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

Giuseppe Garfì

CNR-Istituto di Genetica Vegetale, Palermo (ITALY)
giuseppe.garfi@igv.cnr.it

LIFE10 NAT/IT/000237 ZELKOV@ZIONE

Urgent actions to rescue *Zelkova sicula* from extinction

Azioni urgenti per salvare *Zelkova sicula* dall'estinzione

Coordinatore beneficiario

REGIONE SICILIANA
Dipartimento Regionale dell'Ambiente

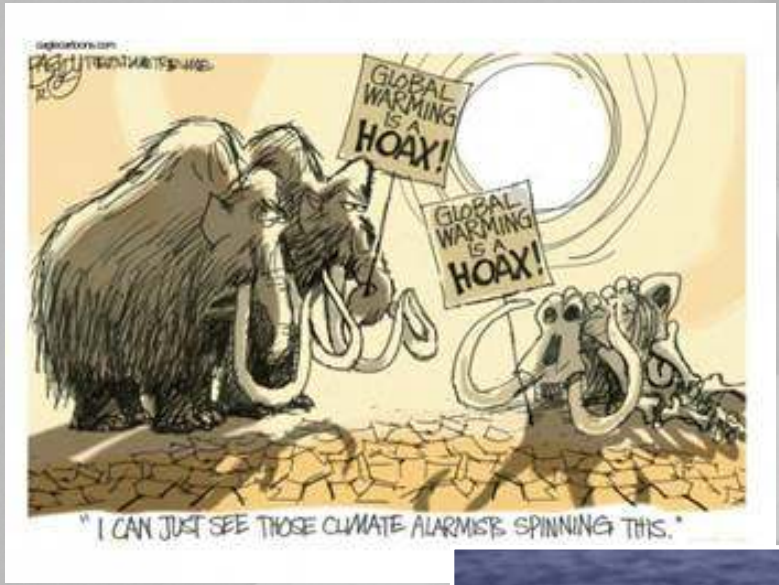
Beneficiari associati

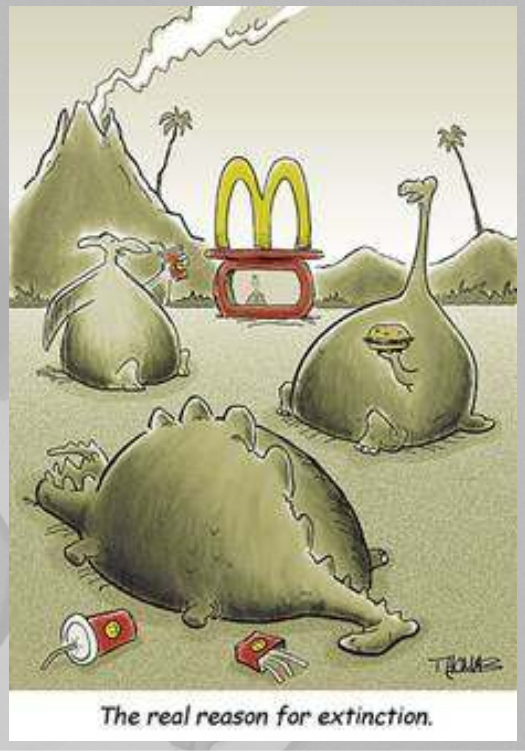
DRAFD
Dipartimento Regionale Azienda Foreste Demaniali

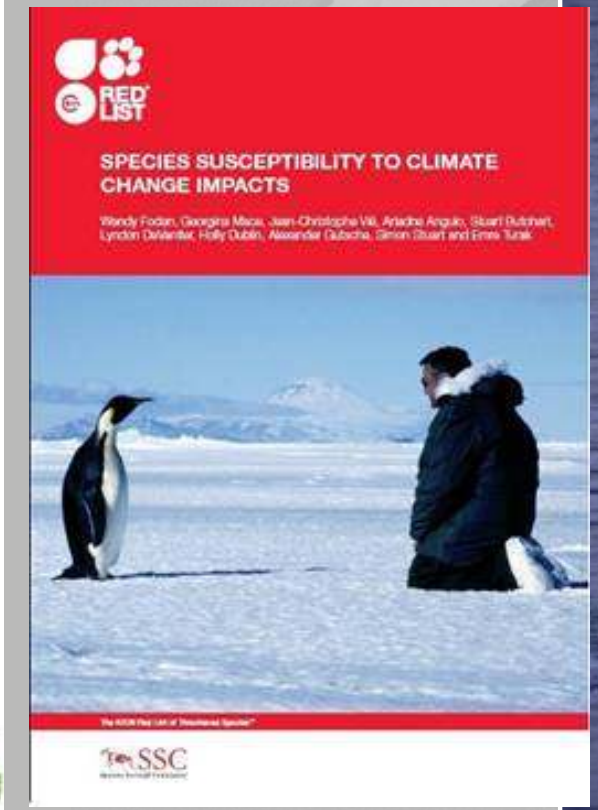
IGV
Istituto di Genetica Vegetale

LEGAMBIENTE

Biotic turnover or biotic stressors?

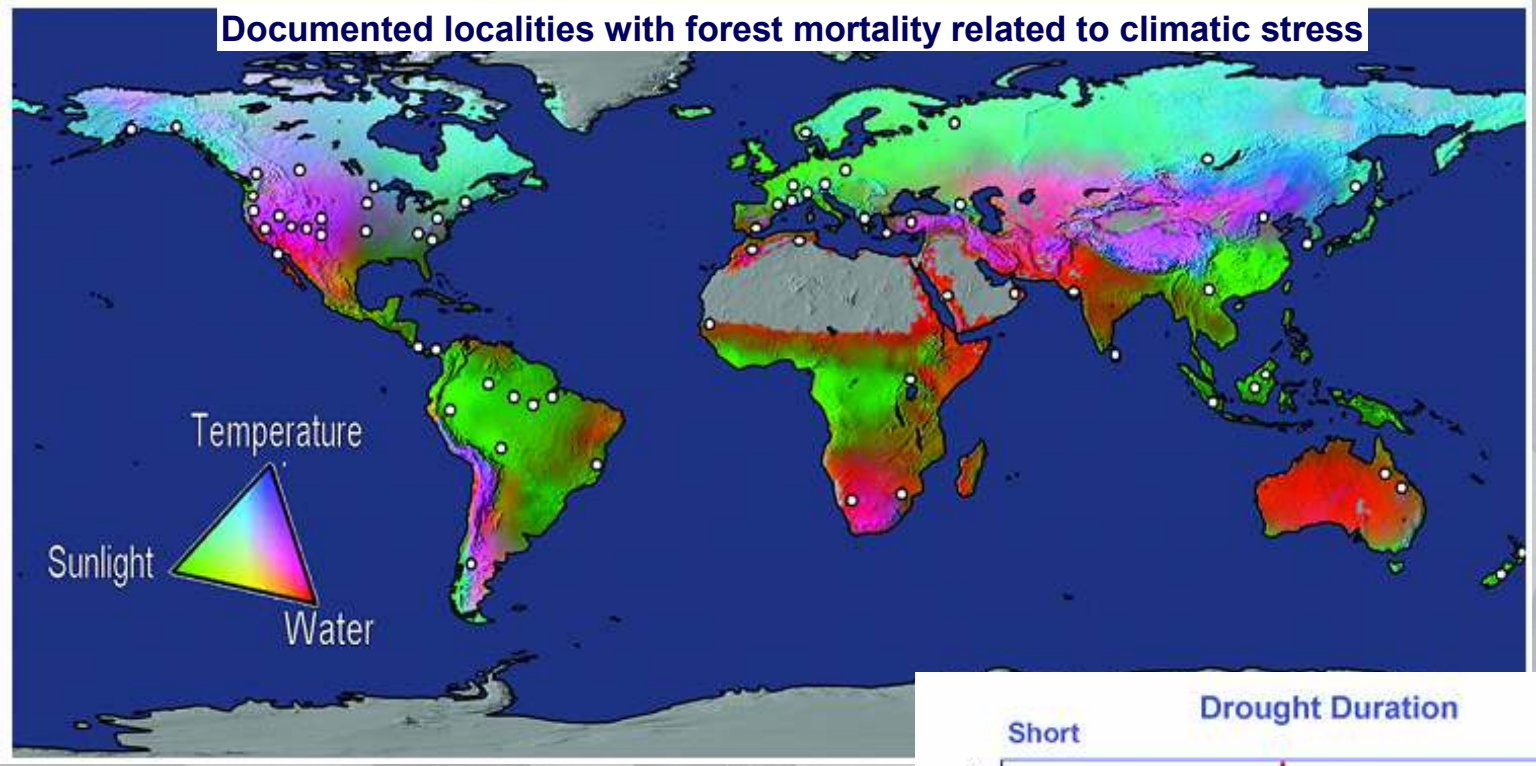




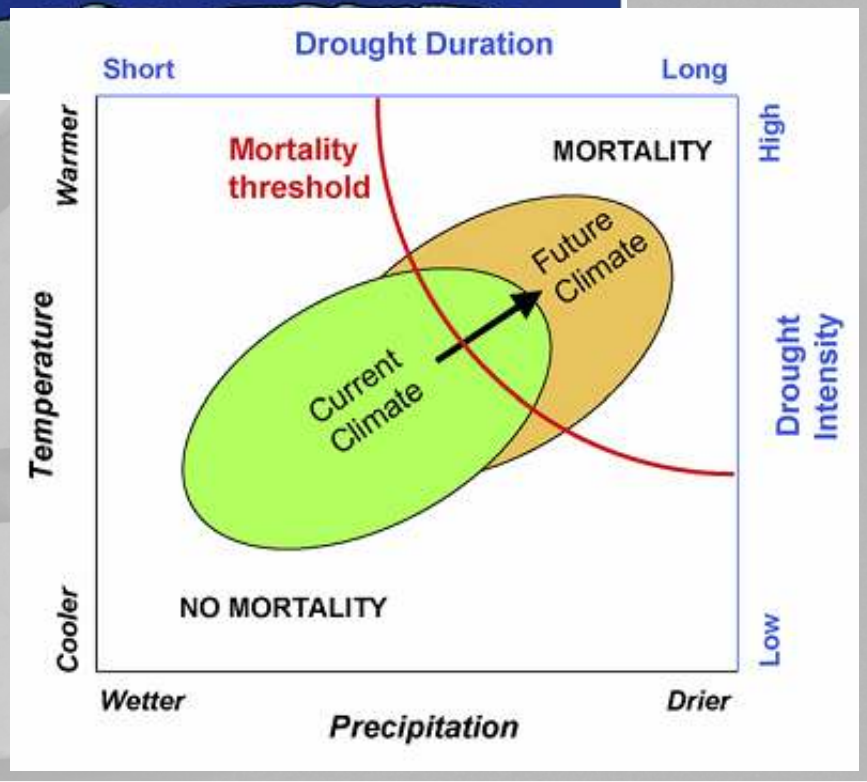


Climate change threatens Haleakalā silversword, one of Hawaii's iconic plants (*after Krushelnycky et al., 2013*)

Climate changes risks for forests



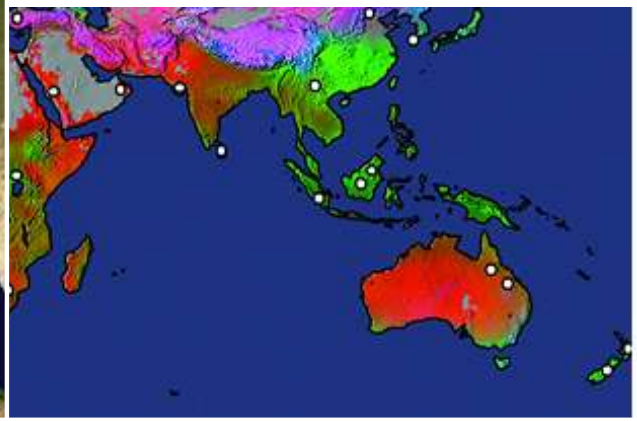
(*after Allen et al., 2010*)

