Transfers and climate change

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A framework for using niche models to estimate impacts of climate change on species distributions

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Environmental variables

Effect of species on predictor variable (Hutchinson 1978)

Scenopoetic  Not affected by presence of focal species

Non-scenopoetic  Affected by presence of focal species
Environmental variables

Relative degree of causality (Austin 2002)

Proximal
- Determines the organism’s response

Distal
- Linked to proximal variable that determines response
Environmental variables

Physiological effect on species (Austin 2002)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect</td>
<td>Does not affect focal species physiologically; correlated with distribution via correlations with other factors</td>
</tr>
<tr>
<td>Direct</td>
<td>Affects focal species physiologically but is not consumed by it</td>
</tr>
<tr>
<td>Resource</td>
<td>Affects focal species physiologically and is consumed by it</td>
</tr>
</tbody>
</table>
Environmental variables: examples

Effect of species on predictor variable (Hutchinson 1978)

<table>
<thead>
<tr>
<th>Scenopoetic</th>
<th>Temperature or precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-scenopoetic</td>
<td>Water or nutrients consumed by a plant</td>
</tr>
</tbody>
</table>
Environmental variables: examples

Relative degree of causality (Austin 2002)

Proximal: Available soluble [P] at root hair;

Distal: Total soil phosphate;
Environmental variables: examples

*Relative degree of causality (Austin 2002)*

**Proximal**
- Available soluble [P] at root hair;
- Freeze durations that affect survival of cacti along poleward range margin

**Distal**
- Total soil phosphate;
- Mean temperature of coldest month, or annual mean temperature (relatively more distal than the former)
## Environmental variables: examples

*Physiological effect on species (Austin 2002)*

<table>
<thead>
<tr>
<th>Indirect</th>
<th>Direct</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation; latitude or longitude</td>
<td>Temperature; pH</td>
<td>Water or nutrients in soil</td>
</tr>
</tbody>
</table>
Environmental variables: guidelines

Effect of species on predictor variable (Hutchinson 1978)

Scenopoetic  Not affected by presence of focal species
USE!

Non-scenopoetic  Affected by presence of focal species
AVOID!
Environmental variables: guidelines

Relative degree of causality (Austin 2002)

Proximal  Determines the organism’s response

USE!

Distal
Environmental variables: guidelines

Relative degree of causality (Austin 2002)

Proximal

Determines the organism’s response

USE!

Distal

Linked to proximal variable that determines response

MAYBE: use for transfer only if the correlation with the driving variable is likely to hold across space/time

(see also indirect and direct)
### Environmental variables: guidelines

*Physiological effect on species (Austin 2002)*

<table>
<thead>
<tr>
<th>Indirect</th>
<th>Direct</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affects focal species physiologically but not consumed by it: <strong>USE!</strong></td>
<td>Affects focal species physiologically and is consumed by it: <strong>MAYBE: Use if scenopoetic</strong></td>
<td></td>
</tr>
</tbody>
</table>
Environmental variables: guidelines

*Physiological effect on species (Austin 2002)*

<table>
<thead>
<tr>
<th>Indirect</th>
<th>Does not affect focal species physiologically; correlated with distribution via correlations with other factors: MAYBE (depends on correl.)</th>
</tr>
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<tbody>
<tr>
<td>Direct</td>
<td>Affects focal species physiologically but not consumed by it: USE!</td>
</tr>
<tr>
<td>Resource</td>
<td>Affects focal species physiologically and is consumed by it: MAYBE: Use if scenopoetic</td>
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Environmental variables: guidelines

Physiological effect on species (Austin 2002)

Indirect

AVOID if correlated with distribution because of associations with factors related to dispersal/demography or with the distributions of important biotic interactors;
Environmental variables: guidelines

*Physiological effect on species (Austin 2002)*

Indirect

AVOID if correlated with distribution because of associations with factors related to dispersal/demography or with the distributions of important biotic interactors;

USE if correlated with distribution because of correlations with driving abiotic variables; use for transfer only if the correlation with the driving variable is likely to hold across space/time
Extrapolation in environmental space
Extrapolation in environmental space

![Graph showing extrapolation in environmental space](image-url)
Niche Space Assumption

The study contains the full range of conditions that the species can inhabit (for the examined abiotic variables)
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Consequences of violation:

Existing fundamental niche smaller than fundamental niche; species’ response is truncated for one or more abiotic variables
Niche Space Assumption

The study contains the full range of conditions that the species can inhabit (for the examined abiotic variables)

Consequences of violation:
Existing fundamental niche smaller than fundamental niche; species’ response is truncated for one or more abiotic variables

Recommendation:
Use presence records from many portions of species’ range and over multiple time periods; examine response curves and detect truncations
Extrapolation in environmental space

The graph illustrates the relationship between suitability and environmental conditions. The x-axis represents conditions existing in the study region and non-analog conditions (extrapolation), while the y-axis represents suitability. The curve shows the variation of suitability with changes in environmental conditions.
Extrapolation in environmental space

A graph showing the relationship between suitability and an abiotic variable. The graph indicates conditions existing in the study region and non-analog conditions (extrapolation).
Extrapolation in environmental space
Extrapolation in environmental space
Extrapolation in environmental space
Dispersal/demographic Noise Assumption

Factors related to dispersal, establishment, and persistence do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.
Dispersal/demographic Noise Assumption

Factors related to dispersal, establishment, and persistence do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

Biotic Noise Assumption

Biotic interactions do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.
Dispersal/demographic Noise Assumption

Factors related to dispersal, establishment, and persistence do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

Biotic Noise Assumption

Biotic interactions do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

Human Noise Assumption

Human modifications of the environment do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.
Noise Assumptions

These factors do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.
Noise Assumptions

*These factors do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas*

**Consequences of violation:**

Occupied niche space is smaller than existing fundamental niche; species’ response is truncated and/or distorted for one or more abiotic variables
Noise Assumptions

These factors do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

Consequences of violation:
Occupied niche space is smaller than existing fundamental niche; species’ response is truncated and/or distorted for one or more abiotic variables.

Recommendation:
Use data (presence and comparison) only from regions where species is at equilibrium or where limitations do not cause it to inhabit environmentally biased subset of abiotically suitable areas.
Conflicts between assumptions

Which is more important?

Niche Space Assumption

The study contains the full range of conditions that the species can inhabit (for the examined abiotic variables)

Noise Assumptions

These factors do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas
Summary of assumptions

Try to fulfill Noise Assumptions, even if that means violating Niche Space Assumption, then be cautious when extrapolating in environmental space.

Danger!

More danger!

Safe
Niche-based models are critical …
but must be coupled with Dispersal simulations

- Occurrence records
- Environmental data

Algorithm

Model of niche

- another place
- suitable areas here and now
- another time
Niche models coupled with Dispersal simulations

Model of niche

Future suitable areas

Future variables (climate)
Niche models coupled with Dispersal simulations

Model of niche → Future suitable areas → Simulation
Niche models coupled with Dispersal simulations

- Model of niche
  - Current suitable areas
  - Future suitable areas
  - Simulation
Niche models coupled with Dispersal simulations

Sampling data

Land cover and current occupied areas of interacting species

Current suitable areas → Current occupied areas

Model of niche

Future suitable areas → Simulation
Niche models coupled with Dispersal simulations

Model of niche → Current suitable areas → Current occupied areas → Simulation

Model of niche → Future suitable areas → Current suitable areas → Current occupied areas
Niche models coupled with Dispersal simulations

Model of niche

- Current suitable areas
- Future suitable areas

- Current occupied areas
- Simulation

- Dispersal and demographic data
- Future land cover and occupied areas of interacting species

Future occupied areas
Niche models coupled with Dispersal simulations

Sampling data

Land cover and current occupied areas of interacting species

Current suitable areas

Current occupied areas

Future land cover and occupied areas of interacting species

Future variables (climate)

Model of niche

Future suitable areas

Simulation

Future occupied areas

Dispersal and demographic data
Niche models coupled with Dispersal simulations

Algorithm

Sampling data
- Land cover and current occupied areas of interacting species

Algorithm

Occurrence records

Niche model

Environmental data (climate)

Future suitable areas

Current suitable areas

Current occupied areas

Dispersal data
- Future land cover and occupied areas of interacting species

Future variables (climate)

Future occupied areas
Thank you

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Cary Institute of Ecosystem Studies: “Climate change and species interactions: Ways forward”

http://web.sci.ccny.cuny.edu/~anderson