Introduction to ecogeographic / botanical surveys

Promoting In-situ conservation of Agrobiodiversity

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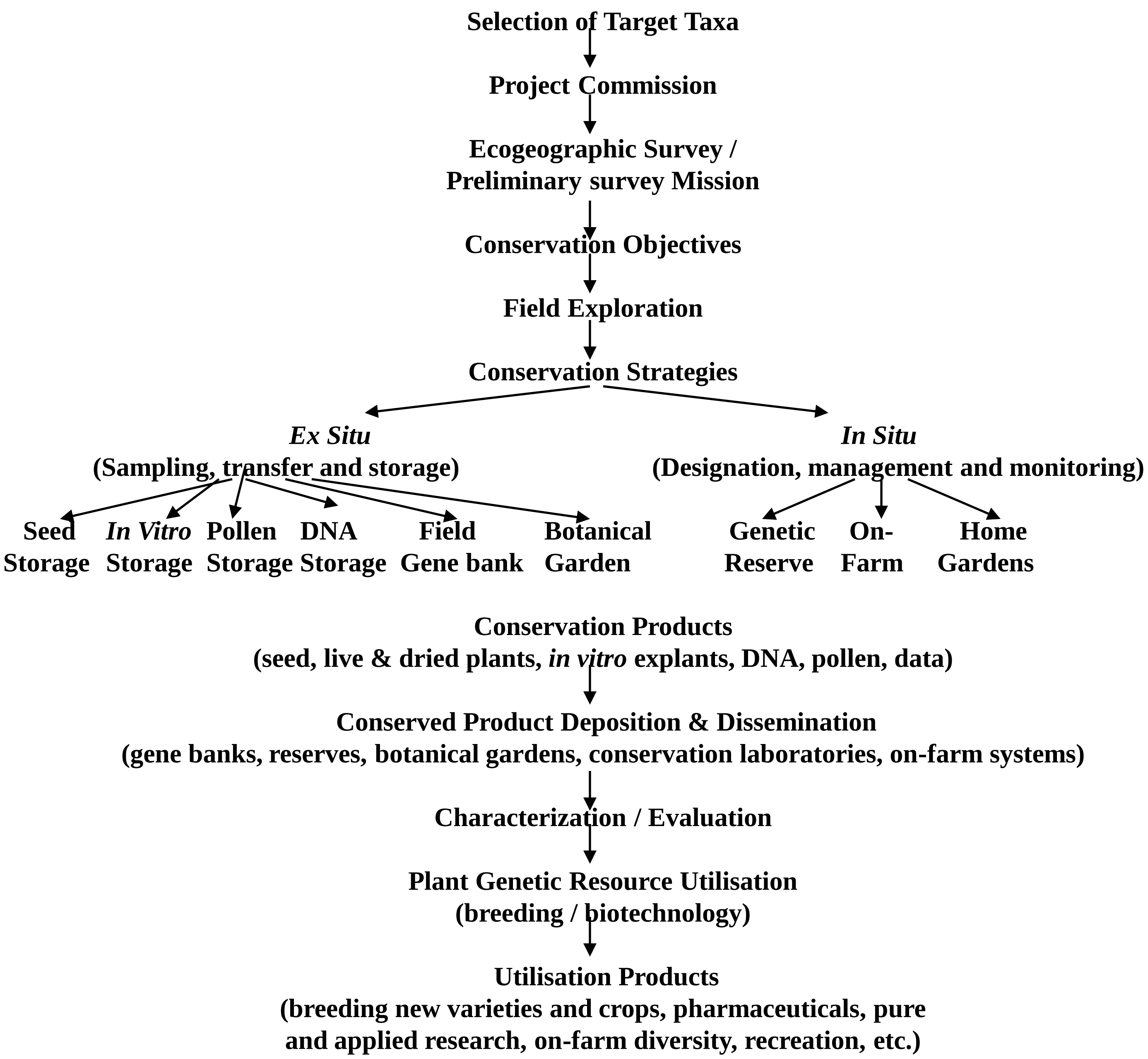
Proposed Model of Plant Genetic Conservation (Taken from Maxted *et al.*, 1997a).



