IUCN Red List Criteria and Climate Change Impacts on Biodiversity

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IUCN –
The World Conservation Union

- Founded in 1948, IUCN is a union of:
  - 82 states
  - 111 governmental agencies
  - 800+ non-governmental organizations
  - ~10,000 individual scientists and experts
- Staff: ~1000 in 62 countries
- Organized into 7 commissions;

  Species Survival Commission (SSC) is the largest, with ~7000 scientists and experts

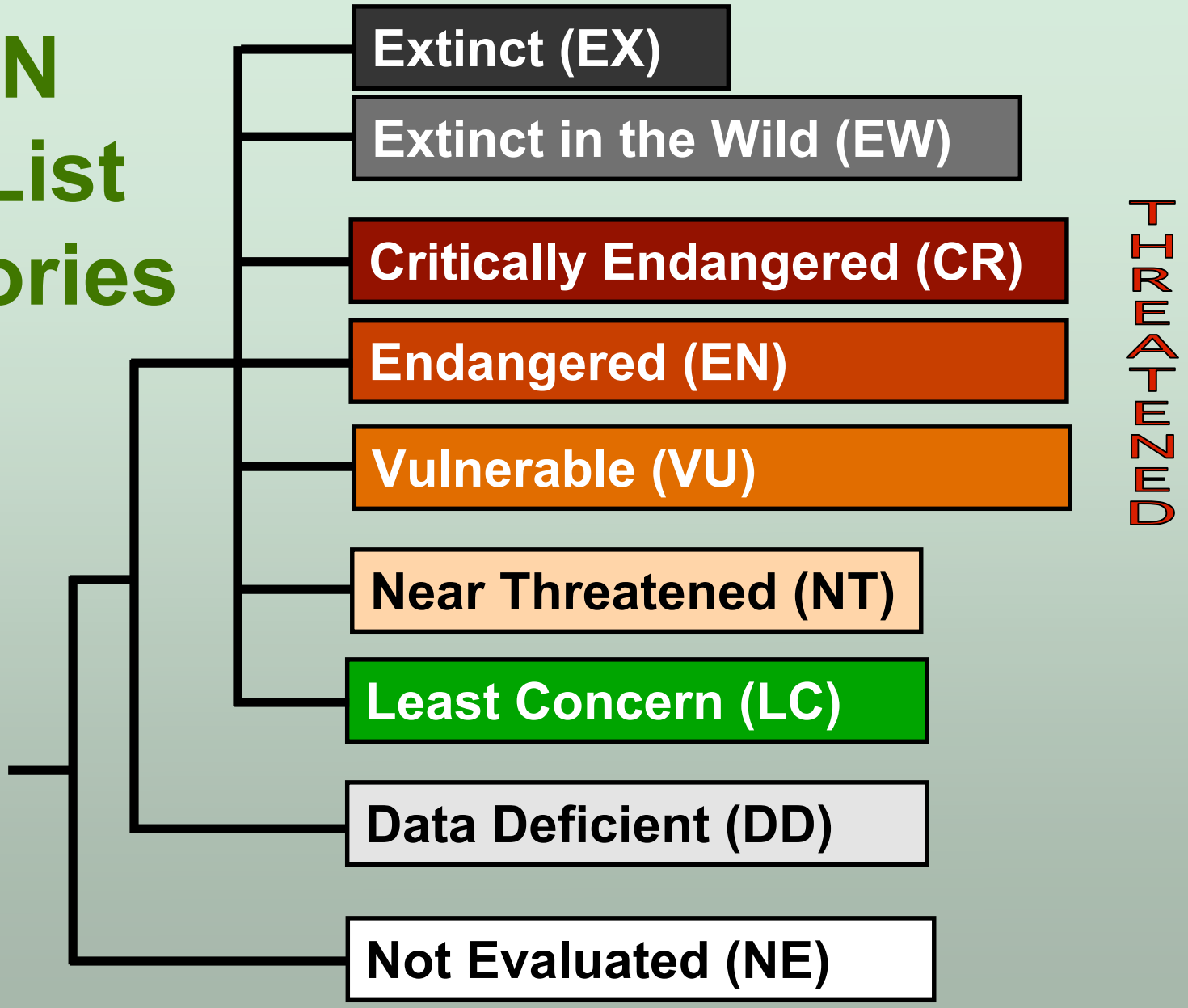
Main Points

1. Recent attempts at projecting climate change impacts on biodiversity have been based on the IUCN Red List Criteria. In these studies, the Red List Criteria are often misapplied, introducing bias and uncertainty.
2. One of the most effective ways of drawing attention to species threatened by climate change is to include them in the *IUCN Red List of Threatened Species*. This requires new guidelines for identifying species vulnerable to climate change.
3. Much uncertainty in climate change impact projections comes from interactions among demography, landscape structure, and range shifts. The guidelines should address these interactions.

Outline

1. A brief overview of the IUCN Red List Criteria
2. Incorporating uncertainties in Red List assessments
3. Common mistakes in using the IUCN criteria in projecting climate change impacts on biodiversity
4. Red List Criteria relevant to climate change impacts, and their shortcomings
5. Research suggestion for:
   - red-listing species threatened by climate change
   - incorporating uncertainties due to demography and landscape in assessing climate change impacts
   - general insights into the interaction between spatial and demographic factors in making species vulnerable

