In situ conservation of crop wild relatives in Europe: a strategic approach

S. Kell[1], N. Maxted[1], L. Frese[2] and J.M. Iriondo[3]

[1]University of Birmingham, UK; [2]Julius Kühn-Institute, Quedlinburg, Germany; UK,
[3]Universidad Rey Juan Carlos, Madrid, Spain

Towards the establishment of genetic reserves for crop wild relatives and landraces in Europe

13–15 September 2010
University of Maderia, Funchal, Portugal

AEGRO

UNIVERSITY OF BIRMINGHAM

Objectives of this presentation

1. Define crop wild relatives (CWR)
2. Emphasize the value of CWR
3. Stress the need for *in situ* CWR conservation
   - number of species
   - conservation challenges
4. Propose a strategy for *in situ* conservation of European CWR
   - approaches to *in situ* CWR conservation
   - prioritizing CWR
   - identification of target genetic reserve sites

Mauricio Parra

Lupinus perennis

Crop wild relatives defined

A crop wild relative is a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the crop (Maxted *et al*., 2006)

László Udvardy

Trifolium alpestre

Crops can be any cultivated species, including:

–food, fodder and forage

–medicinal plants and condiments

–ornamental and forestry species

–industrial crops (e.g., oils and fibres)

The value of CWR

- Vavilov was instrumental in recognizing the potential of CWR for crop improvement and they have been used in plant breeding since the early 20th century

- CWR have provided vital genetic diversity for crop improvement, e.g.
  - resistance to pests and diseases
  - improved tolerance to environmental conditions, such as extreme temperatures, drought and flooding
  - improved nutrition, flavour, colour, texture and handling qualities

- In monetary terms, CWR have contributed significantly to the agricultural and horticultural industries, and to the world economy

N.I. Vavilov Research Institute of Plant Industry

N.I. Vavilov

The value of CWR cont'd

- CWR are recognized in a number of legal and policy documents, including the International Treaty on PGRFA and European Strategy for Plant Conservation
- They are likely to be increasingly important as gene donors in the face of climate change
- They are an important socio-economic resource that may offer the genetic diversity needed for future food security

László Udvardy

Vicia pannonica

The need for *in situ* CWR conservation

How many CWR are there?

- CWR account for around **21%** of the world's flora (Maxted and Kell, 2009)
- **> 15,000** CWR species native to Europe (**>13,000** in the EU)
- **> 8,000** CWR species endemic to Europe
- **> 300** CWR species native to Madeira
- How can we conserve all these species?

www.pgrforum.org/cwris/cwris.asp

Kell *et al*., 2005, 2008

The need for *in situ* CWR conservation

CWR conservation challenges

- CWR are under threat from habitat loss, agricultural intensification, over-collection, climate change and lack of conservation attention
- It is not economically or practically viable to conserve all CWR *ex situ*
  - Very large number of species
  - Ecogeographically and genetically diverse (compared to crops)
  - No chance to adapt to changing environment
  - Relatively few have immediate use potential
- *Ex situ* conservation of CWR is currently inadequate
  - Only 5.6% of *ex situ* PGR accessions reported by EURISCO are CWR
  - 24,448 accessions of 1,095 species
  - < 7% of EU CWR

László Udvardy

Trifolium rubens

The need for *in situ* CWR conservation

CWR conservation challenges cont'd

- Many CWR are found in existing protected areas, but are not being monitored and actively managed

- Examples of active *in situ* CWR genetic reserve conservation around the world are few and far between and are a 'drop in the ocean'
  - *Triticum* species in Ammiad, Eastern Galilee, Israel
  - *Aegilops* species in Ceylanpinar of South-east Turkey
  - *Zea perennis* in the Sierra de Manantlan, Mexico,
  - *Citrus*, *Oryza* and *Alocasia* species in Ngoc Hoi, Vietnam
  - *Solanum* species in Pisac Cusco, Peru

- European Strategy for Plant Conservation (2008)
  - **Establishment of 25 European CWR genetic reserves**
  - Gap analysis review of *ex situ* holdings and gap filling

