/yr (cf. Garfì et al., 2011).

Additional aspects distinguish the Sicilian species. Both populations are currently restricted to gullies bottom and streamsides. Furthermore, in contrast to its relatives, usually represented by medium to tall trees, *Z. sicula* in population ZS1 currently exhibits an explicit shrubby growth form (maximum height 2.5 m), with many plants stunted and a general poor conservation; in population ZS2, which can enjoy of a bit more favorable water

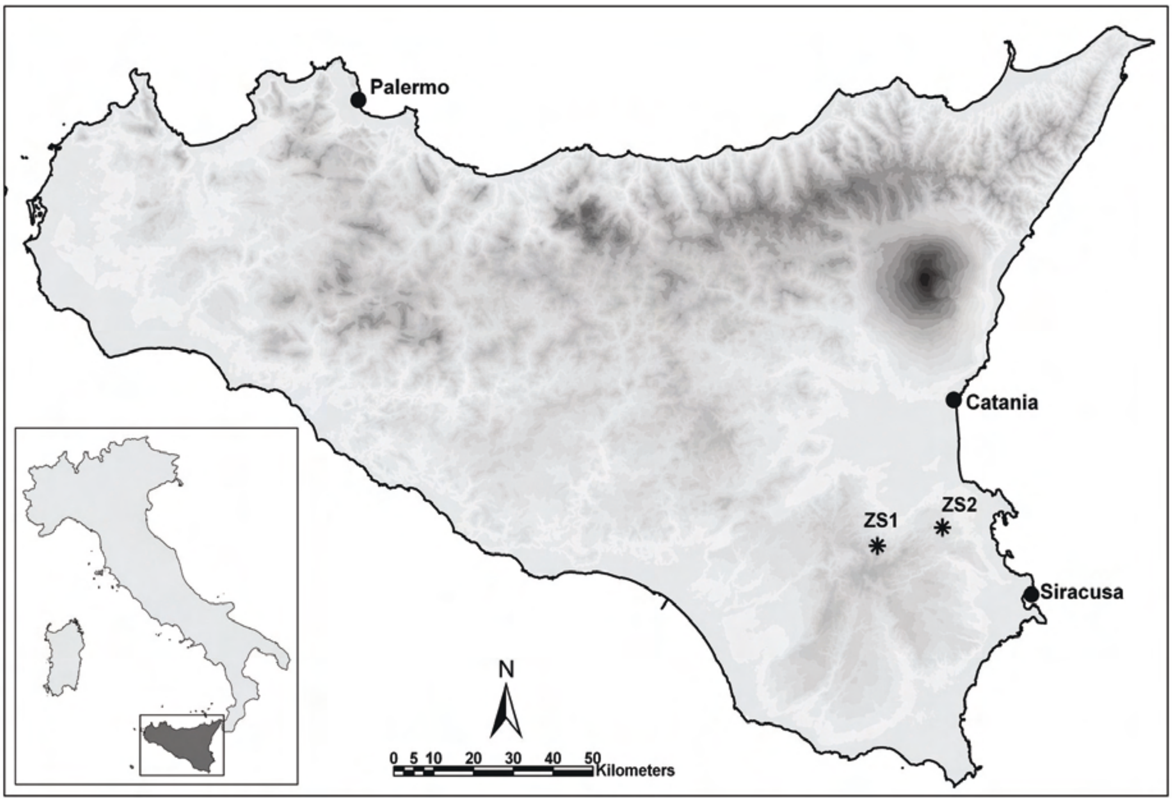

Figure 2. Current distribution map of *Zelkova sicula* (see text for abbreviations).

supply, the overall conditions look much better in terms of health and vigour, either at tree as well as at population level, with many plants that can attain the height of 5-6 m (Fig. 3) (Garfì et al., 2011). Indeed, a few individuals cultivated ex-situ in less constraining environmental conditions (no water stress, milder temperature, partial shadowing) revealed a growth potential of veritable trees. In accordance with that it is suggested that in the past the species was probably more widespread in fresher and more humid environments.

