Ecology – What is it all about?

Dan Malkinson, University of Haifa, Haifa, Israel
dmalk@geo.haifa.ac.il

Ecology – What is it all about?

Ecology (from Greek: οἶκος, "house"; -λογία, "study of" [A]) is the scientific analysis and study of interactions among organisms and their environment. It is an interdisciplinary field that includes biology and Earth science.

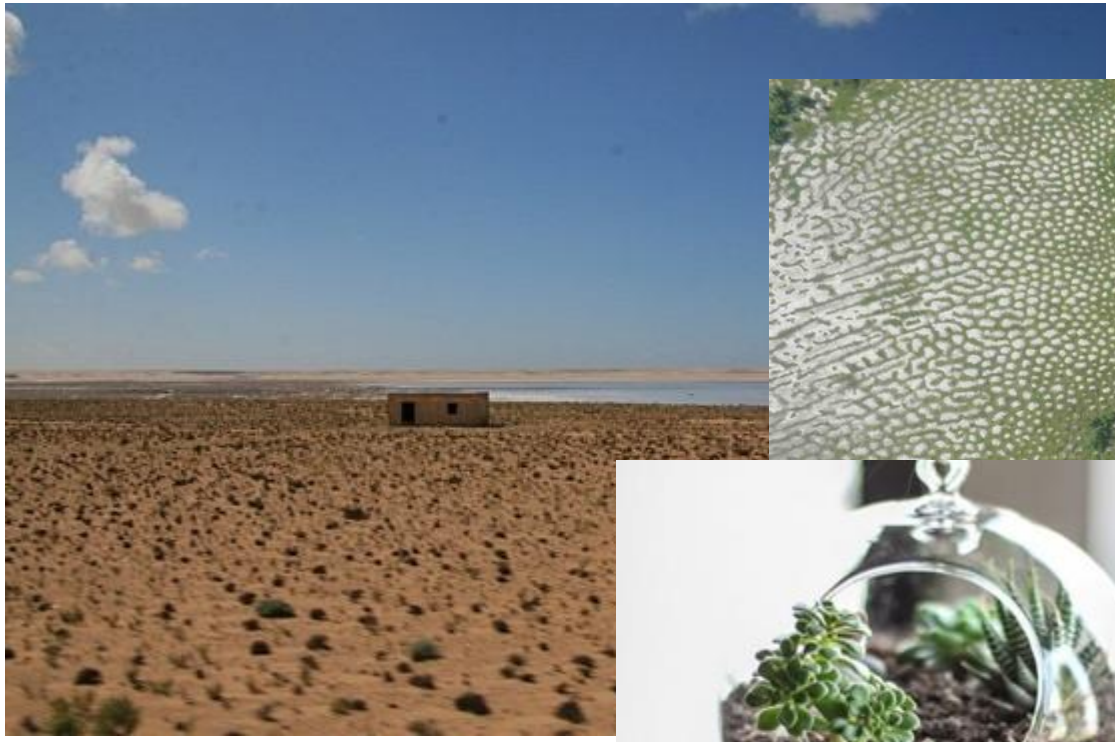
And among organisms and themselves

Ecology - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/**Ecology**

Ecology – What is it all about?

Sub-disciplines of Ecology:

- Physiological Ecology
- Behavioral Ecology
- Population Ecology
- Community Ecology
- Ecosystem Studies
- Landscape Ecology
- .
- .
- .



Ecology – What is it all about?

Principal types of ecological interactions (biotic factors)

	organism I	organism II
Competition	−	−
Facilitation	+	=
Symbiosis	+	+
Predation	+	−
Parasitism	+	−

(**abiotic factors**)

Ecology – What is it all about?

These interactions dictate ecological processes, ecological patterns and the interaction between them.

The three fundamental ecological processes are:

- Recruitment (birth)
- Mortality (death)

} **Time**

- migration/dispersal → **Space**

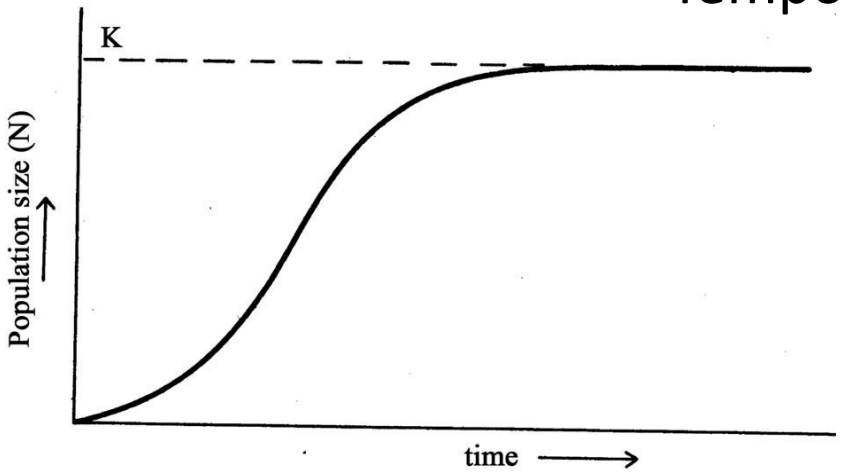
Processes are dictated by biotic and abiotic factors.

Process generate temporal and spatial patterns.

Patterns can feedback into the processes…

Ecology – What is it all about?

Temporal patterns



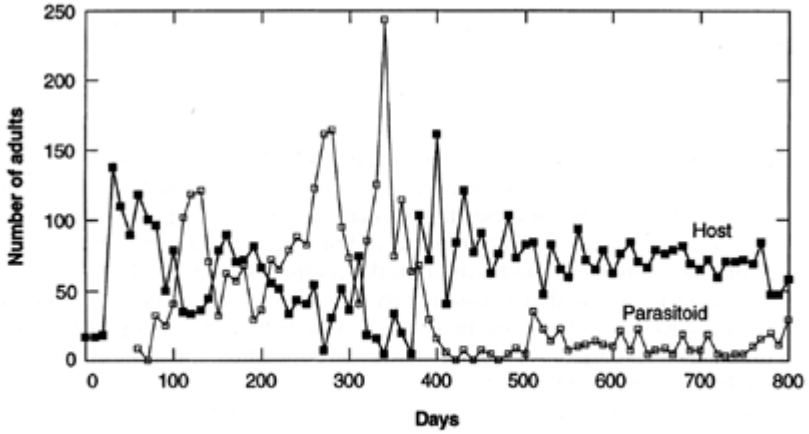
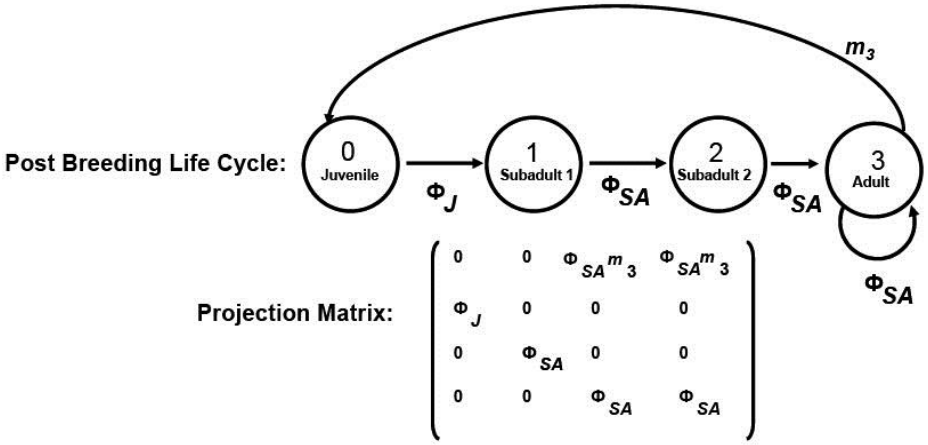


