BIOLOGY AND GENETICS OF RARE AND ENDEMIC PLANT SPECIES:THEIR CONSERVATION STRATEGIES

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OVERVIEW

- Species
- Speciation models
- Species diversity and Mediterranean Region
- Rare species diversity in the world
- Species diversity in Turkey
- Rarity and genetic variation in rare plants
- Reproductive biology of rare plants
- Possible causes of extinctions
- Conservation strategies
  - *In situ*
  - *Ex situ*

WHAT IS THE SPECIES?

- Species are distinguished as sets of populations separated by a detectable morphological discontinuity from other sets.
  - e.g., "Species are the smallest groups that are consistently and persistently distinct, and distinguishable by ordinary means" (Arthur Cronquist)

- Species is a group of interbreeding populations which are reproductively isolated from other such groups" (Ernst Mayr)

SPECIATION MODELS

Models grouped by major forces initiating the speciation event

1. Geographic speciation--initiated by geographic distance;
   a. Classic allopatric speciation
   b. Founder effect speciation
   c. Peripheral isolates
2. Polyploid speciation--initiated by chromosome doubling
   a. Allopolyploid
   b. Autopolyploid
3. Chromosomal speciation--initiated by chromosomal rearrangements
   a. Homoploid hybrid
   b. Quantum ("catastrophic")
   c. Stasipatric
4. Ecological speciation--initiated by ecological shifts; includes recent models of "sympatric" speciation and some parapatric speciation
5. Asexual speciation

GEOGRAPHIC SPECIATION-I

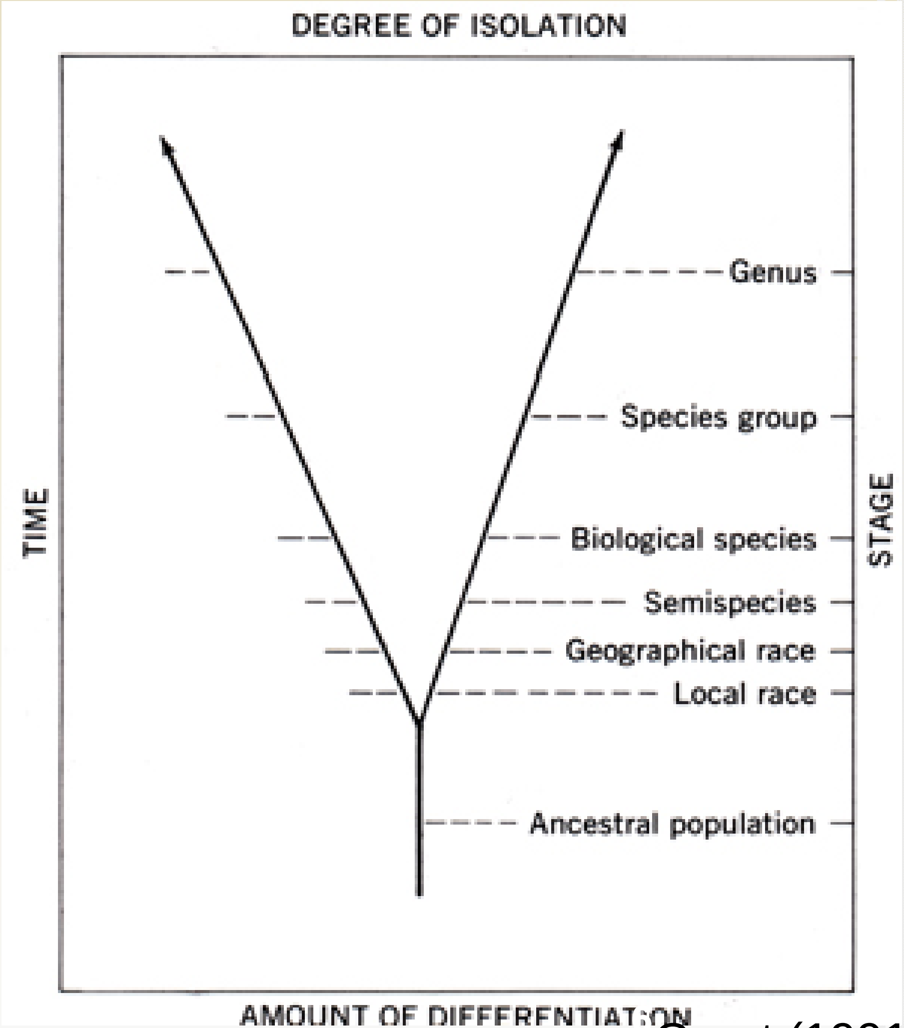
General principles

- Requires separation of two (sets of) populations by distance sufficient to prevent long-term interbreeding
- Long regarded as the most common mode of speciation in both plants and animals—largely insisted upon by zoologists for animals
- Lots of circumstantial evidence from investigations of geographic races

