Lecture 9

Model Uncertainty

Geog 490/590
Spatial Modeling
Spring 2015

Deterministic vs Stochastic Models

Deterministic: Results will always be the same for a given set of boundary conditions and input parameters.

Tradeoff: Tractability at the cost of realism

Deterministic vs Stochastic Models

Stochastic: Include some random component in the process.

Tradeoff: Intractable but more realistic.

"Few, if any, systems show no variation in time and space, or are perfectly understood and measured." (O'Sullivan and Perry, 2013)

Model Evaluation

Three categories of stochastic simulation model analysis:

1. Model-based Uncertainty
2. Confrontational
3. Exploratory/Heuristic

Confrontational Analysis

Confrontational		Section 7.4
Visual 'diagnostics'	Visual comparison of empirical observations and model predictions (e.g. visual inspection for systematic bias via residual plots, etc.)	Mayer and Butler (1993)
Statistical methods	Summary of differences between observations and predictions (non-spatial and spatial difference measures)	Mayer and Butler (1993)
	Quantitative comparison and analysis of predictions and observations (via linear models, correlation, etc.)	

Exploratory Analysis

Exploratory/heuristic		Sections 7.6 and 7.7
Pattern-oriented modelling	Use of *multiple* observed patterns to evaluate and refine models and select between alternate representations (drawing on the methods listed above)	Grimm and Railsback (2012), Grimm et al. (2005), Wiegand et al. (2003)
Participatory modelling	Methods of model evaluation that seek to involve all stakeholders in the modelling process from conceptualisation to application This might, for example, involve assessing a model's legitimacy based on whether users believe it adequately represents the system of interest—this may or may not include structural and confirmatory evaluation	Castella et al. (2005), Millington et al. (2011)

Uncertainty Analysis

Method	Description and purpose	Section/Reference
Model-based uncertainty		Section 7.3
Error analysis	Analysis of error in model output(s) as a function of the uncertainty associated with each parameter input to the model, including error propagation analysis and error budgeting	Haefner (2005), Jager and King (2004)
Sensitivity analysis	Identification of model components most sensitive to *local* parameter uncertainty	Haefner (2005), Hamby (1994)
Uncertainty analysis	Identification of how uncertainty in multiple (interacting) parameters and their representation will affect a model	Haefner (2005)
Robustness analysis	Analysis of the extent to which different representational decisions influence model dynamics	Levins (1966), Railsback and Grimm (2012)

Sensitivity Analysis

Identification of model components most sensitive to ***local*** parameter uncertainty.

Three Objectives of Sensitivity Analysis

1. Model evaluation: does our model behave like its suppose to?

2. Research design: helps determine the precision at which parameters need to be collected or represented.

3. Understanding: reveals the processes and parameters that drive the system.

(O'Sullivan and Perry, 2013)

How to Conduct A Sensitivity Analysis

1. Determine which model parameters you want to test.

2. Determine the appropriate parameter settings that you want to test (consider tradeoffs between precision and computation time).