Such an assumption is quite consistent with the data issuing from palaeobotanical investigations, showing *Zelkova* remains within floristic assemblages dominated by deciduous broadleaved trees, from several European localities up to the Late Pleistocene (e.g. Follieri et al., 1986; Garfì, 1996; De Paola et al., 1997). Actually, the genus *Zelkova* belongs to a hygro-mesothermic floristic unit which was very common in the luxuriant Tertiary forests throughout the Northern Hemisphere. In Eurasia, climate changes occurred since the late Pliocene/early Pleistocene with the onset of the Ice Age, caused the progressive rarefaction from northern to southern latitudes of the less cold-resistant elements. The Italian peninsula, among others, played in this regard a major role of refuge allowing the persistence at Valle di Castiglione (Central Italy) of the last *Zelkova* remnants until 31000 years B.P. After that time, according to Follieri et al. (1986), the genus *Zelkova* became definitively extinct from the whole continental Europe. Only in the two Mediterranean Islands of Crete and Sicily, where glaciations effects were less severe, the two endemics *Z. abelicea* and *Z. sicula* survived until the present-day (Quézel et al., 1993), tolerating more or less efficiently the summer drought stress of the current Mediterranean climate.

According to recent investigations (Fineschi et al., 2002; Christe et al., in press), *Z. sicula* is genetically depauperated and seems to have had a history of severe isolation. It is suspected to be a species of hybrid origin and its parents are suggested to be close to *Z. abelicea* and *Z. carpinifolia* ancestral species. This is rather consistent with results of Nakagawa et al. (1998), which point out that leaf fossils, formerly referred by palaeobotanists to as *Z. carpinifolia*, most likely might instead be attributed to *Z. sicula*. Whatever the case, it seems quite alike that such harsh and complex vicissitudes could be invoked as responsible of mutations resulting in the current triploid caryotype of *Z. sicula*, which differs in this regard, too, from all its diploid relatives (Garfì, 1997a). This is very rare within the angiosperms and further emphasizes the great concern of this species.

In the whole, the aforementioned issues finally highlight the extreme importance of this taxon for both studies of conservation biology and the reconstruction of historical biogeography of the genus *Zelkova* (Kozlowski & Gatzfeld, in press).

WHY IS *Z. SICULA* SO VULNERABLE? CURRENT CONSERVATION AND THREATS

At present a variety of causes threaten a satisfactory conservation or, what is more, the survival itself of *Z. sicula*. Some factors are strictly depending on its biology, others on different exogenous agents. A general review can be summarized as follows.

Unsuccessful sexual regeneration

The fructification of *Z. sicula* is quite irregular (Garfì, 1997a), as already known for its Cretan relative *Z. abelicea* (Egli, 1997). In the Sicilian species it seems usually coinciding with the rainiest winter years and has been most often observed on the same, very few trees. Moreover, according to current knowledge (Garfì, 1997b) seeds seem sterile due to its triploid conditions. Therefore, at present-day regeneration is exclusively depending on vegetative mechanisms such as root suckering and layering (Fig. 4).

Consequently, in both populations most trees are very probably of clonal origin. This situation, in addition to the long geographic isolation, most likely involved severe decline in gene flow and a rapid decrease of intra-specific genetic variability (Fineschi et al., 2002; 2004; Christe et al., in press). The suspected predominance of clonality could have contrasting implications: i) on the one side it can represent the mechanism that assured the perpetuation of a successful genotype differentiated in response to the hardiness of a changing environment throughout the geologic times, and then the survival of the species until present-day; ii) on the other side, since clonal recruitment implies absence of gene recombination and then strong genetic impoverishment, it hugely diminishes populations' viability, raising vulnerability to any external adversity. In the same time, clonality adds a further element of exceptionality to such an emblematic species. If future investigations would reveal that both two current disjunct stands are entirely clonal populations, this could mean that, as for *Lomatia tasmanica* (Linch et al., 1998), each of them is a very old organism, even aged many thousand years, therefore becoming among the oldest living plant individuals (!) known to date.

In any case, the lack of functional seeds strikingly enhances the risk of extinction of the species as it surely involves major difficulties in propagating it, both for in-situ and ex-situ conservation actions. Designing efficient protocols for in-vitro and in-vivo vegetative multiplication is to be considered an irreplaceable goal for any efforts of active and efficient conservation. In this regard, propedeutic investigations about the residual genetic diversity need to be carried out in order to conserve as much as possible intra-specific variability.

Anthropic disturbance and habitat degradation

According to current knowledge (Garfì et al., 2011), *Z. sicula* is supposed to be a species thriving in typical forest habitat. Heavy human pressure (grazing, wildfires, past silvicultural over-exploitation), in addition to the foreseen climate deterioration are responsible of its current habitat degradation, as involving failure in natural regeneration of forest species and the further impoverishment in forest composition and structure.