GEOGRAPHIC SPECIATION-II

- Theoretical relation noted between degree of genetic differentiation between two (sets of) populations and ability to interbreed:

- Polymorphism → local races → geographical races → semispecies → biological species → distinct groups



Grant (1991)

Geographical isolation

Cercis canadensis

Cercis occidentalis

Cercis siliquastrum

POLYPLOID SPECIATION-I

- Chromosome doubling subsequently prevents interbreeding of polyploid with individuals of lower ploidy because of meiotic imbalances in interploid hybrids
- New polyploid free to diverge through "silencing" of different duplicated gene loci
- Abrupt" speciation--arises spontaneously in plants
- Does not require geographic separation--truly "sympatric" speciation

<u>Autopolyploidy</u>
Adiantum pedatum
Epilobium augustifolium
Tolmeia menzesii

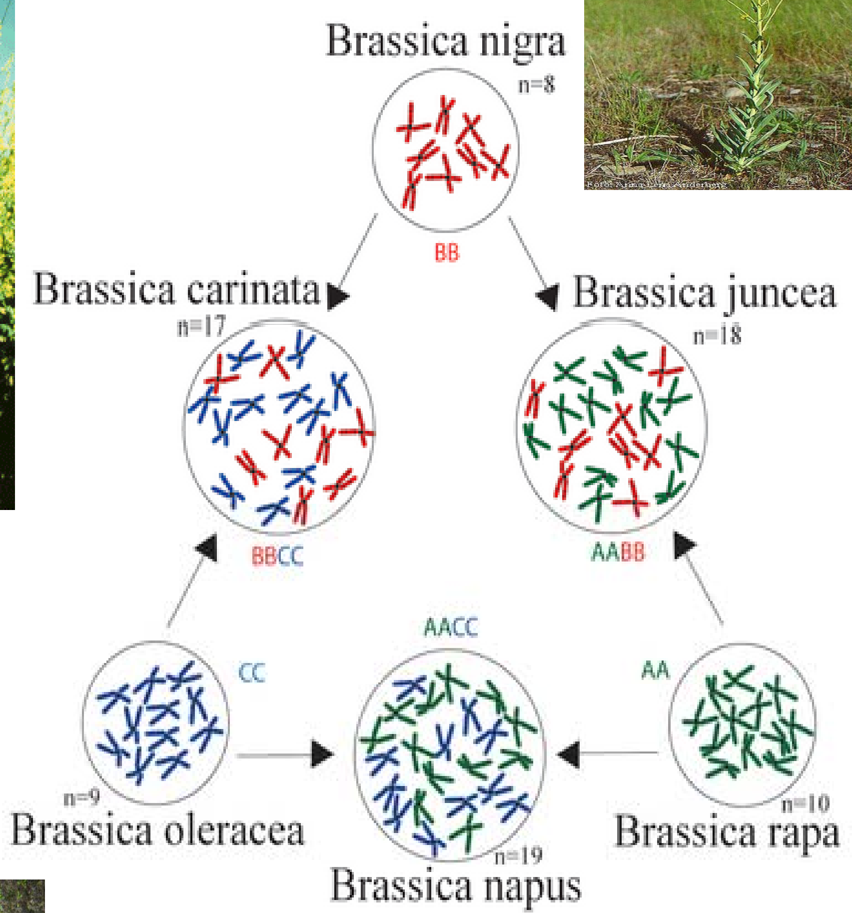
<u>Allopolyploidy</u>
- *Brassica* sp.
- *Raphanobrassica*
- *Tragopogon miscellus*
- *Triticale*
- *Selaginella sp.*

POLYPLOID SPECIATION-II

BRASSICA TRIANGLE

Black mustard

Ethiopian mustard



Indian mustard

Cabbage

Rapeseed

Turnip

ECOLOGICAL SPECIATION-I

- Numerous plant groups with weak intrinsic reproductive isolation evolved through this; e.g., oaks, violets
- Probably a very widespread process—

  -Otherwise, why is ecological differentiation almost universal among related plant species?

