RELLICT PLANTS IN TIME OF GLOBAL CHANGES:
preventing extinction through integrated conservation approaches

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Biotic turnover or biotic stressors?

Climate change threatens Haleakalā silversword, one of Hawaii’s iconic plants (after Krushelnytsky et al., 2013)
Climate changes risks for forests

Documented localities with forest mortality related to climatic stress

(after Allen et al., 2010)
Climate changes risks for forests

18: Pinus sylvestris mortality, Valais, Switzerland; 1999. 17: Pinus sylvestris die-off, Sierra de los Filabres, Spain.

Documented drought-induced mortality in Asia (2008).

(after Allen et al., 2010)
Towards the 6th mass extinction?

The proportion of extant (i.e., excluding Extinct) species in *The IUCN Red List of Threatened Species*. Taxa are ordered according to the horizontal red lines, which show the best estimate for proportion of extant species considered threatened (CR, EN, or VU) (after IUCN, 2012)

Present extinction rate some hundreds times higher than in the past

(after Barnosky et al., 2011)
An ancient treasure: Tertiary relict trees

- Coping with changing environmental conditions for millions of years
- A unique opportunity to understand past and recent biogeographical and evolutionary processes

Five main refugia of Tertiary relict trees

1. Liquidambar formosana
2. Diospyros lotus
3. Parrotia persica
4. Albizia julibrissin
5. Pterocarya fraxinifolia
6. Parrotiopsis jaquemontiana
7. Zelkova carpinifolia
8. Parrotiopsis jaquemontiana

(after Kozlowski & Gratzfeld, 2013)
An international conservation project

Unprecedented, rapid global transformations in recent history (e.g. demographic pressure, climatic changes) could irreversibly threaten survival of Zelkova

PROJECT MAIN ISSUES

1. Conservation:
   - review of conservation status assessments
   - analysis of ex situ collections
   - development of a Global Action Plan
     addressing recovery and/or population reinforcement measures

2. Basic and applied research:
   - molecular phylogeny
   - phylogeography
   - population genetics and structure
   - genetic analysis of wild Zelkova populations compared with ex situ collections

3. Public awareness:
   - travelling exhibitions
   - national and international conferences
   - seminars to exchange knowledge and conservation expertise

(after Kozlowski & Gratzfeld, 2013)
The genus *Zelkova* in the world

- **Z. sicula**: Sicily (Italy)
- **Z. abelicea**: Crete (Greece)
- **Z. carpinifolia**: Turkey, Georgia, Armenia, Azerbaijan, Iran
- **Z. sinica**: China
- **Z. serrata**: Japan, Korea, Kuril Islands (Russia), Taiwan, China
- **Z. schneideriana**: China
- **Z. serrata (Thunb.) Makino**: Japan, Korea, Kuril Islands (Russia), Taiwan, China

Species:
- *Z. sicula* Di Pasquale, Garfi & Quezel
- *Z. abelicea* (Lam.) Bois.
- *Z. carpinifolia* (Pall.) K. Koch
- *Z. sinica* C. K. Schneider
- *Z. serrata* (Thunb.) Makino
- *Z. schneideriana* Hand.-Mazz.
- *Z. formosana* Hayata
- *Z. keaki* Maxim.
- *Z. acuminata* Planch.
- *Z. hirta* C. K. Schneider
- *Z. tarokoensis* Hayata
- *Z. japonica* Dippel.
The western species: *Zelkova carpinifolia*
The western species: *Zelkova abelicea*

Past and present distribution of *Zelkova abelicea*.

**Black circles:** recently observed and/or described populations (1993-2010). **White circles:** presumably extinct populations known from old literature and herbaria (1700-1992) (after Kozlowski et al., 2012)
Zelkova sicula: the rarest and most endangered

AN EXTREMELY RARE ENDEMISM

- **Current distribution:** 2 sole, isolated populations, some hundreds trees in total
- **Area:** 0.5 ha (site 1), 0.8 ha (site 2)
The Top 50 Mediterranean Island Plants

Wild plants at the brink of extinction, and what is needed to save them

IUCN/SSC Mediterranean Islands Plant Specialist Group
Edited by Bertrand de Montmollin and Wendy Strahm

Zelkova sicula: the rarest and most endangered
Some main features of the species and its habitat

- **Habit**: shrub to small tree
- **Habitat**: sparse disturbed sclerophillous forests
- **Elevation**: 400-450 m a.s.l.
- **Conservation**: bad
- **Legal protection**: none
“Feet into water”: restricted to thalwegs
Cariology and the environment pressure