Objective:

- Define ecogeographic survey and learn their applications in Plant Genetic Resources work
- Summarize the three different phases of ecogeographic survey listing objective, activities and outputs of each
- List different types of data which are collected during an ecogeographic survey
- Identify problems commonly encountered when collecting and analyzing ecogeographic data and suggest ways to deal with them
- Brief the different methods available for analyzing and displaying ecogeographic data
- List the contents of and ecogeographic conspectus and report and summarize the criteria used in setting conservation priorities

Introduction - The threat of genetic erosion

- Genetic erosion – a global issue
  - Loss of genetic diversity between and within populations of the same species over time or reduction of the genetic base of a species
- Threats: **HIPPCO**
  - **H**
  - **I**
  - **P**
  - **P**
  - **C**
  - **O**

Introduction - The threat of genetic erosion

- Genetic erosion – a global issue
  - Loss of genetic diversity between and within populations of the same species over time or reduction of the genetic base of a species
- Threats: **HIPPCO**
  - **H**abitat loss and destruction
  - **I**nvasive species
  - **P**opulation growth
  - **P**ollution
  - **C**limate change
  - **O**verexploitation

Introduction - The threat of genetic erosion

- To recognize, assess and react to any threat to plant diversity, accurate information is needed

- a basic understanding of the taxonomy, genetic diversity, geographic distribution, ecological adaptation and ethnobotany of a plant group, as well as of the geography, ecology, climate and human communities of the target region, is essential

  - An ecogeographic data can provide this informaiton

Introduction – a definition

- An ecogeographic study:
  - uses considerable resources to carry out and may take several years to complete
  - It is common to gather (NEW) data by sampling directly the target species
  - The data collected and analyses conducted is usually very detailed
- An ecogeographic survey
  - tends to rely on data recorded by other plant workers rather than obtaining NEW data
  - It might reply on collecting data from herbarium specimens and genebank accessions and performing literature studies.

Introduction – a definition

- “An ecogeographic study is a process of gathering and synthesizing ecological, geographical and taxonomic information. The results are predictive and can be used to help formulate conservation strategies and collecting priorities.” Maxted et al (1995)

Aims and purpose

- An ecogeographical survey aims to determine:
- (i) the distributions of particular taxa in particular regions and ecosystems;
- (ii) the patterns of infraspecific diversity; and
- (iii) the relationships between survival and frequency of variants and associated ecological conditions.

- Information can be used to locate significant genetic material and representative populations can be monitored to guide the selection of representative samples for conservation and utilization

- A full ecogeographic survey requires considerable resources to carry out and may take several years to complete, especially in the case of wide-ranging species. While highly desirable, especially for CWR of major importance, this will seldom be possible and much more concise studies are often undertaken. Examples of ecogeographic surveys are given

Examples of ecogeographic surveys

- *Coffea* (Dulloo et al, 1999; Maxted et al, 1999): an herbarium-based ecogeographic survey was made, supplemented by detailed field surveys of wild *Coffea* species in the Mascarene Islands. The geographical and ecological distribution of the different *Coffea* species in the Mascarene Islands, principally in Mauritius, was determined. Genetic diversity hotspots were mapped and an assessment was made of the IUCN conservation status of native *Coffea* species.
- *Medicago* (Bennett et al, 2006).
- *Phaseolus* (Nabhan, 1990).
- Annual legumes (Ehrman and Cocks, 1990).
- South American *Solanum* (Smith and Peralta, 2002).
- *Trifolium* (Bennett and Bullitta, 2003): an ecogeographical analysis of six species of *Trifolium* from Sardinia, with the aim of designing future collection missions and for the designation of important *in situ* reserves in Sardinia

Promoting in-situ conservation of dryland Agrobiodiversity in the Near East Project

- Countries: Lebanon, Syria, Jordan, Palestine
- Target Species: wild relatives and landraces of agricultural crops and fruit trees
  - Wheat, barley, Vetch, stone fruits, figs, grapes, etc..

Note:

- Steps differ when studying a crop as compared to a wild plant taxon.
- There is a difficulty in generalizing about a methodology that could be applied to anything from a weedy species used as a leafy vegetable to a semi-domesticated fruit tree to a staple crop, and from a country's province to a sub-continent

The main phases involved in an ecogeographic study

- **Phase 1: Design the project**
  - Commission the project
  - Identify taxon expertise
  - Select target taxon taxonomy
  - Delimit and characterize the target region
  - Identify taxon collections
- **Phase 2: Collect and analyze data**
  - Inventory conserved germplasm
  - Collate data from taxon collections
  - Survey other sources of information
  - Analyze the data
- **Phase 3: Generate ecogeographic products**
  - Ecogeographic database, conspectus and report
  - Identify conservation priorities

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Phase 1: Project design – Project commission

The first step in any ecogeographic study is to commission the conservation activity.

The commission statement should:

1. set out the objectives of the work and its scope with regard to the taxon and geographic area to be investigated, and whether a brief survey, or in-depth study, is to be undertaken.
2. outline some specific requirements as well as link conservation and the use of plant diversity.

This should be laid out in the form of a statement such as the example below:

- The Malawi Plant Genetic Resources Centre is to carry out an ecogeographic survey for *Sorghum bicolor* (L.) Moench in Malawi.

- The survey has the dual objectives of identifying areas that contain novel genetic diversity not already conserved that could be utilized in selection or breeding programmes for the benefit of Malawian agriculture and helping ensure the conservation of Malawian sorghum diversity for future generations.