Ecological Speciation-II

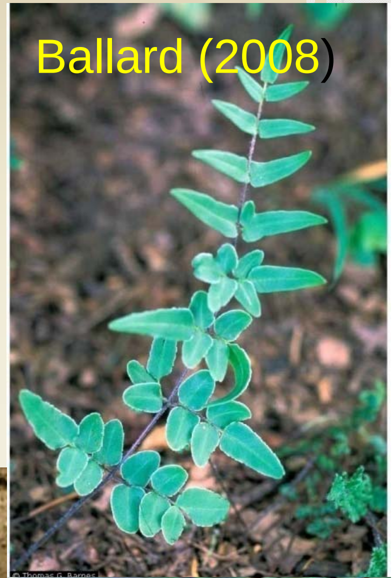
- Two populations gradually adapt to different niches or ecological conditions
- With extension, can embrace allochronic and other types of sympatric and parapatric speciation
- Proposed for various closely related plant species pairs showing ecological divergence
- Certainly could act with other models

ASEXUAL SPECIATION

- e.g., hybrid apomictic complexes in dandelions (*Taraxacum*) and other Asteraceae, blackberries (*Rubus*) in Rosaceae

- Genus *Pellaea* (ferns), one widespread species is apogamous triploid, two are apogamous tetraploids, all of hybrid origin (Gastony, 1988)

P. atropurpurea **(3x)**



P. glabella **(4x)**

P. suksdorfiana **(4x)**
E. Alverson, photo

Number of Plant Species

Category	Species	Totals
Vertebrate Animals		
Mammals	5,416	
Birds	9,956	
Reptiles	8,240	
Amphibians	6,199	
Fishes	30,000	
Total Vertebrates		59,811
Invertebrate Animals		
Insects	950,000	
Molluscs	81,000	
Crustaceans	40,000	
Corals	2,175	
Others	130,200	
Total Invertebrates		1,203,375
Plants		
Flowering plants (angiosperms)	**258,650**	
Conifers (gymnosperms)	**980**	
Ferns and horsetails	**13,025**	
Mosses	**15,000**	
Red and green algae	**9,671**	
Total Plants		**297,326**
Others		
Lichens	10,000	
Mushrooms	16,000	
Brown algae	2,849	
Total Others		28,849
TOTAL SPECIES		1,589,361

Numbers of plant species occurring in and endemic to each of the 34 hotspots

Hotspot	Plant Species	Endemic Plant Species	Endemics as a Percentage of World Total
Atlantic Forest	20,000	8,000	2.7
California Floristic Province	3,488	2,124	0.7
Cape Floristic Region	9,000	6,210	2.1
Caribbean Islands	13,000	6,550	2.2
Caucasus	6,400	1,600	0.5
Cerrado	10,000	4,400	1.5
Chilean Winter Rainfall - Valdivian Forests	3,892	1,957	0.7
Coastal Forests of Eastern Africa	4,000	1,750	0.6
East Melanesian Islands	8,000	3,000	1.0
Eastern Afromontane	7,598	2,356	0.8
Guinean Forests of West Africa	9,000	1,800	0.6
Himalaya	10,000	3,160	1.1
Horn of Africa	5,000	2,750	0.9
Indo - Burma	13,500	7,000	2.3
Irano - Anatolian	6,000	2,500	0.8
Japan	5,600	1,950	0.7
Madagascar and the Indian Ocean Islands	13,000	11,600	3.9
Madrean Pine - Oak Woodlands	5,300	3,975	1.3
Maputaland - Pondoland - Albany	8,100	1,900	0.6
Mediterranean Basin	**22,500**	**11,700**	**3.9**
Mesoamerica	17,000	2,941	1.0
Mountains of Central Asia	5,500	1,500	0.5
Mountains of Southwest China	12,000	3,500	1.2
New Zealand	2,300	1,865	0.6
Philippines	9,253	6,091	2.0
Polynesia - Micronesia	5,330	3,074	1.0
Southwest Australia	5,571	2,948	1.0
Succulent Karoo	6,356	2,439	0.8
Sundaland	**25,000**	**15,000**	**5.0**
Tropical Andes	**30,000**	**15,000**	**5.0**
Tumbes - Choc	11,000	2,750	0.9
Wallacea	10,000	1,500	0.5
Western Ghats and Sri Lanka	5,916	3,049	1.0

http://www.biodiversityhotspots.org/

MEDITERRANEAN ECOSYSTEMS

•2.2 %of the Earth's land Surface

•20% of the known plant species

•Habitat destruction and fragmentation due to urbanization and expanding agriculture

•41% of land converted to agriculture and only 5% is protected

•Every ha is saved /8 ha lost (This ratio is ½ in the tropical rain forests)

www.nature.org/

1 in 10 recorded species is now considered either rare or endangered!