IUCN Red List Categories



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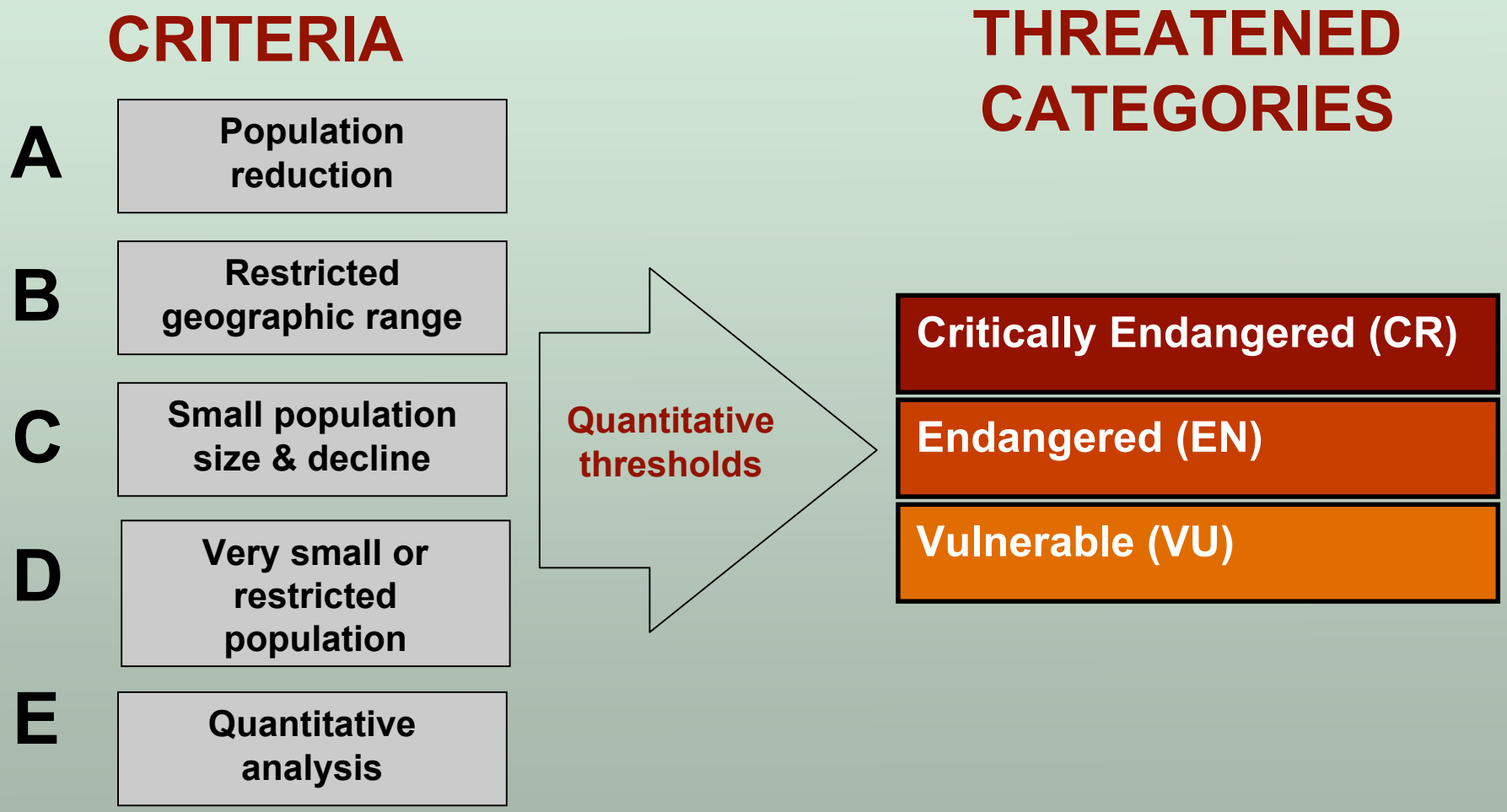
IUCN Red List Criteria

- Five quantitative criteria which are used to determine whether a taxon is threatened or not, and, if threatened, which category it belongs in.
- Based on biological attributes of populations that are threatened with extinction:
  - **A. Population decline**
  - **B. Small range and fragmentation, decline or fluctuation**
  - **C. Small population size and fragmentation, decline or fluctuations**
  - **D. Very small or restricted population**
  - **E. Quantitative analysis of extinction risk**

IUCN Red List Criteria



Example: Criterion A

Criterion A: Past, present and/or future population reduction			
	Critically Endangered	**Endangered**	**Vulnerable**
Reduction in population size over 10 years or 3 generations, whichever is longer, based on **any of**:			
A1:	**≥ 90%**	**≥ 70%**	**≥ 50%**
A2, A3 & A4:	**≥ 80%**	**≥ 50%**	**≥ 30%**
BASED ON **any of**:	**(a)** direct observation **(b)** an index of abundance appropriate to the taxon **(c)** a decline in area of occupancy, extent of occurrence and/or quality of habitat **(d)** actual or potential levels of exploitation **(e)** the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites		
where:			
A1: Population reduction observed, estimated, inferred or suspected in the **PAST** where the causes of reduction are clearly reversible, **AND** understood **AND** have ceased, **based on** (and specifying) **any of (a) to (e)** above.			
A2: Population reduction observed, estimated, inferred or suspected in the **PAST** where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, **based on** (and specifying) **any of (a) to (e)** above.			
A3: Population reduction projected or suspected to be met in the **FUTURE** (up to a maximum of 100 years), **based on** (and specifying) **any of (b) to (e)** above.			
A4: Population reduction observed, estimated, inferred, projected or suspected where the time period includes both the past **AND** the future (up to a maximum of 100 years into the future), and where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, **based on** (and specifying) **any of (a) to (e)** above.			