Figure 1. Population dynamics of a laboratory host–parasitoid system. The solid squares are the abundances of the host, the cowpea bean weevil *Callosobruchus maculatus*, and the open squares are those of the parasitoid, a braconid wasp *Heterospilus prosopidis*. The method is described in Tuda (1996).

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$



Growth rate for species 1

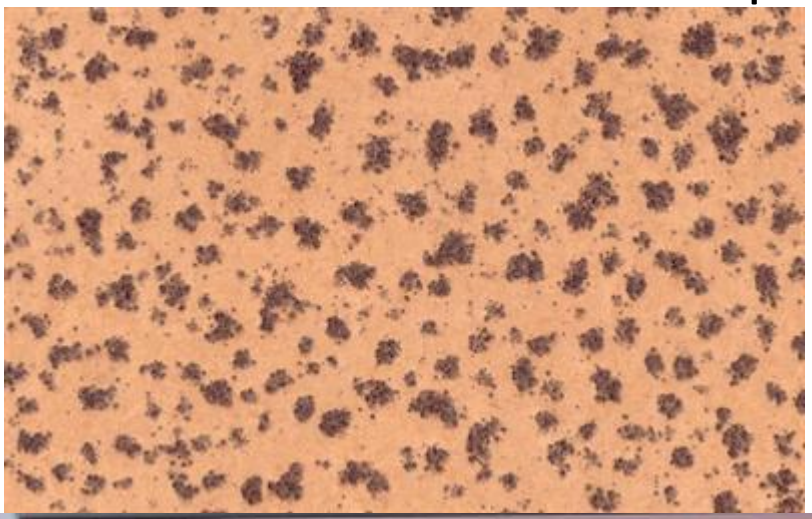
$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \frac{N_1}{K_1} - \frac{\alpha_{12} N_2}{K_1}\right)$$

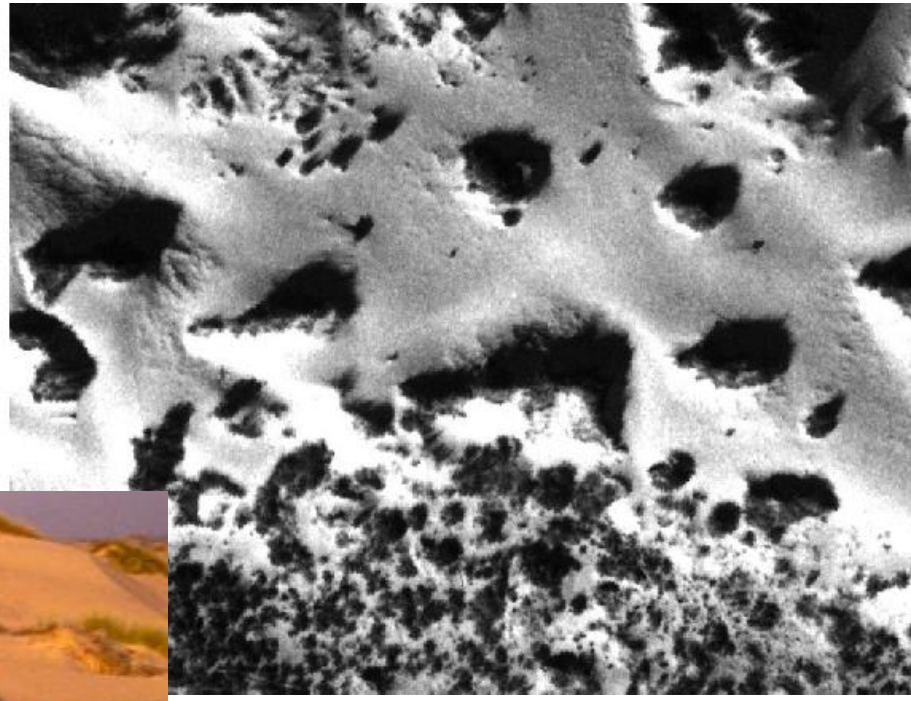
Growth rate for species 2

$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \frac{N_2}{K_2} - \frac{\alpha_{21} N_1}{K_2}\right)$$

Ecology – What is it all about?