The ratio of Rare and Threatened Plants

- •10% of Flora in the US
- •17 % of Flora in Europe
- •17% of Flora in Australia
- •9% of Flora in South Africa
- •9 % of Flora in New Zealand
- •11.7% of Flora in Turkey

(Briggs & Leigh 1988; Davis et al 1986)

The National Biological Diversity Strategy and Action Plan of Turkey, 2007

Plant Groups	Defined Species/ subspecies	Endemic Species	Rare and Endangered Species	Extinct species
Algae	2.150	----	unknown	unknown
Lichen (Lichenes)	1000	----	unknown	unknown
Moss (Bryophytes)	910	2	2	unknown
Pteridophytes Ferns	101	3	1	unknown
Gymnospermae (Gymnosperms)	35	5	1	unknown
Monocotyledonous (Monocotyledons)	1.765	420	180	-
Dicotyledonous (Dicotyledons)	9.100	3500	1100	11

Distribution of endemic plant species among the phyto-geographical regions (including subspecies and varieties)/Turkey

Phytogeographical regions	number of endemics
•Euro-Siberian	320
•Mediterranean	1325
•Irano-Turanian	1250
•Non-specific to particular phytogeographical region	1030
Total	3925

High-Mountain Ecosystems	
•Euro-Siberian	11
•Mediterranean	25
•Irano –Turanian	19

The National Biological Diversity Strategy and Action Plan of Turkey, 2007

Rare Plants

<u>Small populations</u>

- •ecological causes (Harper 1977)
  - •A few available sites
  - •Low carrying capacity
  - •Habitability of site is short
  - •Early colonization stage
- •Genetics & Evolution
  - •Rarity (Wide vs Narrow; Large vs. Small)
  - •Small Population (recently rare vs always rare)

BIOLOGY AND GENETICS OF RARE PLANTS

Classes of rarity

- Sparse species (low local density)
- Habitat specialist (edaphically restricted taxa)
- Geographical restrictions (threatened and endangered species)

Biology and genetics of Rare Plants/Genetic variation in Rare Plants

Levels of Genetic variation

•Reduced levels of genetic variation (genetic drift, founder effects; strong directional selection towards uniformity)

•Restricted species/low genetic variation
vs.
widespread species/high genetic variation

•Geographical range is a poor predictor for level of genetic variation

Genetic variation in rare vs common plants

Cole, CT.2003. Annual Review of Ecology, Evolution, and Systematics

- Isozyme variation in 247 plant species (57 generic-level comparisons of rare and common species)

- The reduction in gene flow (N*m*) among populations of rare species

- Species monomorphic for isozymes are predominantly endemic and self-fertile.

- Studied populations of virtually all rare species had higher levels of genetic erosion than levels at which theory would predict.

Biology and genetics of Rare Plants/ Levels of Genetic variation

Taxon	Range (R,W)	P / %P	Mean alleles / Locus
Astragalus linofolius	**R**	**12 / 33.3 %**	**2.3**
A. pectinatus	W	12/33.3	3.3
Layia discoidea	**R**	**21 / 90.5**	**2.7**
Layia Glandulosa	W	21/81	3.6
Eucalyptus grandis	W	20/60	Not reported
Eucalyptus caesia	**R**	**18 / 38.8**	**2.1**
Oenothera organensis	**R**	**15 / 6.7**	**2.0**
O. biennis	W	18/33.3	2.8
Pinus longaeva	**R**	**14 / 78.6**	**2.6**
Pinus radiata	**R**	**22 / 45.4**	**2.2**
Pinus toreyana	**R**	**59 / 3.45**	**2.0**
Pinus resinosa	W	27/11.1	2.0
Pinus contarta	W	25/92	3.2
Abies equitrojani	R	19/44.7	1.6 (Gülbaba et al., 1997)

Allozyme data (From Karron, 1987)