Wildfires represent a major hazard in the whole forest area. In the past large patches of forest cover have been destroyed or severely damaged by wildfires, whereas very recently fire injuries have even directly concerned the population ZS2. Their origin is usually to be related to human activities. As in many Mediterranean areas, since ancient times fire has represented a kind of very "primitive", but extremely deleterious method of land management and in the last years it has become also a means of social claim. The general consequences could be the simplification of the ecosystem and

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Figure 3. Population of *Zelkova sicula* from site Contrada Ciranna (ZS2) with trees 5-6 m high. Figure 4. Vegetative propagation through root suckers. Figure 5. Withered leaves following summer water stress in August 2011. Figure 6. Massive proliferation of epicormic short shoots due to browsing (a) and detail of a decapitated tip (b). Figure 7. Sclerophillous species diffusion at site Bosco Pisano (ZS1) after grazing exclusion. Figure 8. Fencing and irrigation plant built at site Bosco Pisano (ZS1) within actions of the LIFE project Zelkov@zione.

landscape mosaic, with a decrease of ecosystem functions. The habitats suffering the greatest risk are those directly related to *Z. sicula* (i.e. 9330 - *Quercus suber* forests, and 6220 - Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea), but the other habitats could be also concerned at various extent. Reiterated events can involve the definitive loss of most vulnerable species and the selection of fire-resistant taxa. Notwithstanding its great ability of resprouting after an injury, *Z. sicula* for its rarity and punctiform distribution could easily disappear as a consequence of repeated wildfires at short intervals.

As far as concerns grazing, historical data testify that it has been one of the main types of local land use. Its pressure became heavier since the last sixty-years period, after land abandonment and the migratory flows abroad of local population that made possible the settlement of transhumant graziers originating from the mountainous area of Northern Sicily (Garfì & Di Pasquale, 1988; Di Pasquale & Garfì, 1989).

In contrast to fire, in some particular cases (e.g. for the habitat 6220 - Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea) grazing is considered a promoting factor for plant richness. However, it must be kept in mind that in the area of interest it has been in the time a formidable cause of forest ecosystem degradation. Such an issue must be carefully evaluated in the conservation planning perspective, especially in a region like Sicily where forest cover has been destroyed on large areas since the antiquity. The great worry is that in the next future the unregulated way this practice is currently carried out can notably enhance the destruction of the last remnants of "natural" forest patches of this part of Sicily. In the specific case of *Z. sicula*, browsing is proved responsible of severe growth suppression (Fig. 5), flowering inhibition and even death of trees, already hardly weakened by a constraining environment (Garfì, 1997b).

Summer water stress

Due to its incomplete adaptation to the Mediterranean climate seasonality, since its discovering *Z. sicula* has suffered periodical summer drought stress (Fig. 6), and several evidences indicate similar occurrences also in past times (Garfì et al., 2002). Water stress cause moderate to severe injury to the peripheral parts of the crown. Premature senescence and shedding of leaves have been most frequently noticed, whereas in case of abrupt dehydration leaves withered and died but remained attached. Sometimes, severe increasing water stress also leads to the death of twigs and branchlets, or even of the entire stem. The plants can recovery in the following season, but repeated episodes of stress along more than one single year involve the death of trees (Garfì et al., 2002). For instance, in summer 2007 the entire population ZS1 suffered very severe water stress and demographic follow-up enabled to assess that almost 20% of trees have died.

Furthermore, recent trends in climate changes at global scale depict scenarios characterised by an increase in summer drought, both in terms of less rainfall amount and duration and raise of temperature. Major detrimental effects can then be expected for the conservation of the species in the nature (Allen et al., 2010; Borghetti et al., 2012).

Potential inter-specific competition

Some years after its discovery, the population ZS1 was fenced in order to protect it against browsing. During the years following the exclusion of grazing disturbance, *Z. sicula* experienced a rather remarkable growth increase. But in the same time progressive succession processes were observed in its habitat: vegetation communities' patterns began to change and woody species cover became more and more relevant. Xerophilous taxa, such as *Calicotome infesta* (C. Presl) Guss., *Pyrus spinosa* Forssk., *Phillyrea latifolia* L., *Sarcopoterium spinosum* (L.) Spach and some trees like *Quercus suber*, *Q. virgiliana* and *Celtis australis* L. began to spread (Fig. 7).