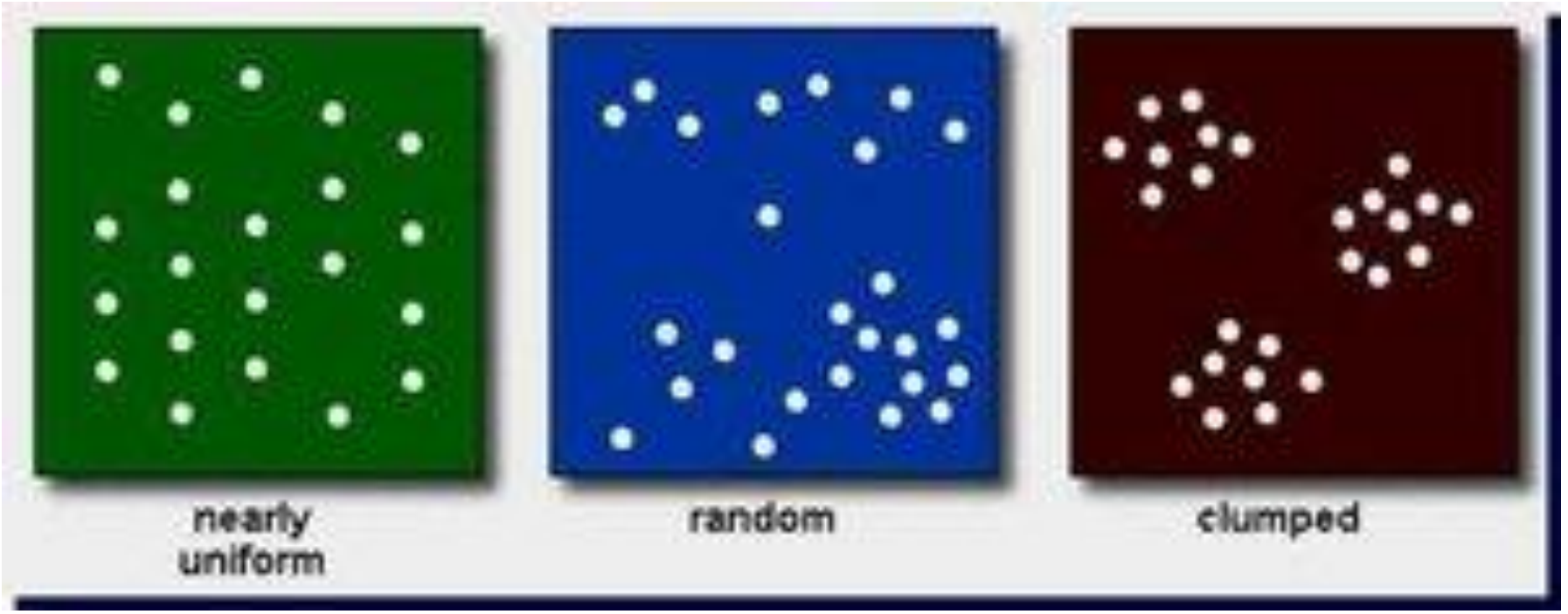
Spatial patterns

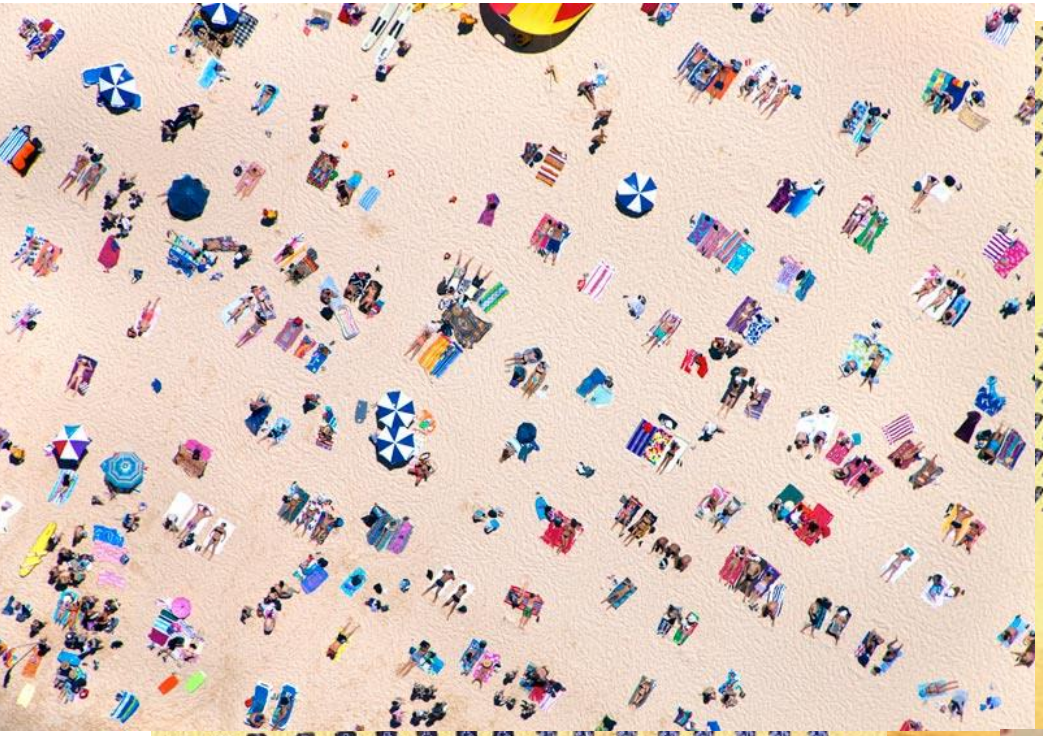


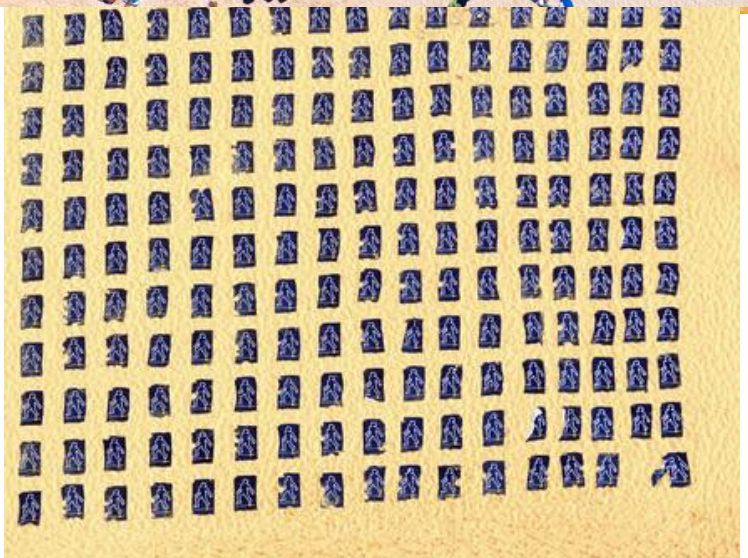


Ecology – What is it all about?