BIOLOGY AND GENETICS OF RARE PLANTS /GENETIC VARIATION-GEOGRAPHICAL RANGE

Geographical Range	# of studies	Ht	Gst	Ap	Pa (%)
Endemic	10	.275	.200	3.26	63.9
Narrow	31	.261	.275	2.96	60.9
Regional	38	.238	.312	3.23	57.3
Widespread	43	.380	.253	3.70	70.2

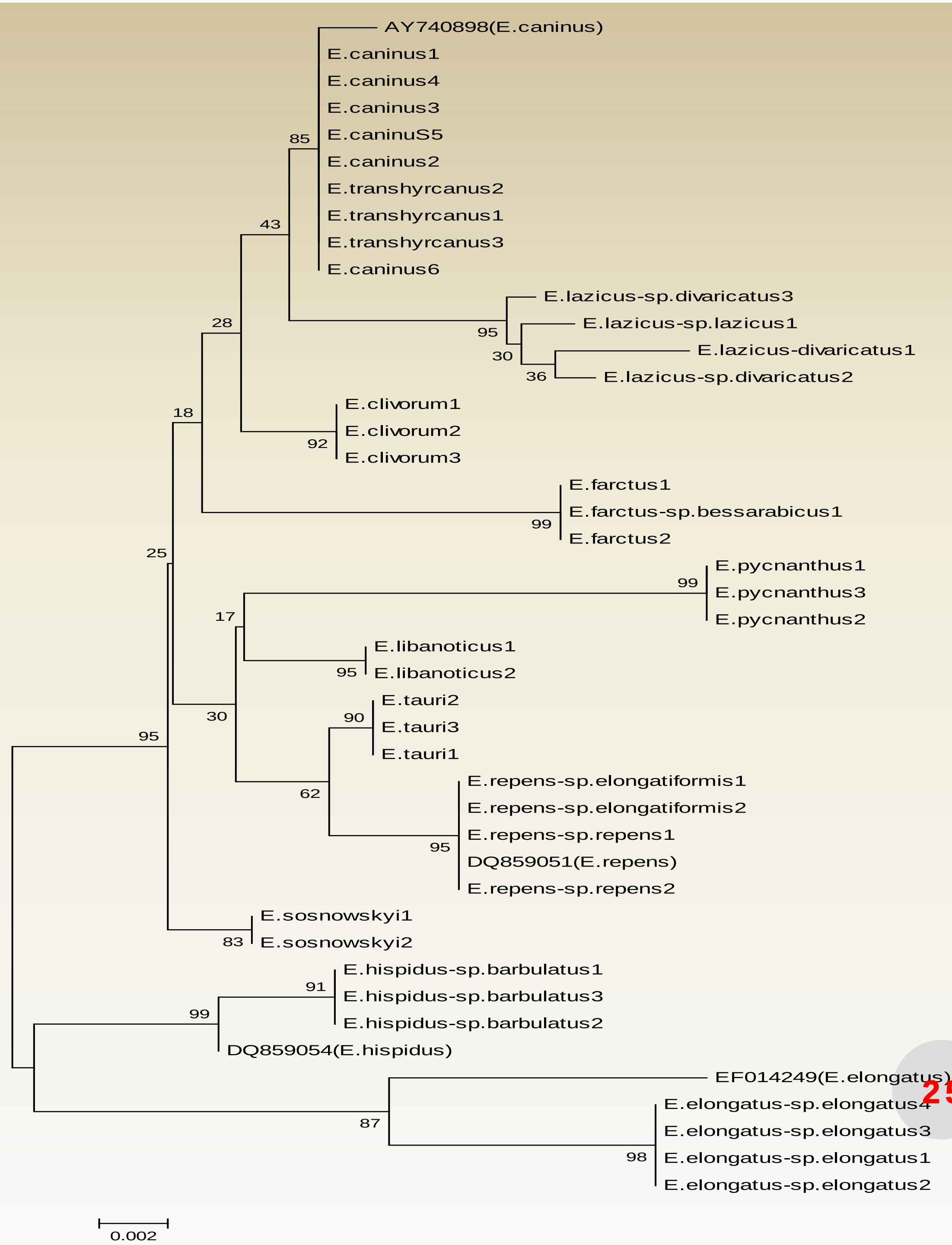
Allozyme variability in 91 species of seed plants (Hamrick,1983)

