Workshop on R and movement ecology:

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Lecture 7

Simulating Movement: When and Why?

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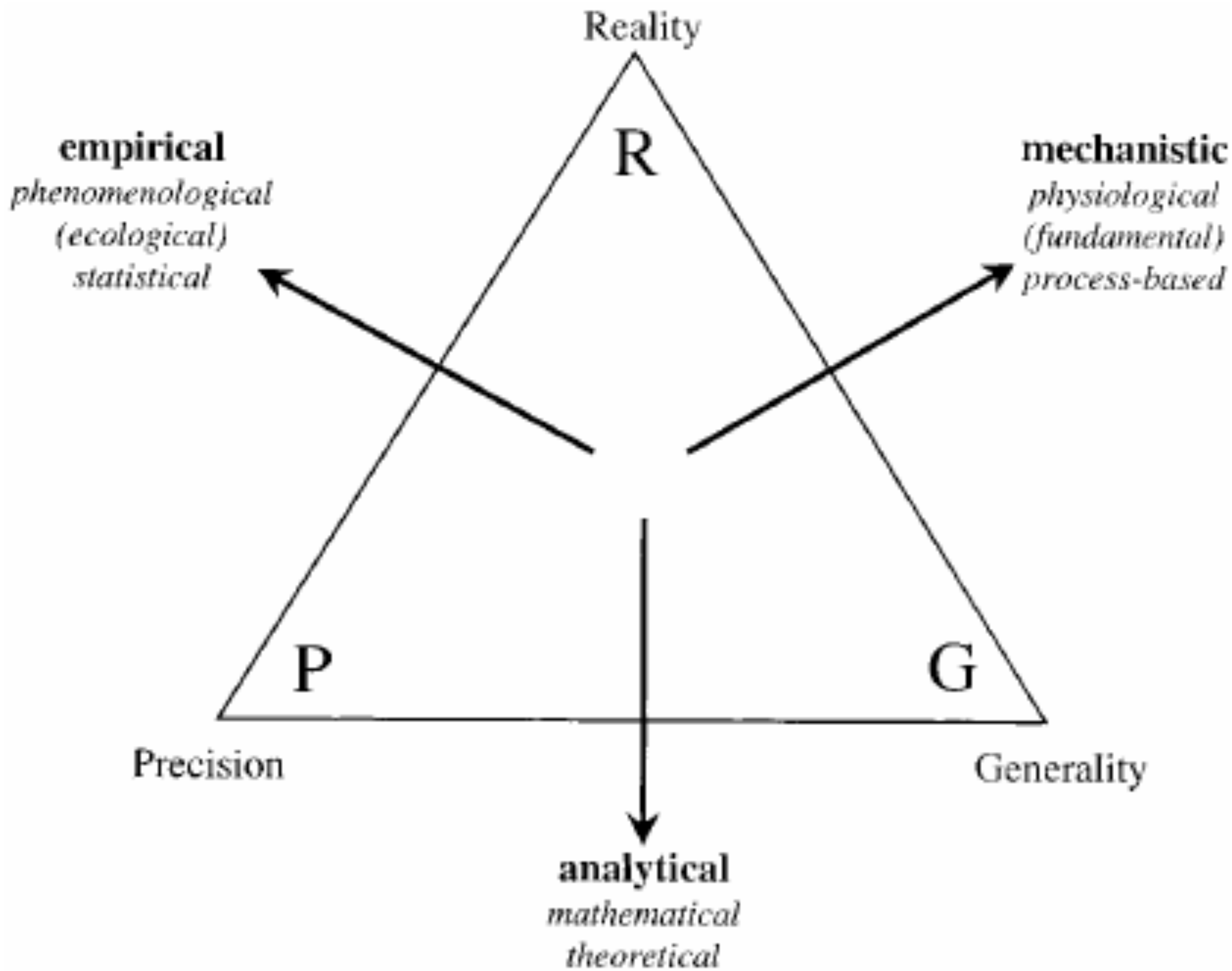
Why do we model?

1. Explanatory: To provide conceptual understanding
2. Predictive:
    - Forecasting: To provide a prediction before it happens
    - Projection: To predict what would happen if…
        - Useful aid policy design, management decisions…
3. Operational: To inform intervention delivery, recommend metrics for surveillance, inform trial design

Adapted from slides by John Marshall in UCB's Public Health C205

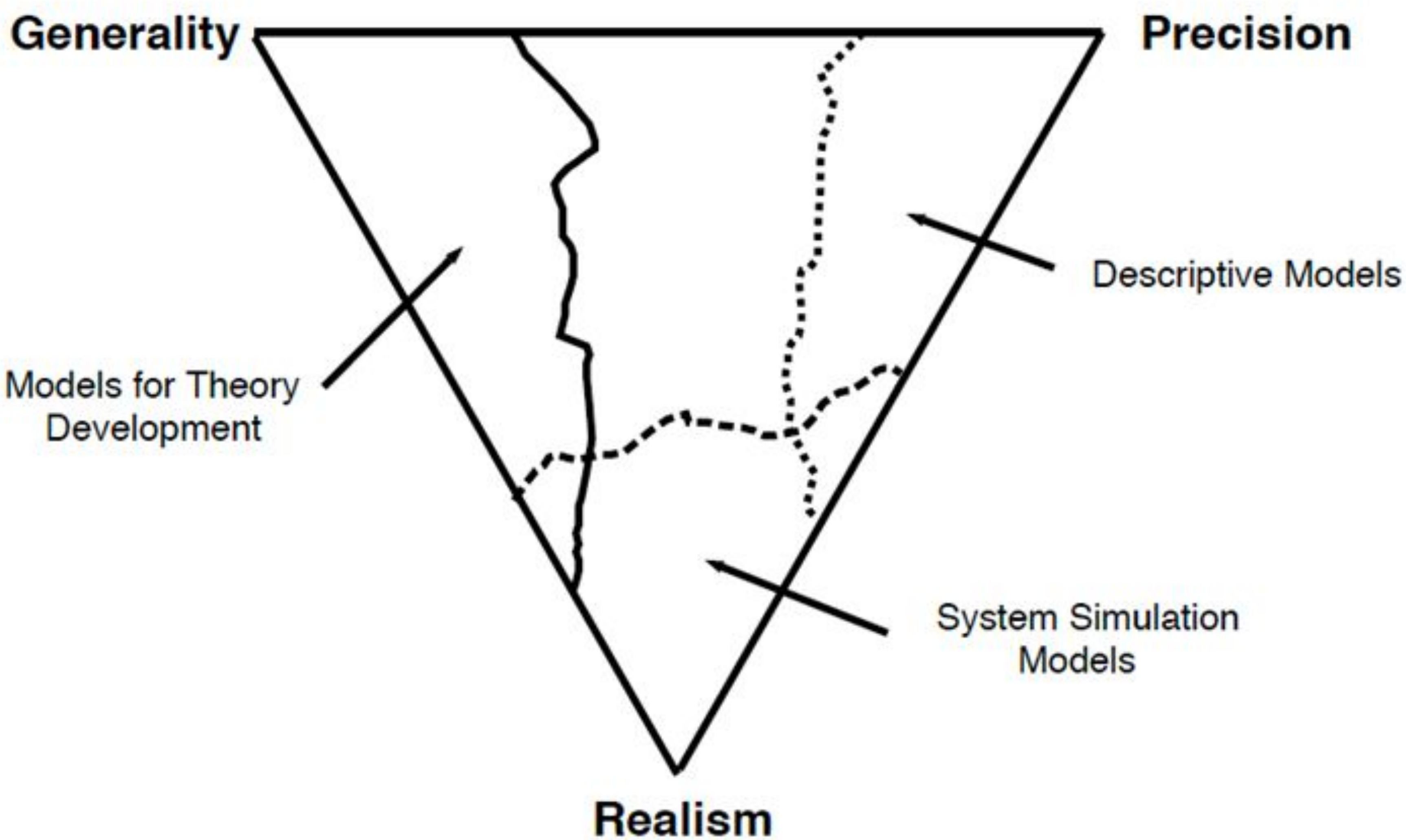
What kind of models?