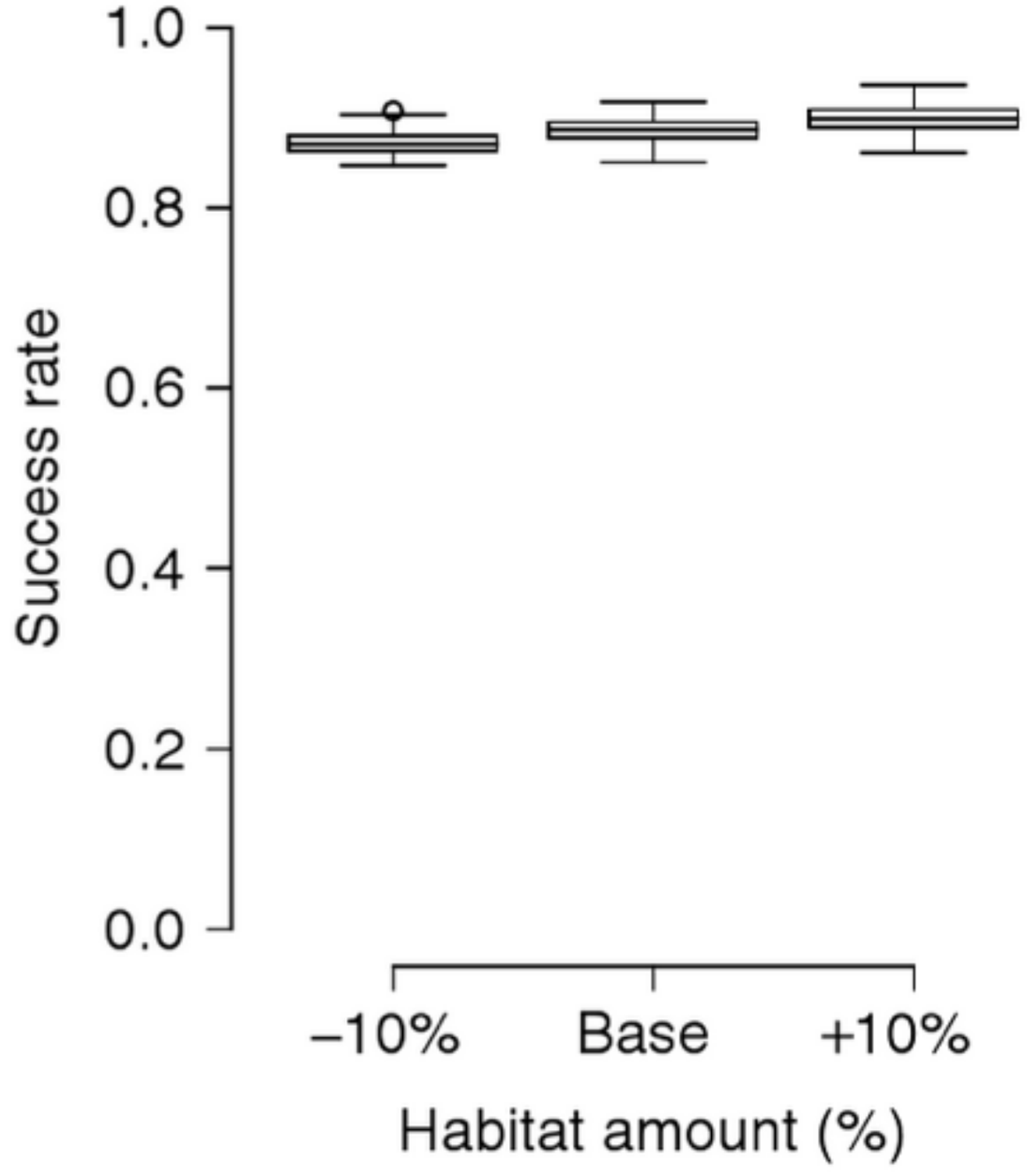
3. Determine the number of runs you want for each parameter setting.