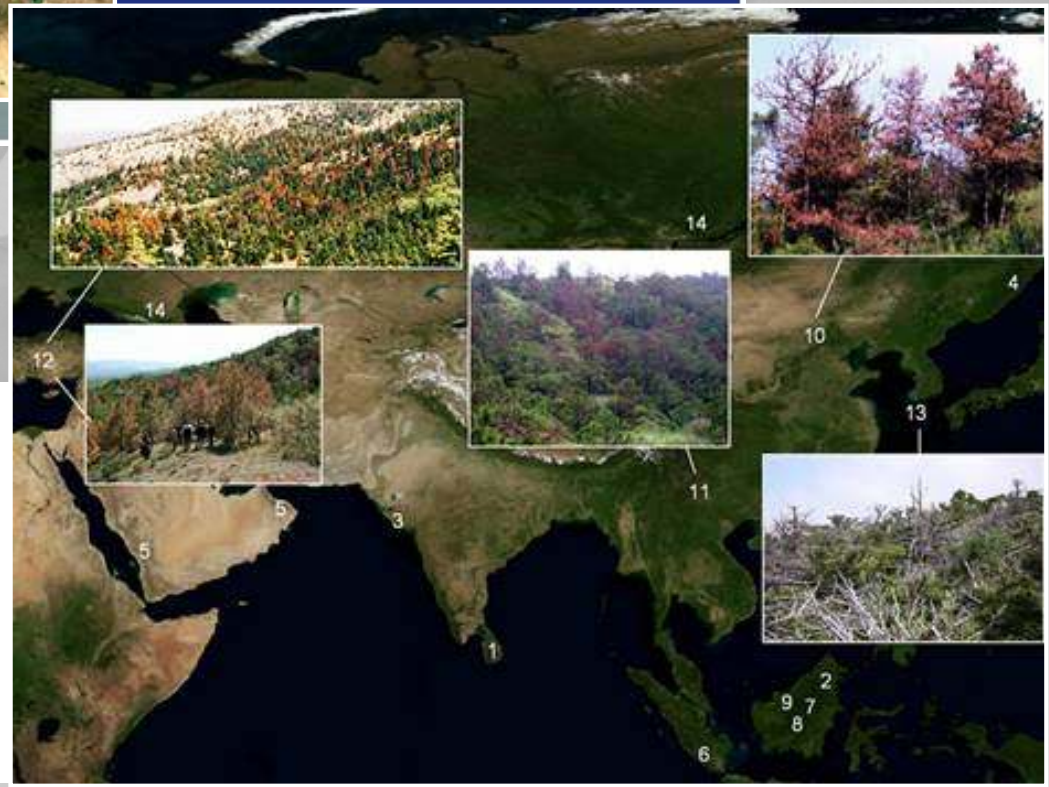


Climate changes risks for forests

(*after Allen et al., 2010*)

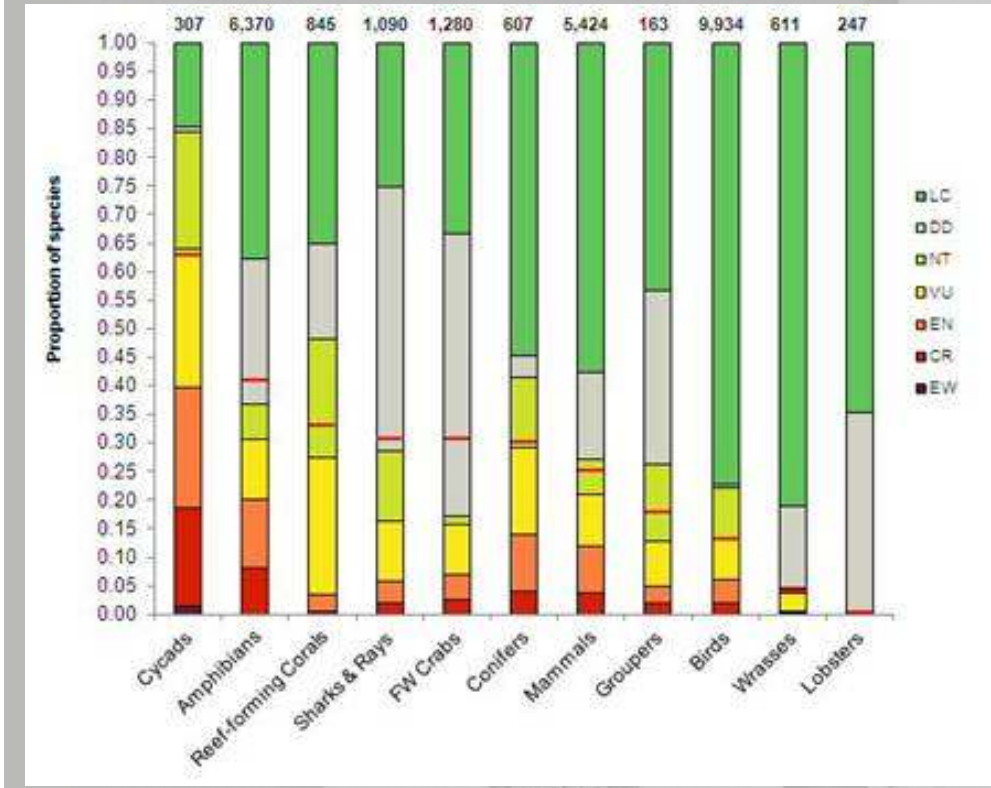
Documented drought-induced mortality in Europe (2006).
18: Pinus sylvestris mortality, Valais, Switzerland; 1999. 17: Pinus sylvestris die-off, Sierra de los Filabres, Spain.





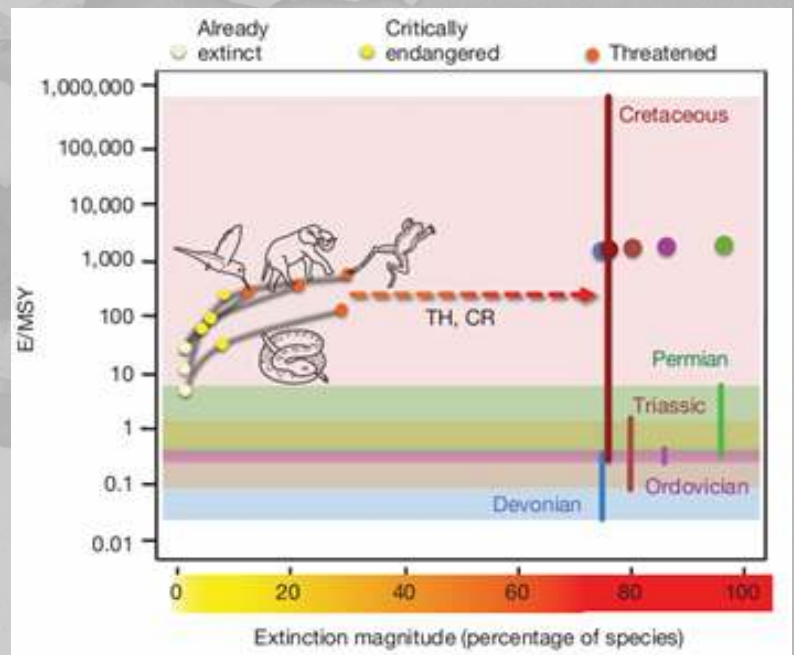
Documented drought-induced mortality in Asia (2008).
13 Dead *Abies koreana*, Mount Halla, South Korea; 2008. 10: *Pinus tabulaeformis* mortality in Shanxi Province, China; 2001. 11: Dying *Pinus yunnanensis* in Yunnan Province, China; 2005. 12 Up: *Abies cilicica* mortality in the Bozkir-Konya region,Turkey; 2002. 12 Low : Dying *Pinus nigra* near Kastamonu,Turkey

Towards the 6th mass extinction?



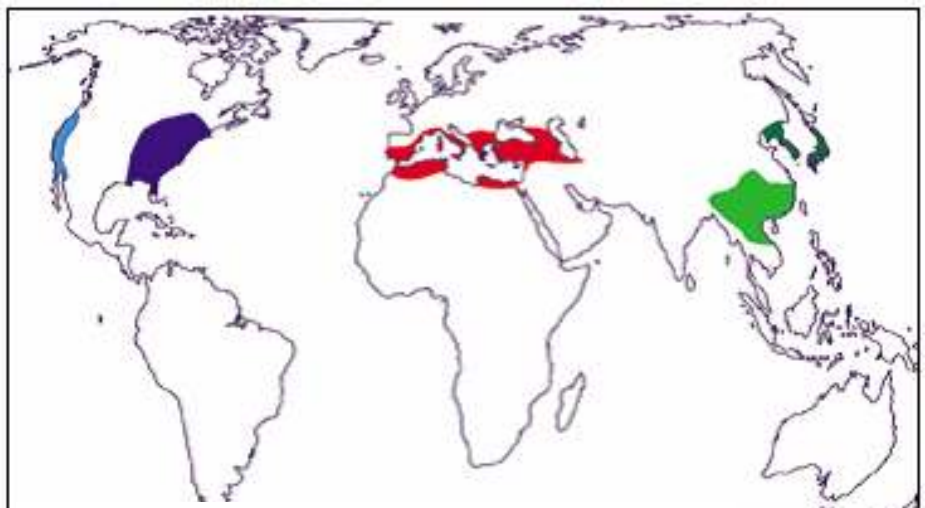
The proportion of extant (i.e., excluding Extinct) species in *The IUCN Red List of Threatened Species*.
Taxa are ordered according to the horizontal red lines, which show the best estimate for proportion of extant species considered threatened (CR, EN, or VU)
(*after IUCN, 2012*)

Present extinction rate some hundreds times higher than in the past



(*after Barnosky et al., 2011*)