A classification of models based on their intrinsic properties. After Levins (1966), and Sharpe (1990).

(Guisan & Zimmerman 2000)

All models are wrong… some are useful. - George Box



No one model can do everything

NIMBioS
National Institute for Mathematical and Biological Synthesis

Types of stochastic models

Population based:

- Keep track of total number of individuals in each compartment
- Simulate the events that will happen to that group of individual
- Can either model in discrete or continuous time
- Faster to simulate

Individual based/agent based:

- Simulate each individual and events which happen to each individual
- Can include much realistic detail, but can be slow to simulate

How do we model movement?

Population Level:

- Distributional, or metapopulation models
- modeling by diffusion, percolation, or wave-front

Individual Level:

- Agent based models
- Random walk, CRW, BCRW

Additionally, we may choose to simulate the landscape animals move on…

Some definitions:

Stochastic: Random

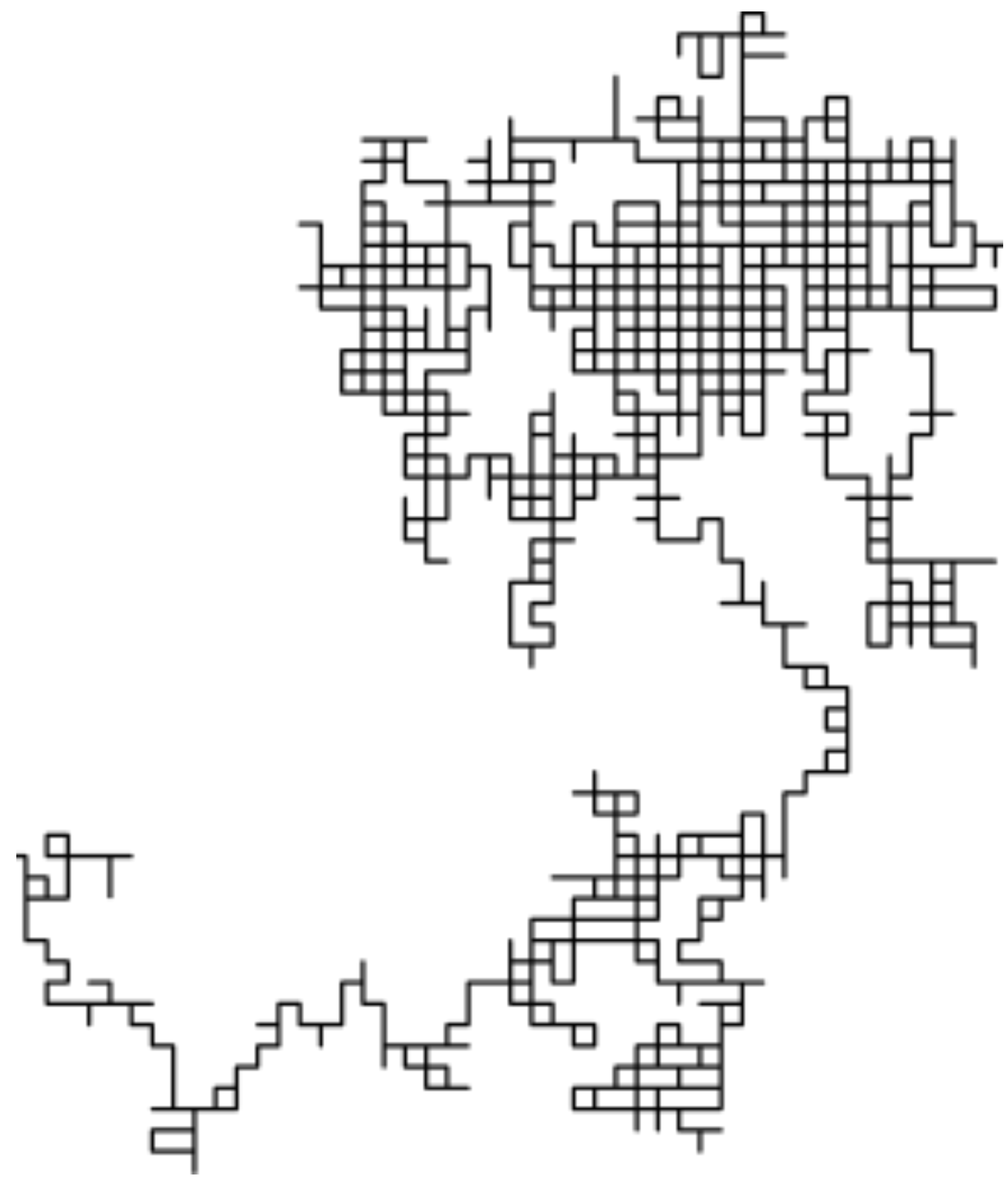
Markov process: A process whose future probabilities are determined by its most recent values.

A **Markov chain**: "a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event."