Approaches to *in situ* CWR conservation

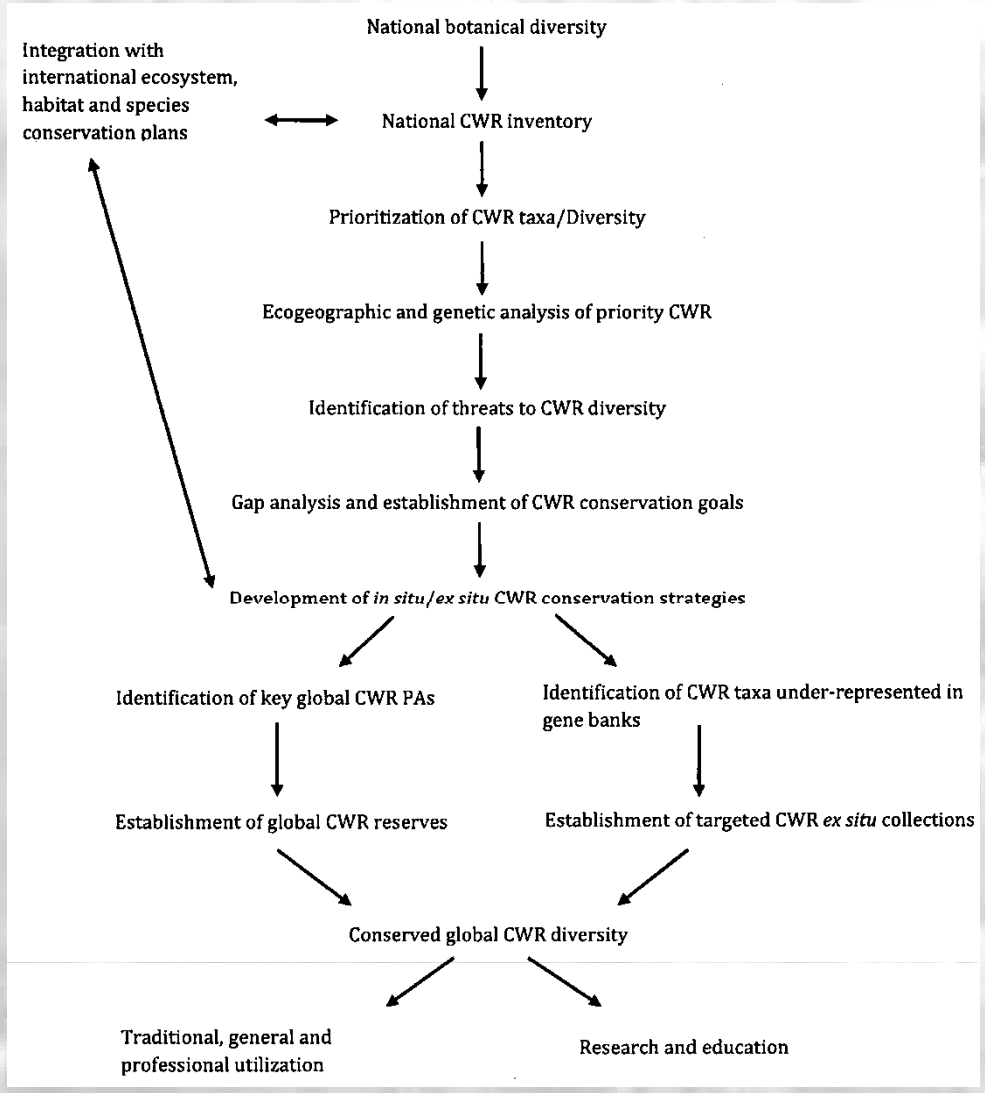
- We need to actively conserve CWR in genetic reserves (e.g., see Iriondo *et al*., 2008)
- But which species to conserve and where?
- Various approaches, depending on scale (+ time and resources)
- Scale
  - Geographic: global, regional, national
  - Taxonomic: floristic or monographic