An ancient treasure: Tertiary relict trees

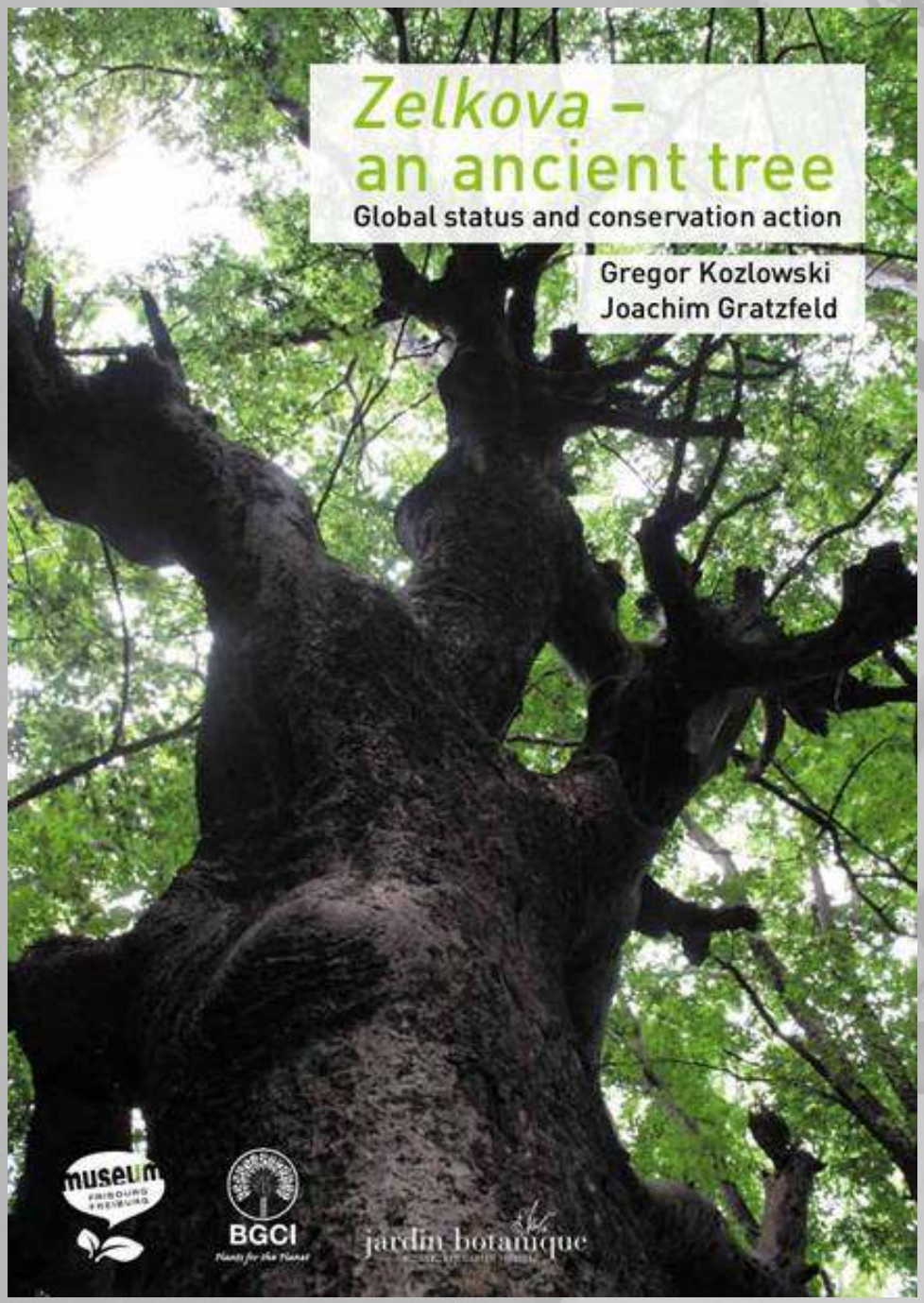


Five main refugia of Tertiary relict trees

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

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

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

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

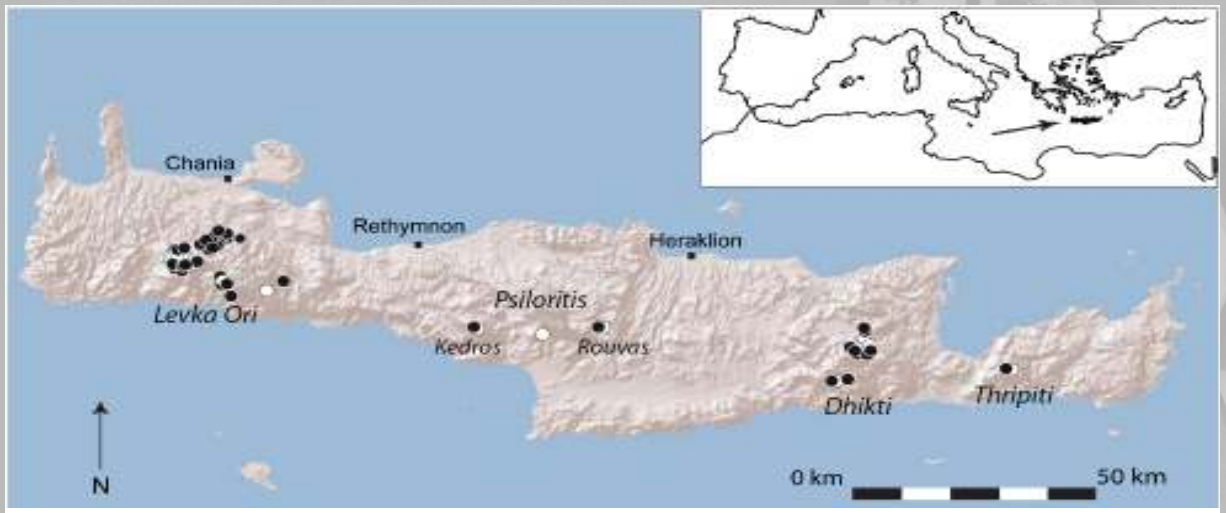
(***after Kozlowski & Gratzfeld, 2013***)

The genus *Zelkova* in the world

Species:	Distribution:
Z. sicula Di Pasquale, Garfì & Quezel	Sicily (Italy)
Z. abelicea (Lam.) Boiss. (*Z. cretica* Spach.)	Crete (Greece)
Z. carpinifolia (Pall.) K. Koch (*Z. ulmoides* Schneid.) (*Z. crenata* Spach.) (*Z. hyrcana* Grossh. & Jarm.)	Turkey, Georgia, Armenia, Azerbaijan, Iran [perhaps a separate species from the Hyrcanian region in Iran/Azerbaijan]
Z. sinica C. K. Schneider	China
Z. schneideriana Hand.-Mazz. (*Z. schneiderana*)	China
Z. serrata (Thunb.) Makino (*Z. formosana* Hayata) (*Z. keaki* Maxim.) (*Z. acuminata* Planch.) (*Z. hirta* C. K. Schneider) (*Z. tarokoensis* Hayata) (*Z. japonica* Dippel.)	Japan, Korea, Kuril Islands (Russia), Taiwan, China

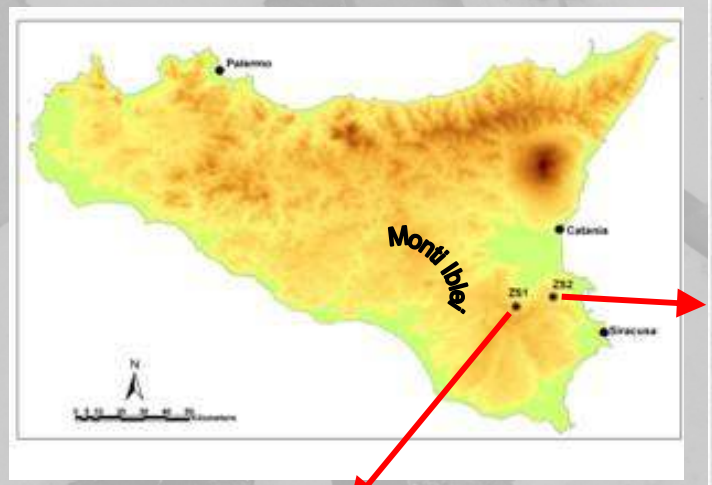
The western species: *Zelkova carpinifolia*

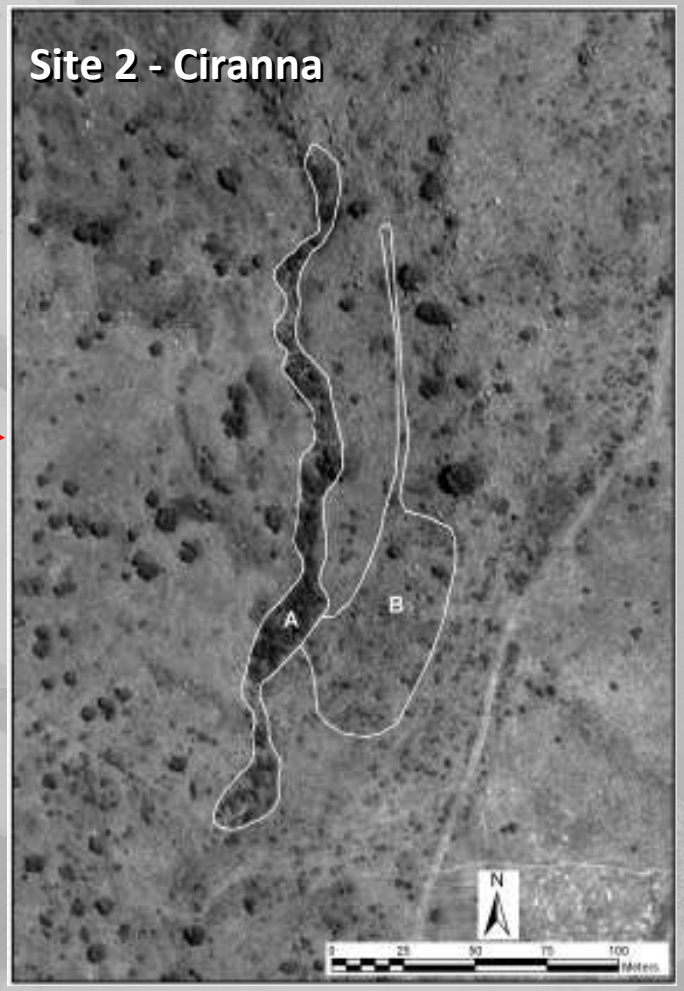
The western species: *Zelkova abelicea*

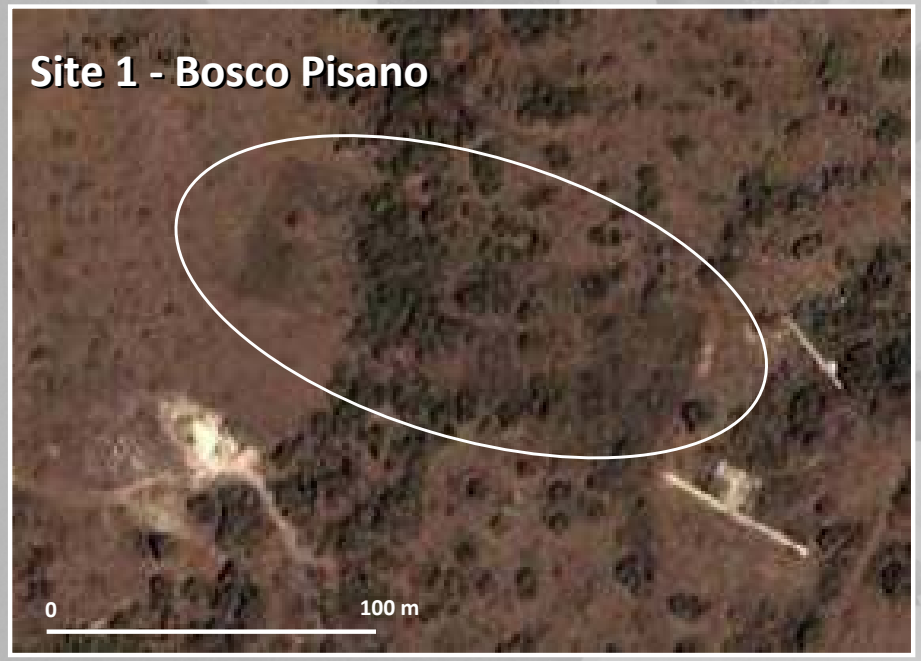


Past and present distribution of Zelkova abelicea.
***Black circles**: recently observed and/or described populations (1993-2010). **White circles**: presumably extinct populations known from old literature and herbaria (1700-1992) (after Kozlowski et al., 2012)*

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)

