Salamander movement in a patchy environment

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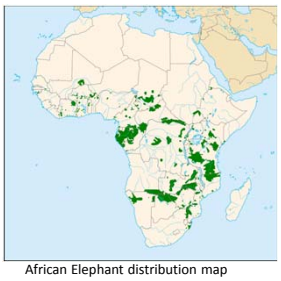
Outline

- What is a patchy environment?
- Fire salamander movement
  - Ephemeral pools as patches in an arid environment
- Mathematical models of movement strategies
- Genetic indications of salamander movement strategy

Patchy habitats



African Elephant distribution map
http://en.wikipedia.org/wiki/File:African_Elephant_distribution_map.svg

http://www.columbia.edu/~mu2126/BDFFP.jpg

Patchy habitats

- Suitable "core" habitat surrounded by unsuitable "matrix"
- Can mean:
  - Severe barriers

How are patches isolated?

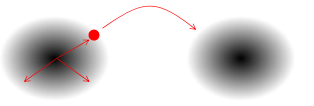
Severe barriers

Reduced fitness in matrix

So why disperse through a matrix?

Patchy habitats

Vital resource in core

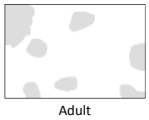


Density-dependent dispersal from natal site

Only those arriving at another patch will survive

Life cycle constraint

Juvenile



Adult

Patchy habitats

- Suitable "core" habitat surrounded by unsuitable "matrix"
- Can mean:
  - Severe barriers
    - Probability of dispersal is low
  - Reduced fitness in matrix
    - Differential mortality
  - Vital resource in core
    - No choice but to seek them out
  - Life cycle constraint
    - Fitness maps may differ by life cycle stage

What affects the final distribution?

- Differential mortality in matrix
- Behavioural preferences for environment
- Life cycle constraints

Amphibians

- Differential mortality
  - Physiological requirement for moisture
- Behavioural preferences
  - Cognitive orientation abilities
- Life cycle constraints
  - Aquatic breeding

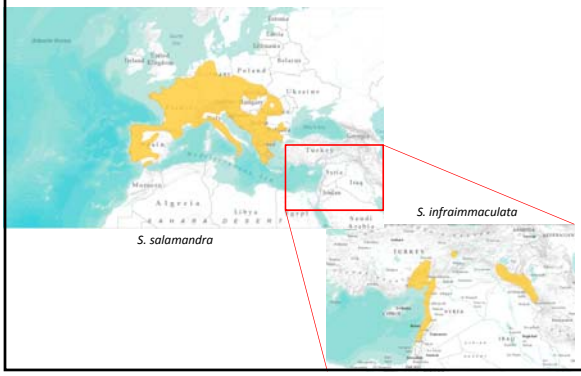
Hypotheses

- Differential mortality
  - Physiological requirement for moisture
    - Will stay close to aquatic environments
- Behavioural preferences
  - Cognitive orientation abilities
    - Will avoid arid environments
- Life cycle constraints
  - Aquatic breeding
    - Will head for aquatic environments

Fire salamander

- *Salamandra infraimmaculata*

Fire salamander distribution



Life history

- Active in the wet winter, aestivates in dry summer
- Females deposit live larvae in pools
  - Mate after larvaposition
  - Gestate until the following winter

Constraints of an arid environment

- Few pools are year-round
  - Strong competition
  - Support large predators (fish)
- Ephemeral ponds are commonly used

Constraints of an arid environment

- Larvaposit in ephemeral ponds early in season
  - Risk of desiccation
- Larvaposit late in season
  - Risk of cannibalism

Movement

- Sounds like activity should be concentrated around pools
  - Males want to mate with females immediately after larvaposition
  - Fitter males might be expected to compete for positions near high quality pools

Testing this hypothesis



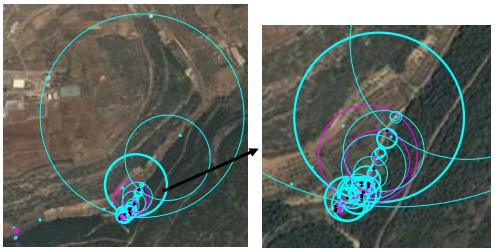


How to study individual movement

- Record animals on multiple visits
- Record GPS position
- Identify individuals using spot patterns

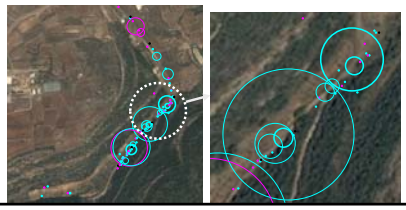
Pools as the main “meeting place”?

- Those spotted close to the pool, often remained close to the pool, but…



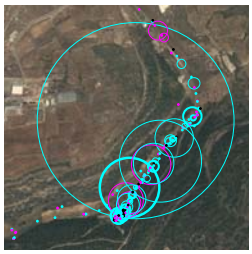
Alternative activity centres

- Those never seen near a pool, remained near non-pool activity centres
- 35% of individuals never found within 100 m of a pool



Movement range

- Maximum range observed: 764 m
- Maximum daily movement: 690 m



Implications

- Activity is not restricted to pools
  - Salamanders have a night-life outside of the bar
  - Males can find females away from contested breeding pools
- "Matrix" environment appears important for conservation, as well as "core" environment
- Post-larvaposition movement of females (foraging?) may drive male movement

Implications

- Dispersal range is probably underestimated
  - *S. salamandra:*
    - 48 m (Joly 1968, cited in Wells 2007)
    - 30 m (Rebelo and Leclair 2003)
    - 503 m over a whole season (Schulte et al. 2007)
    - 1200 m over multiple seasons (Bar-David et al. 2007)
    - **690 m in a single day**
  - *Ambystoma maculatum:*
    - 175 m (Madison 1997)
    - 38 m (Rittenhouse and Semlitsch 2006)

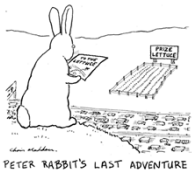
Movement strategies

- What kind of patch connectivity would you prefer?