On the one side such positive dynamic trend is expected to improve in the long period the global habitat stability and ecosystem functions. On the other side, such processes are believed to be able to trigger in the short period inter-specific competition at the expense of *Z. sicula*, which surely cannot express a comparable adaptive and growth ability of typical Mediterranean xerophilic species.

This could entail problems of decrease or even survival of the species of concern, so that a periodical monitoring of both populations should be required in order to assess the demographic trends and population resilience and get information for conservation management.

Improper use of plants or parts of them

Considering the peculiarities of *Z. sicula* (e.g. its ancient origin, its troubled history throughout the geological periods, its rarity) since its discovery a special interest has arisen about it from a rather variegated multitude of people, such as scientists, environmentalists, common tourists, plants collectors, bonsai producers, nurserymen, etc.. Small to large groups of people, usually not controlled by any official guide or surveillance, during their visits scamper everywhere in the area causing soil subsidence, overall injuries to vegetation and even involuntary trampling of small *Zelkova* plants. Moreover, the last four categories of visitors are the most dangerous since they often gather parts of plants as souvenir and, especially the bonsai lovers, even uproot young plantlets for their collections.

Although not a priority cause, like for *Z. abelicea* from Crete (Egli, 1997), this kind of disturbance/misuse could reveal detrimental for conservation since responsible for reduction of populations' size and, given its rarity, significantly increase the risk of extinction.

AN INTEGRATED STRATEGY FOR THE CONSERVATION OF *Z. SICULA*

As previously outlined the entire genus *Zelkova* is a taxon of special concern. Accordingly, in recent years it has deserved a particular interest within the scientific community and conservationists (BGCI, 2010; Kozlowski et al., 2011). This resulted in a global conservation plan, set out into three main complementary goals (Kozlowski & Gratzfeld, in press): i) conservation, comprising elaboration of an action plan, proposing concrete recovery and/or reintroduction measures, etc.; ii) basic and applied research, including molecular phylogeny, phylogeography, population genetics, population structure, genetic comparison of wild populations with ex-situ collections, etc.; iii) public awareness and outreach, involving development of travelling exhibitions, and organisation of national and international conferences and seminars to exchange knowledge and share conservation expertise. In parallel, a specific project entirely addressed to the conservation of the Sicilian species was presented by a composite partnership (i.e. the Sicilian Department of Environment - DRA, the Sicilian Regional Authority of Public Forests - AFDRS, the Institute of Plant Genetics of the Italian National Research Council - IGV-CNR, the National Botanic Conservatory of Brest - France - CBNB, and Legambiente, an Italian environmental association) within the frame of the LIFE+ EC programme, specially conceived for the conservation of nature and biodiversity in the EU territory.

The project, named "Zelkov@zione - Urgent actions to rescue *Zelkova sicula* from extinction" (http://www.zelkovazione.eu/) was funded in 2011 and, given its evident relevance with the international initiative, a sharing relationship was soon established with it. The project aims to ensure the survival of *Z. sicula* through in-situ and ex-situ conservation integrated actions to be carried out along almost five years. It entails four comprehensive topics all related each other (Table 1): i) knowledge and monitoring, ii) active conservation, iii) expertise and communication, and iv) education/awareness. Some short remarks can help catching the fundamentals of the project strategy.

Collecting information for conservation planning

Albeit a conspicuous literature already exists (cf. reference list), much still need to be understood both in terms of basic knowledge and issues to address conservation. The viability of *Z. sicula* is a preliminary information required to correctly plan conservation policy. In this regard the first step to assess the current status of the target species involves the inventory and mapping of all discrete trees (i.e. single/multiple trees or shoots apparently originating from spatially distinct stumps), in addition to the implementation of a georeferenced database including biometric data (stem height and diameter), phenological features (e.g. flowering trees, fruiting), individual vigour, past damages (water stress, biotic disturbances), microsite characteristics and spatial distribution patterns. Periodical monitoring will allow appraising the demographic trends of the target species and the forest stand dynamics with the aim to prevent inter-specific competition phenomena following disturbance suppression.

Genetic investigations are propaedeutic to any actions of multiplication, in order to detect residual genetic variability, if existing, and allow conservation of the most diverse genotypes. Vegetative propagation through in-vivo and in-vitro techniques is an immediate successive step.