Zelkova sicula: the rarest and most endangered

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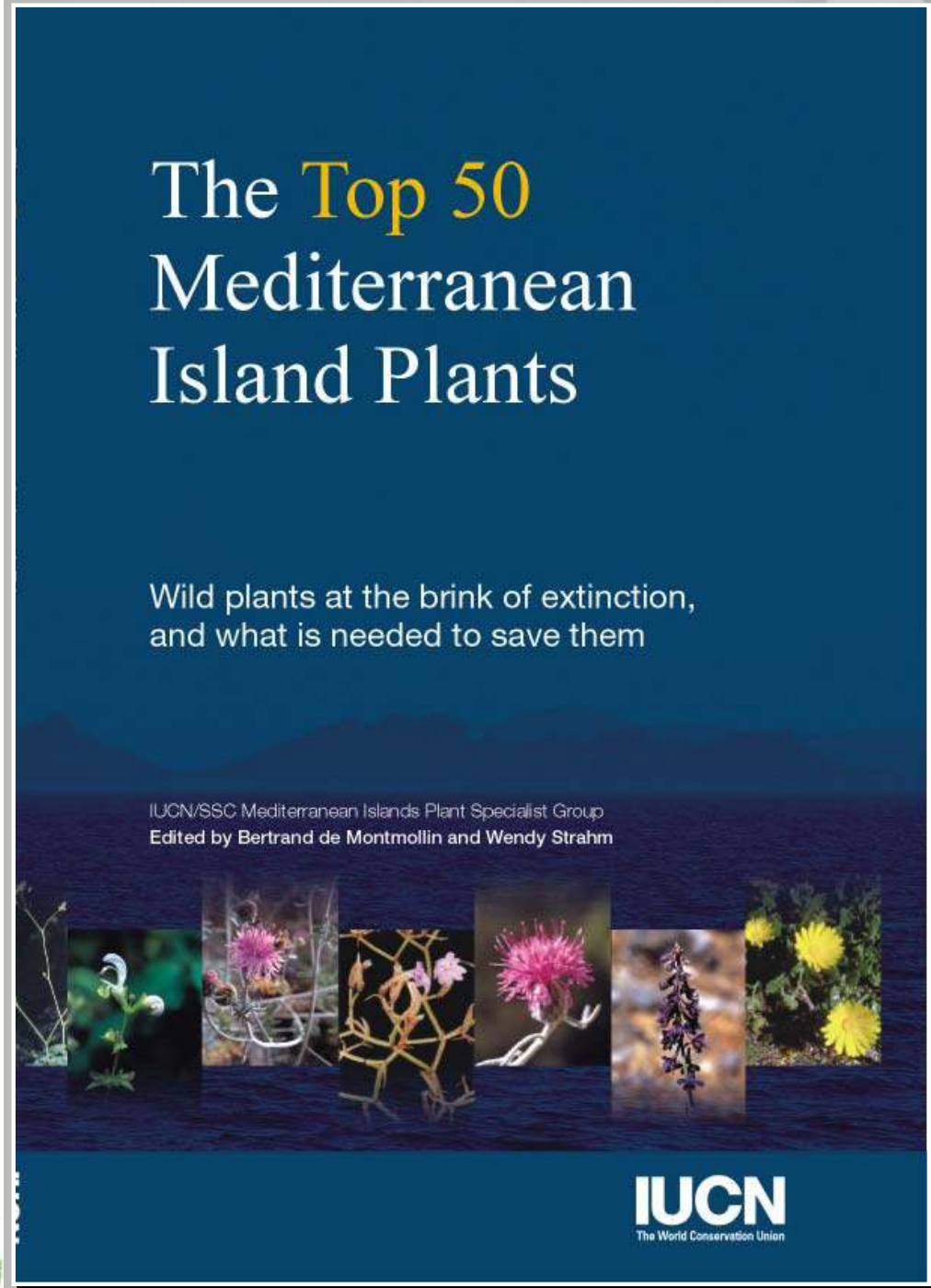


The Top 50 Mediterranean Island Plants

Zelkova sicula

Latin name:	Zelkova sicula Di Pasquale, Garfì & Quézel
Common name:	Zelkova siciliana (Italian)
Family:	Ulmaceae (elm family)
Status:	CRITICALLY ENDANGERED (CR)

Where is it found?

Discovered in 1991, some 200-250 individuals of *Zelkova sicula* exist, growing in a very old cork oak (*Quercus suber*) forest. This single remnant population extends 200 m along the banks of a stream on the northern slopes of the Iblei Mountains in south-eastern Sicily.

How to recognise it

The tree species has a bushy habit and usually grows to 2-3 m tall. Its greyish bark is smooth on the young twigs, and tends to turn brownish-grey and peel off in plates on older trees. Leaves are oval shaped, bear teeth on the edges, and are densely covered by bristly hairs on both sides of the leaf. They are symmetric at their base (unlike many other members of the elm family), and are shed every autumn. The flowering period is in April.

Male and female flowers, as well as bisexual flowers, can be found on the same individual. Its pollination has so far been observed, and most of the seeds produced are sterile. Consequently most of the reproductive success is due to root suckers, which are new stems that originate from the root system. Individuals produced in this manner are genetically identical to the original plant. Preliminary studies indicate that the remaining population probably goes back to just one individual or at most a few. The vegetative propagation mode of *Zelkova* makes it difficult to determine the exact number of functionally independent individuals in the population.

This species has evolved in a Mediterranean climate with pronounced dry periods during summer. In extreme years, such conditions can lead to the withering of branches or of entire individuals, but a second regrowth can take place at the end of summer or beginning of autumn.

Interesting facts

The genus *Zelkova* only has a few species, of which a few grow in Western and Eastern Asia, plus two in the Mediterranean basin (this species in Sicily and another, *Zelkova abelicea*, which is a threatened endemic from Crete). These two species represent relicts that have persisted over a long period of time and may have been more widespread in the past. Both are threatened by habitat change.

Why is it threatened?

This species has been classified CR (Critically Endangered) according to IUCN Red List Criteria B1ab(i,ii,v)+2ab(i,ii,v); C2a(ii); D. This means that the area in which this species is found is very small, and both the area as well as the number of individuals continue to decline. The small number of individuals in a single declining population makes the probability of extinction of this species very high.

The ancient cork forest hosting this species is rather degraded due to overexploitation (logging, grazing, and removal of cork) for several centuries. In addition, over the last few years several major droughts have caused the death of several trees. *Zelkova sicula* requires relatively moist conditions. Therefore, if rainfall remains low, this species is almost certain to become extinct.

What is being done to protect it?

Legally: Currently, there is no legal protection for this species.

In situ: The area where this species is found is fenced to prevent grazing. It is entirely situated within an SCI (Site of Community Importance) area, which is part of the European Natura 2000 network.

Ex situ: This species is cultivated at the Botanical Garden of the University of Catania, the Arboretum "Monna Giovannella" of the University of Florence, and at the Botanical Conservatory of Brest.

What conservation actions are needed?

A restoration plan including both *ex situ* and *in situ* activities needs to be established. In order to determine the degree of affiliation between all the individuals in the population, a broader genetic study needs to be undertaken.

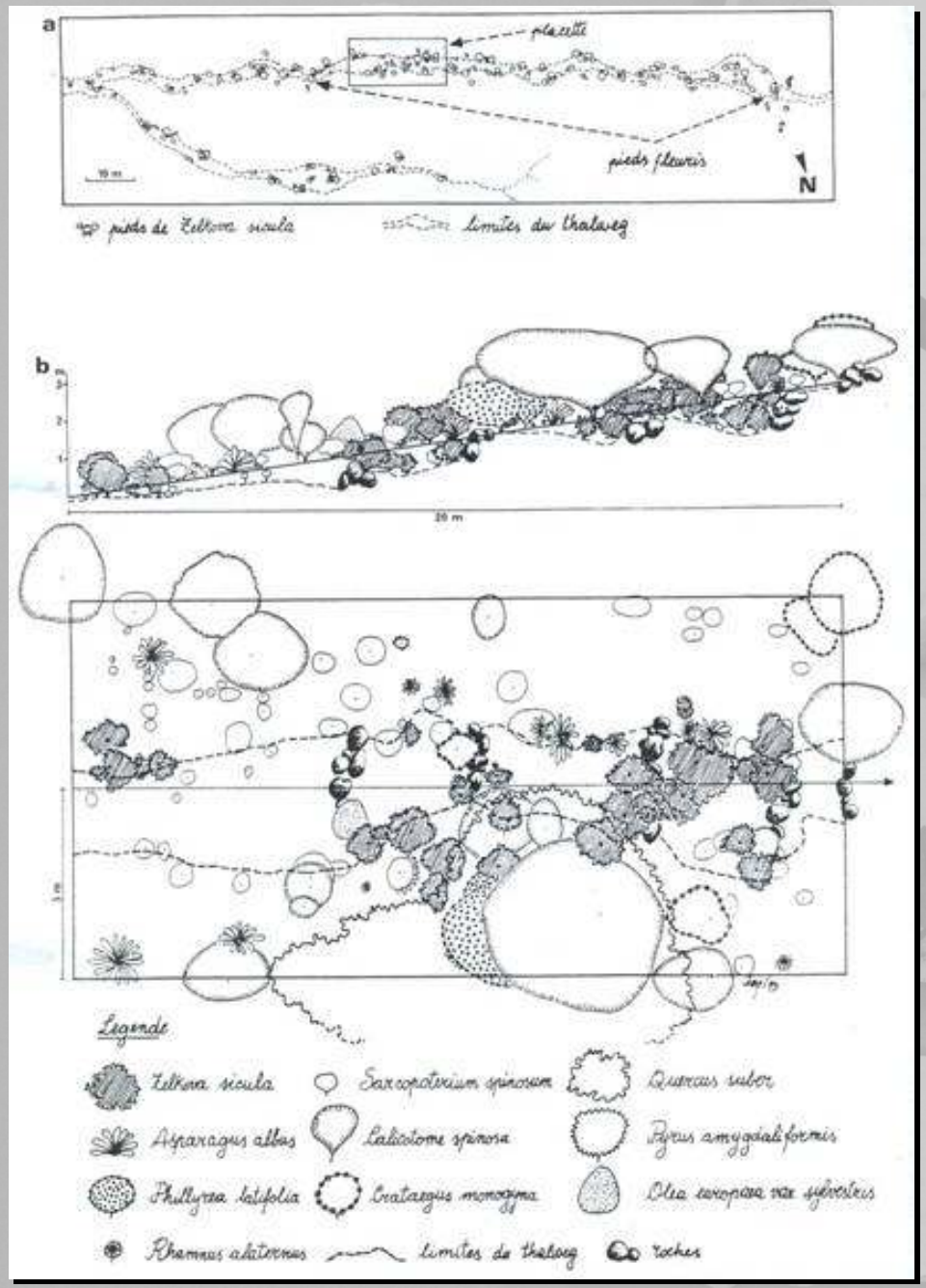
Scientific coordination

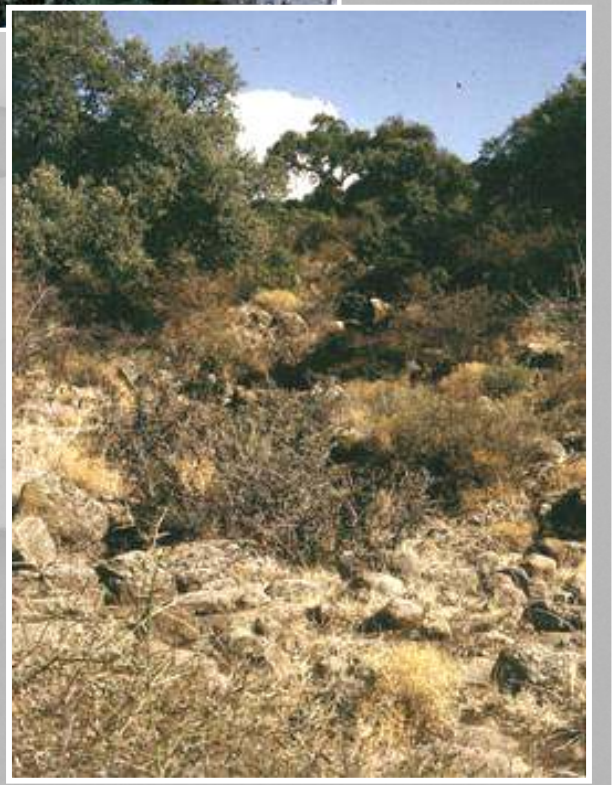
Dr Giuseppe Garfì, CNR – Istituto per i Sistemi Agricoli e Forestali del Mediterraneo (ISAFoM), Sezione di Ecologia ed Idrologia Forestale, Rende, Italy.