In other words, your state at t+1 is determined solely by your state at t. A second or third order Markov process is instead a process where by t+1 dependent on t-1 or t-2

Random Walk

- A **random walk** is a stochastic process, that describes a path that consists of a succession of random steps.
- Markov random walks, are a special category of Markov Chains.
- Not all random walks are Markov processes



Random walks, cont.

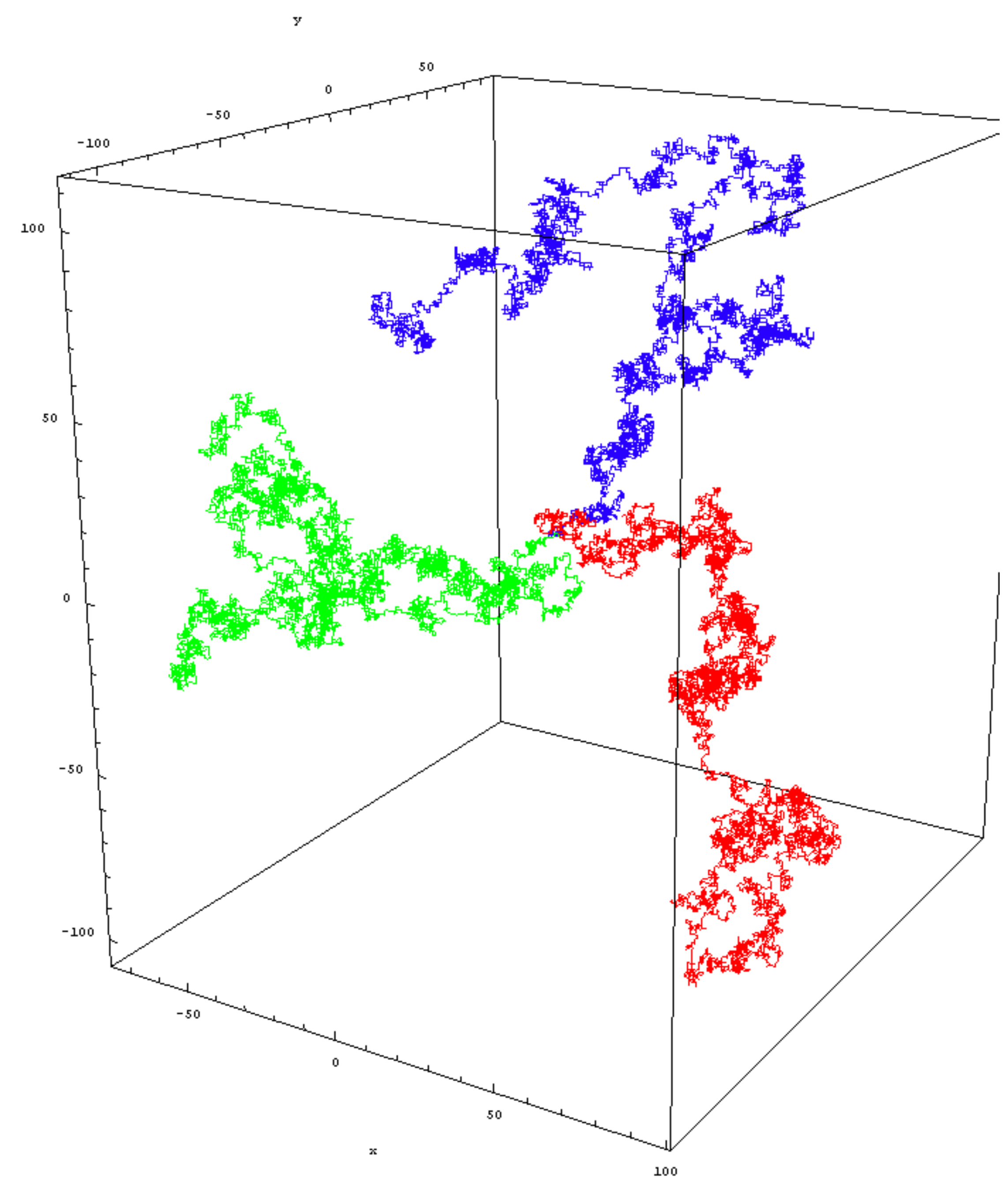
Random walks can used to model:

- The search path of a foraging individual

- Nomadic animals

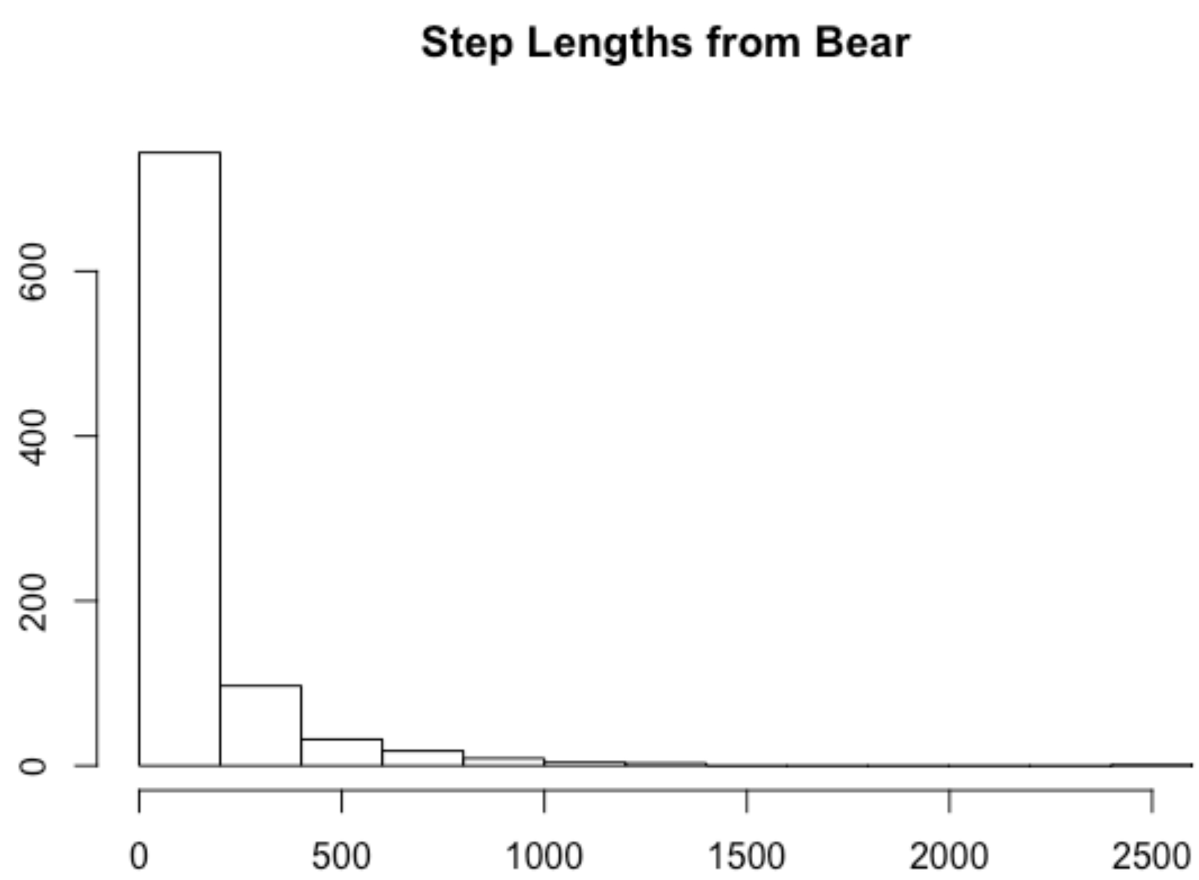
In a random walk for animal movement, an individual takes steps at regular intervals with step length and direction chosen randomly.