Type of actions	Involved activities	Expected results
Knowledge/ Monitoring	1.Updated inventory of both ZS1 and ZS2 populations, including the position of each tree trough submetric GPS device, the implementation of a georeferenced database with biometric, biological and micro-topographic attributes 2.Monitoring of both the target species demographic trends and the forest community dynamics in current and future populations 3.Genetic investigations 4.Definition of an efficient in-vitro and in-vivo vegetative propagation protocol for the target species	•Improvement of knowledge about the biology and the ecology of the target species •Evaluate the viability of *Zelkova* populations and prevent any inter-specific competition phenomena following disturbance elimination •Evaluation of the residual genetic diversity in order to preserve the as highest as possible rate of variability •Contribute to a more efficient conservation planning
Active conservation	1.Building an efficient system of fencing 2.Setting up of an emergency irrigation system 3.Massive production of multiplication material of *Z. sicula* and native forest species 4.In-situ plantation of the target species and establishment of 5 new populations, 2 within the current habitat and 3 in supposed more favourable bioclimatic conditions 5.Plantation of native forest species on about a 10 ha area including the current site of ZS1 6.Ex-situ cultivation of at least 200 trees from both ZS1 and ZS2, at the CCG and CBNB 7.Prompting formal procedures to release a regional administrative Act for the legal protection of *Z. sicula* and the SCI Bosco Pisano 8.Starting of formal procedures for the inclusion of *Z. sicula* in the list of priority species of the Habitat Directive	•Improving the protection in the nature against disturbance from grazing or improper collecting of plant material •Attenuation of summer water stress episodes for the population ZS1 •Reinforcement of the current populations of *Z. sicula* •Increase the number of population in the nature and test the feasibility of uncommon conservation approach as "assisted colonization" •Habitat enforcement/rehabilitation in order to create a more suitable ecological environment, through recovering the as highest as possible ecosystem functionality under controlled situation and in reasonably fast times •Securing through ex-situ conservation the as highest as possible genetic diversity in public conservation centres •Recognition of the status of protected species at regional/national level and starting of the procedure for its ackowledgement as priority species (sensu Habitat Directive) •Implementation of a standard normative procedure for protection of all threatened species in public/private lands
Expertise/ Communication	1.Implementation of operative conservation planning according to the rules proposed in the Management Plan "Monti Iblei" 2.Drawing of a grazing management plan for the Bosco Pisano to attenuate the pressure on the concerned habitat according to the rules proposed in the Management Plan "Monti Iblei" 3.Planning of special operative procedures for wildfires prevention 4.Activation of training activities for local people (e.g courses for naturalistic guides) to improve knowledge and introduce young people to the labour market	•Applying site-dedicated concrete conservation measures according to the Management Plan "Monti Iblei" •Involving the competent local Forest Authority to improve surveillance and protection of the species and habitat through active policy •Realisation of a communication network among public bodies, stakeholders, schools, etc., in order to share and monitor experience and results
Education/ Awareness	1.Establishing a permanent round-table among partnership, public authorities, no-profit organisations and local stakeholders to monitor the procedures of LIFE+ project. 2.Carrying out of campaigns of awareness and divulgation on the specific project and the general problem of conservation of biodiversity 3.Realisation of a dedicated website to inform and divulgate objectives, procedures, monitoring, feed-backs and results	•Removing/reducing principal economic/social type threats for the species and habitat by involving authorities, organizations and stakeholders •Involving local people in efforts to improve local economy on green tourism •Improving the didactic value of the CCG, with beneficial feed-back on the territory in regards to public awareness about the global problem of biodiversity conservation •Prompting local awareness and information about the problems of loss of biodiversity

Table 1. Main activities foreseen in the LIFE+ project "Zelkov@zione".

The active actions: habitat rehabilitation, assisted colonisation and legal protection

Active conservation mainly includes a number of concrete measures directly in the field, in addition to traditional ex-situ conservation. Outright actions as fencing against grazing/misuse disturbances and the setting up of an emergency irrigation system (Fig. 8), can contribute to eliminate or significantly reduce some of the most flagrant threats.