Tünde Kovács

Aegilops cylindrica

Approaches to *in situ* CWR conservation

National CWR conservation strategy

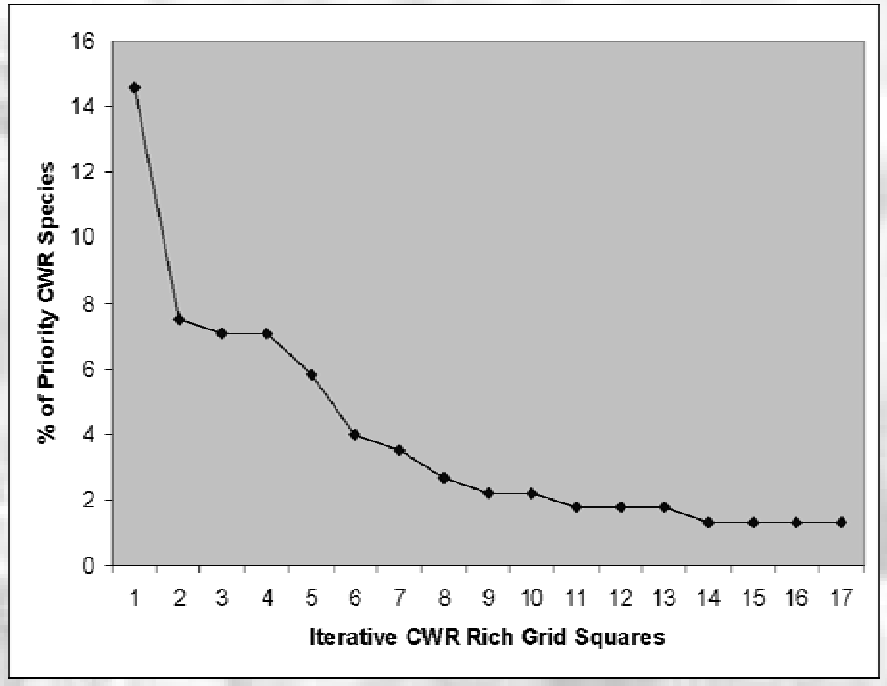


- National flora
- CWR inventory
- Prioritization
- Ecogeographic study
- Gap analysis
- Complementary conservation for national CWR diversity :
  - Genetic reserves *in situ*
  - Back-up *ex situ* collections

Maxted *et al*. (2007)

Approaches to *in situ* CWR conservation

National CWR conservation strategy (UK)



- 17 sites with 152 (67.3%) of UK CWR
- Methodology applied in Ireland, Portugal, Switzerland and UK (Maxted *et al*., 2007)

Approaches to *in situ* CWR conservation

Regional CWR conservation strategy (Europe)

- Combined floristic and monographic approach
  - Floristic = national CWR conservation strategies
  - Monographic = regional CWR conservation strategies for target crop gene pools
- How to select target crop gene pools?
- How to develop crop gene pool conservation strategies?

Brian Ford-Lloyd

Beta vulgaris subsp. *maritima*, *Crambe maritima* and *Lathyrus japonicus* subsp. *maritimus*

Prioritizing CWR

- Due to limited resources, rarely can we effect immediate conservation action for all taxa in a gene pool or in a national or regional CWR flora

- Prioritization is therefore a fundamental step in efficient PGR conservation

- Many approaches to prioritizing species and some progress in CWR prioritization (e.g., Maxted *et al*., 1997; Mitteau and Souzipet, 2000; Flor *et al*., 2006; Barazani *et al*., 2008; Ford-Lloyd *et al*., 2008; Maxted and Kell, 2009; Magos Brehm *et al*., 2010.)

- However, for CWR, an initial, simple prioritization on the basis of priority crop gene pools, ease of utilization and relative threat provides a solid basis for planning strategies for taxa in most urgent need of conservation action

Prioritizing CWR

Prioritizing crop gene pools

- Categories of use: food, fodder/forage, industrial, condiment, medicinal, ornamental, forestry/agroforestry

- Priorities will vary according to scale of prioritization (i.e., global, regional, national) and may even vary according to the implementing agency

- Highest priority are likely to be:
  - Food crops (important for nutrition and food security)
  - Crops of high economic value
  - Crops with multiple use values

Sarah Watson-Jones

Brassica nigra

Prioritizing CWR

Intra-gene pool prioritization: utilization potential

- All wild species are potential gene donors to crops using biotechnological techniques; however, they are relatively expensive and technically challenging and not available to all economies