Spatial patterns

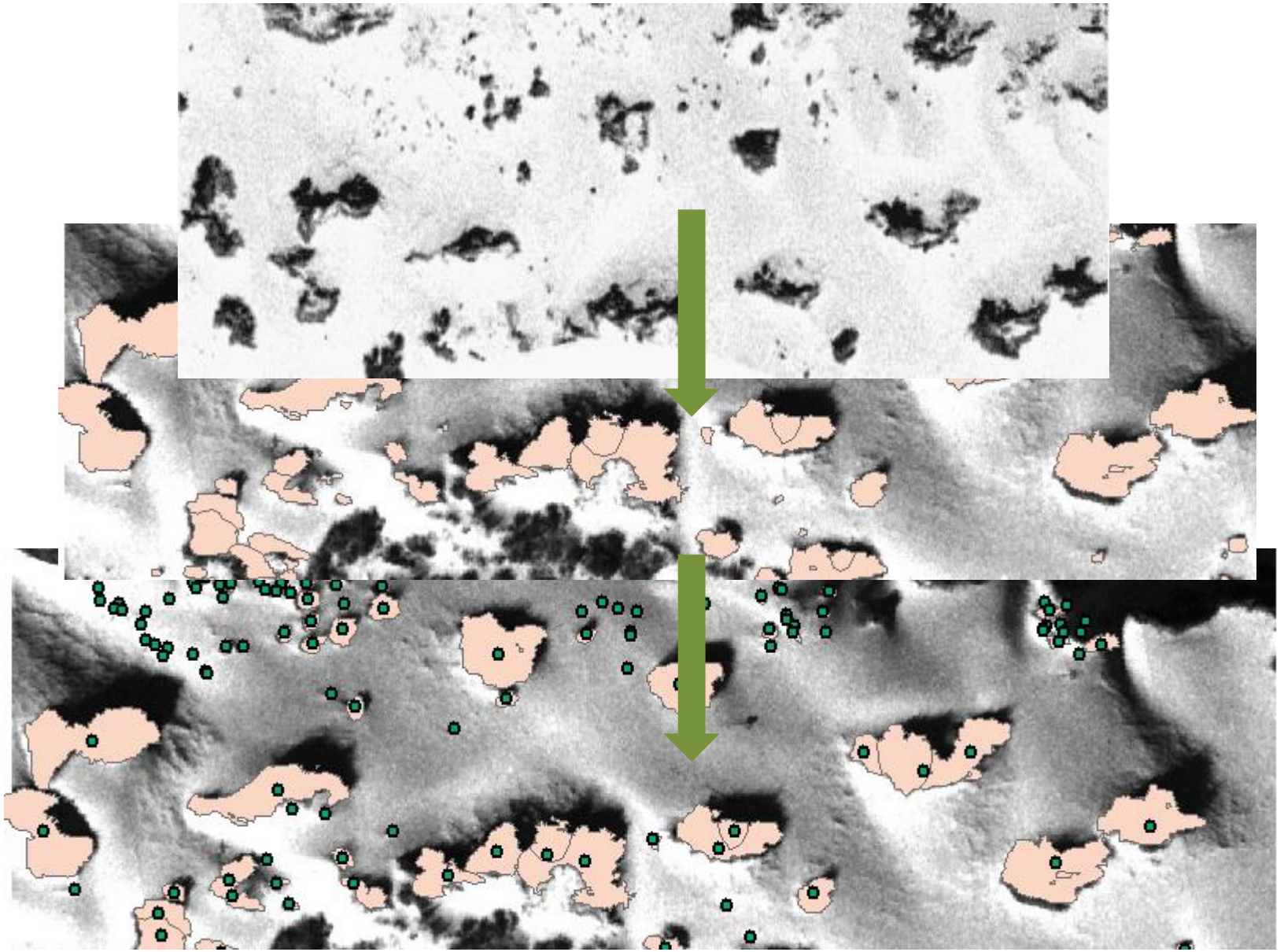






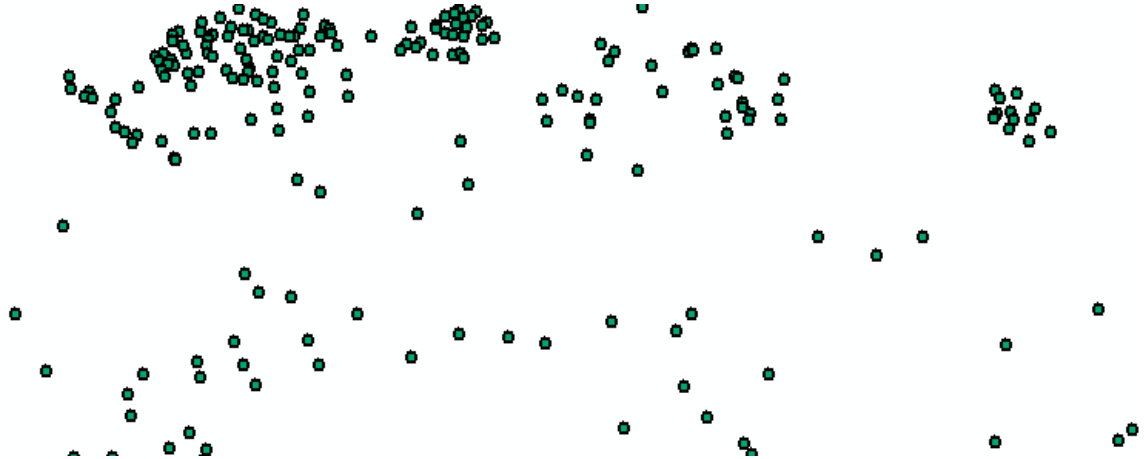
Ecology – What is it all about?

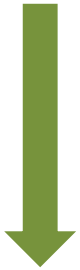
Spatial patterns

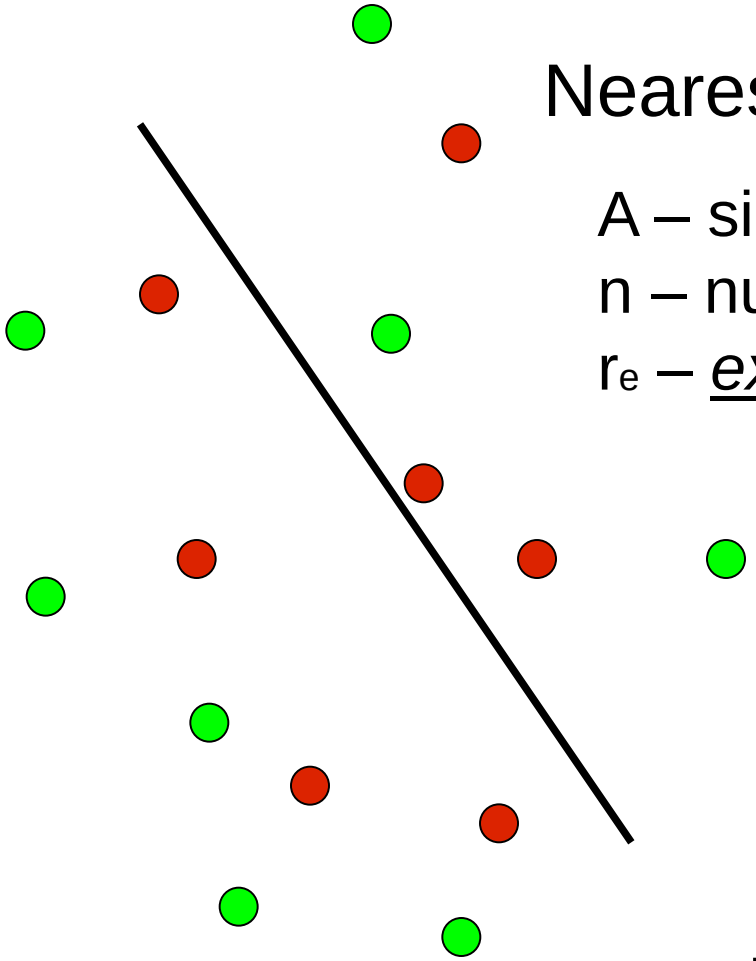


Ecology – What is it all about?

Quantifying Spatial patterns







Nearest neighbor method

A – size of area

n – number of individuals

r_e – *expected* distance to nearest neighbor

$$r_E = \frac{1}{2\sqrt{n/A}}$$

r_o – observed distance to nearest neighbor

X_i _ the ith individual

$$r_O = \frac{\sum X_i}{n}$$

Nearest Neighbor Index

$$R = \frac{r_O}{r_E}$$

If R > 1 then…..