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

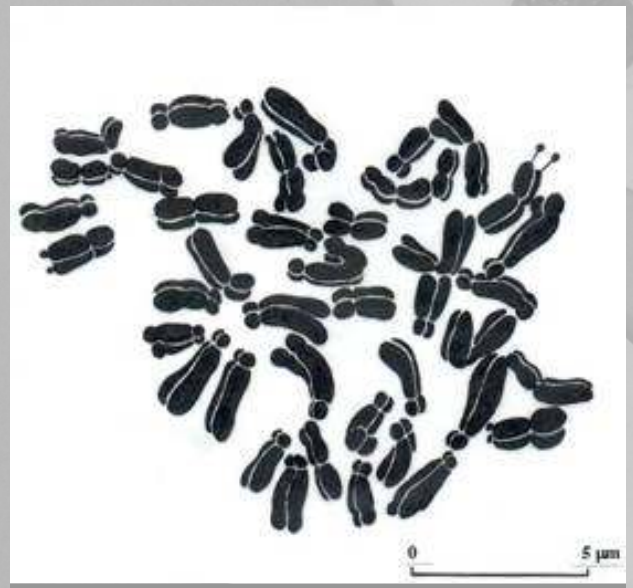




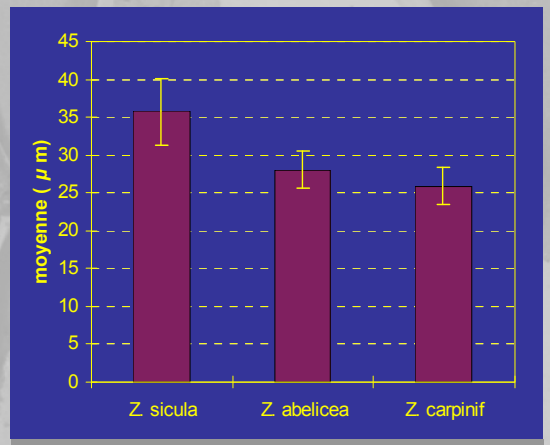
Cariology and the environment pressure

CHROMOSOME NUMBERS

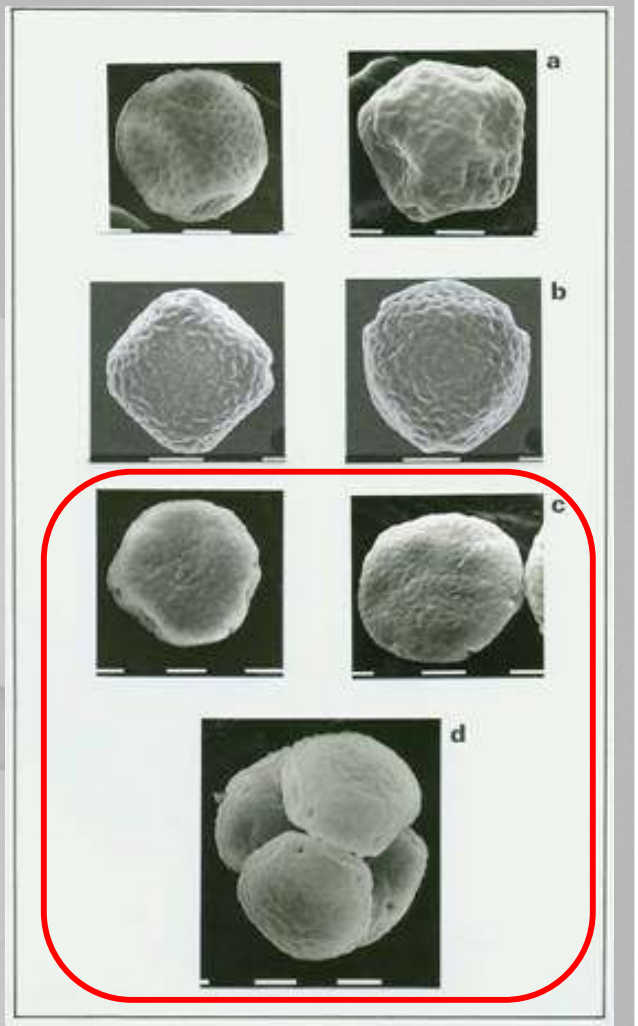
Z. carpinifolia	2n = 28	diploid
Z. abelicea	2n = 28	diploid
Z. sicula	**2n = 42**	**triploid**



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



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



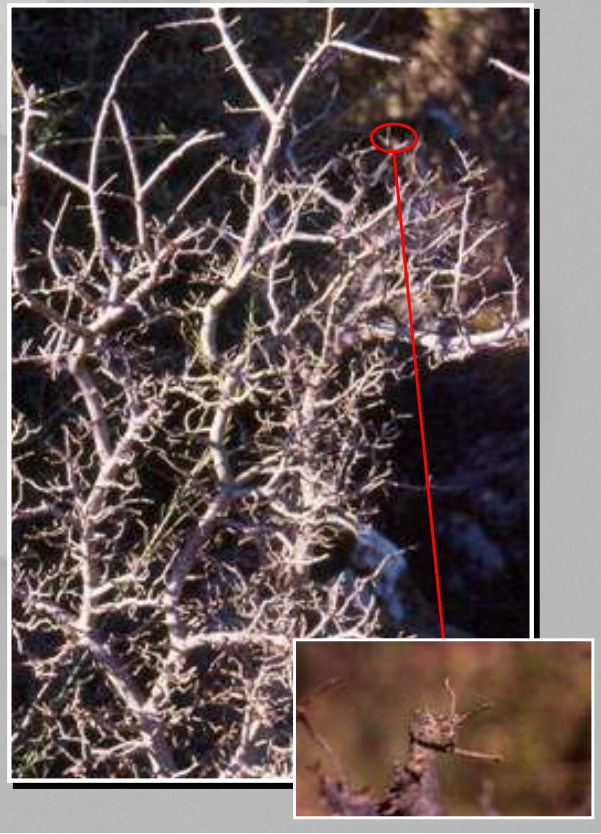
Pollen grains of (a) *Z. carpinifolia*, (b) *Z. abelicea* (after Stafford, 1995), (c) *Z. sicula*, (d) tetrad of *Z. sicula*

MAIN FEATURES OF POLLEN GRAINS

species	*pore number*	*equatorial diameter (µm)*	*tetrads %*	*exine sculpture*
Z. carpinifolia	4-(5)	36.8-(42.6)-48.3	0.0	coarsely rugulate (-reticulate)
Z. abelicea	3-(4)-5	32.0-(36.5)-41.0	-	coarsely rugulate
Z. sicula	**5-(6)**	**43.7-(49.9)-59.8**	**17.7**	**slightly rugulate**

Conservation and threats

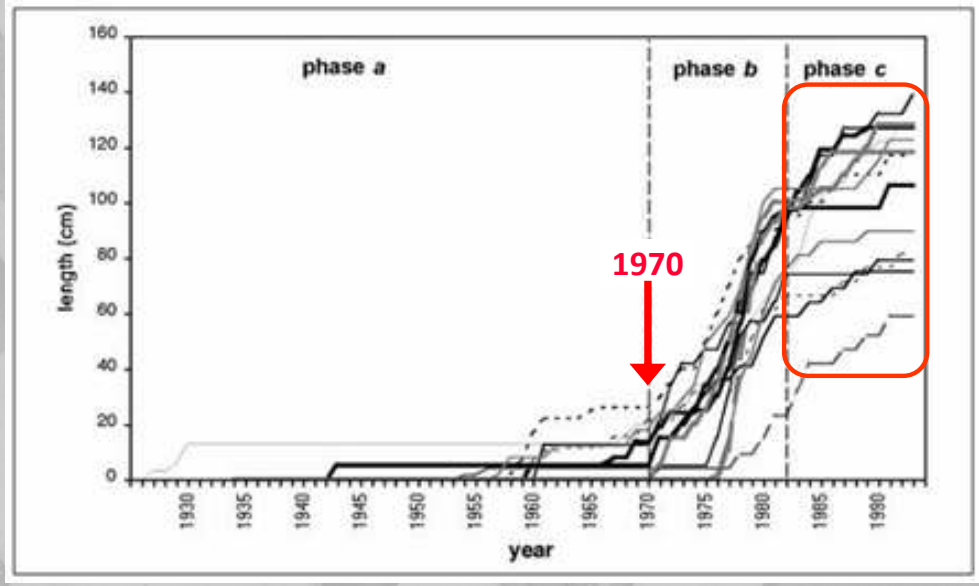
- Extremely small populations
- No sexual reproduction
- Poor genetic diversity
- Drought stress
- Anthropic pressure



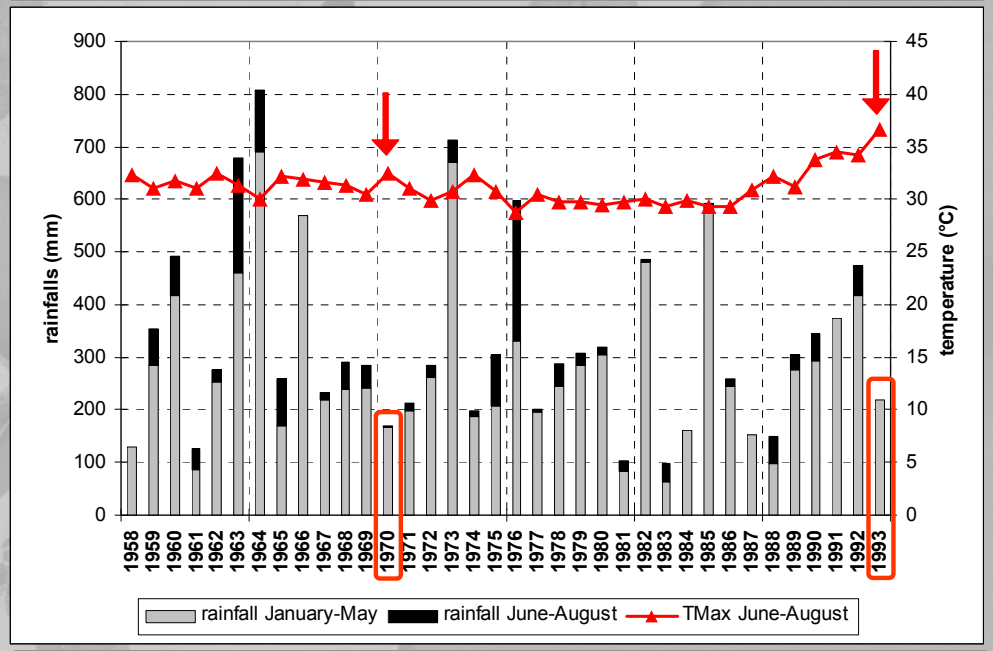
1970 and 1993: climatic constraints and partial death

Abrupt withering of leaves in August 1993

Release of reiterated shoots along the trunk length



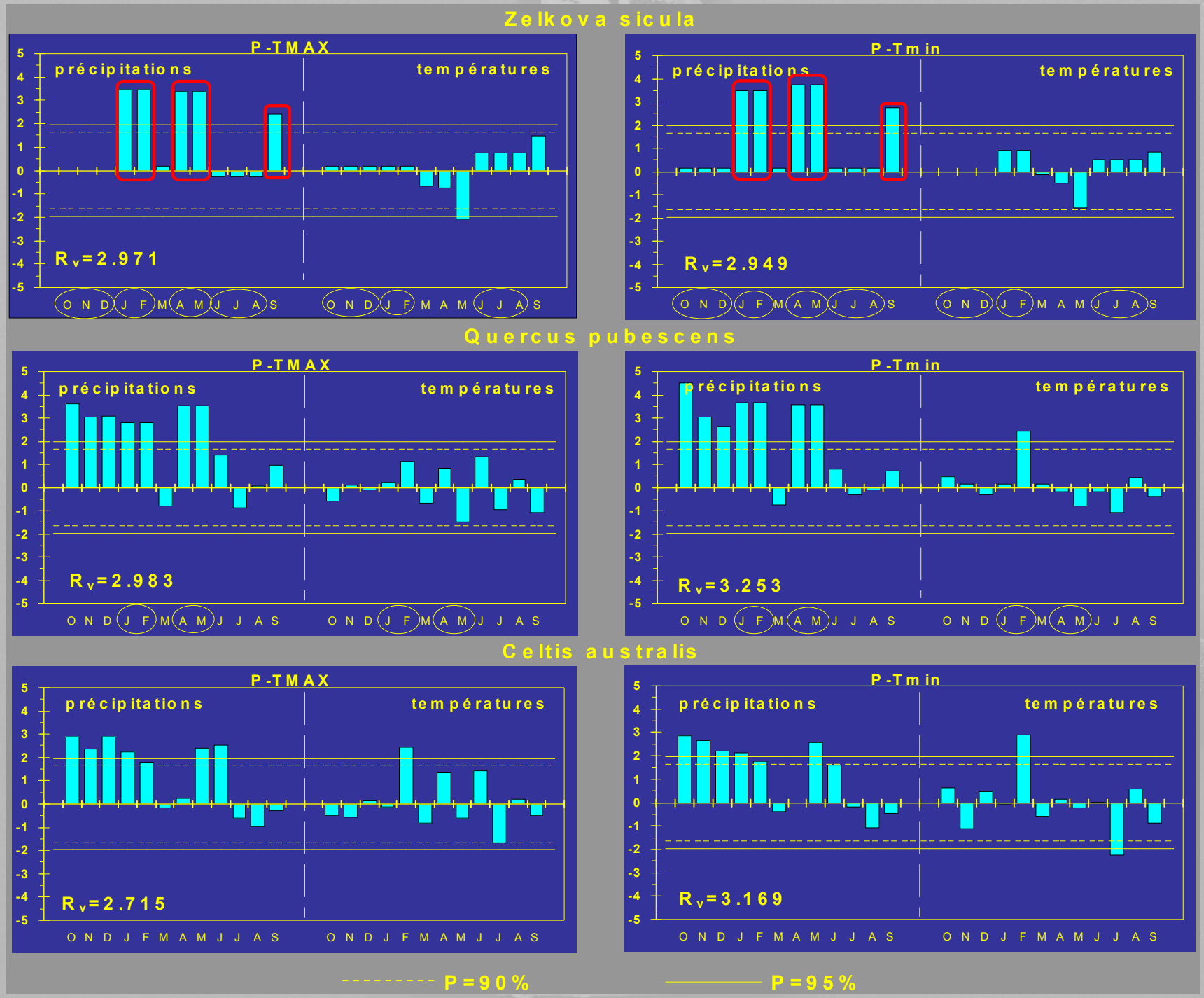
Individual height growth curves of 13 trees. Syncronic abrupt changes in stem elongation can be noticed in 1970 after reiteration