Nigel Maxted

Luigi Guarino talking to plant breeders in Zambia. Foreground–sorghum

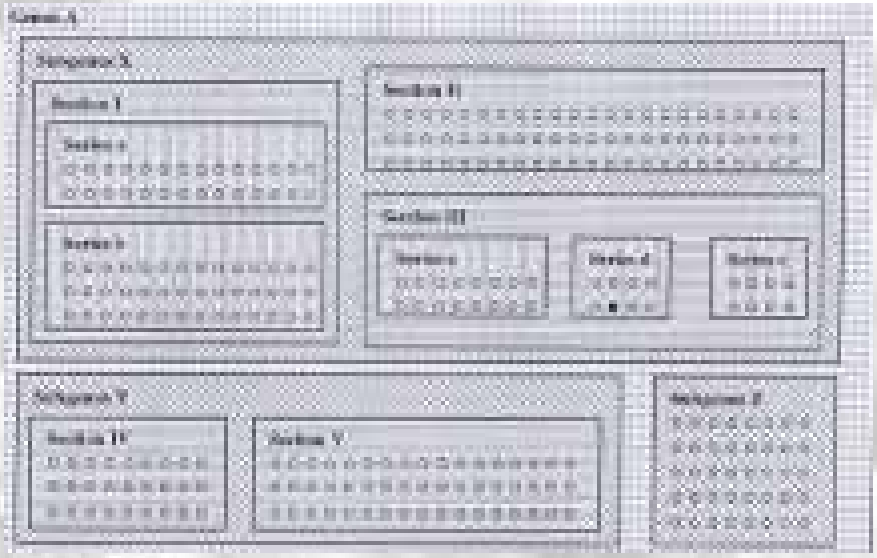
- The use of close CWR in inter-species gene transfer is likely to remain the global norm

Prioritizing CWR

Intra-gene pool prioritization: utilization potential

- Closest relatives (GP1b, GP2, TG1b, TG2)

Gene Pool concept
(Harlan and de Wet,1971)



Taxon Group concept
(Maxted *et al*., 2006)

- **AND** notable examples of tertiary wild relatives that have already shown promise for crop improvement

Prioritizing CWR

Intra-gene pool prioritization: relative threat

- Those in most **urgent** need of conservation based on relative threat
  - Threat assessment
    - IUCN Red List (but few CWR have been globally Red Listed)
    - National Red Lists
    - European Red List (coming soon!)
    - Threatened by association (e.g., habitat loss)
    - Literature
  - Endemism
  - Relative distribution

Lothar Frese

Ex situ sample of *Beta patula*

Developing crop gene pool conservation strategies: the AEGRO project

Crop gene pool methodology

A generic methodology for identification of priority sites for *in situ* CWR conservation, providing a framework for application to any crop gene pool

Four steps:

1. Taxon delineation
2. Selection of target taxa
3. Ecogeographic diversity analysis
4. Selection of target sites

Vavilovia formosa

Ivan Gabrielyan

Developing crop gene pool conservation strategies: the AEGRO project

A. Katsiosis

Avena sterilis, southern Spain

Crop gene pool methodology

- Tested with four crop case studies: *Avena, Beta, Brassica* and *Prunus*
- Case studies selected by the ECPGR crop networks

- Examples provide an opportunity of testing conservation methodologies in detail for four diverse crops—a grain, root, leafy vegetable and fruit crop

1. Taxon delineation

a) Generate a list of taxa that occur in the crop gene pool

- Adopt an accepted taxonomy to form the basis of the taxon list and the subsequent conservation strategy
- List accepted names and synonyms, with authorities (important because different information systems use different accepted taxonomies)
- Not all taxa in the gene pool will necessarily be immediately included in the CWR conservation strategy, but the complete list of taxa provides a reference point for future potential conservation actions of lower priority taxa or taxa in other geographical areas

b) List the taxa that occur within the geographical area of the conservation strategy

- For AEGRO, one list for the EU and one list for the national or subnational case study

2. Selection of target taxa

Utilization potential (GP1 & 2)

Example: Beet, *Beta vulgaris* subsp. *vulgaris*

Gene pool	Genus *Beta* L.
Primary	Section *Beta* Transhel *B. vulgaris* L. subsp. *vulgaris* (cultivated beets) subsp. *maritima* (L.) Arcang. subsp. *adanensis* (Pamuk.) Ford-Lloyd & Will. *B. macrocarpa* Guss. *B. patula* Ait.
Secondary	Section *Corollinae* Ulbrich Base species *B. corolliflora* Zosimovich *B. macrorhiza* Steven *B. lomatogona* Fisch & Meyer *B. nana* Boiss. & Heldr. Hybrid species *B. intermedia* Bunge *B. trigyna* Wald. & Kid.
	Genus *Patellifolia* Williams, Scott & Ford-Lloyd (syn. *Beta* Section *Procumbentes*)
Tertiary	*P. procumbens* (Smith) A.J.Scott, Ford-Lloyd & J.T.Williams *P. webbiana* (Moq.) A.J.Scott, Ford-Lloyd & J.T.Williams *P. patellaris* (Moq.) A.J.Scott, Ford-Lloyd & J.T.Williams