4. Run.

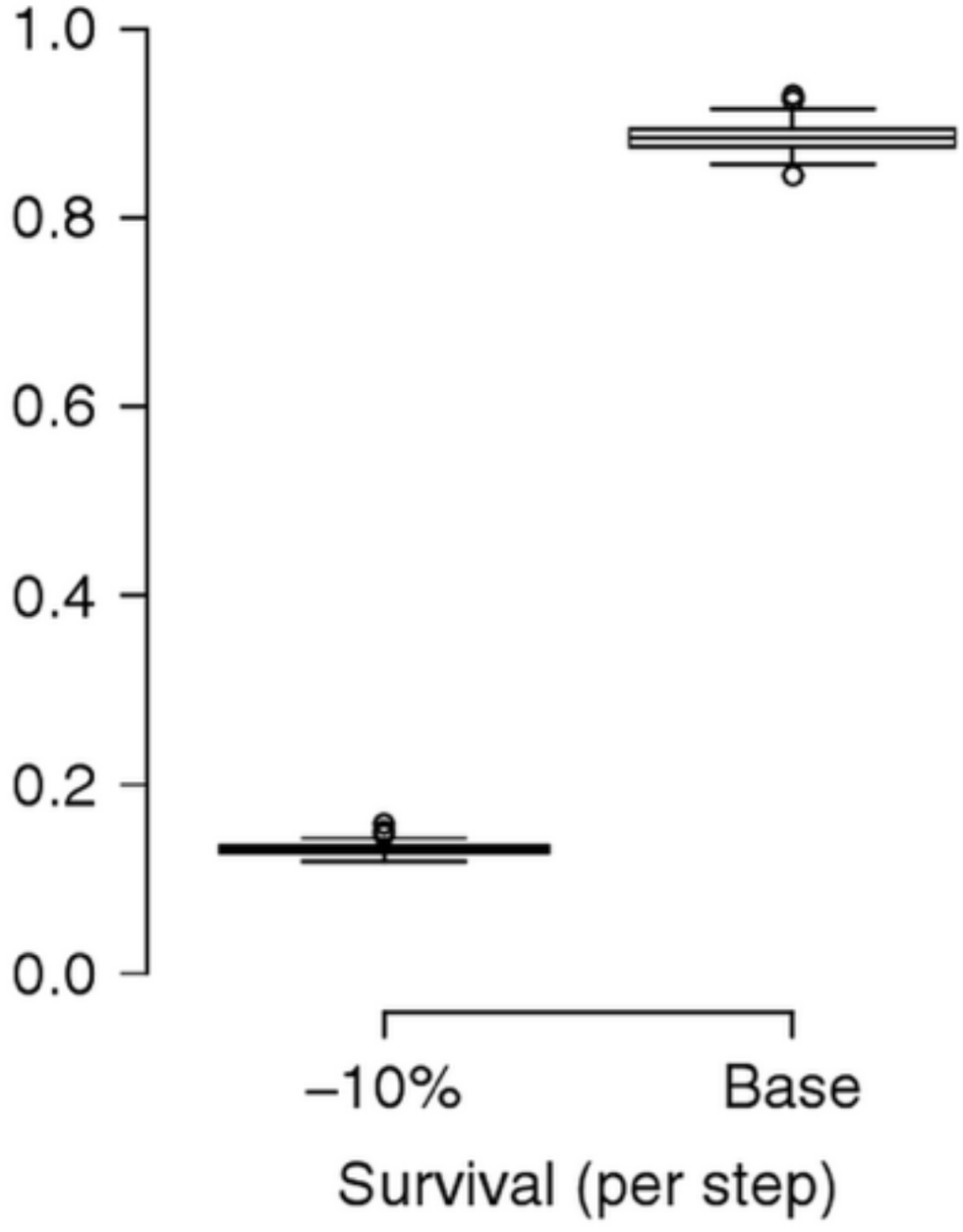
5. Analyze results in a temporal and/or spatial format.