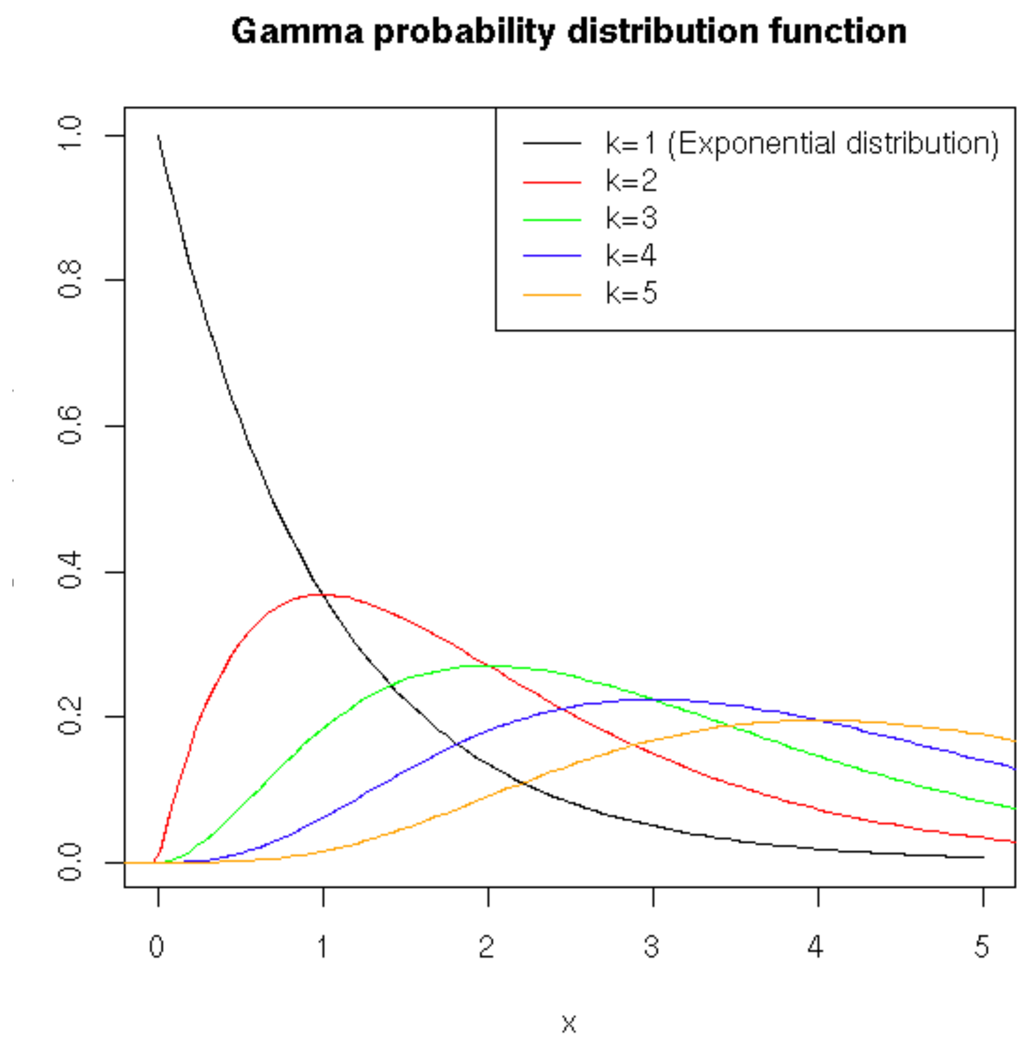
A random walk can be three dimensional.