= CLOSE WILD RELATIVES

2. Selection of target taxa cont'd

Relative threat

R. Hannan

Beta nana—known from 7 localities in Greece

Lothar Frese

Beta macrocarpa

Example: *Beta* gene pool

- **High priority taxa**: *B. vulgaris* subsp. *adanensis*, *B. macrocarpa*, *B. patula*, *B. corolliflora*, *B. macrorhiza*, *B. lomatogona*, *B. nana*
- **Why?** Because they are primary and secondary CWR with limited distributions and/or specific habitat niches known to be under threat (e.g., *B. macrocarpa* in disturbed soils with high salinity)

2. Selection of target taxa cont'd

Utilization potential (GP3)

- **However**, in some cases, more distantly related taxa (GP3) have been highlighted as gene donors (or potential gene donors)

- These taxa are also of conservation priority

Example: *Beta* gene pool

- **High priority taxa**: *Patellifolia* species (GP3) (*P. procumbens*, *P. webbiana* and *P. patellaris*)

- **Why?** Donors of beet cyst nematode resistance (now successfully used in sugar beet production worldwide) and other resistance traits

Lothar Frese

Patellifolia procumbens on La Gomera, Canary Islands

2. Selection of target taxa cont'd

Relative threat cont'd

- If distribution data are readily available for all taxa in the gene pool, assess relative threat for all of them, not just the closest wild relatives (depends on size of gene pool, time and resources)
- Less closely related taxa may also be important as gene donors and should not be ignored in conservation planning!
- More widespread and common taxa should also not be ignored (e.g., *B. vulgaris* subsp. *maritima*—widespread but has useful traits linked to specific locations)
- Many of these taxa could become more restricted and threatened in the future, particularly in response to climate change!

Lothar Frese

Kalundborg Fjord, Denmark—origin of BNYVV resistance genes used in sugar beet breeding and production

3. Ecogeographic diversity analysis

1. Gather geographic (distribution) data on the target taxa (coordinate and descriptive)

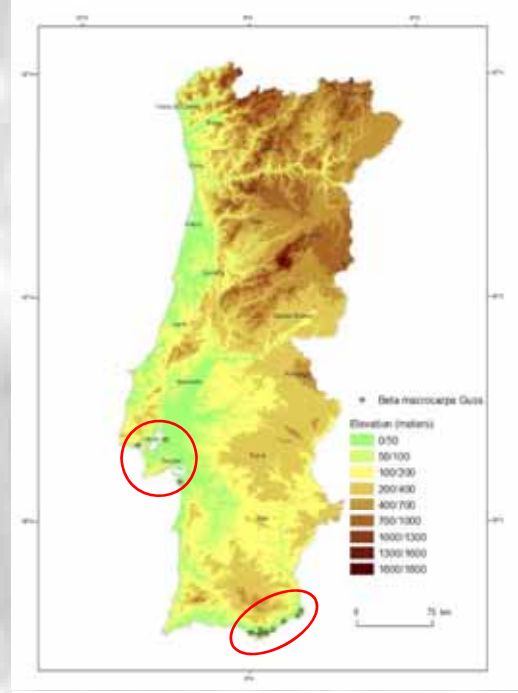
2. Gather ecological and environmental data on the target taxa (actual or predictive)

3. Gather genetic data on the target taxa (only possible where genetic diversity information already exists or where resources permit the generation of novel genetic diversity information)

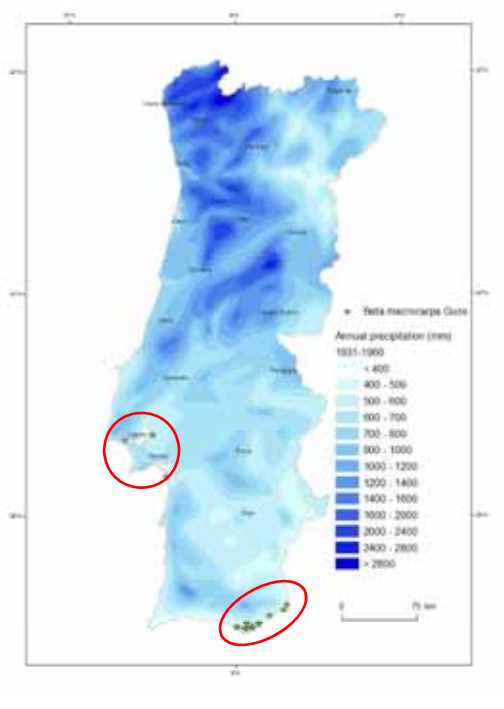
4. Analyse the ecogeographic data to build detailed taxon ecogeographic profiles – GIS programs can be used to create distribution maps overlaid with ecological, environmental and genetic data, and locate complementary reserve locations