Climate parameters from 1958 to 1993

(after Garfì, 2002)

Cambial growth response to climate



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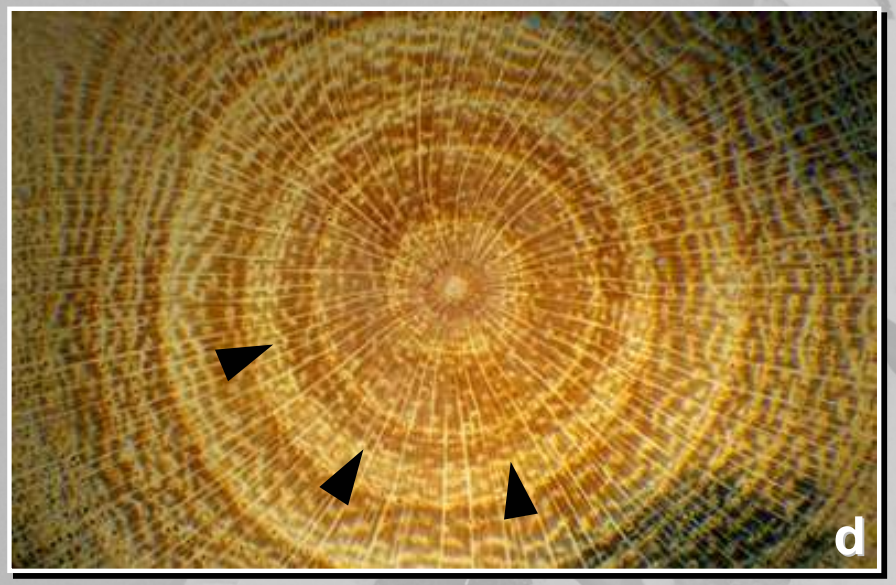
Polycyclic growth and false growth rings



Late-summer growth flushes (a, b, c) and false ring (d)

A LIFE+ project to save *Z. sicula*

http://www.zelkovazione.eu/

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Some main items of the project Zelkov@zione

5 PARTNERS

Coordinatore beneficiario

REGIONE SICILIANA
Dipartimento Regionale dell'Ambiente

Beneficiari associati

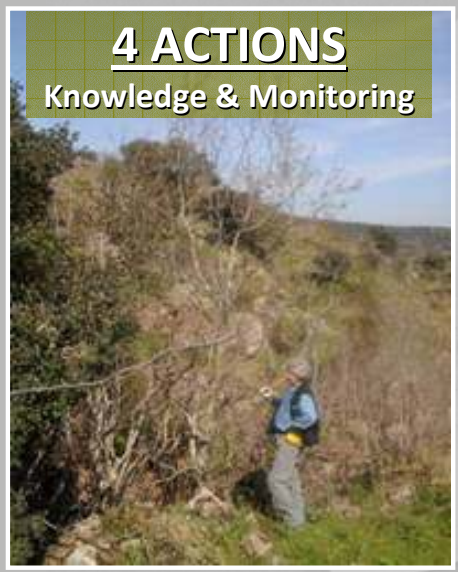
DRAFD
Dipartimento Regionale Azienda Foreste Demaniali