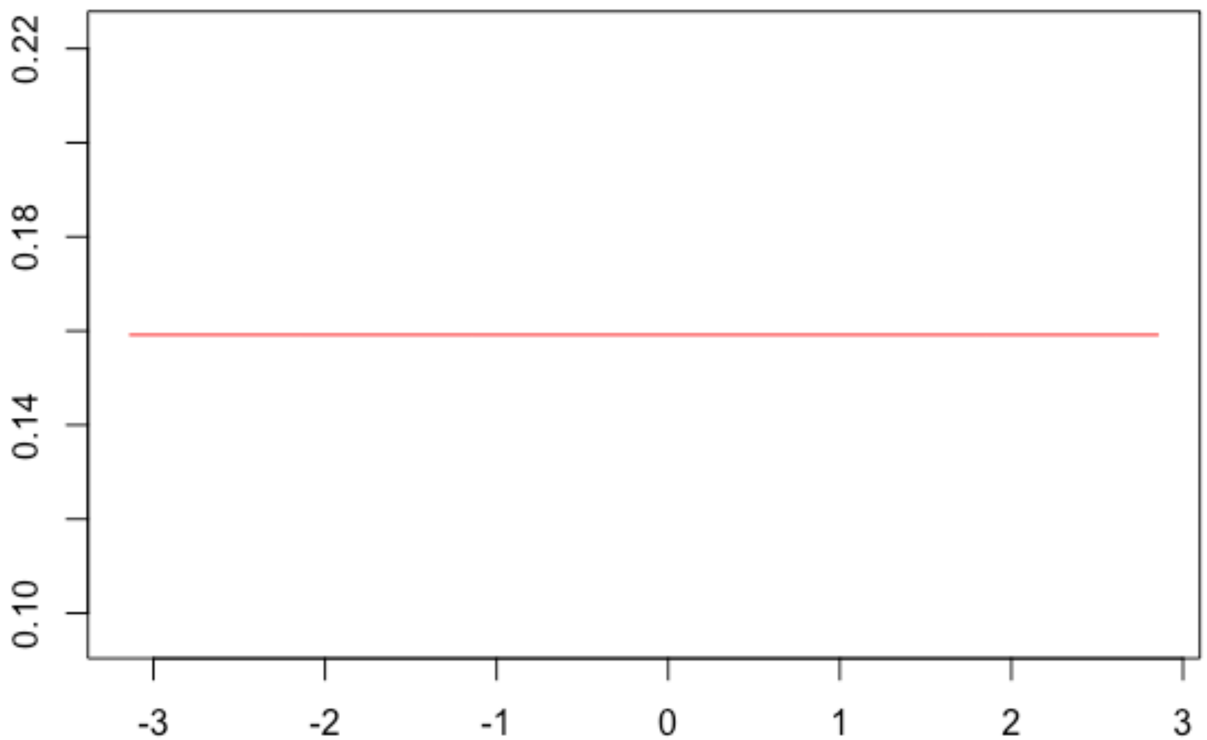
Underlying Distributions

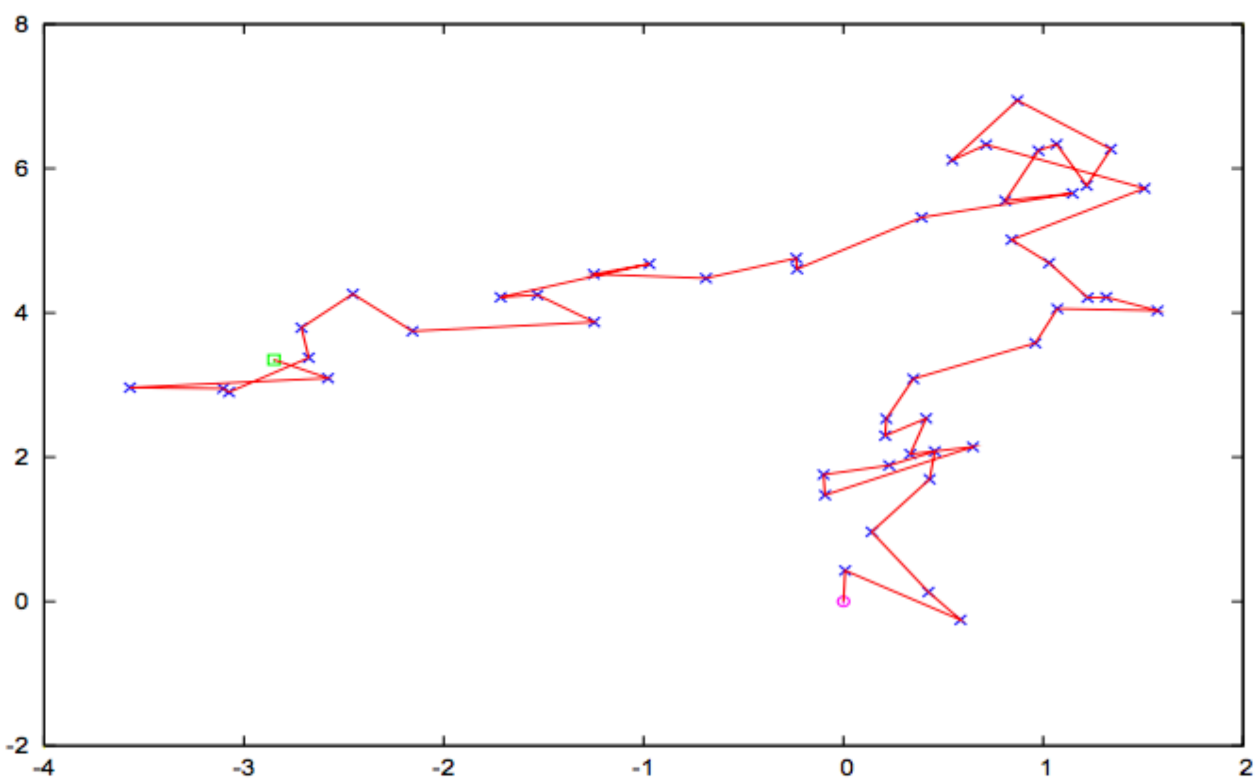
When modeling movement by ***random walk***, the direction and size of a random walker's steps is chosen at random, but some directions or step lengths may be more likely than others based upon the distributions drawn from.