- The ecogeographic report should contain a detailed discussion of various potential conservation strategy options for the crop, including collecting routes, timing and suitable regional contacts and whether on-farm conservation is appropriate. It should also attempt to identify any accessions of immediate and medium-term potential value to Malawian agriculture that are not currently being utilized.

Phase 1: Project design – Identify taxon expertise

- The criteria used in selecting a researcher for the ecogeographic survey should be carefully considered.
- A. For crop wild relative:
  - The researcher must have at least a basic knowledge of the target taxon as there may be difficulties in the taxonomic identification when dealing with some wild plant groups.
  - Ideally a specialist with the appropriate botanical skills should be selected.
  - Consulting taxonomic experts within the target region with a specialization in the target taxon (genus, section, or species) at an early stage of the ecogeographic survey.

- Identify taxonomic experts
    - by looking at the authorship of relevant scientific publications,
    - by asking botanists at local herbaria,
    - by consulting the *Plant Specialist Index* (Holmgren and Holmgren, 1992) and/or through various internet resources, e.g. the Taxacom discussion group

Phase 1: Project design – Identify taxon expertise

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- B. For crops:

Phase 1: Project design – Identify taxon expertise

- The criteria used in selecting a researcher for the ecogeographic survey should be carefully considered.
- B. For crops:
    - Taxonomists may not be helpful in supplying information about the genetic level of variation within cultivated species.
    - familiarity with documenting, interpreting, and using genetic diversity at the infra-specific level is more important than classic taxonomic expertise
    - collectors, agronomists, pathologists and breeders working on the target crop in national and international agricultural research systems can be more helpful.

- These germplasm users will be able to :
  - provide advice on the perceived gaps in existing collections,
  - constraints in the use of collections,
  - regions known or suspected to harbour interesting germplasm, and
  - what traits to look for and pay particular attention to when in the field.

- Extension agents and rural development workers (non-governmental organisations (NGOs), governmental, or international agencies):
  - act as guides and go-betweens with the local communities.
  - identify communities where landraces are still grown, or where there is imminent threat of genetic erosion.
- Identify these experts:
  - Through scientific publications , specialized databases and directories.
  - Specialized institutes and centres such as those of the CGIAR are important sources of expertise and information on their various mandate crops.
  - Global and regional crop-specific networks

The leading ecogeographer should:

- 1. consult sociologists, anthropologists, ethnobotanists:
  - Indigenous Knowledge
  - Farming systems
- Social scientists with expertise in a specific region or crop(s) can be identified
- 2. Women play key roles in the management of many crops and wild plant genetic resources particularly MAPs.

Examples of possible sources of expertise on crops

Sources of information on finger millet in Kenya

- 1. Gramineae botanist - East Africa Herbarium, National Museums of Kenya, Nairobi
- 2. Breeder, agronomist, pathologist, economist – National Agricultural Research Centre, Kenya Agricultural Research
- 3. Staff of Regional Research Centres in finger millet growing regions, e.g. Kakamega
- 4. District and Divisional Agricultural Officers in finger millet growing areas
- 5. Field extension officers in finger millet growing areas
- 6. NGOs active in finger millet growing regions, e.g. Organic Matter Management Network in Western Kenya
- 7. ICRISAT Regional Office, Nairobi; IPGRI Regional Office for Sub-Saharan Africa, Nairobi

Sources of information on common bean in Zimbabwe

- 1. Bean breeder, legume agronomist, legume pathologist, legume entomologist - Department of Research and Specialist Services (DR&SS), Harare
- 2. Pathologist, virologist, agronomist, breeder, entomologist - Department of Crop Sciences, University of Zimbabwe, Harare
- 3. Commercial Farmers' Union (CFU) and the Oil Seeds Producers' Association
- 4. AGRITEX (extension branch of Ministry of Agriculture)
- 5. CIAT bean programme staff in Kampala, Uganda (Pan-Africa Bean Research Alliance)

Phase 1: Project design – Select the target taxon taxonomy

- For wild plants:
  - Understand the taxonomy of the target group
  - Set taxonomic limits to the study and provide a solid nomenclatural foundation.
  - Consulting experts, recent revisions, monographs, floras and databases.

The synonymy problem

the same species may be listed under different names

- Taxonomic synonymy ex: *Triticum* and *Aegilops*, which have been commonly treated as separate while some taxonomists include *Aegilops* in *Triticum*.

    - The consequence of these discrepancies is that the same CWR taxon may occur in the taxonomic literature under a range of different names or synonyms.

- Nomenclatural synonymy, whereby the same taxon (species, genus etc.) occurs in the literature and herbarium under more than one name, can be intractable for the non-specialist.

- A plant may have more than one name because:
  - it has been described independently more than once by different taxonomists;
  - a taxon, such as a species, is later shown to be the same as other earlier published species; or
  - a taxon, such as a species, is treated by different taxonomists at different ranks, such as subspecies, or variety, or is placed in different genera by different specialists.