If R < 1 then….

If R ≈ 1 then….

Ho: Complete spatial randomness, R ≈ 1 =>

$$Z = \frac{r_O - r_E}{SEr_E}$$

Where

$$SEr_E = \sqrt{\frac{(4-\pi)A}{4\pi N^2}} = \frac{0.26136}{\sqrt{N^2/A}}$$

Ripley's K function

$$\hat{K}(d) = \frac{n^{-1} \sum_{i \neq j} \sum W_{ij}^{-1} I_d(u_{ij})}{\lambda}$$

$$\hat{L}(d) = \sqrt{\hat{K}(d) / \Pi} - d$$

n – number of observations

λ - point density- n/A

d – scale/distance

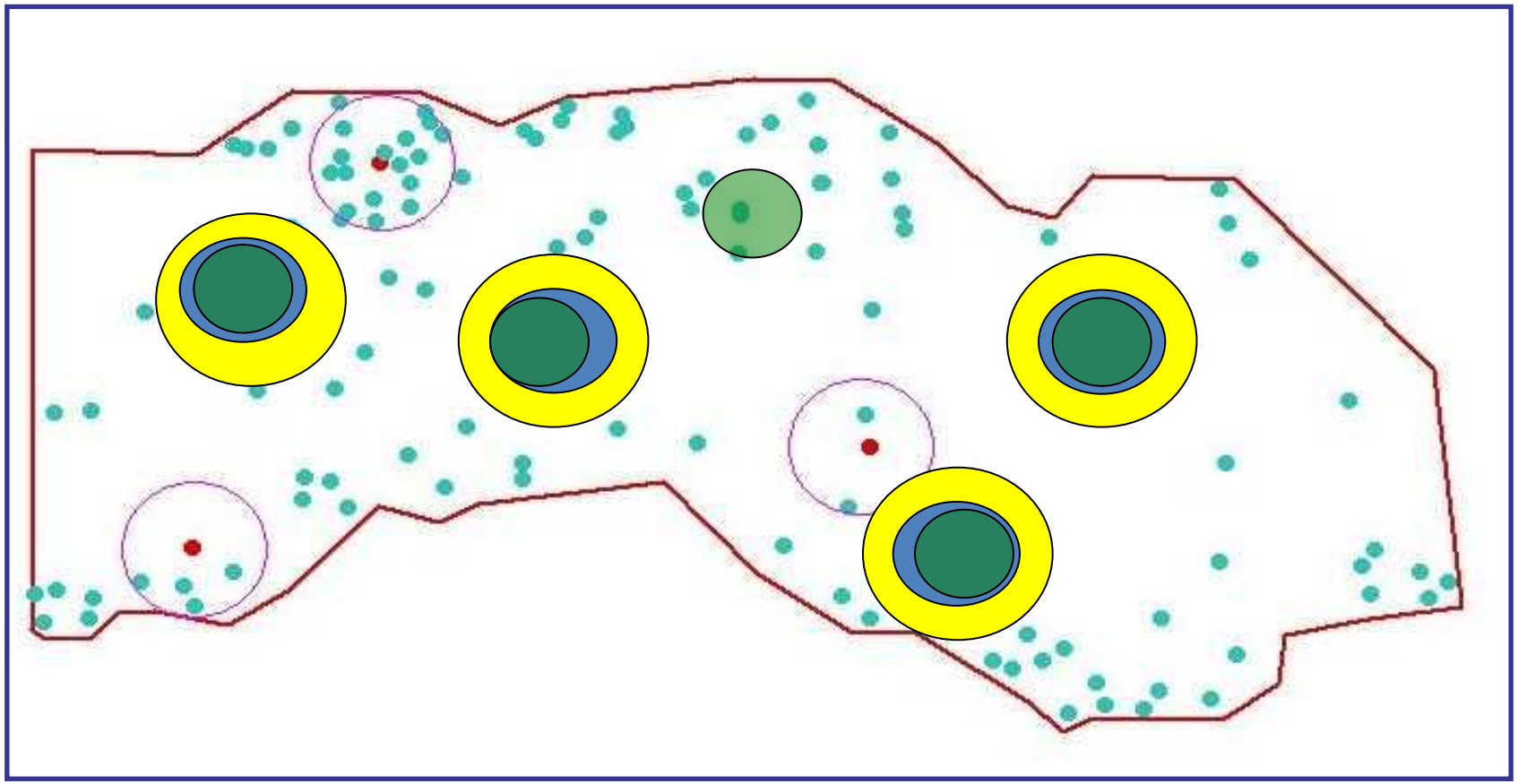
I_d – Indicator function

W_{ij} – edge/border correction

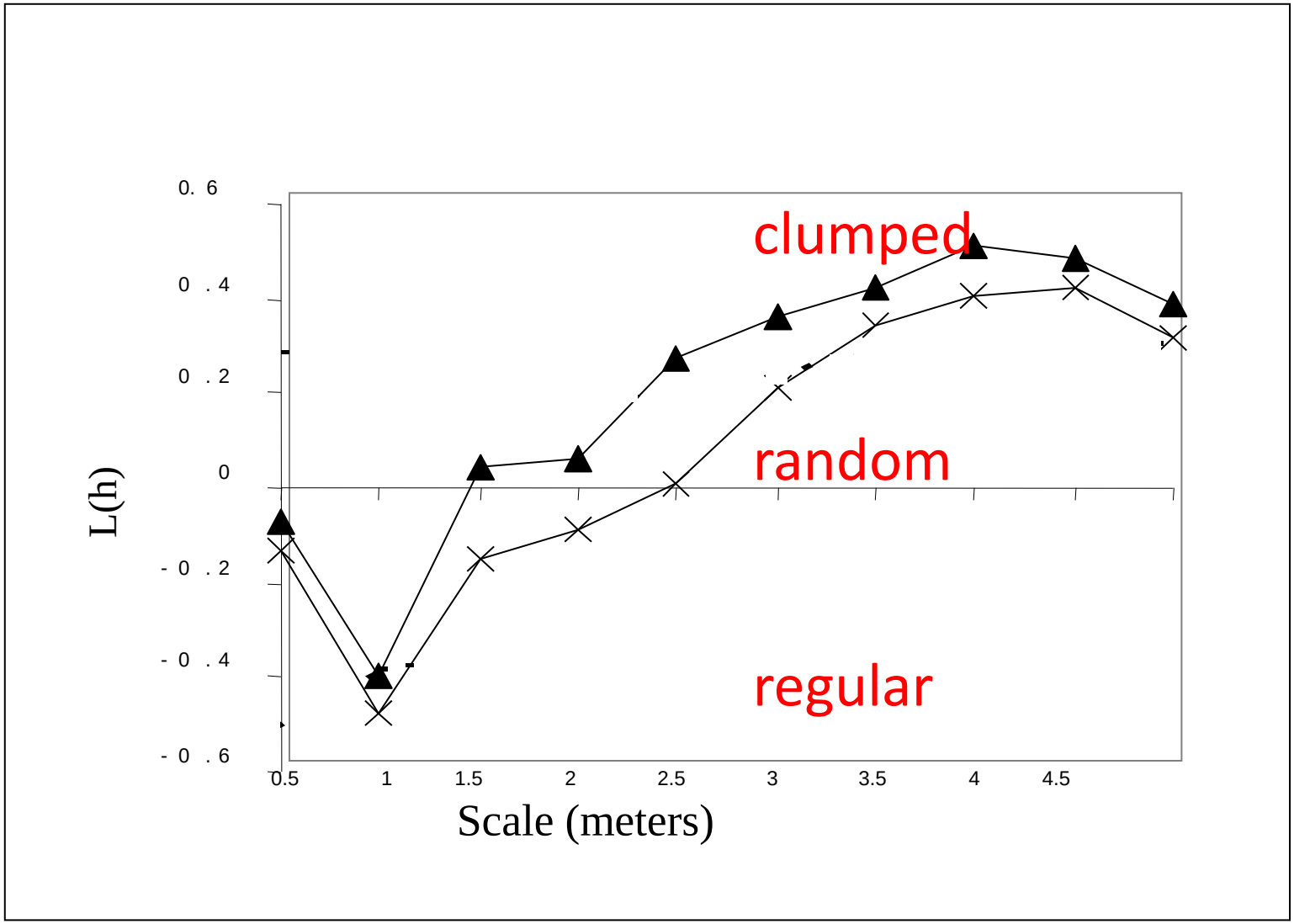
The index does not consider the attributes of the observations, just their spatial location.