Example: Criterion B

Criterion B:	**Restricted geographic range and fragmentation, continuing decline or extreme fluctuations**		
	Critically Endangered	**Endangered**	**Vulnerable**
Either:			
B1: Extent of occurrence estimated to be:	**< 100 km_**	**< 5,000 km_**	**< 20,000 km_**
OR:			
B2: Area of occupancy estimated to be:	**< 10 km_**	**< 500 km_**	**< 2,000 km_**
AND at least **TWO** of:			
a. Severely fragmented or known from:	**1 location**	**≤ 5 locations**	**≤ 10 locations**
b. Continuing decline in any of:	**(i)** extent of occurrence **(ii)** area of occupancy **(iii)** area, extent and/or quality of habitat **(iv)** number of locations or subpopulations **(v)** number of mature individuals		
c. Extreme fluctuation in any of:	**(i)** extent of occurrence **(ii)** area of occupancy **(iii)** number of locations or subpopulations **(iv)** number of mature individuals		

Sources of Uncertainty

- **Semantic uncertainty and vagueness**
  - “Extreme fluctuations”
  - “Mature individual”
- **Natural variability**
  - Environmental fluctuations
  - Demographic stochasticity
  - Spatial variability
- **Measurement error**
  - Lack of precision
  - Bias
  - Experts’ opinions

Characterizing Uncertainty

Numerical parameters

(e.g., Number of mature individuals)

- Point estimate = 90 individuals

  90

- Best estimate = 90 individuals; Range of plausible values = 70–120

  [70, 90, 120]

- Best estimate = 85–95 individuals; Range of plausible values = 70–120

  [70, 85, 95, 120]

- Range of plausible values = 70–120

  [70, 120]

Characterizing Uncertainty

Logical parameters

(e.g., Extreme fluctuations)

- Certain estimate = TRUE

  1

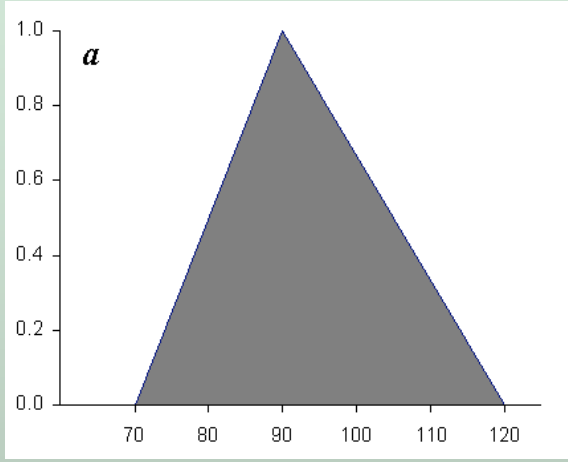
- Probability of being true = 60%

  0.6

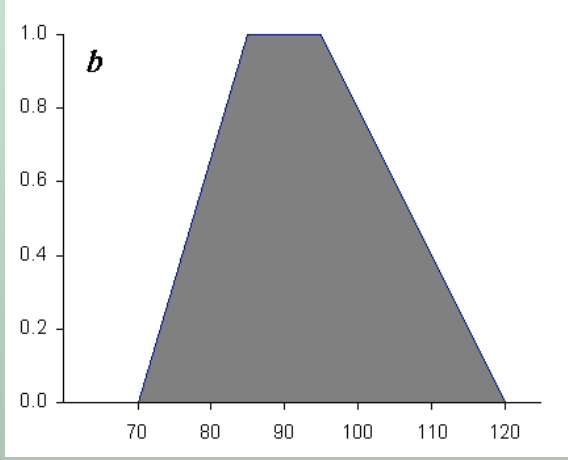
- Range of opinion = 40% – 100%

  [0.4, 0.6, 1.0]

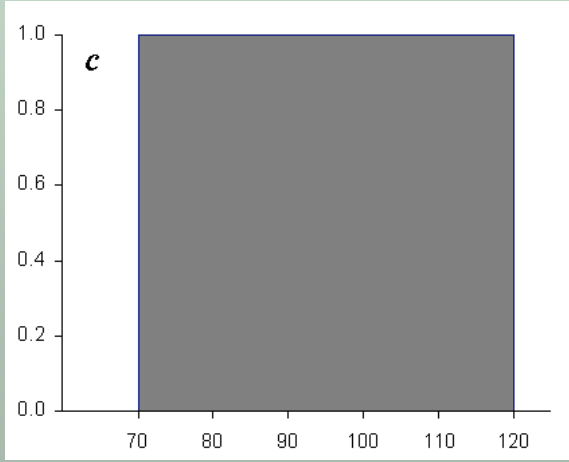
Characterizing Uncertainty with Fuzzy Numbers



[70, 90, 120]



[70, 85, 95, 120]

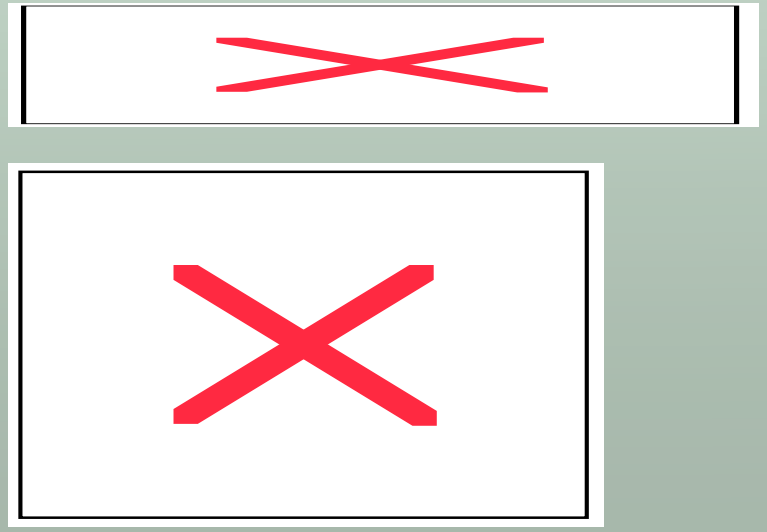


[70, 120]