CHROMOSOME NUMBERS

<table>
<thead>
<tr>
<th>Species</th>
<th>ploidy</th>
<th>Chromosome number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z. carpinifolia</td>
<td>diploid</td>
<td>2n = 28</td>
</tr>
<tr>
<td>Z. abelicea</td>
<td>diploid</td>
<td>2n = 28</td>
</tr>
<tr>
<td>Z. sicula</td>
<td>triploid</td>
<td>2n = 42</td>
</tr>
</tbody>
</table>

Stomata size of the three Western Zelkova species (after Garfì, 1997)

Somatic metaphase of a vegetative meristem of Z. sicula (after Garfì, 1997)

MAIN FEATURES OF POLLEN GRAINS

<table>
<thead>
<tr>
<th>species</th>
<th>pore number</th>
<th>equatorial diameter (μm)</th>
<th>tetrads %</th>
<th>exine sculpture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z. carpinifolia</td>
<td>4-(5)</td>
<td>36.8-(42.6)-48.3</td>
<td>0.0</td>
<td>coarsely rugulate (-reticulate)</td>
</tr>
<tr>
<td>Z. abelicea</td>
<td>3-(4)-5</td>
<td>32.0-(36.5)-41.0</td>
<td>-</td>
<td>coarsely rugulate</td>
</tr>
<tr>
<td>Z. sicula</td>
<td>5-(6)</td>
<td>43.7-(49.9)-59.8</td>
<td>17.7</td>
<td>slightly rugulate</td>
</tr>
</tbody>
</table>

Pollen grains of (a) Z. carpinifolia, (b) Z. abelicea (after Stafford, 1995), (c) Z. sicula, (d) tetrad of Z. sicula
Conservation and threats

- Extremely small populations
- No sexual reproduction
- Poor genetic diversity
- Drought stress
- Anthropic pressure

BOSCO PISANO: August 2007

- 90% of trees experienced more or less severe drought stress
- ~10% of trees dead!
1970 and 1993: climatic constraints and partial death

Individual height growth curves of 13 trees. Synchronous abrupt changes in stem elongation can be noticed in 1970 after reiteration.

Climate parameters from 1958 to 1993.

(after Garfi, 2002)
Cambial growth response to climate

**Zelkova sicula**

- Precipitations vs. P-TMAX
- Precipitations vs. P-Tmin

- R_v = 2.971

**Quercus pubescens**

- Precipitations vs. P-TMAX
- Precipitations vs. P-Tmin

- R_v = 2.983

**Celtis australis**

- Precipitations vs. P-TMAX
- Precipitations vs. P-Tmin

- R_v = 2.715

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**P = 90%**

**P = 95%**

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Catania (Italy) 18-20 April 2013

“Ensuring the survival of endangered plants in the Mediterranean Islands”
Polycyclic growth and false growth rings

Late-summer growth flushes (a, b, c) and false ring (d)
A LIFE+ project to save *Z. sicula*

http://www.zelkovazione.eu/
Some main items of the project Zelkov@zione

5 PARTNERS

31 ACTIONS

4 ACTIONS
Knowledge & Monitoring

4 ACTIONS
Technical & Administrative Management

14 ACTIONS
Active Conservation

9 ACTIONS
Communication & Education
Current status: preliminary data - 1

Total n. of trees

ZS1: 262 trees  
ZS2: 1425 trees  
ZS2 ext: 116 trees
What to be conserved?
Intra-population genetic diversity

- **ONLY 2 (4?) GENOTYPES**
- **EXTENSIVE CLONALITY**
  (SUSPECTED JUST 2 SINGLE CLONAL INDIVIDUALS!!)

<table>
<thead>
<tr>
<th>PRIMERS</th>
<th>LENGHT (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>134/140</td>
</tr>
<tr>
<td>111</td>
<td>208/212</td>
</tr>
<tr>
<td>112</td>
<td>232/238</td>
</tr>
<tr>
<td>113</td>
<td>117/117</td>
</tr>
<tr>
<td></td>
<td>119/119 (ZS13)</td>
</tr>
<tr>
<td>117</td>
<td>143/145</td>
</tr>
<tr>
<td>118</td>
<td>186/186</td>
</tr>
<tr>
<td>120</td>
<td>189/189</td>
</tr>
<tr>
<td>121</td>
<td>190/190</td>
</tr>
<tr>
<td>122</td>
<td>137/139</td>
</tr>
</tbody>
</table>

SSR primers designed for *Z. serrata* tested on *Z. sicula*

Double-analysis of amplificates of ZS01 (red) and ZS13 (green) by primer 113.
Conservation when seed recruitment has been lost - 1