Ripley's K function

Estimates spatial patterns at various scales (*d*)



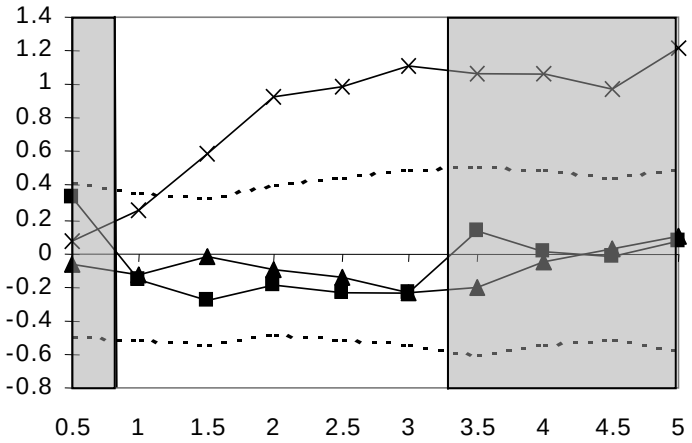
Ripley's K function



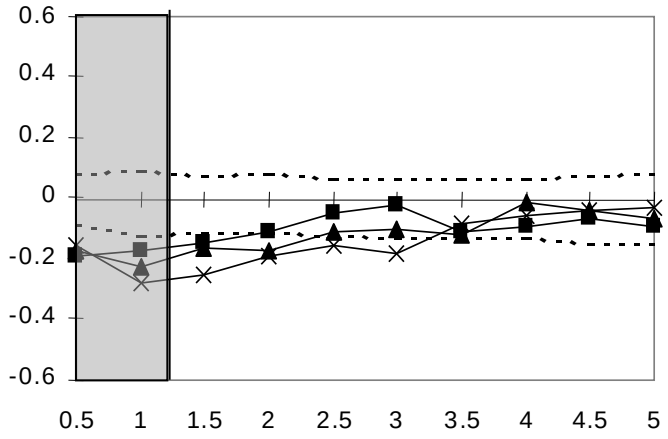
Ripley's K function – interspecies interactions

Functional scales

S. scoparia* - *H. digynum



M. ciliata* *E. philistaeus



Spatial pattern analysis

But what processes and interactions generate the observed spatial patterns:

Regular – competition

Clumped/clustered – facilitation, seed dispersal kernels, resource heterogeneity, …

Random – no interactions, canceling interactions, above:below ground competition

Spatial pattern analysis

Pattern analysis provides a proxy, or an insight to the processes operating, which were not measured.

Why were they not measured?

What are the relevant scales for the analysis?