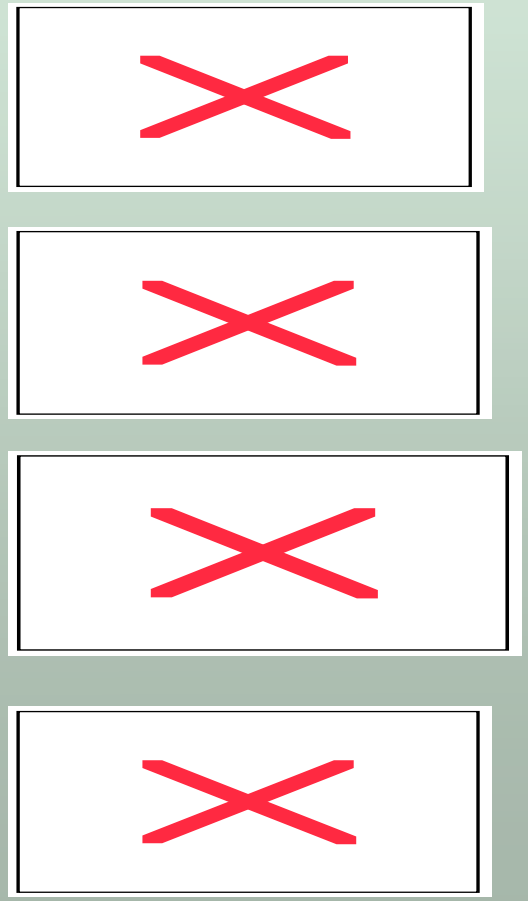
Fuzzy arithmetic rules for propagating uncertainty

Fuzzy number: a set of nested intervals $[a_{li}, a_{ri}]$ at each level i = 0 to 1, where $a_{li} \le a_{ri}$ for all $i \in [0,1]$, and $a_{li} \le a_{lj}$ and $a_{rj} \le a_{ri}$ whenever $i \le j$.
All arithmetic operations are level-wise on the intervals (subscripted i's are omitted for the sake of simplicity):

Conjunction (AND) and Disjunction (OR):



Comparisons:



Expressing Data Uncertainties in the Results

RAMAS
Red List

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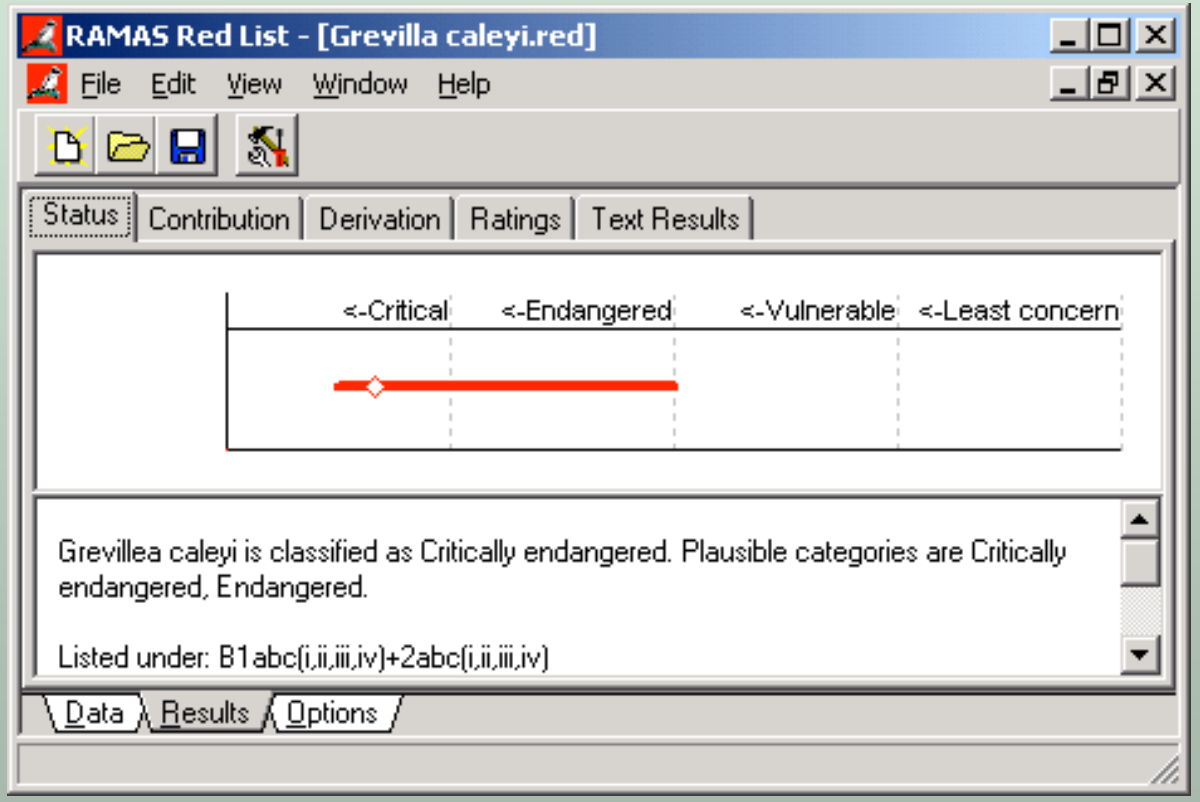


Red List and Climate Change Impacts on Biodiversity

1. **Adding species to the IUCN Red List**
   - *The IUCN Red List of Threatened Species* is widely regarded as the most authoritative list of globally threatened species.
   - Thus, the most effective way of drawing attention to species threatened by climate change is to red-list them.
   - This requires new guidelines for identifying species that will be impacted with climate change.
2. **Using the IUCN Criteria to estimate extinction rates due to climate change**

(Both approaches are useful, but for different purposes)

Using the IUCN Criteria to estimate extinction rates due to climate change

- Recent studies (e.g., Thomas et al. 2004; Thuiller et al. 2005) use IUCN Red List criteria to project climate change impacts on biodiversity.
- In these studies, the Red List Criteria are often misapplied:
  1. **Data uncertainties are ignored.**
  2. **Temporal and spatial scales are arbitrarily changed.**
  3. **Area measures AOO and EOO are confused.**
  4. **Linear relationship between population size and range area (spatial distribution) is assumed.**

2. Changed scales

- IUCN Red List Criteria A, C, and E include time horizons (3 to 100 years; 1 to 5 generations).
- Quantitative thresholds (% decline and probability of extinction) are assessed within these time horizons.
- Changing these time horizons while keeping the same quantitative thresholds introduces inconsistencies, and makes results incomparable to IUCN categories.
- The IUCN Red List is a global assessment. Ignoring part of species' ranges in incompatible with the Criteria.