12 in vivo multiplication trials
Conservation when seed recruitment has been lost - 2

apical shoots

root suckers

7 in vitro multiplication trials
Active conservation

Grazing exclusion through fencing
Emergency irrigation

Temporary nursery for forest habitat rehabilitation
Floristic rélevés to draw a Management Plan of Grazing
Candidate species for ST will have
- High risk of extinction in current range
- Fragmented distributions and/or limited dispersal potential
- Suitable future climate space
- Limited capacity for in-situ adaptation

Factors making ST acceptable and likely to succeed
- Risks from climate change
- ST being the “last resort” for the species
- Low impact on donor populations
- Selection of sufficiently diverse and suitable genetic stock
- Selection of appropriate site for introduction, including suitable metapopulation dynamics
- Recreation of necessary biotic interactions
- Low impact on recipient communities

Risks of ST
- Altering ecosystems processes (nutrient cycling, primary and secondary production, hydrology and disturbance)
- Disrupt key ecological interactions, including the plant–animal mutualisms that drive pollination and seed dispersal
- Spread parasites and diseases
- Potential invasiveness
- Risk of hybridization and introgression with close relatives that can erode native populations and create new invasive pests
**Torreya taxifolia**, a threatened plant that was "left behind" in its peak glacial pocket refuge

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**ECOLOGICAL STANDARDS FOR AC**

1. **NEEDINESS.** The plant is **highly threatened** or endangered in the wild in its **current range**

2. **IRREVERSIBLE PROBLEMS IN CURRENT RANGE.** Ecological and/or **climate change** is a major cause of the plant's threatened status in its current range. Remedial efforts in that range are or would be **unsatisfactory for recovery**

3. **SUITABILITY OF TARGET RANGE.** There is **evidence** (e.g., specimens thriving in botanical gardens or on other grounds within the target range) that the **problems of ecological or climate change could be lessened/overcome by AC**

4. **LOW RISK FOR RECIPIENT ECOSYSTEMS.** Dispersal mode, pathogens it may carry, and other characteristics pose little or **no concern that the plant will become noxious** to other organisms in the target range

5. **BARRIERS TO UNASSISTED MIGRATION.** **Corridors** for unassisted and timely movement **do not currently exist**

6. **RECONSTRUCTING PAST RANGE.** The historical, near-time, or deep-time range of the plant encompassed the target range and/or the **kinds of life communities now found in the target range**

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http://www.torreyaguardians.org/index.html
...inter-situ conservation recovery

WHEN

IN-SITU conservation inadequate in the short term

EX-SITU conservation insufficient for survival of unique floras

INTER-SITU conservation: restoration of declining species outside their current range, but within historical ranges as inferred from palaeoecology

THREATS:
1. Phytophtora cinnamomi dieback
2. Grazing
3. Inappropriate fire regime
4. Climate changes

Table 1. Overview of numbers (and percentage) of extant and extinct wild populations of Banksia anatoma, B. brownii, B. montana and Lambertia fairallii.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Extant</th>
<th>Extinct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banksia anatoma</td>
<td>4 (80%)</td>
<td>1 (20%)</td>
</tr>
<tr>
<td>Banksia brownii</td>
<td>17 (63%)</td>
<td>10 (37%)</td>
</tr>
<tr>
<td>Banksia montana</td>
<td>4 (67%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>Lambertia fairallii</td>
<td>4 (57%)</td>
<td>3 (43%)</td>
</tr>
</tbody>
</table>

(after Cochrane et al., 2010)
The current “optimum” habitat for *Zelkova sicula*?
Fig. 4. Lago di Pergusa (Sicily, southern Italy). Stable isotopes, pollen, and microcharcoal selected curves (after Sadori et al., 2008)
Planning long-term conservation for Z. sicula

SUPRA-MEDITERRANEAN BELT

Quercus ilex
Qu. dalechampii
Qu. congesta
Ulmus canescens
Acer pseudoplatanus
Fraxinus ornus
Daphne laureola
Ruscus aculeatus
Hedera helix
Asparagus acutifolius

SUPRARMEDITERRANEAN BELT

Ficuzza - Ciacca di Mezzogiorno (1097 m l.m.)

Quercus petraea
Ilex aquifolium
Fagus sylvatica
Daphne laureola
Adenoscilla bifolia
Luzula sicula

(MESO-)SUPRA-MEDITERRANEAN BELT

Monti Madonie - Ponterecchiuso (1341 m l.m.)

Monti Madonie - Pomieri (1341 m l.m.)

Quercus congesta
Q. dalechampii
Q. ilex
Acer campestre
Ruscus aculeatus
Hedera helix
Euphorbia meuselii
Daphne laureola
Rosa sempervirens

Ficuzza – Alpe Ramosa (951 m l.m.)
THANKS FOR YOUR ATTENTION