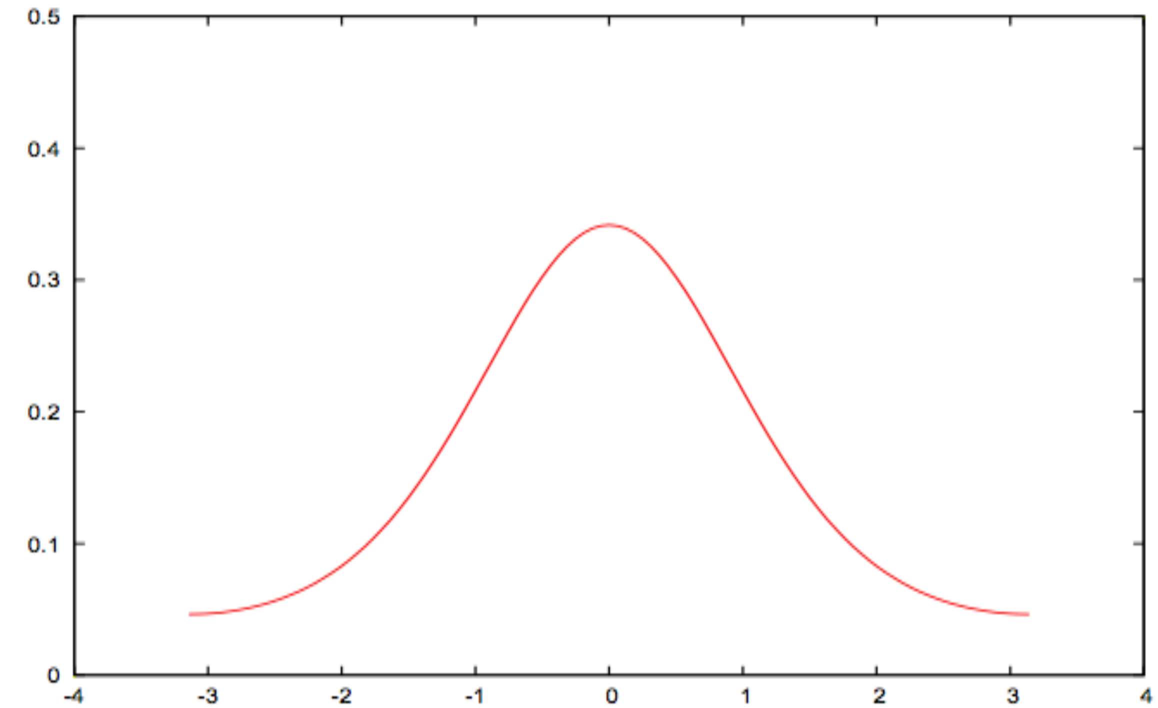
Uniform Turning Angle Distribution

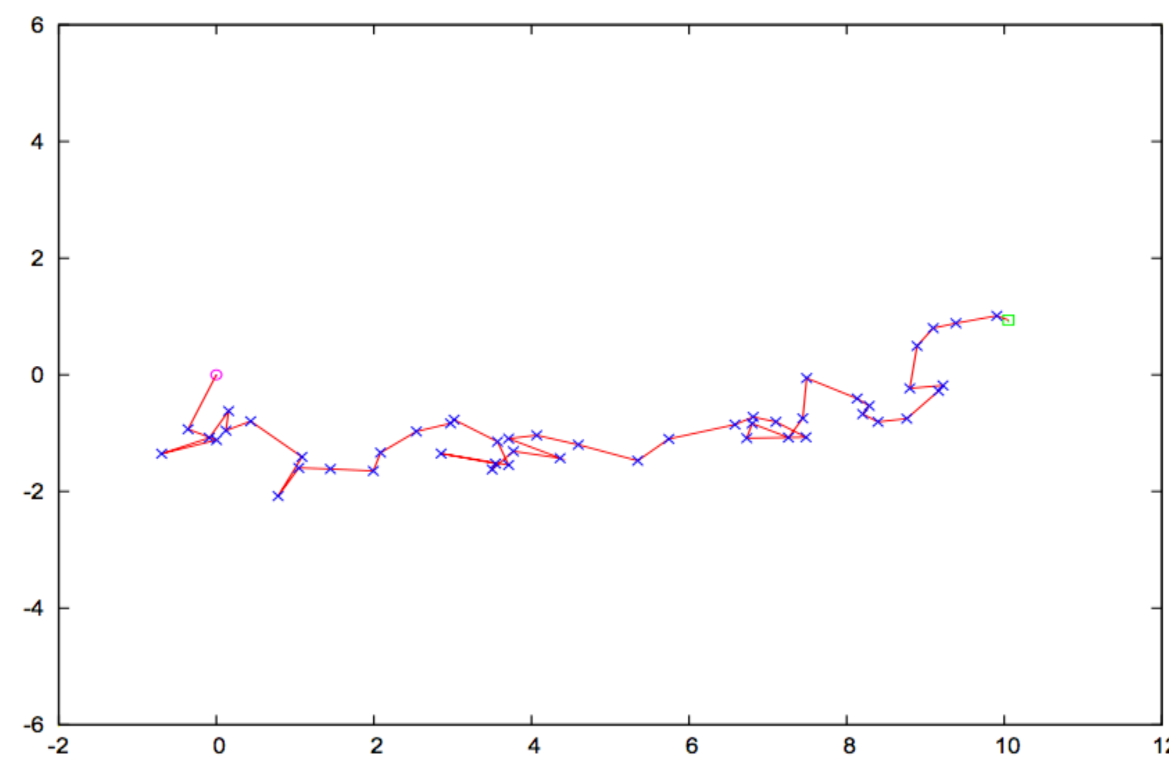




http://www.stat.ufl.edu/STA6934/corrRW.pdf

NonUniform Turning Angle Distribution

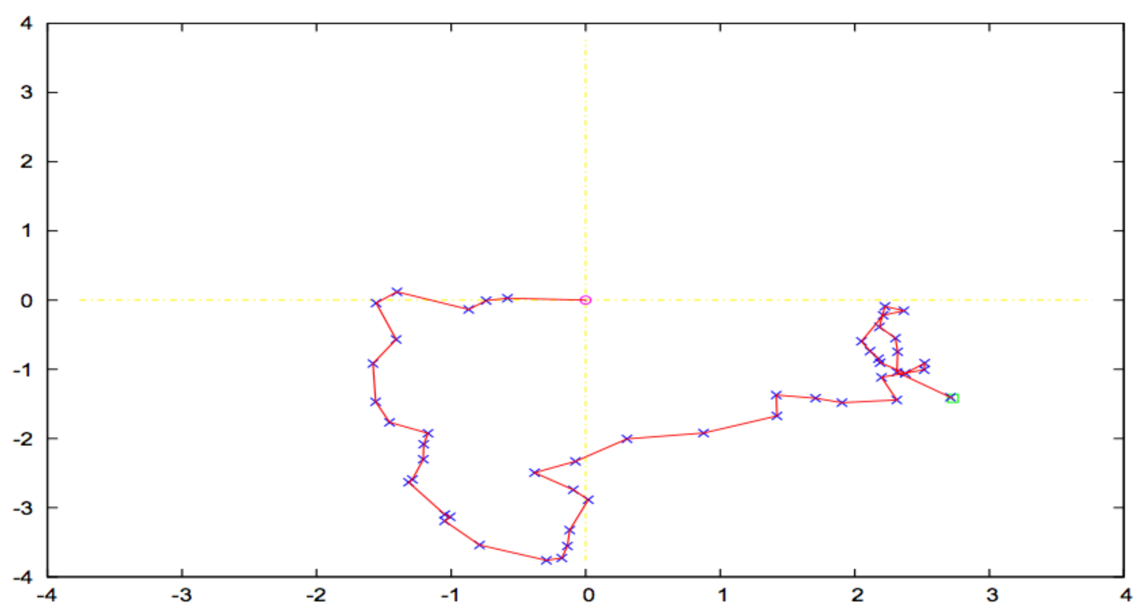




Plots from UFL STA 6934/5805

Correlated Random Walk

- In **random walks**, choice of direction at step i is unrelated to direction of previous step.
- In much animal motion, however, direction is persistent. The animal changes its direction gradually from step to step. This is commonly modeled with **correlated random walk**.
- In **correlated random walks**, direction chosen at step i+1 is related to direction of step i. What is randomly chosen is *the change in direction from step i to step i + 1.* This change in direction is the **turning angle** for step i + 1.