3. Ecogeographic diversity analysis

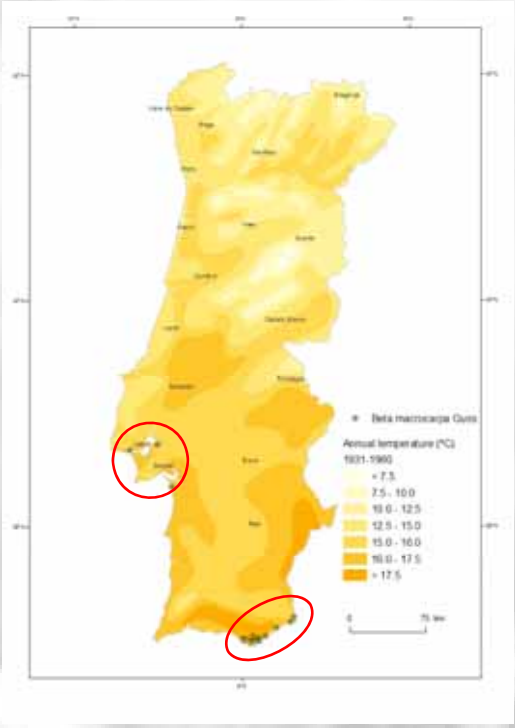
Example: *Beta macrocarpa* in Portugal



Elevation



Mean annual precipitation



Mean annual temperature

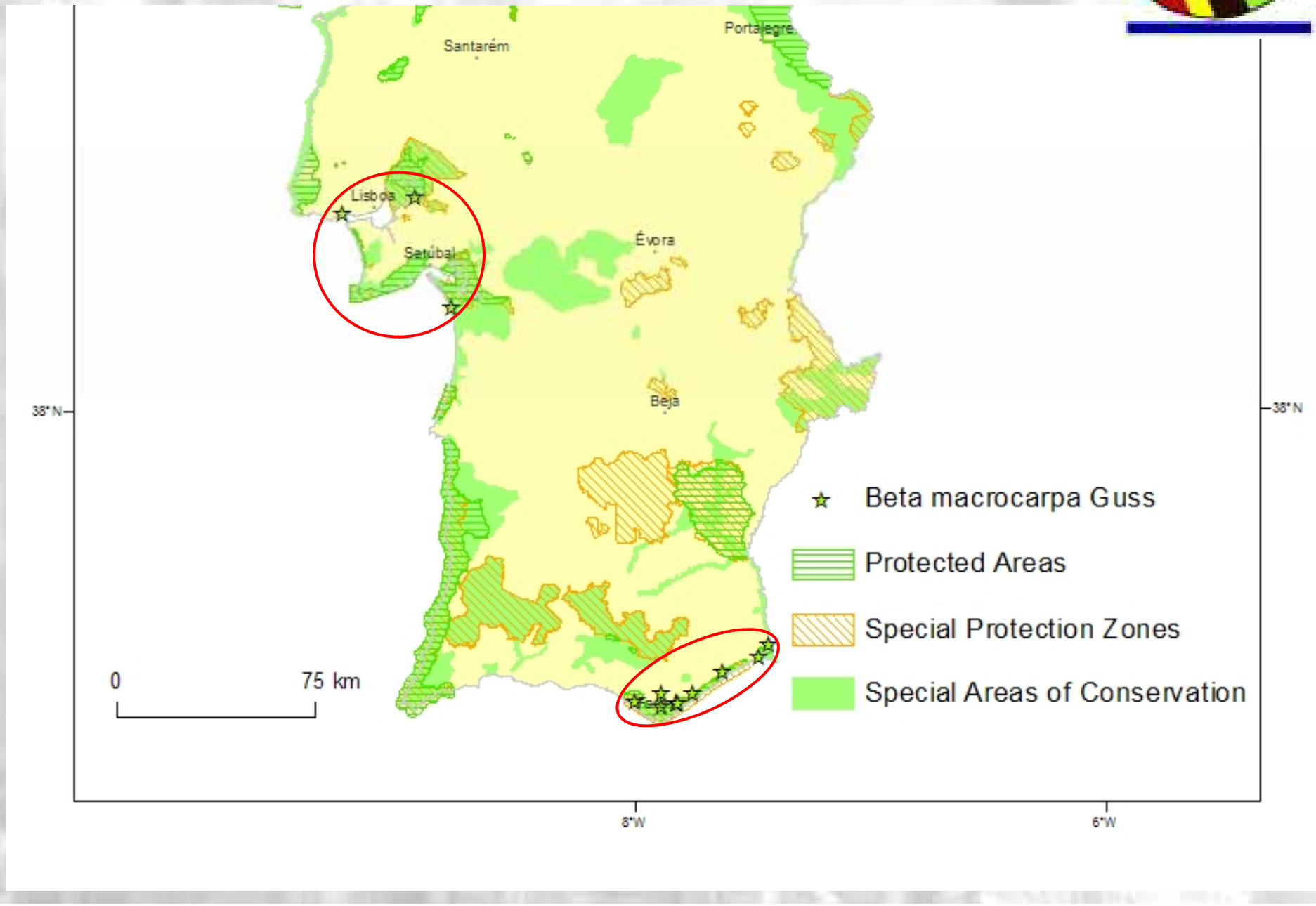
B. macrocarpa occurs almost exclusively in saline soils