- For crops:
  - Nomenclature, botanical identification and species boundaries usually are not significant issues for crops, though that does not mean that some aspects may not be controversial for some crops.
  - More important is an understanding of morphological, agronomic and genetic variation within the crop.
  - The pattern of variation within cultigens caused by the activities of farmers is often quite different from that found in wild species
  - When a crop receives formal taxonomic treatment, the result is often over-classification

The taxonomy of cultivated sorghum: Results of a literature search

- Snowden’s (1936) treatment: recognizes 31 species, 158 varieties and 523 forms.
- Wet and Huckabay (1967): 4 races within the cultivated grain sorghums.
- Harlan and de Wet (1972) and de Wet (1978): 5 basic races, and 10 intermediate
- More recently, the classification of cultivated sorghum into 5 basic races,
- In contrast, a study of isozyme polymorphism (Ollitrault et al., 1989) revealed a diversity continuum organized around 3 geographical groups, rather than morphological races

Taxonomic pitfalls

- The level of accuracy of identification of plant taxa in scientific literature is very variable and often quite low.
- Often the scientific identification of the taxa is not checked for accuracy: misidentified;

Reasons for the difficulties:

- taxonomy and classification are highly specialized subjects and the formal products of taxonomy have traditionally not been user-friendly.
- Floras, monographs, revisions, checklists can be very daunting to the non-specialist as they are highly technical to the less specialized users.
- Some identification guides are not written clearly and leave out fundamental information, such as an illustration of the species or keys are missing.

Species concept: a word

Species concept: a word

- Despite the unique role of species as the basic unit in both biological classification and biological diversity, there is no universal agreement on how to define a species.
- In the majority of cases, it is likely that a conventional taxonomic species concept, i.e. one based primarily on morphological differentiation will be employed for identifying target species.
- In practical terms, the standard Flora(s) of the country should be used for species identification and the nomenclature adopted by the Flora(s) should be followed.
- If a recent revision of the genus or group of species is available that should be used.
- In addition, species may be interpreted in some Floras in a wide sense, including species that are regarded as separate ones in other Floras.
- Likewise, some Floras will treat a particular taxon as a species, while others will treat the same taxon as a subspecies or even as a variety.

- Infra-specific variants such as subspecies, ecotypes or chemical races or individual populations, rather than species, are the focus of attention in agrobiodiversity

- There is a widespread tendency in much work on biodiversity and conservation (e.g. in Red Lists) to treat most species as though they were uniform, whereas many contain a great deal of variation

- It will clearly make a difference when planning conservation actions if distinctive variants are recognized. This is especially true for CWR where particular alleles in a species' population may be the focus of interest.

Identify taxonomic collections

- National herbaria
  - Good local coverage
  - Better label data
  - Regional expertise

  - Poor in other resources
  - Lack of target taxon specialists

- Regional herbaria
  - Broad coverage
  - Older specimens: difficulty in labels;
  - Other resources: Specialists, Libraries

Sources of taxonomic information

- The taxonomic literature is enormous, stretching back centuries and is daunting for the non-professional user.
- Electronic databases and electronic floras are increasingly being developed and should be consulted when available.
- major international enterprises such as
    - GRIN Taxonomy for Plants (http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl),
    - TROPICOS (http:// www.tropicos.org/) and Species 2000 (http://www.sp2000.org/), to national, local
- The Global Biodiversity Information Facility (GBIF) estimates that three-quarters or more of biodiversity data is stored in the developed world.
- However, most of the data that may be needed cannot be transferred because they are not digitized and/or the capacity to handle digital information is lacking.
- GBIF is a global network of data providers building biodiversity information infrastructure and promoting the growth of biodiversity information content on the internet by working with partner initiatives and coordinating activities worldwide.

Practical hints for dealing with taxonomy and names

- Remember that if a species has a different name in a Flora or in a herbarium specimen from the one you recognize or are used to, it does not necessarily mean that it is a separate species – it may just be a synonym of that species.
- Remember that the names given to species in the literature (scientific papers in journals, inventories, phytosociological or ecological surveys, etc.) may be incorrect and need checking.
- If you cannot find a species in a particular Flora or handbook, consider whether it may be 'masquerading' under a different name (synonym) or in a different genus.
- If you are unable to identify a specimen, prepare a herbarium sample to take to a taxonomist for identification. Make sure the sample has flowers and fruits, if possible.
- If in doubt, consult with a taxonomist for assistance or advice.