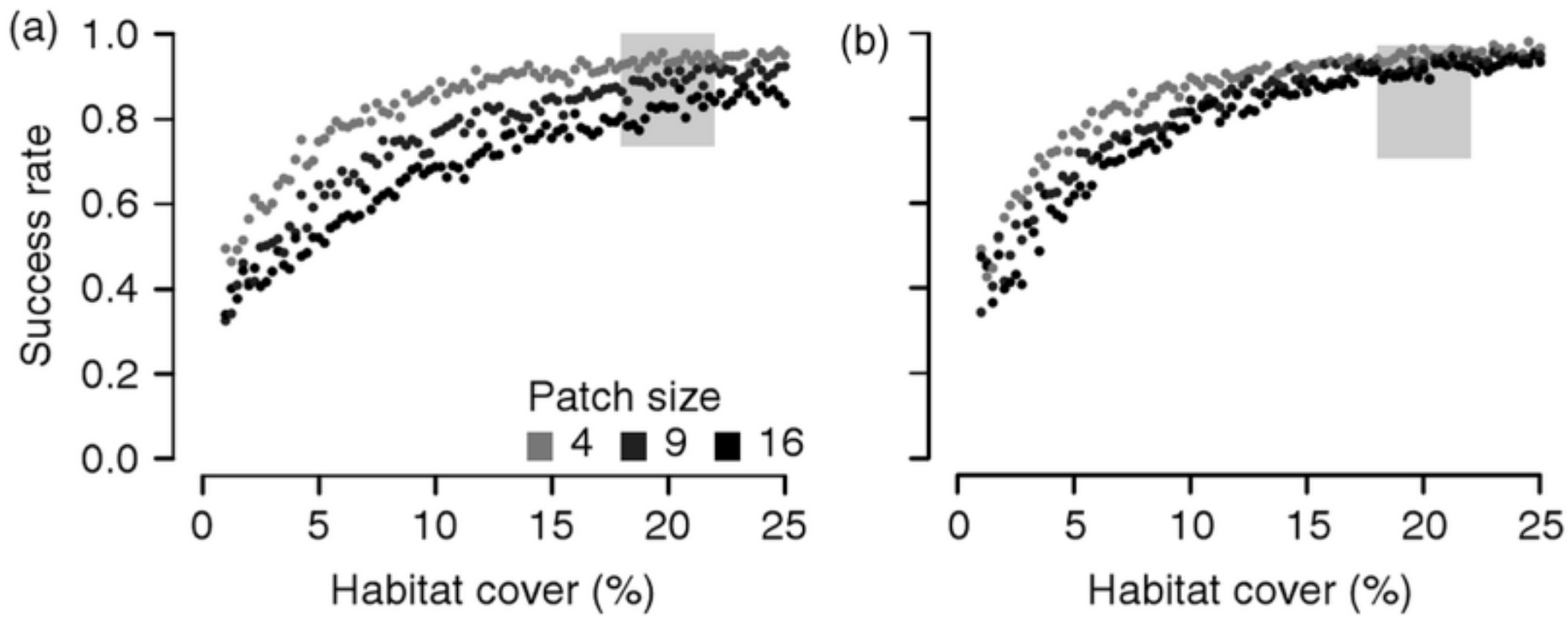
How to graph results

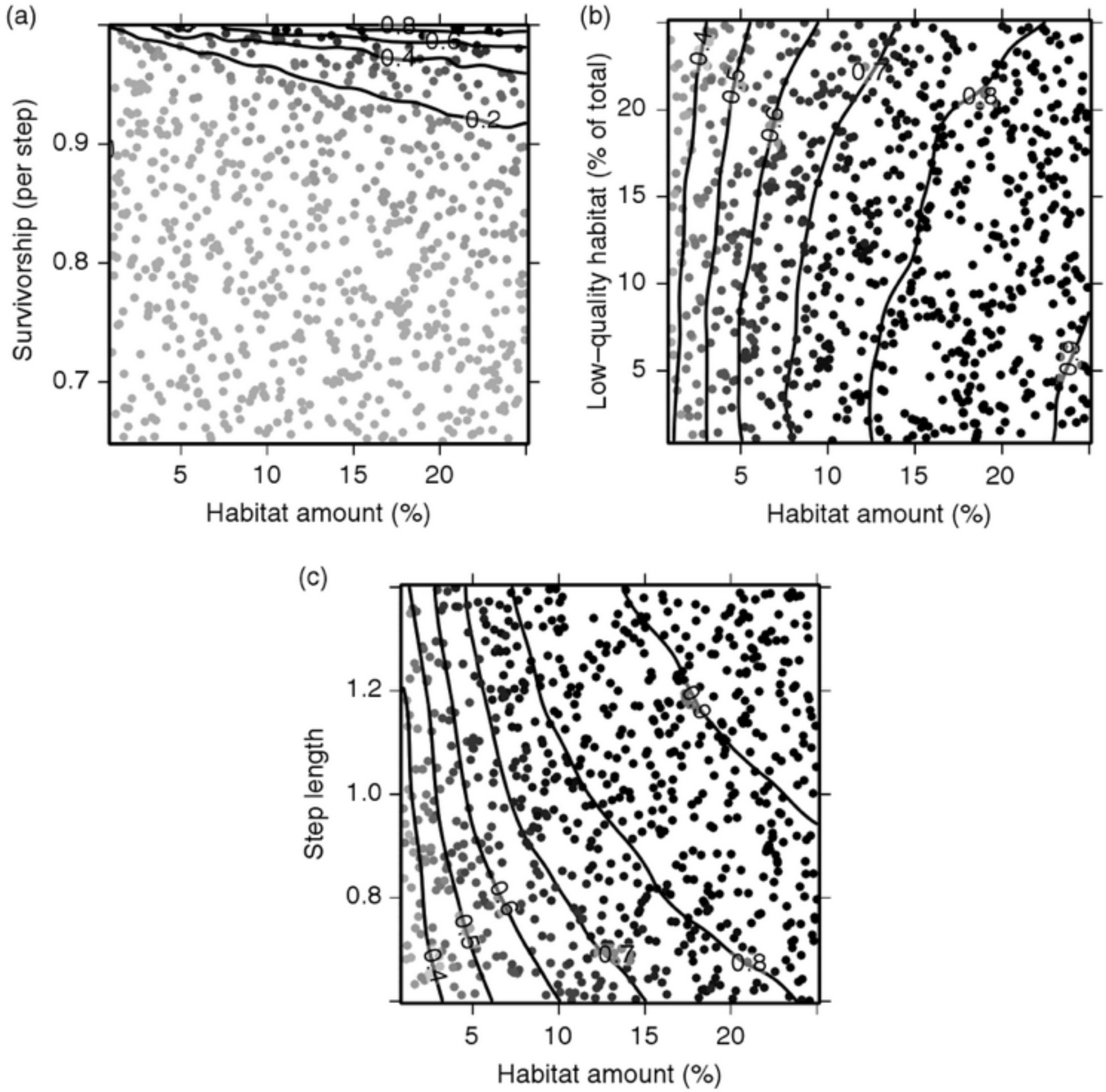
(a)