3. Confused area measures

- IUCN Criteria include 2 area measures with very specific definitions and guidelines for estimation:
  - Extend of Occurrence (EOO)
  - Area of Occupancy (AOO).
- The future distribution areas projected by climate change scenarios often correspond to neither one (because of resolution or measurement differences).
- To use the EOO or AOO thresholds with these projected areas, the modeled distributions must first be processed to estimate EOO and/or AOO, as defined by the IUCN Criteria and guidelines.

4. Assumed relationship between range area and population size

- Biodiversity impacts simulated are often based on (or even limited to) changes in projected range of the species.
- Using these changes to predict extinction rates based on IUCN Criteria assumes a linear relationship between abundance and range area.
- This relationship is rarely linear, esp. in the context of clime change impacts.
- Demographic factors and spatial structure are likely to intensify the effects of climate change on species viability beyond the effects predicted by range shifts or changes in available habitat area.

Effect of demography and spatial structure

- Fragmentation (e.g. shifts to higher altitudes or to human-modified landscapes)
- Increased isolation (e.g., shifts to areas separated by less hospitable habitat)
- Time delays in habitat suitability (e.g., old-growth forests)
- Behavioral (such as site fidelity) or demographic characteristics (population growth rate) may further decrease ability to respond to shifts in habitat quality.
- Reduced recolonization ability of declining species (even if isolation did not increase)
- Increased fluctuations (due to increased frequency of extreme weather events) increases extinction risk.

Incorporating Demography and Spatial Structure

- These factors involve demographic processes and the spatial structure of the landscape, and are ignored by assessments that are based solely on projected range area changes.
- Much of the uncertainty in climate change impact projections comes from interactions among these factors and range shifts.
- These factors are incorporated into the IUCN Red List Criteria through the use of several variables, as well as by explicit calculation of extinction risk in Criterion E. (But each option has its shortcomings.)

Red List Criteria Relevant to Climate Change Impacts

A3 (future population reduction)

- Requires justifying any assumed relationship between abundance and habitat/range
- Limited time horizon for short-lived species (3 generations/10 yr)

B (restricted range or habitat area)

- Also requires decline/fluctuations/fragmentation or few locations
- Based on current (not projected future) conditions.

D2 (few locations)

- Vulnerable only

E (probability of extinction)

- Data often not available for building models
- Somewhat limited time horizon (3, 5 generations & 100 years)

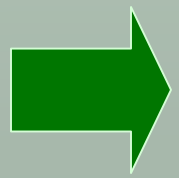
A Metapopulation Modeling Approach

Develop guidelines for using Criterion E, based on combinations of:

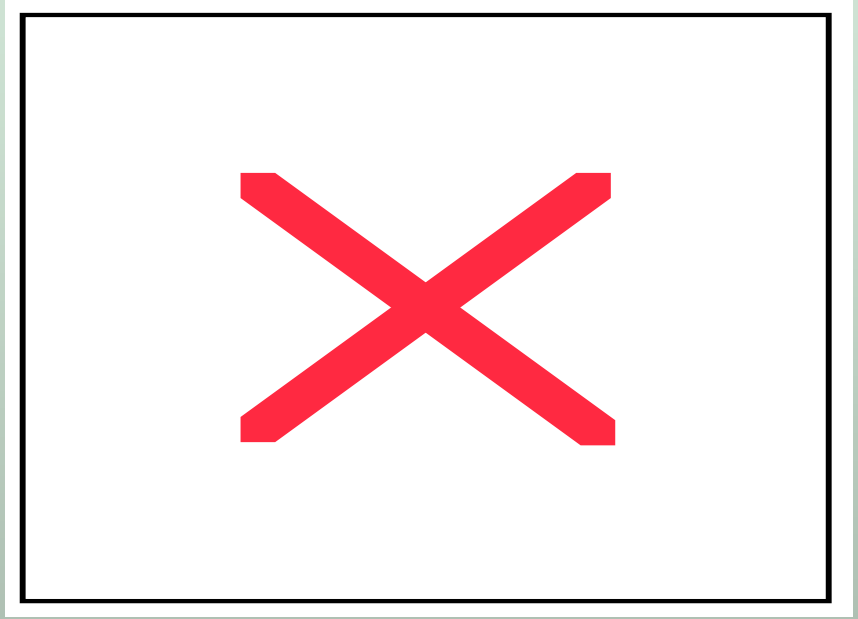
- *Life history characteristics:* dispersal ability, population growth rate, degree of population fluctuations
- *Landscape characteristics:* fragmentation and isolation (number of, and distance between, habitat patches)

Method:

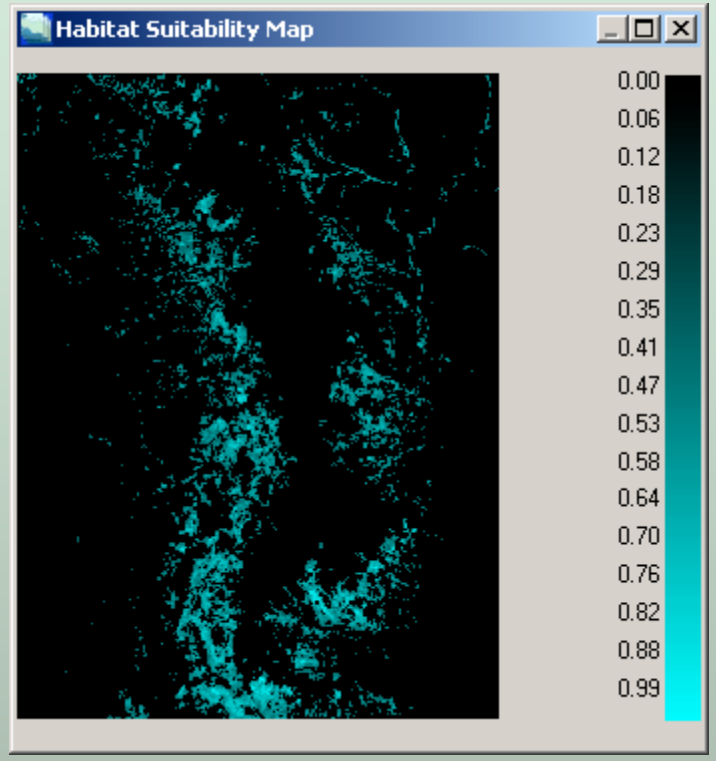
- Create a variety of models with above combinations of life history and dynamic spatial structure
- Run simulations to estimate extinction risks
- Analyze results to determine quantitative thresholds for risk categories corresponding to CR, EN, VU
- Generalize results to practical guidelines for red-listing