Maps by C. Duarte

4. Selection of target sites

- Overlay target taxa distribution data with protected area shape files
- GIS analysis to ascertain whether populations occur within the boundaries of existing PAs
- Verify analysis with detailed ecogeographic and field studies where necessary
- Select sites for the establishment of CWR genetic reserves

Example: *Beta macrocarpa* in Portugal



4. Selection of target sites cont'd

- Aim is to conserve the maximum genetic diversity within and between populations of the target taxa – choose sites that are most likely to represent this diversity based on results of the ecogeographic diversity analysis
- Select sites within existing protected areas where possible – however, a balance will have to be met between ecogeographic suitability of sites and feasibility
- Establish multi-taxon reserves where possible
- Prioritize the selected sites on the basis of conservation of maximum genetic and/or taxonomic diversity
- Other factors to consider include land use, potential development pressures, level and quality of site management, legal status, potential conflict with existing site management aims and climate change

Example: *Beta macrocarpa* in Portugal

According to Villain (2007), Fuseta, Olhao, Portugal shows the highest number of alleles of all continental *B. macrocarpa* occurrences. *B. macrocarpa* grows sympatrically at the site with *B. vulgaris* subsp. *maritima*

http://aegro.bafz.de/index.php?id=188

Crop gene pool methodology testing

- Tested with the *Avena, Beta, Brassica* and *Prunus* gene pools
- Methodology can be applied to all crop gene pools
- Means of selecting target species varies from one gene pool to another, depending on:
  - the number of species in the gene pool (e.g., *Brassica* is a large genus compared to *Avena* and *Beta*)
  - the number of crops in the gene pool (e.g., *Brassica* contains several crops)
  - knowledge of the genetic relationship between species (e.g., better knowledge for *Avena* and *Beta* than for *Brassica*)
  - knowledge of the breeding potential of species (e.g., better knowledge for *Avena* and *Beta* than for *Brassica*)

Crop gene pool methodology testing cont'd

- Means of selecting target sites varies from one gene pool to another, depending on:
  - existing knowledge of intraspecific genetic diversity of target species
  - existing knowledge of localities of target species (e.g., population size, threats, suitability of the site to establish a genetic reserve)
- Application of the methodology highlighted the difficulty of dealing with:
  - taxonomic data (i.e., different nomenclature in different information systems)
  - occurrence data (e.g., lack of coordinates, problems of data quality, evenness of data quality across Europe)
- AEGRO has however developed systems to help manage these problems (e.g., the site converter software)

Conclusions

- CWR are a threatened and neglected resource that are likely to become increasingly important for food security in the face of climate change (FAO, 2009)
- *In situ* and *ex situ* CWR conservation is currently inadequate
- *In situ* CWR conservation is urgently needed with adequate *ex situ* back-up
- We need a logical and systematic framework for CWR conservation in Europe, applicable to any crop gene pool or country, involving both the floristic and monographic approaches
- A strategic approach has been developed and tested globally, regionally and nationally
- The challenge now is to apply the strategy to the highest priority CWR of Europe to secure our critical wild PGRFA

References

Barazani, O., Perevolotsky, A. and Hadas, R. (2008) A problem of the rich: prioritizing local plant genetic resources for *ex situ conservation in Israel. Biological Conservation* 141, 596–600.

FAO (2009) *Draft second report on the state of the world's plant genetic resources for food and agriculture*. Commission on Genetic Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations, Rome, Italy.