MOLECULAR DIVERSITY OF *ELYMUS*, *AGROPYRON*, *LEYMUS*, & *HORDELYMUS* GENERA

Genus	Genetic diversity
Elymus	0.017
Agropyron	0.001
Leymus	0.002
Hordelymus	0.001

(Dizkırıcı et al., 2010)

The evolutionary history was inferred using the neighbor-joining method . Data was obtained from the nrDNA ITS sequences of 12 taxa from *Elymus*



(Dizkirici et al., 2010)

Reproductive biology of Rare Plants

Breeding and reproductive systems/

- Favor the evolution of self-fertility

- Population size fluctuates and population differences occur

- Natural selection increases self-pollinating individuals if there are less mates and pollinators available

- Very little known in reproductive biology of rare plants, but generally reduced spatial separation of stigma and anthers

- Less inbreeding depression

- Locally endemic species with reduced polymorphism

POSSIBLE CAUSES OF EXTINCTION

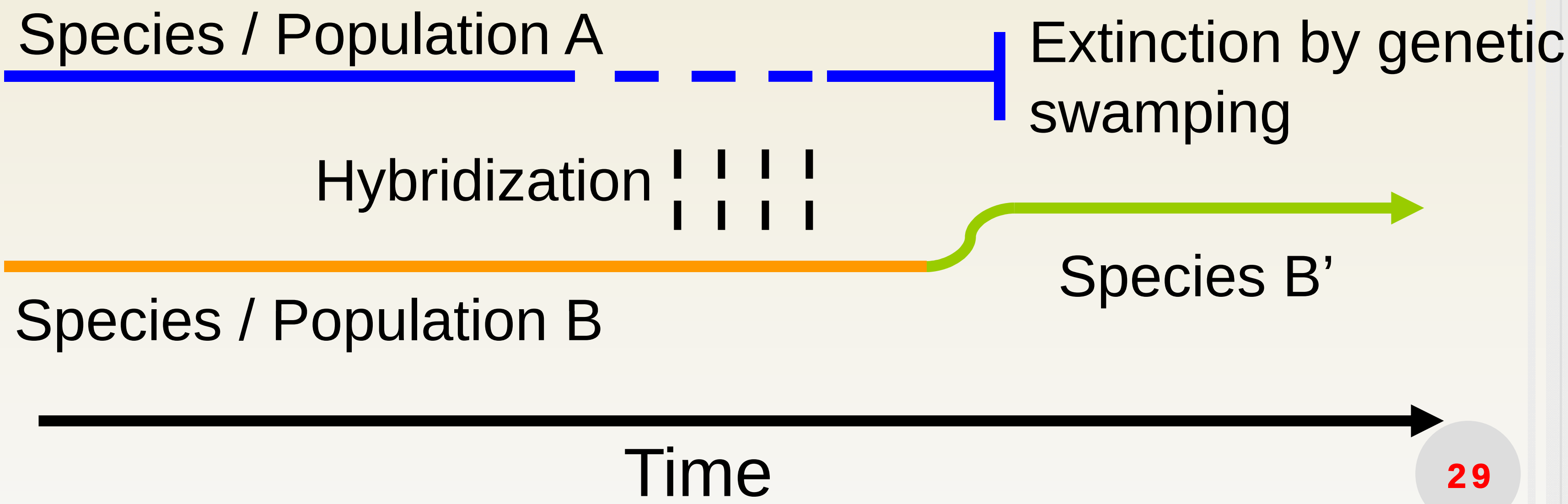
- Deterministic factors (stacked deck)
  - Realized growth rate is negative.
  - Deaths > Births

- Stochastic factors (bad luck)
  - Intrinsic
    - genetic stochasticity
    - demographic stochasticity
  - Extrinsic
    - environmental variation (EV)
    - catastrophe

Deterministic Threats

- Change in physical environment
  - climate change
  - habitat destruction
  - pollution
- Change in biotic environment
  - Competition
  - Ddisease and human gathering
  - Mutualism

CAUSES OF EXTINCTION (GENETIC SWAMPING)



Biology and genetics of Rare & Endemic Plants/ Conservation Strategies

The conservation strategies will depend on:

- Life form of species
- Current conservation status
- Economical Value
- Magnitude and pattern of genetic diversity (moprhological, allozymes, DNA variation (Chlorplast, ribosomal DNA , hypervariable sequences), SNPs , genomic and proteomic data etc..)