More indirect interventions will concern the present habitat. As formerly mentioned, the optimal habitat of *Z. sicula* is assumed to be typical forest, with complex floristic composition and structure. In contrast, the current habitat is heavily degraded due to long-lasting human pressure. Therefore the recovery of ecosystem functions involving actions of reinforcement and rehabilitation needs to be pursued in order to (re-)create a more suitable ecological environment for the target species. The action will be exclusively based on the employ of native forest species, produced from multiplication material collected in the same forest area. Moreover, it will be performed according to the modern principles of naturalistic silviculture and water saving (minimize the impact of preparatory works and conserve as soon as possible the existing vegetation cover, employ native shrub and tree species, use of hydrogels, i.e. polyacrylates of very high molecular weights binding water up to 400 times their mass, that can prolong the survival of trees under water stress up to 300%).

Particular attention will be also paid to the planting patterns, by favouring the creation of hedgerows and the random distribution of various size plant groups in the aims to obtain a variety of habitats and fauna feeding sources. Restoration will also involve the removal of exotic tree groups (*Eucalyptus* spp. and *Cupressus* spp.) introduced near ZS1 population during past afforestations.

At the population level, new plantings in the current sites are aimed to enlarge and reinforce the current stands. But one of the greatest efforts of the project consists in the introduction and establishment of novel populations in new sites, three of which selected in areas supposed to be more suitable for the species. In fact, according to results of recent investigations (Garfì et al., 2002; 2011), palaeoecological data (e.g. Béguinot A., 1929; Follieri et al., 1986; De Paola et al., 1997) and personal observations on cultivated trees, a more humid environment (e.g. supra-Mediterranean or montane forest habitats dominated by *Fagus*, *Acer*, *Carpinus*, *Taxus*, deciduous-type *Quercus* etc.) (Fig. 9) is inferred to better match with the ecological requirements of *Z. sicula*.

A similar approach, in which an endangered species is introduced outside of its historically known native range, is quite uncommon in actions of plant rescue. Actually just in the last few years a lively debate has arisen on this subjects (for a review see Brooker et al., 2011), especially fostered by the increasing recognition of the likely inability of many species to cope with rapid climate warming (Thomas, 2011). Many terms have been proposed to indicate this approach of moving species at risk from their current locations to those areas expected to be suitable for their growth under future climate change scenarios, but the most common used is "assisted colonisation" (Hunter, 2007; Brooker et al., 2011).

Although some conservationists (Ricciardi & Simberloff, 2008) remain very critic in this regard, assisted colonisation is invoked as the "last resort" when other conservation strategies have been proved to be ineffective or are highly prone to fail. This is specially true for narrow endemics confined to very specialised habitat (isolated mountain, single lake, unique geo-pedologic substratum) that are surrounded by environments fundamentally unsuitable for them which became insurmountable barriers (Thomas 2011; Brooker et al., 2001). Genetic patterns are as much as detrimental, since genetic erosion can limit short-term resilience, evolutionary potential for adaptation, and long-term survival of plant species in the face of rapid environmental change (Kramer & Havens, 2009). It is extremely paradigmatic the example of *Torreya taxifolia* Arn., from Florida, that since the fifties of the last century suffered an inexplicable dieback up to the present number of about 500 trees (Barlow & Martin, 2004), therefore having been the object of intensive planting outside its original range.

In the case of *Z. sicula* we can account several reasons to refer to assisted colonisation, especially when related to future climate model of rapid warming (Allen et al., 2010; Borghetti et al., 2012). Firstly, we must consider its propagation ability, that even at the genus level is not quite performing. For

Figure 9. View of the Bosco Tassita (Nebrodi Mts.) as an example of possible (re-)introduction area of *Zelkova sicula* according to assisted colonisation

instance, it has been suggested that the extant distribution of *Z. carpinifolia* is probably also due to the rather inefficient dispersal mechanisms that may have hindered its expansion from Pleistocene refugia to Holocene alluvial plains in the Colchic lowlands (Denk et al., 2001). The situation of the Sicilian species is even more dramatic, given its ineffectiveness to regenerate through seeds that makes its dispersal impossible over long distances.

In addition, its current area is extremely isolated and fragmented, being separated from supposed more suitable habitats (e.g. the Nebrodi Mountain Range, Northern Sicily) by vast lowlands. Moreover, as mentioned by some papers (Jackson & Hobbs, 2009; Brooker et al., 2011), palaeoecological data can provide important information on past occurrence of the species and/or the plant community it took part to, then encouraging our translocation projects. This should be rather innovative for the Mediterranean area, and in case of success, such an action would confirm that our assumptions are sound and show that an apparently 'unnatural' intervention might even decisively contribute to save a species from extinction.