Delimit the target region

- Areas should be chosen carefully
    - to maximize the predictive value of the survey
- Taxon should be studies
    - Throughout its range
    - Throughout a well defined area, biogeographically or floristically

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Inventory conserved germplasm – Assess current conservation status

In ecogeographic surveys of wild taxa:

- to document the range of diversity currently being conserved, either *ex situ* or *in situ*.
- compare this with the overall diversity of the target taxon as shown by analysis of field data and data from herbarium collections/ literature.
- the comparison should highlight geographic, ecological, taxonomic and genetic diversity gaps in the germplasm conserved in – and ex - situ.

In studies of a cultivated species,

- make listings of the germplasm conserved in genebanks and of on-farm conservation projects involving the target taxon

- Problems:
  - Conserved data is incorrectly identified
  - Quantity of material is not sufficient
  - Access to the conserved material is limited
  - Status of the samples conserved: enough variation of not?
  - Few or not passport data available

Survey of geographical, ecological and taxonomic data – Taxon specific data

- Accepted taxon name
- Locally used taxon name
- **Where species grows**
- Time of local flowering / fruiting
- **Habitat preference**
- Topographic preference
- Soil preference
- Geological preference
- Climate and microclimate preference
- Breeding system
- **Genotypic/phenotypic variation**
- Biotic interactions
- Archeological information
- Ethnobotanical information
- Conservation status

Where species grows

- Ascertaining the ecological conditions under which the selected species grows is one of the main concerns of an ecogeographic survey.
- Some information may be derived from the literature and herbarium specimen label data, BUT field work is essential.
  - habitat types –no generally accepted global set of habitat types, many countries have produced their own classifications
  - condition of the habitat;
  - disturbance regimes;
  - threats to the habitat;
  - topography;
  - altitudinal range;
  - soil types;
  - slope and aspect;
  - land use and/or agricultural practice.
- For some species, a phytosociological characterization may be available or may be developed through field-work

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Distribution data

- It is important to determine the full geographical distribution of the wild species being targeted.
- may be obtained, besides field work, from a variety of sources: Floras and monographs; geobotanical, phytosociological and vegetation studies, which often contain lists of species recorded from particular areas; herbarium labels; biodiversity databases; etc

- Various methods and tools have been developed for the prediction of the geographic distribution of species.

- For landraces:
  - Where the crop is grown in the target region;
  - The phenology of the crop in different areas within the target region;
  - The variation displayed by the crop with regard to characterization and evaluation traits;
  - Major agronomic problems faced by the crop (e.g. drought, pests and diseases etc.);
  - The contribution the crop makes to income and nutrition;
  - How the crop is propagated, cultivated and used (including ritually) by the local populace (both genders);
  - How genetic diversity is perceived, managed and maintained by farmers (e.g. folk taxonomy, selection, seed exchange etc.);
  - The history of the crop in the target region;
  - The threat of genetic erosion the crop faces (e.g. from modern varieties, socioeconomic change);
  - The vernacular name(s) of the crop, and of different landraces;
  - What wild relatives may be found in the target region

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Genetic variation

- Genetic variation is at the heart of Agrobiodiversity conservation.
- It occurs at various levels in the populations of species and, in the case of CWR, particular alleles could
- provide the basis of valuable traits for breeding programmes.
- a detailed understanding of the structure of the genetic variation that occurs in a species and its populations, will largely determine the location of the reserves and the design of the conservation strategy and management plan.
- the more genetic variation is captured, the more likely is the species to continue to evolve and generate new variation favouring its long-term persistence and survival;
- the species will also stand a better chance of adapting to face the challenges of climate change.
- Previously, genetic variation was commonly inferred from morphological differentiation: feasible but affected by environment
- In recent years, biochemical and molecular techniques have been developed: effect of environment filtered, costly

Survey of geographical, ecological and taxonomic data – Area specific data

- Geographic and climate data
- Topography
- Geology
- Soil
- Climate
- Landuse

- Sources: from anywhere and everywhere

Survey of geographical, ecological and taxonomic data – Specimen specific data

- Herbaria and genebanks have millions of accessions
  - Select representative specimens
    - Accessions with detailed passport data
    - Select accessions to reflect geographic range
    - Avoid duplicates
  - Confirm identification of each specimen
  - Check integrity of passport data

Survey of geographical, ecological and taxonomic data – Specimen specific descriptors

- Herbarium name
- Collectors name and number
- **Collecting date**
- **Sample identification**
- **Locality**
- **Altitude**
- **Habitat**
- Phenological data
- Soil type
- Vegetation type
- Site slope and aspect
- Landuse
- Phenotypic variation
- Pest and pathogens
- Competitive ability
- Palatability
- Vernacular names
- Plant uses

Survey of geographical, ecological and taxonomic data – Data standards

- Consistent: particularly when different workers go to the field
- Clear and descriptive: essential for meaningful data and reproductivity and information retrieval

When to do the field work

- For wild species:

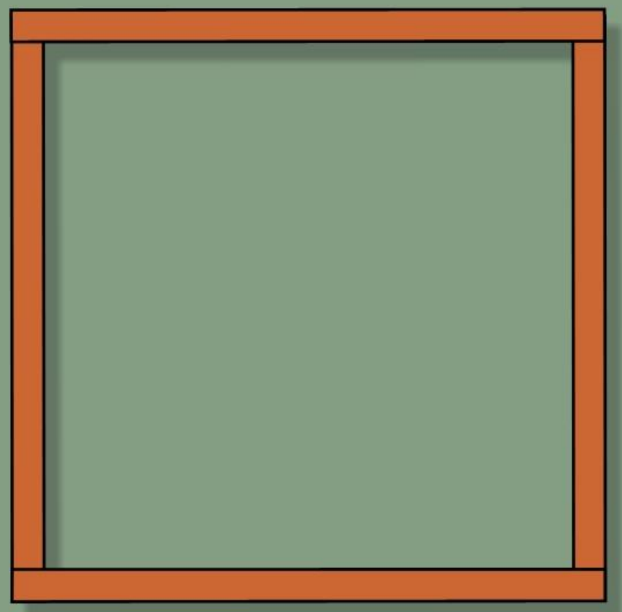
Flowering / fruiting season of target species

- For crops:

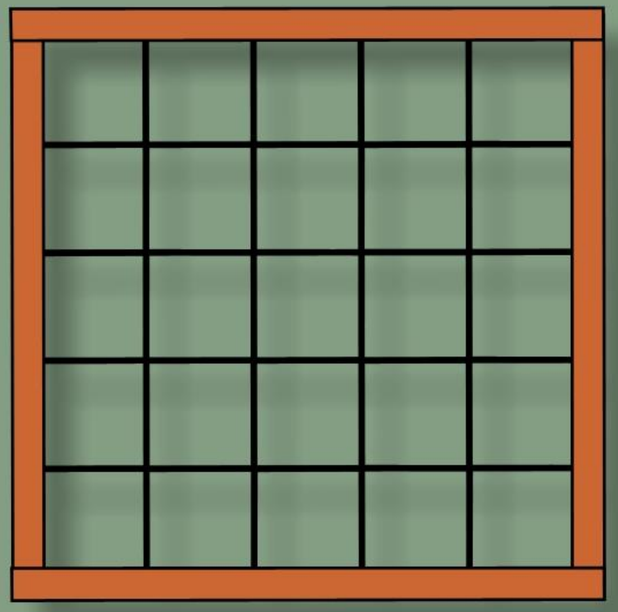
it is important to have near real-time information about the course of a cropping season.

Quadrats

Quadrat frames, constructed from wood or metal, are used to investigate the distribution of species



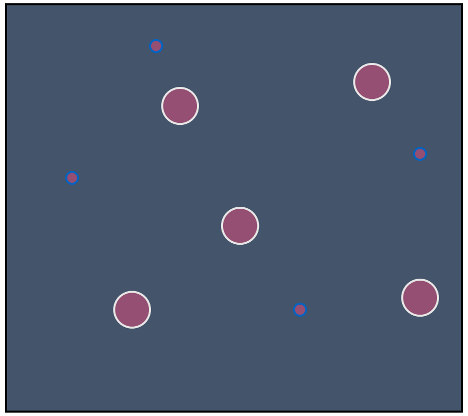
Square quadrat frame for determining population densities



Subdivided quadrat frame for determining % cover of species

Plant Density Quadrats

- Count number of individuals of all seeded species and other species of interest



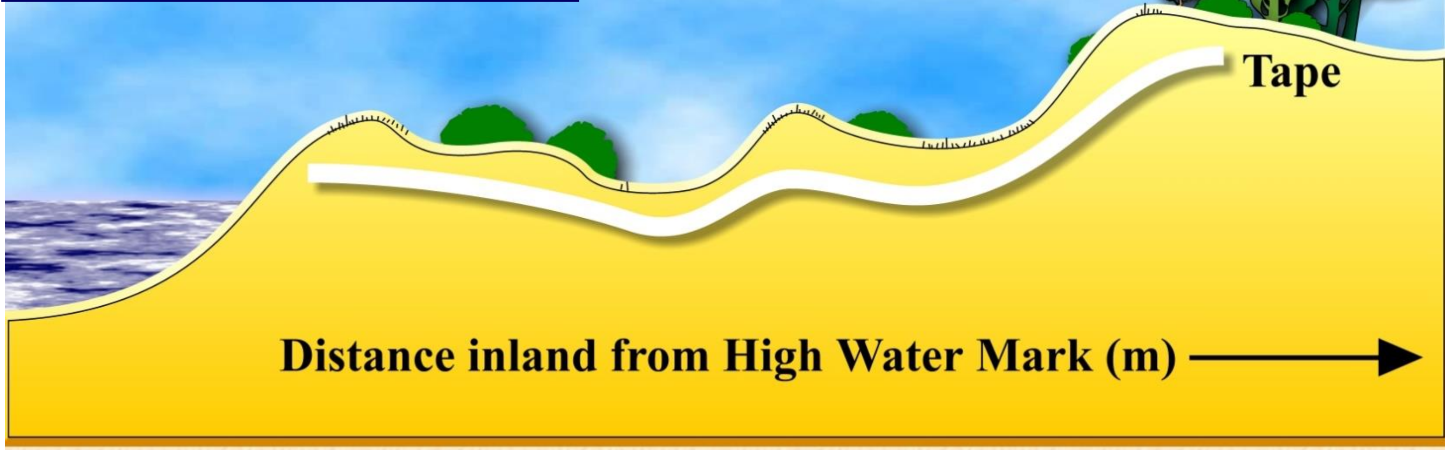
- Count stems of rhizomatous species
- Questionable situations - follow a consistent set of guidelines