GENETIC ARCHITECTURE OF RARE VS WIDESPREAD SPECIES

Rare Species:

•No or Little genetic variation within species (*Pinus resinosa, Thuja plicata*)

•No variation within populations/Variation Among Populations (*Pinus torreyana*)

•Little variation within populations, Little variation among populations (*Abies bracteata*)

Widespread species:

•High variation within populations/ Little variation among populations (*Libocedrus decurrens, Pinus monticola*)

•High variation within populations, High variation among populations

Disontinuous (ecotypic) (*Pinus ponderosa*)

Continuous (Clines) (*Pinus contorta, Pseudotsuga menziesii*)

Millar and Libby (1991)

CONSERVATION APPROACHES

Conservation strategy in general; Advocate management that avoid inbreeding and maintain large populations with unrelated individuals

In Situ

•In rare or species with limited distribution/ Conserving entire species through habitat conservation (*Abies equitrojani*)

•Widespread Species

•If species required cross pollination, especially insect pollination

**In situ* conservation with restriction of pesticides uses

Conserve genetic material from as many populations as possible

→Gene Resource Management Units/ Gene Management Zones

Representing core diversity + buffers, connectivity

Considering;duplication, effective population size, Size and ownership of reserve land, management possibilities, awareness, generation of income etc.

Habitat vs Landscape conservation!

Gene Resource Management Units/ Gene Management Zones

In Situ Gene Conservation Project (1993-1997)

•Zencirci, N., Kaya, Z., Anikster, Y., and Adams, W.T. (eds). 1998. The proceedings of International Symposium on *in situ* Conservation of Plant Genetic Diversity. Central Research Institute for Field Crops Publication, Ankara, 391p.

•Kaya, Z., Kun, E., and Güner, A. 1997. National Plan for *in situ* Conservation of Plant Genetic Diversity in Turkey. Milli Egitim Basimevi, Istanbul, 125p.

CONSERVATION APPROACHES/ *EX SITU*

Conservation strategy in general; Advocate management that avoid inbreeding and maintain large populations with unrelated individuals

Ex situ

1) Which species should be collected?

•rare or species with limited distribution/

•Widespread Species

Sampling procedures are important!

Species should be given high priority if it is characterized as:

- High degree of endangerement
- Decline of population numbers and size
- Taxonomica nd evolutionary uniqueness
- Biological management and recovery
- Value as genetic resources
- Successful cultivation and maintenance in strorage

CONSERVATION APPROACHES/ *EX SITU*

2) How many populations should be sampled per species?

Key biological consideration is degree of genetic difference among populations!

<u>Suggestion that up to five population could be sampled for each species based on following criteria:</u>

- Destruction of populations
- Degree of ecotypic varaition
- Isolated populations
- Biological management and recovery
- Self fertilization
- Recent or anthropgenic rarity
- Successional stage
- Life history traits (annual vs perennial, seed dispersal, monocot vs dicot etc.)

CONSERVATION APPROACHES/ *EX SITU*

3) How many individuals should be sampled per populationspecies?
Sampled individuals vary with size of population, but suggested that sampling of 10-50 individuals per population is reasonable, it could be increased based on following criteria:

- Degree of microsite variation
- Mating system
- Small breeding neighborhood size
- Low seed- survival
- Large population size
- Late successional stage
- Life history traits (annual vs perennial, seed dispersal, monocot vs dicot etc)

CONSERVATION APPROACHES/ *EX SITU*

4) How many propagules should be sampled per individual?

Sufficient numbers of propagules to represent a genotype! It could be determined as follow:

Total number of propagules per population (C_p)= I *1/(s/N)

Where s is surviving propagules and N is total sample size

•Example: If s/N=0.25, I=25 individuals per population

Cp= 25* (1/0.25)= 100

Number of propgaules per individual= 100/25→ 4

5) In what cases a multiyear collection should be done?

Collection should be spread over more than a year if propagules can not be sampled without interfering with the reproductive ecology and demography of the population.

- Year –year variation in population size and or structure (climatic fluctuation, pathogen effects, population dynamics, species flowering pattern etc.)

Future challenges of conservation of plant genetic resources

- Conservation of plant genetic resources are expensive
- Plant genetic resources are threatened
- Plant genetic resources are precious
- Conserving plant genetic resources in their natural habitats and backing up with *ex-situ* programs

➡ With low input, plant genetic resources could be effectively conserved if conservation programs for plant genetic resources are integrated with National Biodiversity Conservation Programs

THANK YOU