Flor, A., Bettencourt, E., Arriegas, P.I. and Dias, S.R. (2006) European crop wild relative conservation criteria –indicators for the CWR species' list prioritization. In: Ford-Lloyd, B.V., Dias, S.R. and Bettencourt, E. (eds.) *Genetic Erosion and Pollution Assessment Methodologies: Proceedings of PGR Forum Workshop 5, Terceira Island, Autonomous Region of the Azores, Portugal, 8–11 September 2004. Bioversity International, Rome,* Italy. Pp. 83–87.

Ford-Lloyd, B.V., Maxted, N. and Kell, S.P. (2008) Establishing conservation priorities for crop wild relatives. In: Maxted, N., Ford-Lloyd, B.V., Kell, S.P., Iriondo, J., Dulloo, E. and Turok, J. (eds) *Crop Wild Relative Conservation and Use.* CAB International, Wallingford, UK. Pp. 110–119.

Harlan, J.R. and de Wet, J.M.J. (1971) Towards a rational classification of cultivated plants. *Taxon* 20: 509–517.

Iriondo, J.M., Maxted, N. and Dulloo, M.E. (eds.) (2008) *Conserving Plant Genetic Diversity in Protected Areas: Population Management of Crop Wild Relatives*. CAB International Publishing, Wallingford. 288 pp.

Kell, S.P., Knüpffer, H., Jury, S.L., Maxted, N. and Ford-Lloyd, B.V. (2005) *Catalogue of Crop Wild Relatives for Europe and the Mediterranean*. Available online via the PGR Forum Crop Wild Relative Information System (CWRIS – http://www.pgrforum.org/cwris/cwris.asp) and on CD-ROM. © University of Birmingham, UK.

Kell, S.P., Knüpffer, H., Jury, S.L., Ford-Lloyd, B.V. and Maxted, N. (2008) Crops and wild relatives of the Euro-Mediterranean region: making and using a conservation catalogue. In: Maxted, N., Ford-Lloyd, B.V., Kell, S.P., Iriondo, J., Dulloo, E. and Turok, J. (eds.), *Crop Wild Relative Conservation and Use*. CAB International, Wallingford, UK. Pp. 69–109.

Magos Brehm, J., Maxted, N., Martins-Loução, M.A. and Ford-Lloyd, B.V. (2010) New approaches for establishing conservation priorities for socio-economically important plant species. Biodiversity and Conservation 19: 2715–2740.

Maxted, N. and Kell, S.P. (2009) *Establishment of a Global Network for the* In Situ *Conservation of Crop Wild Relatives: Status and Needs*. FAO Commission on Genetic Resources for Food and Agriculture, Rome, Italy. 266 pp.

Maxted, N., Hawkes, J.G., Guarino, L. and Sawkins, M. (1997) The selection of taxa fro plant genetic conservation. *Genetic Resources and Crop Evolution* 44: 337–348.

Maxted, N., Ford-Lloyd, B.V., Jury, S.L., Kell, S.P. and Scholten, M.A. (2006) Towards a definition of a crop wild relative. *Biodiversity and Conservation* 15(8): 2673–2685.

Maxted, N., Scholten, M., Codd, R. and Ford-Lloyd, B. (2007) Creation and use of a national inventory of crop wild relatives. *Biological Conservation* 140, 142–159.

Mitteau, M. and Soupizet, F. (2000) Preparation of a preliminary list of priority target species for *in situ* conservation in Europe. In: Laliberté, B., Maggioni, L., Maxted, N. and Negri, V. (compilers), *ECP/GR In Situ and On-farm Conservation Network Report of a Task Force on Wild Species Conservation in Genetic Reserves and a Task Force on On-farm Conservation and Management Joint Meeting, 18–20 May 2000, Isola Polvese, Italy.* IPGRI, Rome, Italy. Pp. 32–42.

Villain (2007) *Histoire evolutive de la section Beta. Mise en évidence des phénomènes d'hybridation et de spéciation au sein des la section dans le bassin méditerranéen*. These pour obtenir le grade de docteur en sciences de l'Université de Lille 1. Spécialité: Sciences de la vie. Université des Sciences et Technologies de Lille 1.

In situ conservation of crop wild relatives in Europe: a strategic approach

Thanks for your attention!

Towards the establishment of genetic reserves for crop wild relatives and landraces in Europe

13–15 September 2010
University of Maderia, Funchal, Portugal

AEGRO

UNIVERSITY OF BIRMINGHAM