- Permanent quadrats
    - provide a good way of reducing between-quadrat variability when changes over time are being monitored.
    - appropriate when monitoring rare sedentary species that occur in a few known locations. For example, specific lichen
    - Another advantage of permanent quadrats is that more data can be collected on the survival and growth of individual organisms (especially plants) within the quadrat: Trees (seedlings, juvenile, mature)
- Temporary quadrats
    - Temporary quadrats have the advantages of being quicker to locate,
    - Temporary quadrat locations are particularly appropriate for ephemeral plant specie

Transect Sampling with reference to a straight line

- **Point transect**
  - Recording presence/absence of species at set distances (x) along a line.
  - Measures frequency.
- **Line transect**
  - Continuous measurements of intercepts along a line.
  - Normally used for estimating vegetation cover.
- **Belt transect**
  - Contiguous (above) or spaced (below) frame quadrats laid along a line. Each quadrat is recorded separately.
  - Measures frequency, cover, density or other variables. Normally used to study changes along an environmental gradient or across vegetation boundaries.
- **Strip transect**
  - Essentially a very long and thin quadrat of fixed width; individuals are counted within this strip.
  - Estimates density.

Belt transect Survey of a Dune System



A **belt transect** was used to investigate the distribution of three species of grass commonly found on sand dunes

The **transect line** stretched from the **high water mark** to the **inland area** and 1m x 1m **quadrats** were used to determine the number of individual plants of each grass species along the profile

NEXT

Plant Density
Belt Transect

- Walk along transect with a PVC pipe and record plants occurring underneath
- Use for larger, less abundant plants

Choosing Between Censusing Designs

- How to choose between sampling layouts?
- Depends on experimental question
- Gradients
  - Probably best to use a transect
  - Ensures comparability
- Relatively uniform sampling area
  - Random probably best – if done frequently enough, get equal representation of areas included
  - Grid may be useful when need to uniformly sample area

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Surveying Design

- Need to equally capture / census entire community (or subset) to be studied
- Be consistent
- Have equal sampling effort in different areas
  - Time, area, quantity sampled
- Appropriately represent area studied
  - Equally sample disparate constituent areas
  - Random vs. orderly (grid, transect)?