- Answer: it depends

Movement strategies

- Having decided
  - Whether to disperse
  - Where to go
- Need to decide
  - How to get there
    - Movement strategies



Simplest strategy: random walk

- Different kinds of random walk
  - Correlation in direction
  - Correlation with environment

Random walk | Habitat preference | Habitat constraint

Non-random walks

- Wandering
  - Random walk
- Migration
  - Least cost
- Diffusion
  - Flow

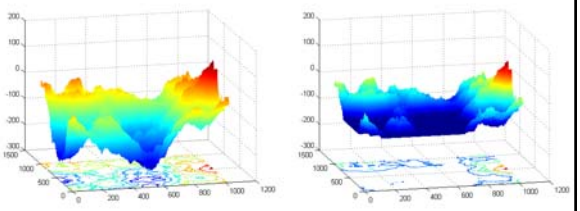
Random wanderer

Directed migrator

Directed diffusor

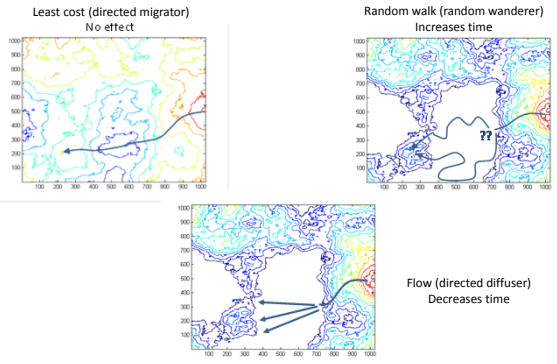
Effect of multiple paths

- What's the quickest way to cross the valley?



Clue: **not** the least energetic way

Effect of multiple paths



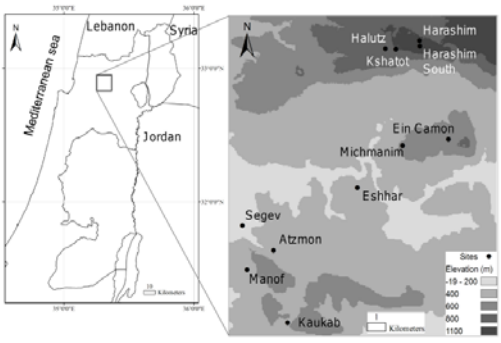
Effect of multiple paths

- Directed migrator (least cost)
  - No effect
  - Least cost path remains least cost path
- Random walker
  - Increases time
  - Will "get lost" and wander around in low cost environment
- Directed diffuser (flow)
  - Reduces time
  - Whichever path animals choose, it will be a good one

So which model fits?

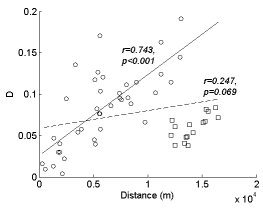
- Genetic data can indicate population flow
- Isolation by distance
  - The further apart populations are, the more genetically different they will be
- Isolation by resistance
  - The harder it is to get from one population to another, the more genetically different they will be
  - What is "resistance"?
    - Landscape features
    - Which features?

An example of the fire salamander

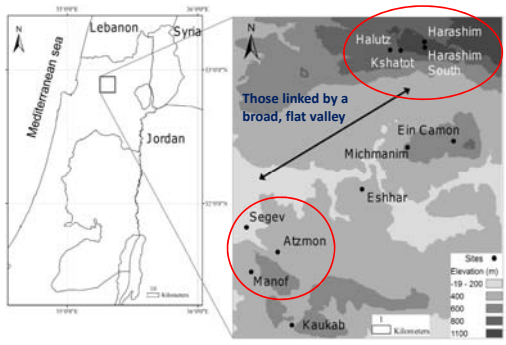


Does distance predict dispersal?

- Distance is not a good predictor of genetic difference
- Some pairs of sites are genetically closer than would be expected
- Removing those sites gives good fit of distance to genetic difference

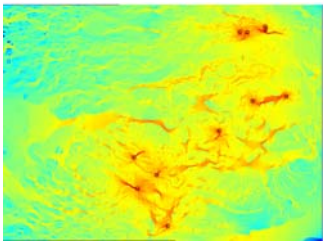


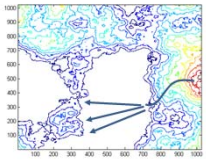
Which sites cause the problem?



Modelling possible gene flow

- Assuming that animal movement is constrained by
  - Slope (energetic considerations)
  - Elevation (habitat suitability)





Flow (directed diffuser)

Conclusions?

- Anomalous genetic distances could be due to
  - Artificial introductions
  - Non-homogenous matrix resistance
- Non-homogenous resistance likely exists
- But is it indicated by genetic distances?
- Correct identification of matrix barriers/corridors can give
  - Conservation strategies
  - Understanding of the animal's movement ecology

Summary

- What are patches
  - Matrix properties
  - Mechanisms of dispersal and constraints
- Fire salamander as an example of amphibian dispersal
  - Large ranges
  - Matrix used as non-breeding environment
- Movement strategies
  - Random walk
  - Least cost
  - Flow
- Genetic tests of movement strategy
  - Matching observed genetics to landscape features
  - Conservation implications