Traditional living ex-situ collection is also contemplated. At least 200 trees from both populations will be cultivated at the CCG and the CBNB, in order to secure the species and conserve the as highest as possible genetic diversity, according to the recommendations of Kozlowski et al. (2011).

The actuation of legal protection is the last but not the least issue of concrete actions. At present indeed *Z. sicula* does not yet enjoy for any legal/formal measure of safeguard. Therefore different actions are addressed to both the sites and the species. Formal procedures are prompted for the recognition of SCI ITA090022 "Bosco Pisano" (site of ZS1) as a Special Area of Conservation (SAC) sensu Habitat Directive 92/43, and to enlarge the perimeter of SCI ITA090024 "Cozzo Ogliastri" in order to include the site ZS2, situated in its close proximity. In parallel, as the target species is not comprised either in the Annex II or IV of the Habitat Directive, the Italian Ministry of Environment will be requested through the DRA to include it in the list of "priority" species (in danger of disappearing, needing particularly strict protection).

At regional/national level the main goal is to obtain also the acknowledgement of the status of protected species through the adoption by the DRA of a normative document (Councilor's Decree) containing appropriate measures that will ensure the legal protection of the target species and its habitat. This will represent the first step to serve for the implementation of a standard normative procedure for protection of all threatened species in public/private areas.

Capitalizing knowledge and expertise and developing public awareness

Knowledge and expertise as well as actions in the field cannot disregard the need of divulgation of the results in order to increase public awareness. The implicated and ongoing expertise will encompass as key outcome the implementation of an operative conservation planning for the areas of concern according to the rules proposed in the Management Plan "Monti Iblei" (ARTA, 2009), already compiled within the Regional Management Plans of SCI and ZSP. This will directly lead to the drawing of a site-dedicated management plan for grazing and the wildfires prevention, aiming to attenuate the pressure on the habitat and reduce the major anthropogenic threats. Accordingly, the competent local Forest Authority will be involved in improving surveillance and protection of the species and habitat through an active policy.

The establishment of a permanent communication network among conservationists, public bodies, stakeholders, protected areas managers, etc. is a complementary goal in order to share and monitor experience and results. Additionally, the actuation of training activities are foreseen for local people (e.g. courses for naturalistic guides) to improve knowledge and stimulate the dissemination of an environmental consciousness.

Dedicated campaign of awareness and divulgation on both the specific project issues and the general problem of biodiversity conservation will be promoted through media, educational programmes in primary and secondary schools at local and regional level, organisation of periodic meetings and workshop on the aims and advancement of the project in public venues. The events will allow to continuously evaluate the "state of the art" and to illustrate the final results.

The organization of a generalist network will aim at sharing the project actions among public authorities, no-profit institutions and local stakeholders involved in the conservation issues of critically endangered species. Finally, the realisation of a project-dedicated website will serve to inform and disseminate as much as possible objectives, procedures, monitoring, feedbacks and results of the project.

CONCLUSIONS

In the frame of the foreseen rapid climate changes at world level, and in the Mediterranean in particular, many plant species unable to cope with unsuitable environment are doomed to become extinct. Insular endemics and relict taxa are the most threatened, especially those suffering for habitat destruction and biological weakness (e.g. low reproductive efficiency, genetic erosion, ineffective dispersal). In this regard *Z. sicula* represents a quite paradigmatic conservation case, which must face to very challenging tasks.

As a general rule, priorities for biodiversity conservation management should be of two kinds: i) priorities for extensive areas where high biological diversity has accumulated over long periods of geological time and ii) priorities for distinctive areas with high endemism. Because of the small extent and high concentration of unique taxa, the risk of rapid and irreversible loss of biodiversity is high and important ecosystem functions may also rapidly be lost. Biogeography has an important role to play in this process of conservation, but much more knowledge is required about the habitat preferences of species and their response to habitat fragmentation resulting from increasing development pressures and climate change.

Landscape ecology will play an increasingly important role, providing the spatial context within which to select ecologically important sites for protection, for monitoring change and for identifying sites for habitat restoration and relict species (re-)introduction. Among all, one of the most intriguing and challenging strategy surely must be referred to the translocation of species in presumed more suitable habitats, becoming the “last resort” to face the deleterious impact of forecasted climate deterioration. Pilot (re-)introductions attempts worth to be carried out and results could notably contribute to the present debate concerning the application of assisted colonization, especially for relict species, as a valuable conservation tool for dealing with the threats of a changing world.

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