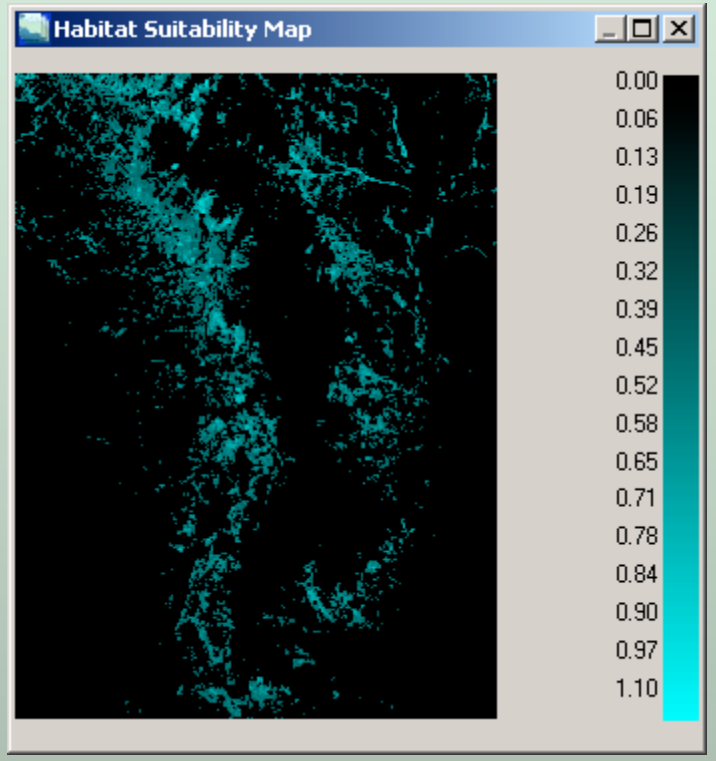


Simulated dispersal



Dynamic Habitat

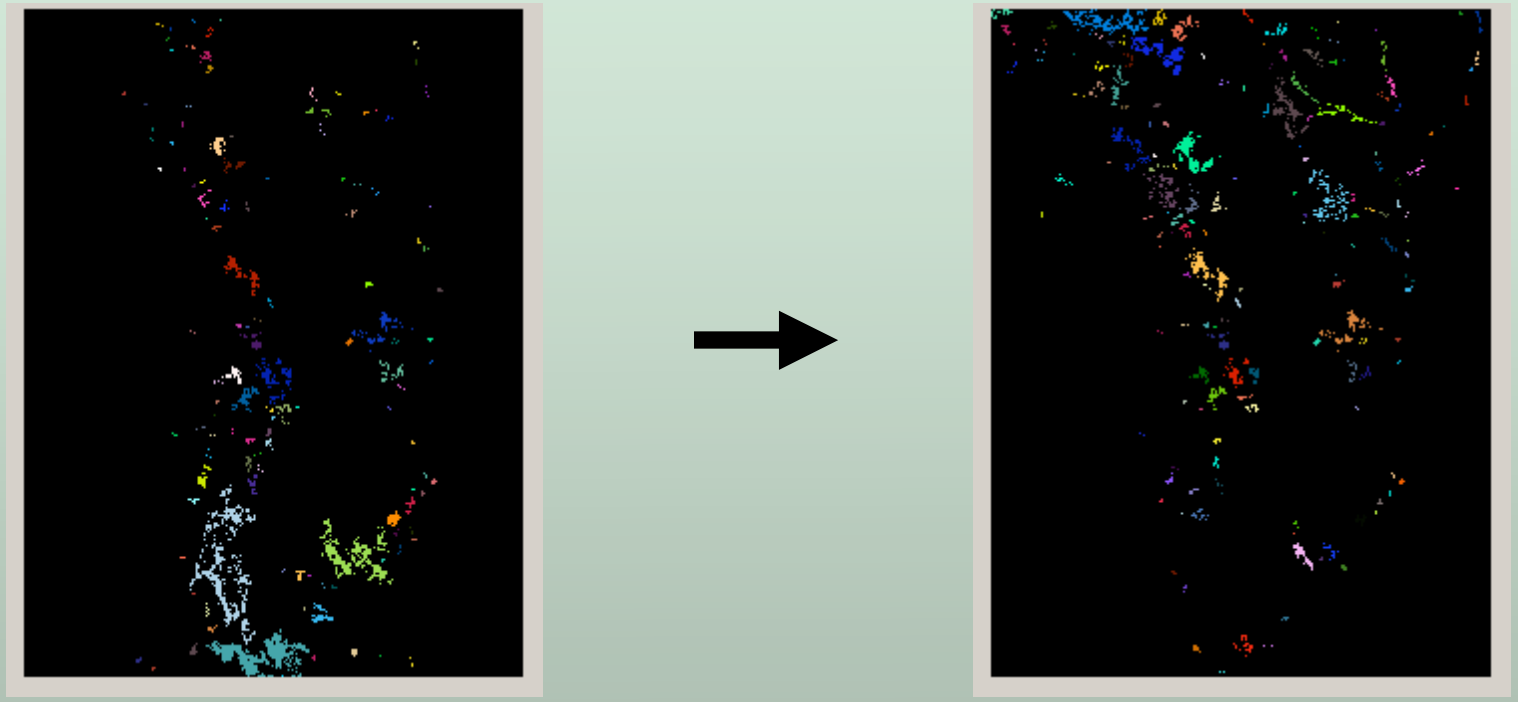




Time step 1 (Year 0)