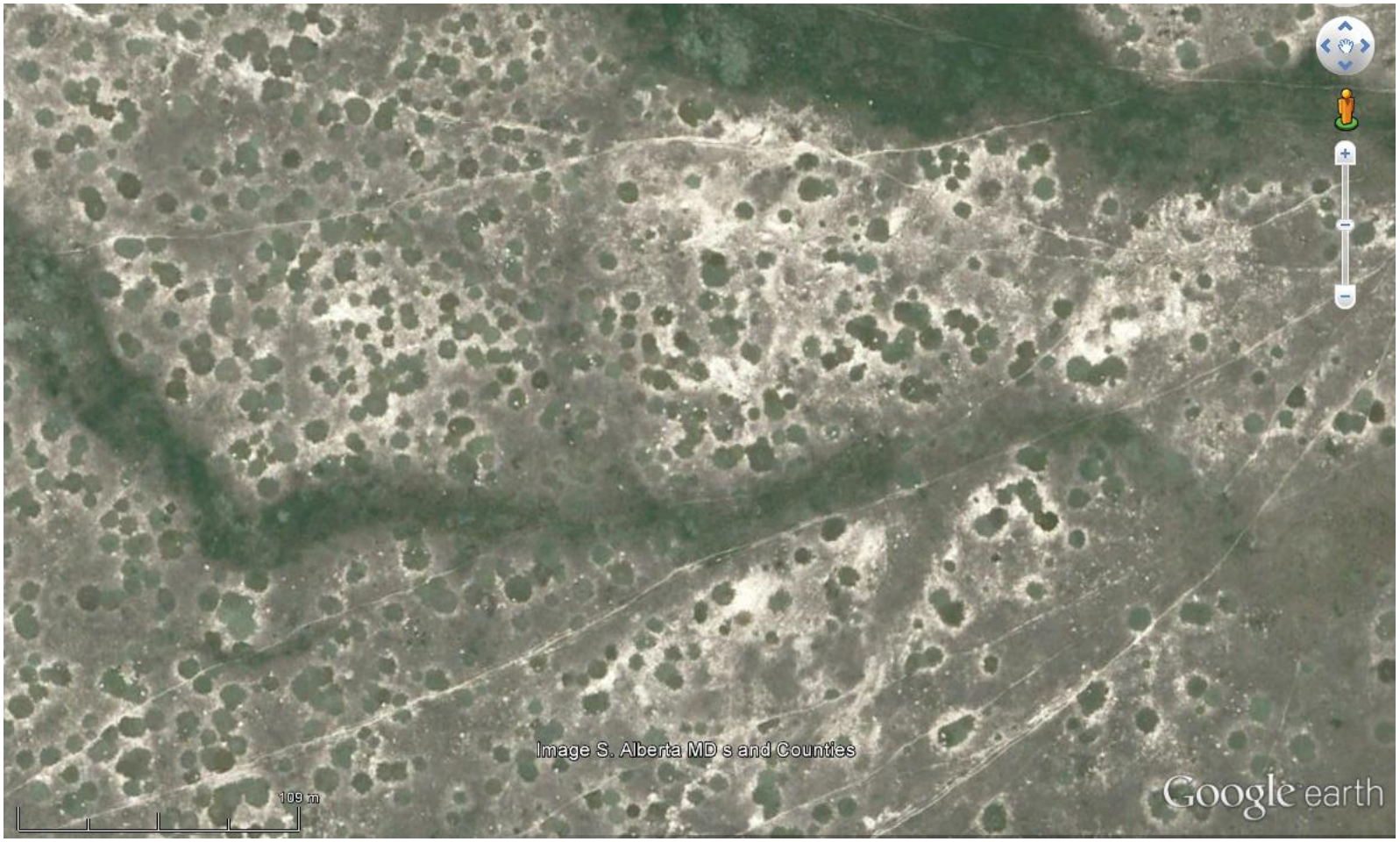
Scale

What is the research question?

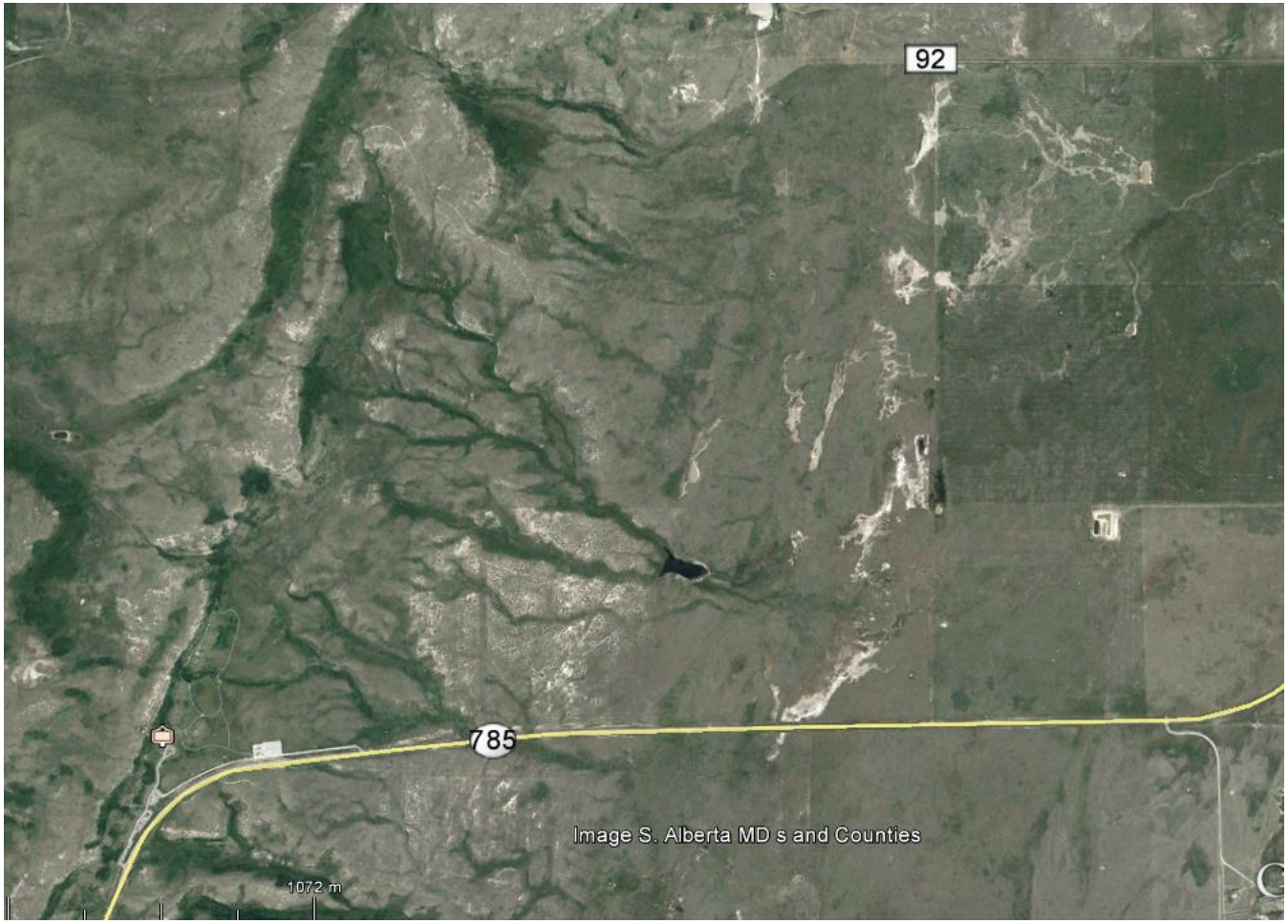
How will the data be collected?

- Spatial resolution
- Temporal resolution

Scale



Scale



Scale

What have we not talked about?

Process – pattern feedbacks.

Disturbances and density dependent disturbances.

Climatic zones of the world

Can be defined by P/PET

hyper arid: ($P/PET < 0.03$),
arid: ($0.03 < P/PET < 0.20$),
semi-arid: ($0.20 < P/PET < 0.50$),
subhumid: ($0.50 < P/PET < .75$).