See Kareiva & Shigesada (1983) or McCulloch & Cain (1989). Slides adapted from UFL STA 6934/5805

Biased (Correlated) Random Walks

In addition to (or in lieu of) correlating the direction of successive steps, you can add a directional bias (and biological realism) to an agents walk by biasing the distribution of turning angles towards or away from things.

BCRWs are commonly used to model “realistic” animal movement.

For instance, Van Moorter et al. 2009 simulated biased correlated random walks where the agents movement was biased towards areas of the landscape with highest resources and biased against areas they had just been (self-avoidance behavior).

So that’s neat but…

What can we actually learn from simulating animal movement??

Exploring mechanisms

Often in ecology we can't run the experiments we dream of :
i.e. what if this animal was in a novel environment? What is resources were distributed differently?
Simulation lets us do so and thereby explore the mechanisms underlying the processes we observe.

Bonnell et al. 2010, evaluated the effect of changing resource distributions to evaluate the impact of spatial aggregation on transmission rates of disease in an endangered population of Red Colobus monkey.

Result: Spatially aggregated resources likely influence transmission rates in species using patchy environments

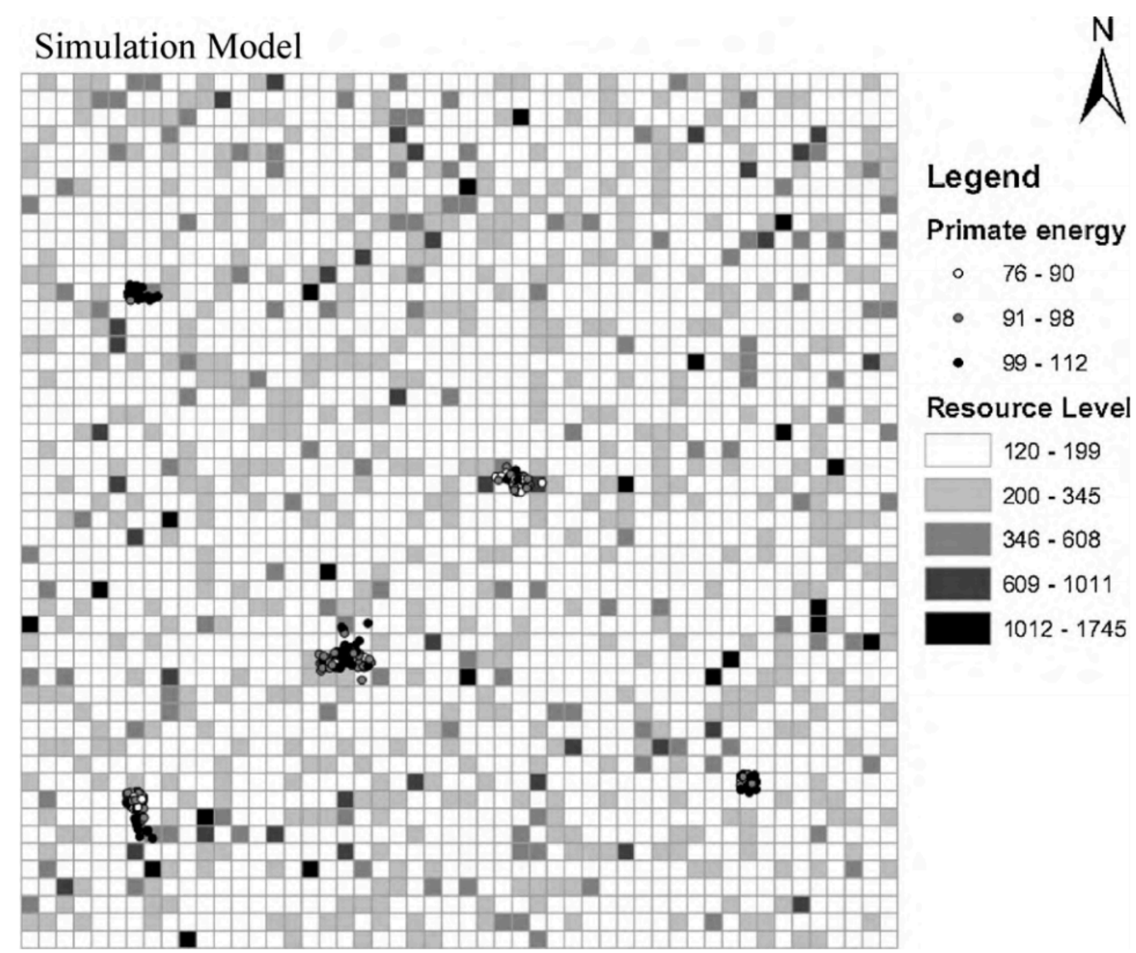


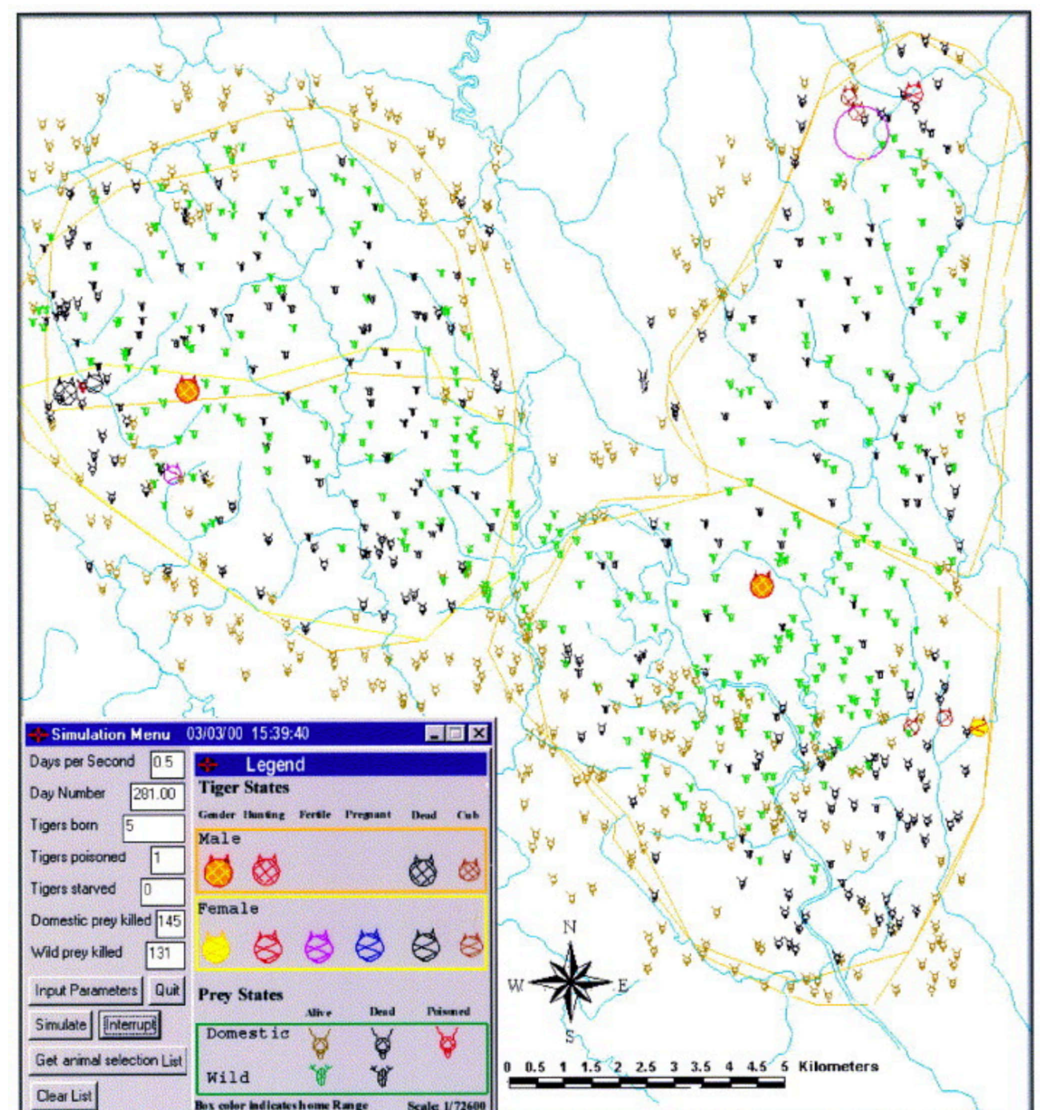
Fig. 2. Simulation environment: individual red colobus agents are represented by circles, resources are represented by grid squares.

Predicting response

Often in policy making and adaptive wildlife management, we want to know what will happen as a result of our decisions.
Simulation can forecast outcomes for decision making.

Ahearn et al. 2010 present a dynamic, spatially explicit model, TIGMOD, as a tool for analyzing the interaction between tigers and humans in multiple use forests. It provides a means of understanding the right balance between forest use by tigers and use by villagers, which can lead to implementation of management strategies that optimize both.