Time step 20 (Year 60)

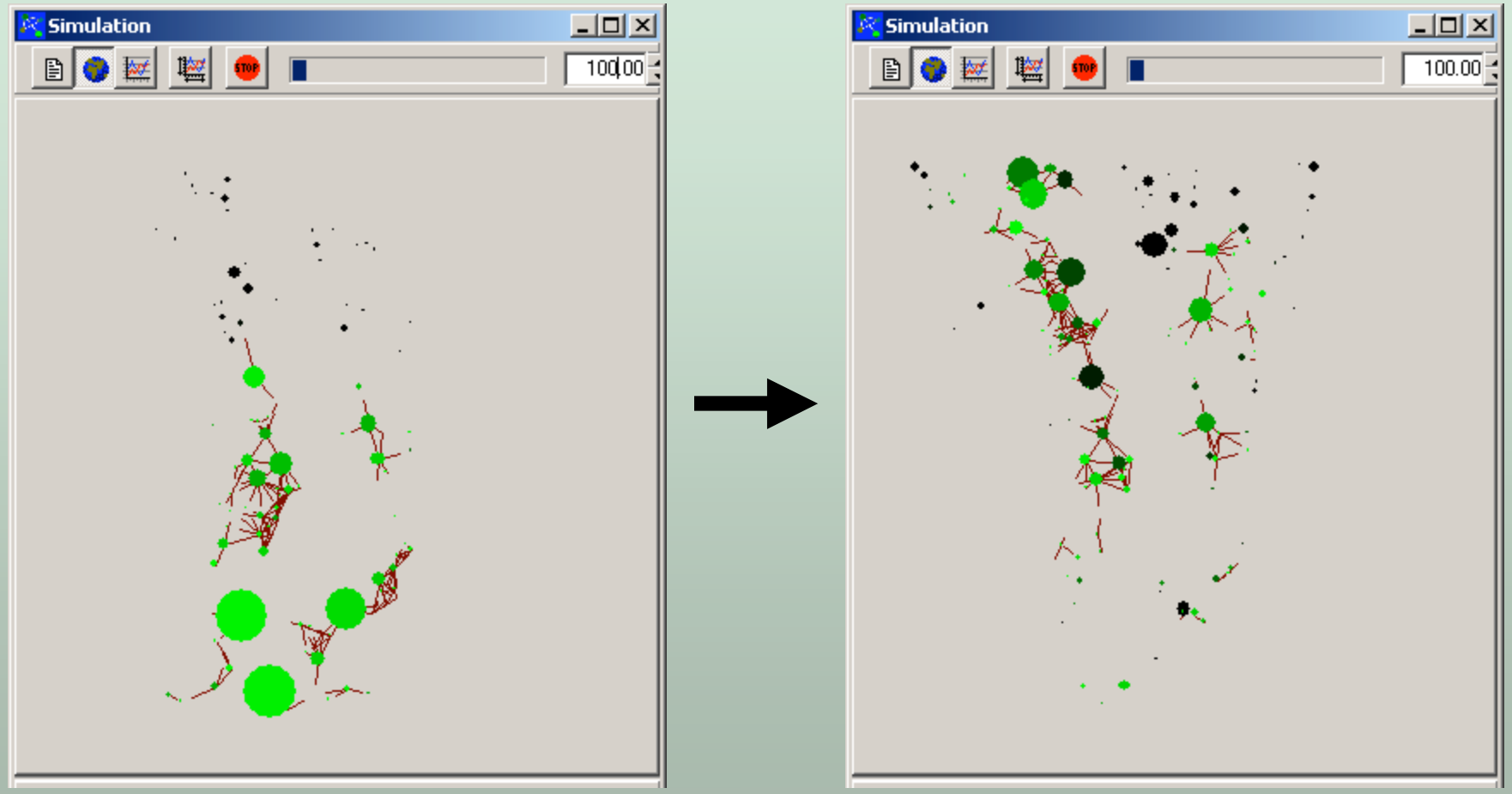
Dynamic Metapopulation Structure



Time step 1 (Year 0)

Time step 20 (Year 60)