IGV
Istituto di Genetica Vegetale

LEGAMBIENTE

31 ACTIONS

4 ACTIONS
Knowledge & Monitoring



4 ACTIONS
Technical & Administrative Management

14 ACTIONS
Active Conservation

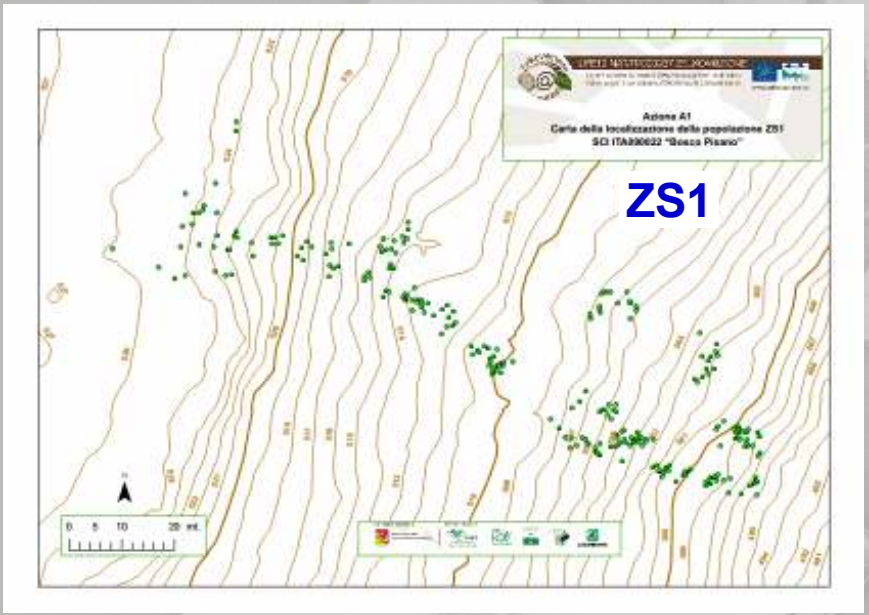
Bosco Pisano - Site ZS1

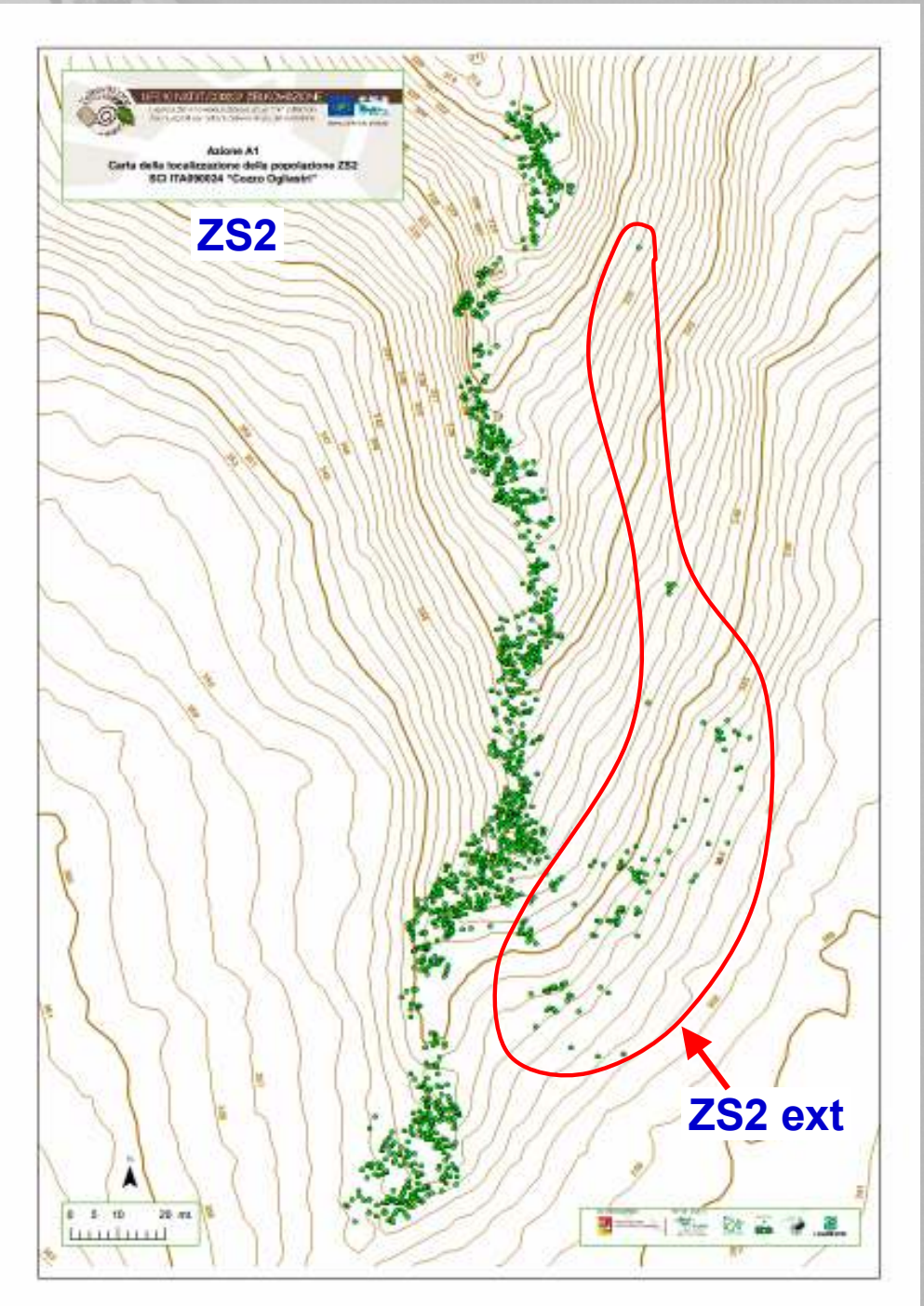
9 ACTIONS
Communication & Education

Current status: preliminary data - 1

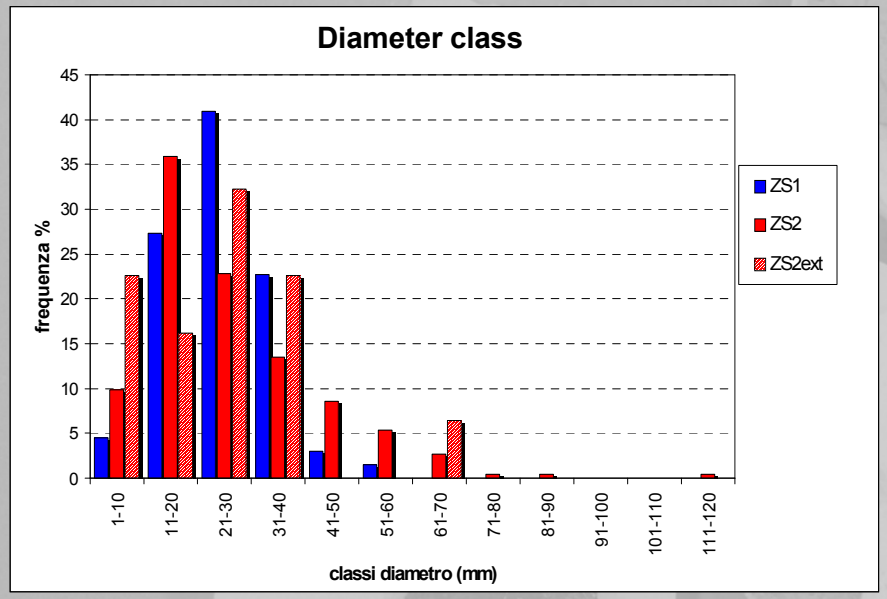
Total n. of trees

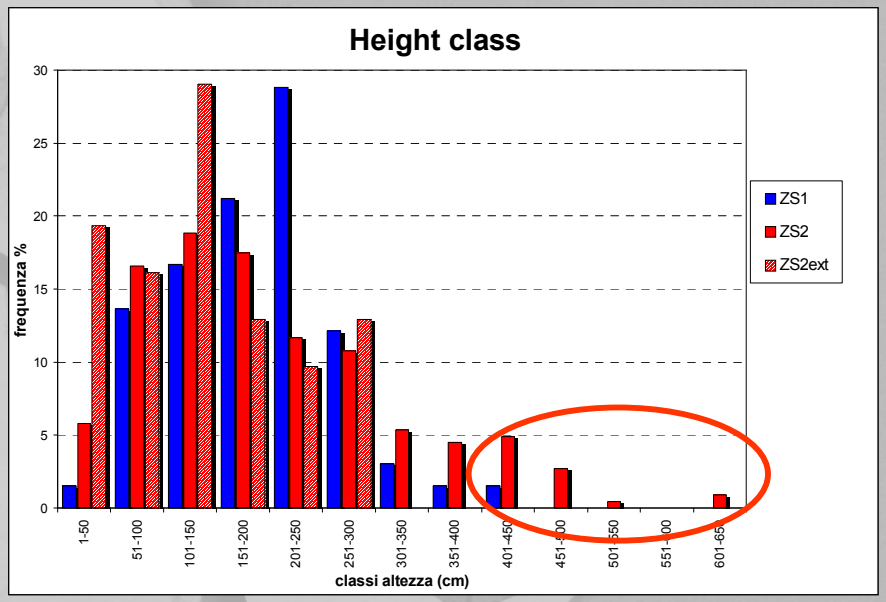
ZS1: 262 trees
ZS2: 1425 trees
ZS2 ext: 116 trees

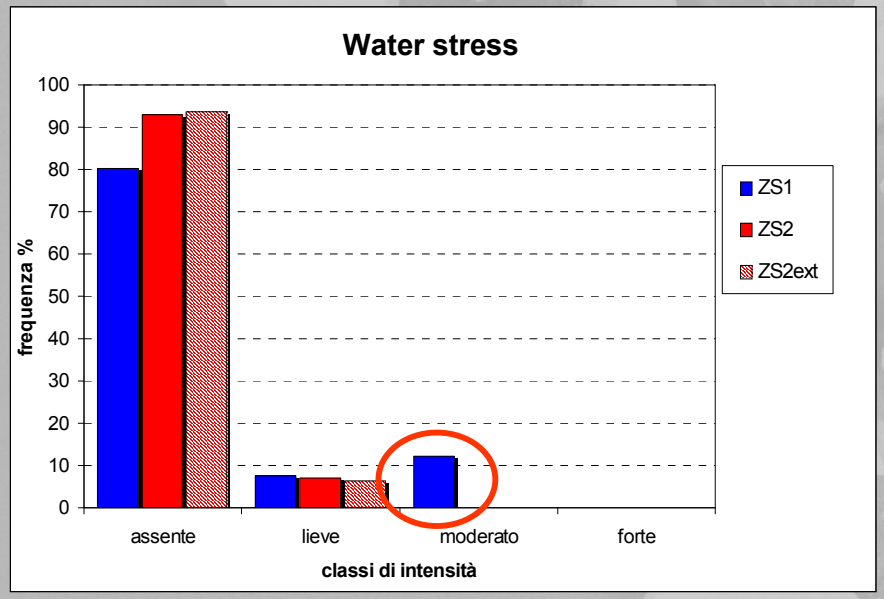


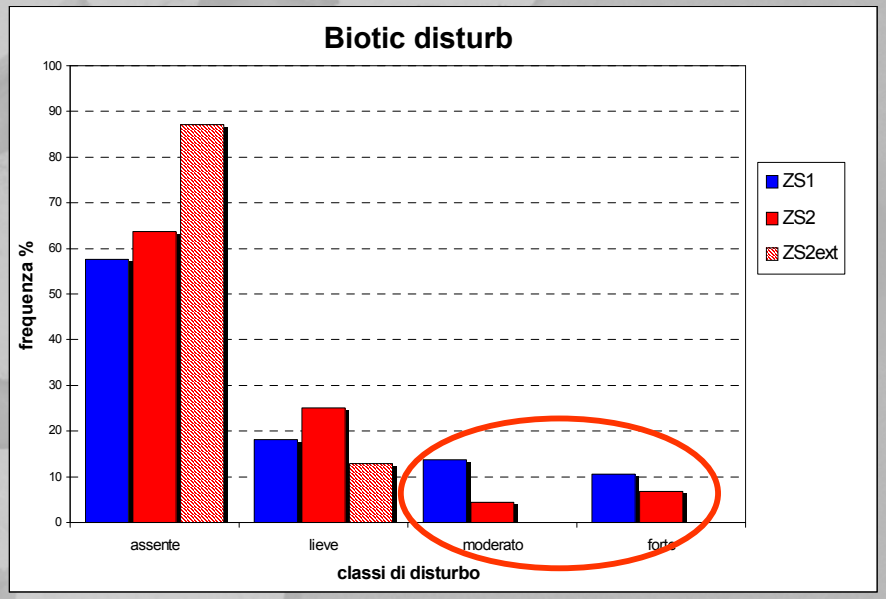


Current status: preliminary data - 2



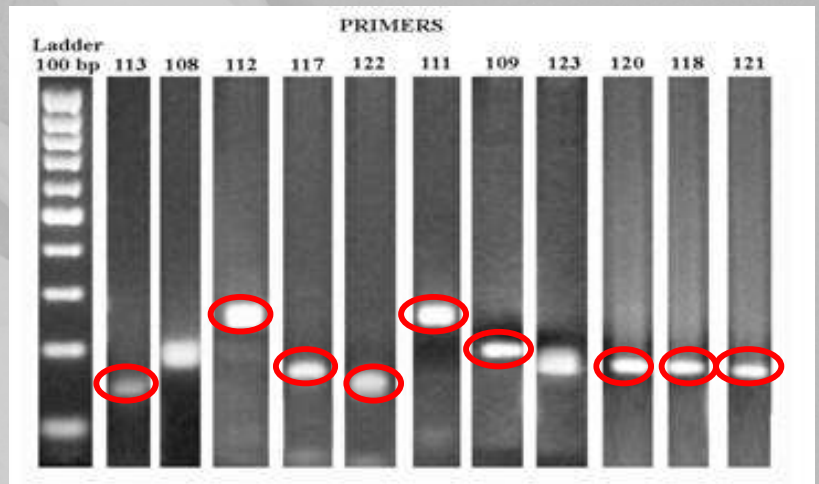






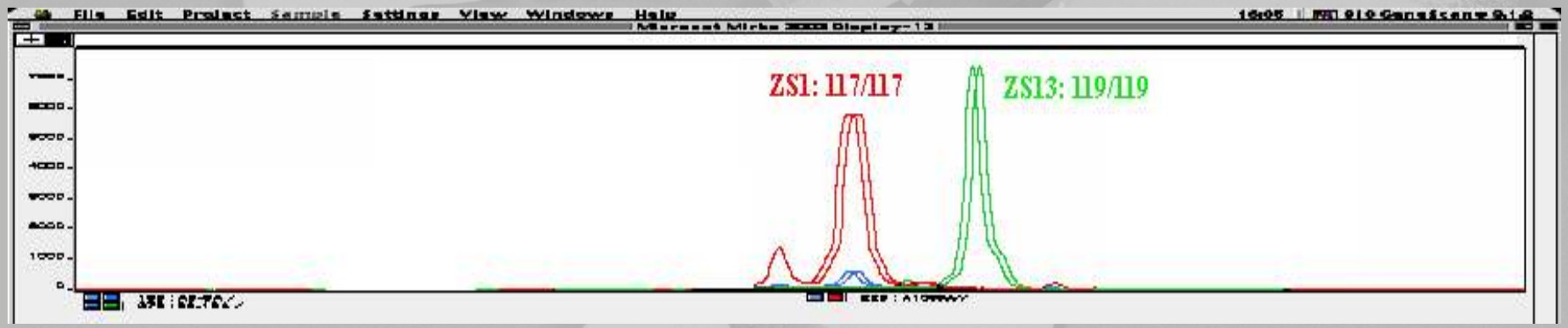
What to be conserved?
Intra-population genetic diversity

PRIMERS	LENGHT (bp)
109	134/140
111	208/212
112	232/238
113	117/117 119/119 (ZS13)
117	143/145
118	186/186
120	189/189
121	190/190
122	137/139



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

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



Double-analysis of amplificates of ZS01 (red) and ZS13 (green) by primer 113

Conservation when seed recruitement has been lost - 1

12 in vivo multiplication trials

Conservation when seed recruitement has been lost - 2

7 in vitro multiplication trials

Active conservation

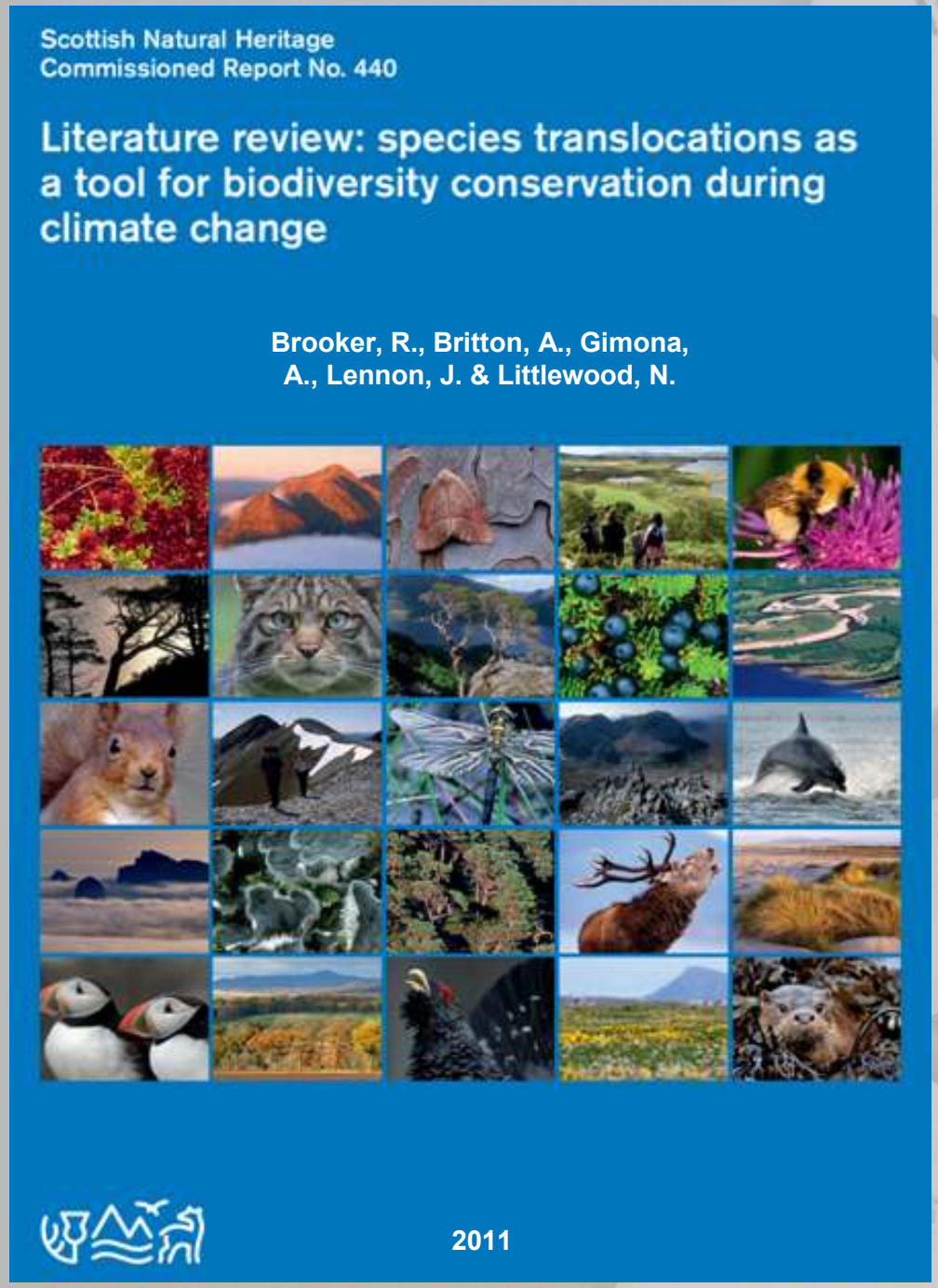
Grazing exclusion through fencing

Emergency irrigation

Temporary nursery for forest habitat rehabilitation

Floristic rélévés to draw a Management Plan of Grazing

Species Translocation (ST): PROs & CONs



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

Assisted Colonisation or…

***Torreya taxifolia*, a threatened plant that was "left behind" in its peak glacial pocket refuge**

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

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 anatona*, *B. brownii*, *B. montana* and *Lambertia fairallii*.