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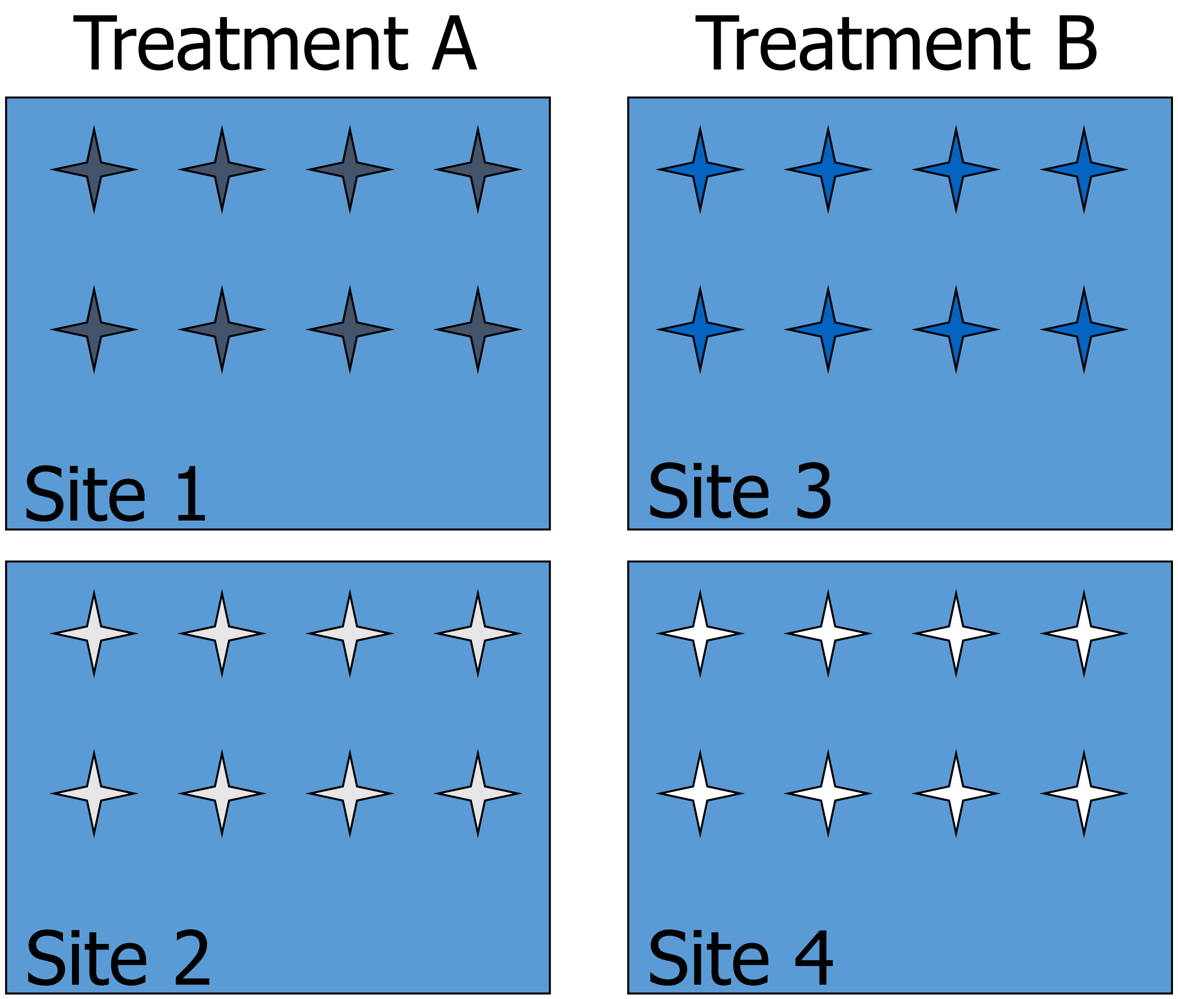
Pseudoreplication Example



- **Question** – What is the affect of treatments A & B?
- **Pseudoreplication** = treating stars of the same color as replicates
- **Replication** = include only a single star of each color, or their average

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Types of Biological Diversity

- Point: diversity at a single point or microenvironment
- Alpha: within habitat diversity
- Beta: species diversity along transects & gradients
  - High Beta indicates number of spp increases rapidly with additional sampling sites along the gradient
- Gamma: diversity of a larger geographical unit (island)
- Epsilon: regional diversity

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Phase 2 – Analyze the data

- The ecogeographic database can be analysed to help identify the geographical location and habitats favoured by the target taxon
  - Allow to discover new populations
  - Inform ex-situ conservation

- The types of analysis can be:
  - Tables and bar charts
    - Can identify ecological niche of a target taxon
    - Can show ecotypic adaptation in wild and cultivated species
  - Maps: Enclosed (shaded) maps, Dots distribution maps, contour maps
  - GIS: dedicated to handling spatial and non spatial data, powerful tool

Phase III. Generate ecogeographic products

- Three major outputs of the ecogeographic survey:

1. The ecogeographic database: containing the raw data of each taxon/site

- NOTE: the researcher should know how complete the database is and complete the surveys were
- Implications: If a particular habitat is under represented in the database, is it because:
  - The taxon is absent from that habitat?
  - The type of habitat has not been sampled adequately?
  - The target taxon has not been recognized in such habitat?

  - Inferences drawn could be misleading

Phase III. Generate ecogeographic products

2. The ecogeographic conspectus: summarizing the data of each taxon
3. The ecogeographic report:
   - Discussing the contents of the database and conspectus
   - Conclusions regarding the groups ecogeography
   - A concise list of conservation priorities - proposing future conservation strategies (in situ and ex situ)

Criteria used in setting conservation priorities

- Biological
  - Richness: the number of populations / species/ ecosystems in the area
  - Rarity
  - Threat: what are the threats and how severe
  - Function: the degree to which a species affects others: key species or not

- Social/ political
  - Utility: economic scientific, social, cultural …
  - Feasibility: political, economic, logistical and institutional considerations

Conclusion

- Herbaria, genebanks, botanical gardens are storehouses for botanica data as mush as the are for plants
- Data can and must be used to facilitate and order plant conservation decision making
- Analysis of a taxon's geography, ecology and taxonomy is a pre-requisite for assessing its conservation status and its potential areas of distribution
- Once located, taxon can be monitored
- Field surveys will always be limited by time and resources, but proper planning will help making better informed conservation and management plans