Result: This study shows that tiger populations are sustainable at low density of domestic prey but not sustainable if domestic prey density increases to three or more per square kilometer. Additionally, change in behavior and attitudes of villagers towards tigers, such as increasing guarding of livestock and higher tolerance of domestic prey kills will significantly reduce tiger mortality caused by poisoning.



Aiding management

Parrott et al. 2011 developed 3TSim, a agent based simulation framework for vessel traffic and marine mammal management in the St. Lawrence River Estuary.

3MTSim includes an individual-based model of marine mammal movement patterns that has been elaborated based on existing telemetry data on fin, blue, and beluga whales as well as on land-based theodolite tracking of humpback and minke whales

The model predicts relative risk of whale collisions and test the efficacy of various scenarios to reduce whale-vessel encounters, such as moving the commercial shipping routes relative to whale feeding grounds.

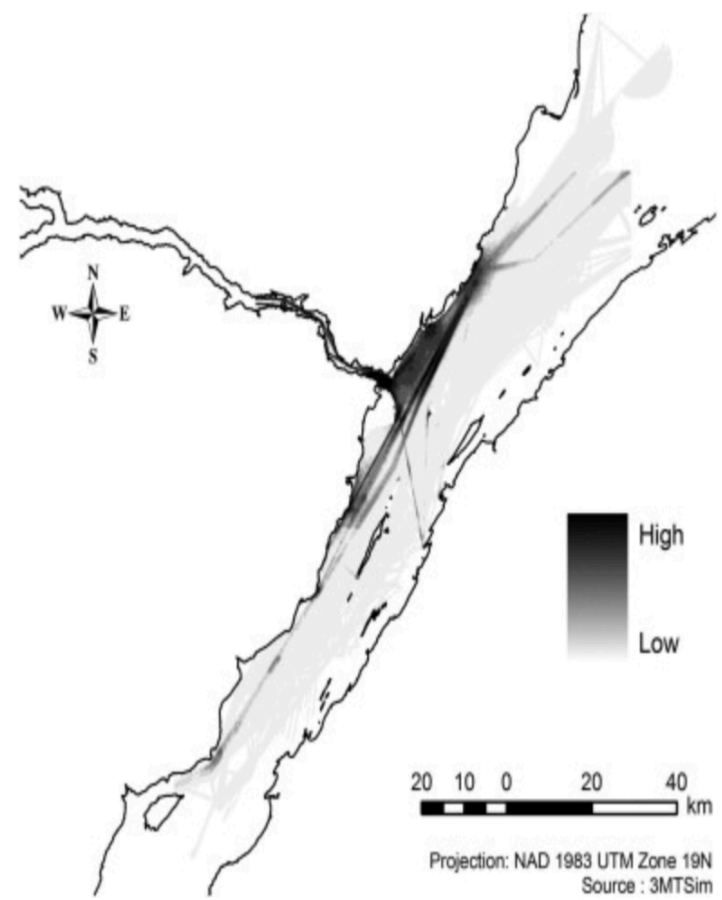


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Fig. 6. Relative risk of lethal collisions between whales and vessels for the 16 knot speed limit scenario (simulated data).

For many more examples, applications, information:

McLane et al. 2011, A highly recommended review of the many types and purposes of agent based models in Ecology

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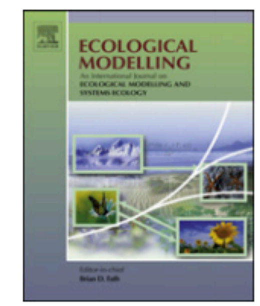

Review

The role of agent-based models in wildlife ecology and management

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ABSTRACT

Conservation planning of critical habitats for wildlife species at risk is a priority topic that requires the knowledge of how animals select and use their habitat, and how they respond to future developmental changes in their environment. This paper explores the role of a habitat-modeling methodological approach, agent-based modeling, which we advocate as a promising approach for ecological research. Agent-based models (ABMs) are capable of simultaneously distinguishing animal densities from habitat quality, can explicitly represent the environment and its dynamism, can accommodate spatial patterns