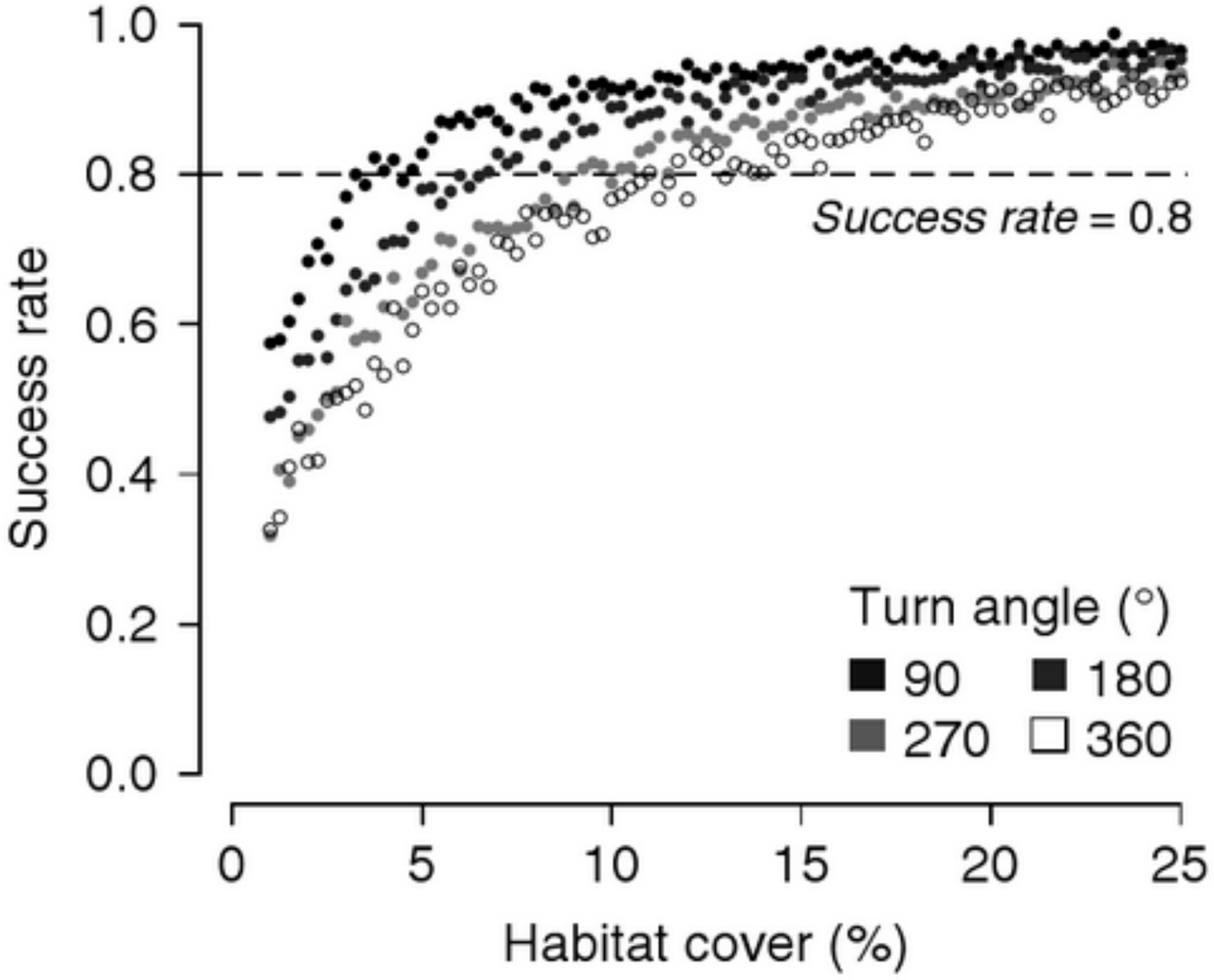

1.0
0.8
0.6
0.4
0.2
0.0
Success rate
–10%
Base
+10%
Habitat amount (%)

(b)


1.0
0.8
0.6
0.4
0.2
0.0
–10%
Base
Survival (per step)


(a)
(b)
Success rate
1.0
0.8
0.6
0.4
0.2
0.0
Patch size
4
9
16
0
5
10
15
20
25
Habitat cover (%)
Habitat cover (%)


(a)
Survivorship (per step)
0.9
0.8
0.7
0.8
0.6
0.4
0.2
5
10
15
20
Habitat amount (%)
(b)
Low−quality habitat (% of total)
20
15
10
5
0.4
0.5
0.6
0.7
0.8
0.9
5
10
15
20
Habitat amount (%)
(c)
Step length
1.2
1.0
0.8
0.4
0.5
0.6
0.7
0.8
0.9
5
10
15
20
Habitat amount (%)


1.0
0.8
0.6
0.4
0.2
0.0
Success rate
Success rate = 0.8
Turn angle (°)
90
180
270
360
0
5
10
15
20
25
Habitat cover (%)