Taxon	Extant	Extinct
Banksia anatona	4 (80%)	1 (20%)
Banksia brownii	17 (63%)	10 (37%)
Banksia montana	4 (67%)	2 (33%)
Lambertia fairallii	4 (57%)	3 (43%)

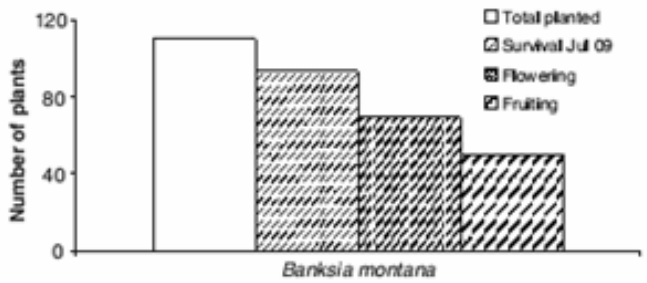
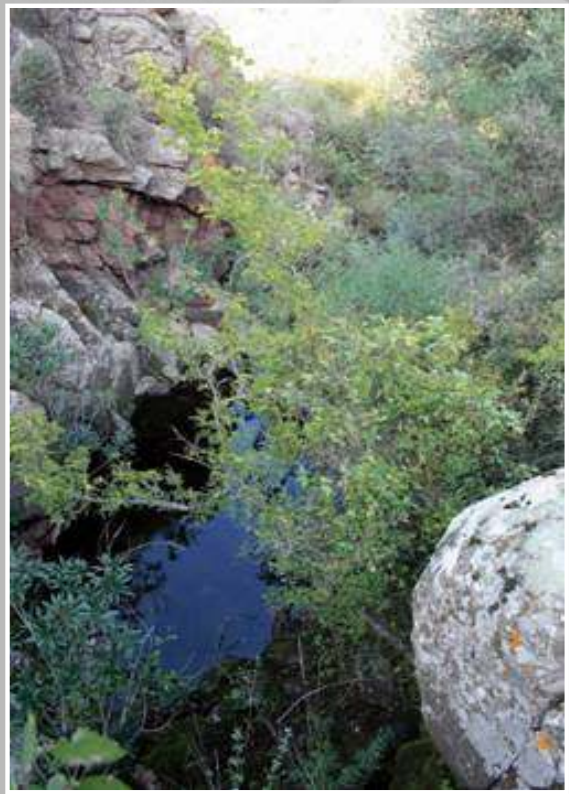


Fig. 2. Overall survival, flowering and fruiting of *Banksia montana* plants at July 2009. Planting commenced 2003.

(after Cochrane et al., 2010)

Fig. 1. A *Banksia anatona* (IMAGE: S. BARRETT); B *Banksia montana* (IMAGE: J. A. COCHRANE); C *Banksia brownii* (IMAGE: R. HARTLEY); D *Lambertia fairallii* (IMAGE: T. ERICKSON).

The current "optimum" habitat for *Zelkova sicula*?



Some suggestions from the past

Valle di Castiglione

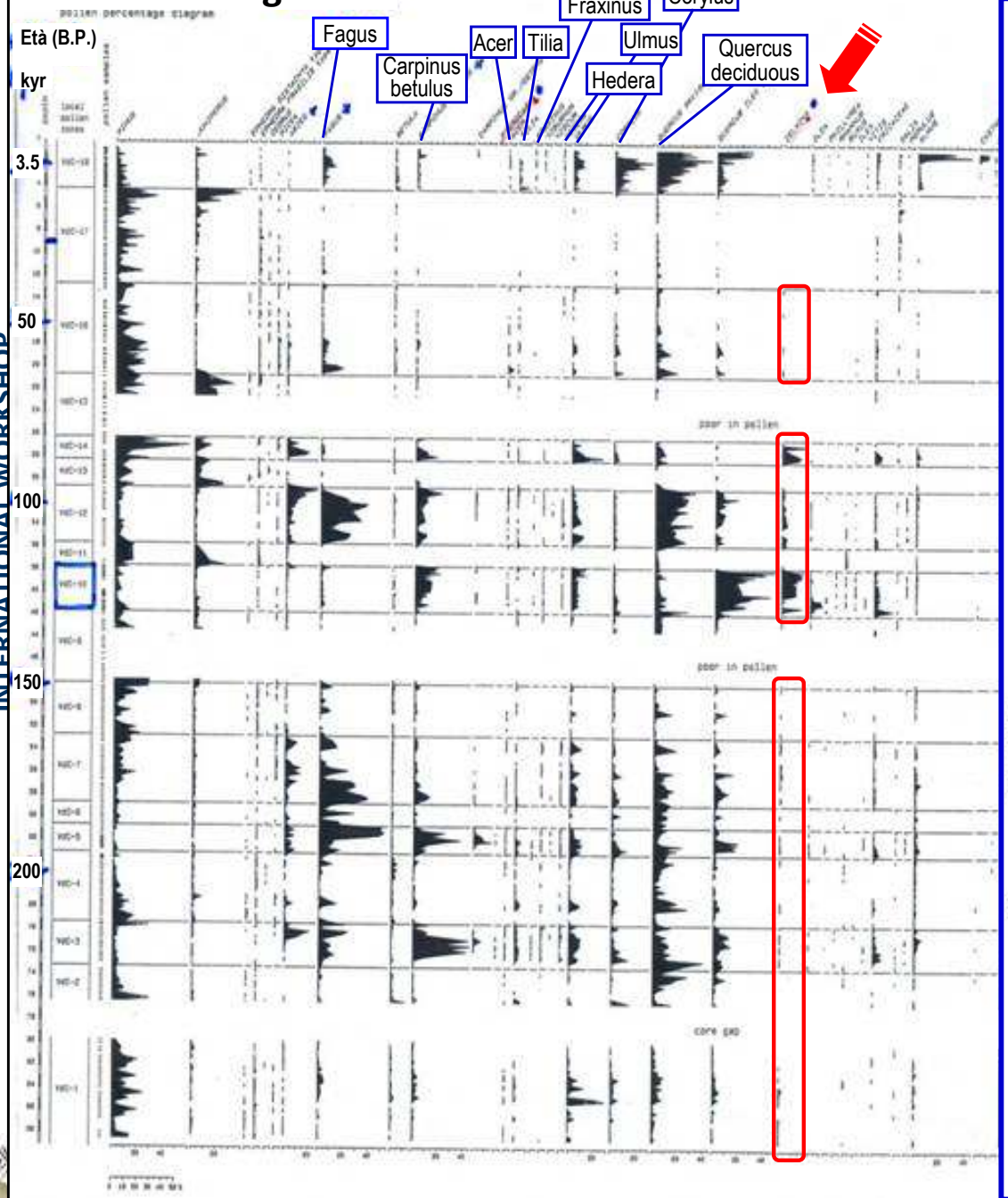


Fig. 3. – Pollen percentage diagram from Valle di Castiglione.

Lago di Pergusa

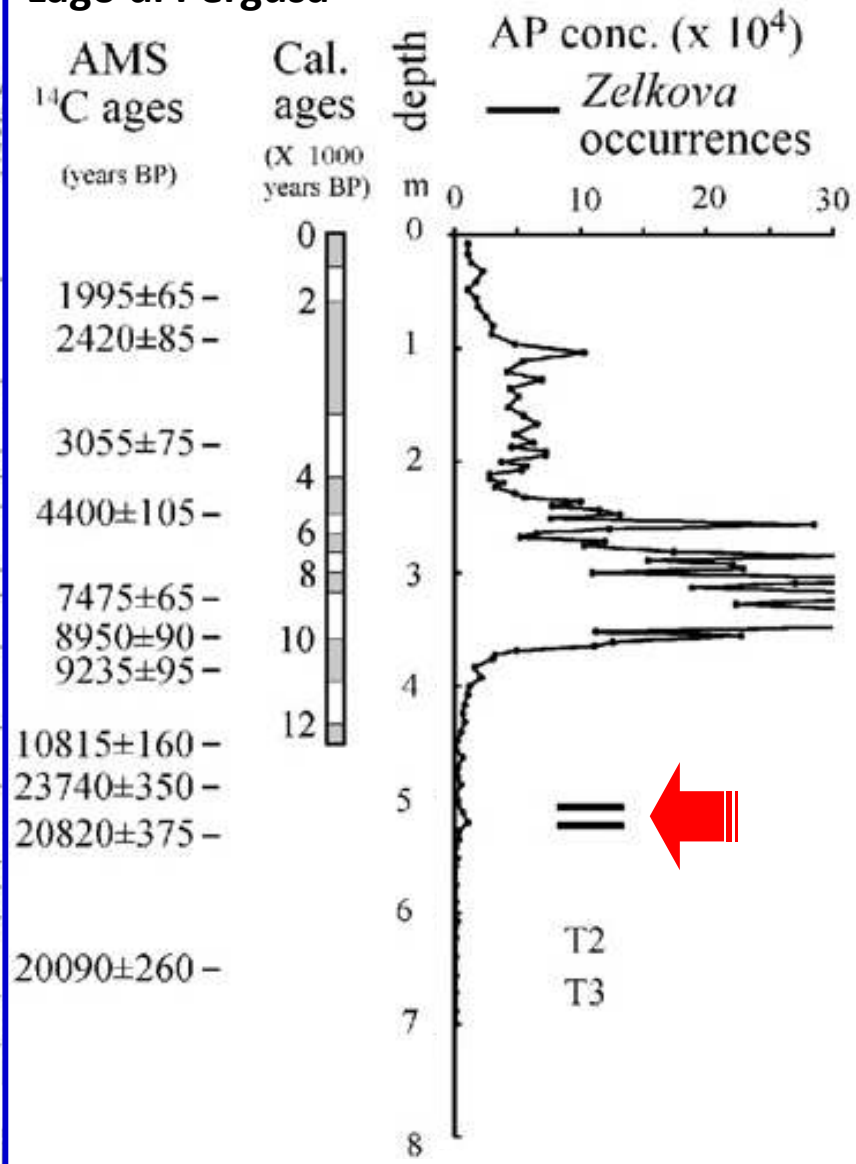


Fig. 4. Lago di Pergusa (Sicily, southern Italy). Stable isotopes, pollen, and microcharcoal selected curves (after Sadori et al., 2008)

Planning long-term conservation for *Z. sicula*

SUPRA-MEDITERRANEAN BELT

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

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

SUPRA-MEDITERRANEAN BELT

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

(MESO-)SUPRA-MEDITERRANEAN BELT

THANKS FOR YOUR ATTENTION