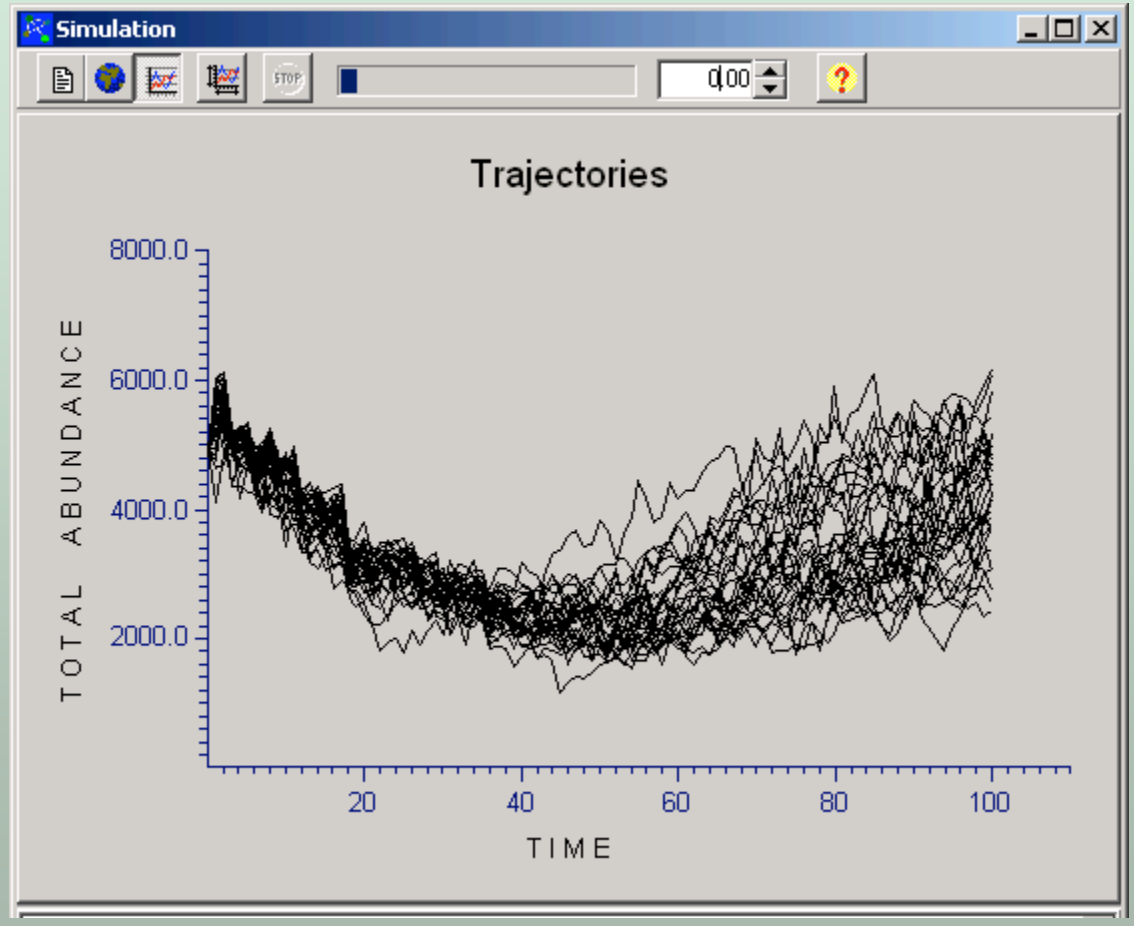
Dynamic Metapopulation Structure



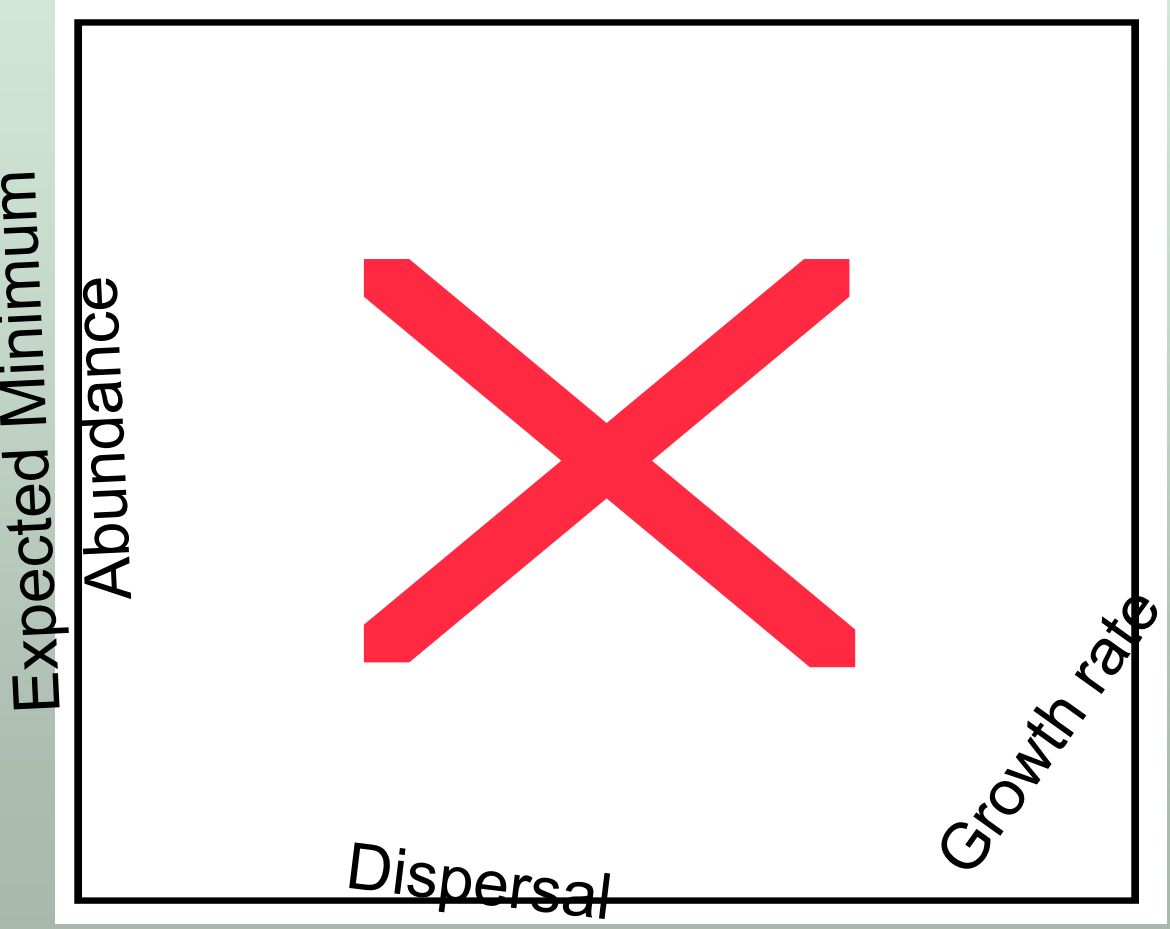
Time step 1 (Year 0)

Time step 20 (Year 60)

Simulations to estimate viability



Effect of Dispersal and Growth



Range of results:
QER: 0.0 to 1.0
EMA: 202 to 5049
5%ile: 93 to 6443

Conclusions

- The *IUCN Red List of Threatened Species* is an effective tool for drawing attention to species threatened by climate change.
- Red-listing species threatened by climate change requires new guidelines for identifying species vulnerable to climate change.
- Much uncertainty in climate change impact projections comes from interactions among demography, landscape structure, and range shifts. The guidelines should address these interactions.
- Analysis of these interactions will also provide general insights into the effects of spatial and demographic factors on projected extinction rates due to climate change.