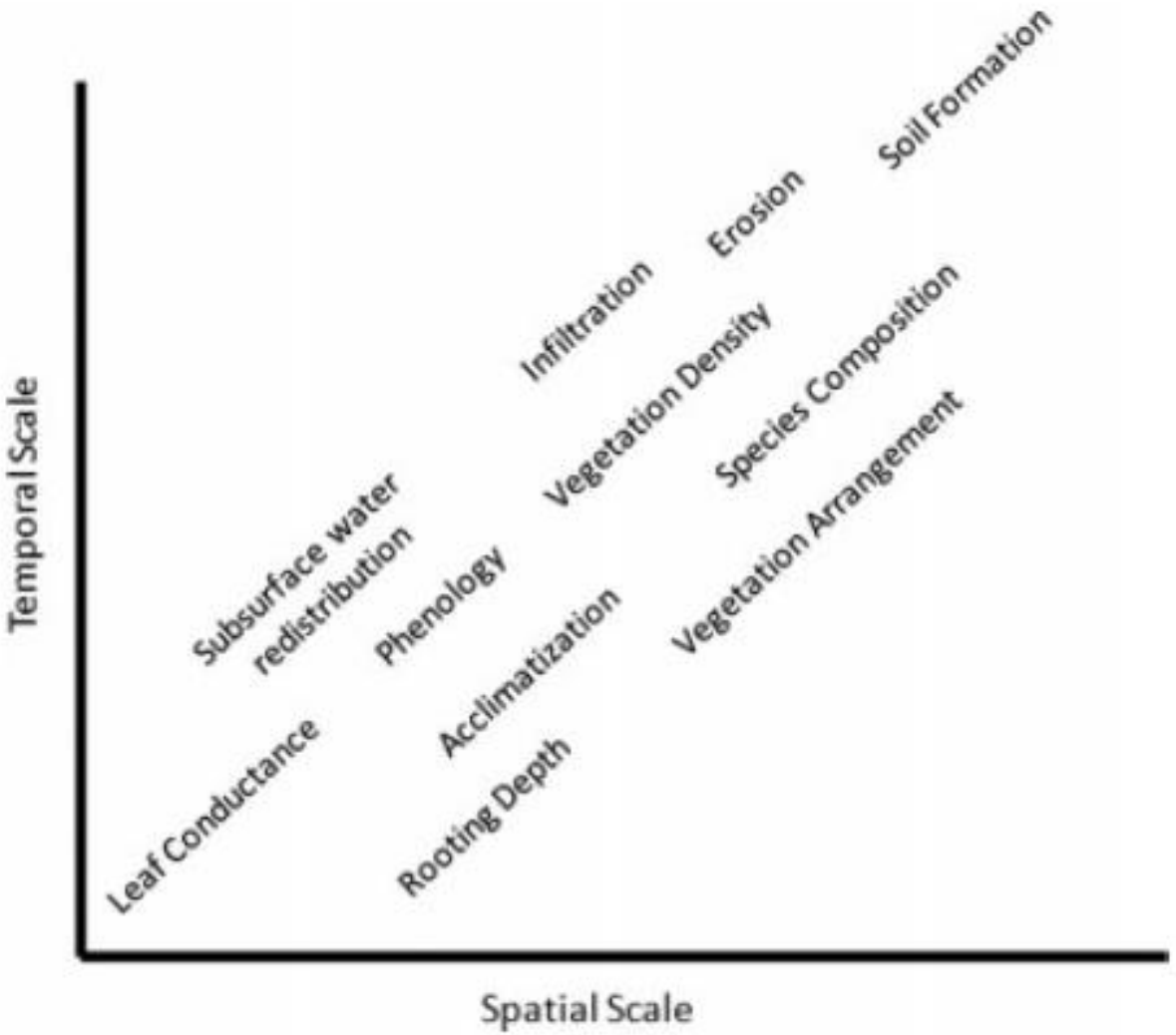


Figure 5. Stommel diagram of possible adaptation mechanisms loosely arranged across a broad range of temporal and spatial scales. At the finest scales, variation in leaf conductance can occur for an individual leaf within an hour. At broadest scales, soil formation can span regions and millennia.

Disturbances

Disturbance – a discrete event in time, which:

- Alters survival probability of an individual, and therefore
- Changes population structure and properties
- And may change resource availability
- Or the physical structure of the environment.

Disturbances

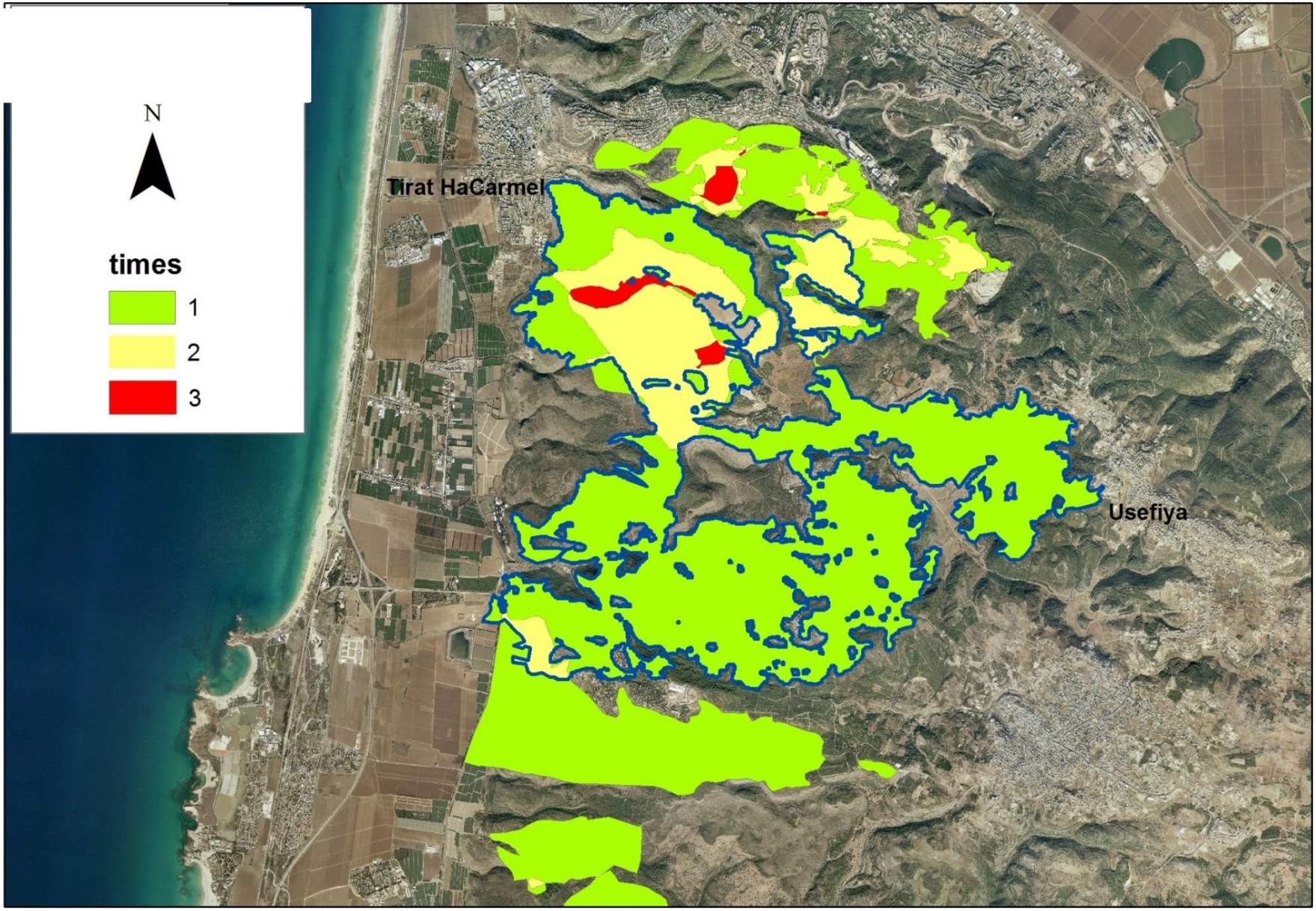
Characterizing disturbances

- Extent (spatial)
- Intensity
- Frequency (temporal)
- Location (spatial distribution)

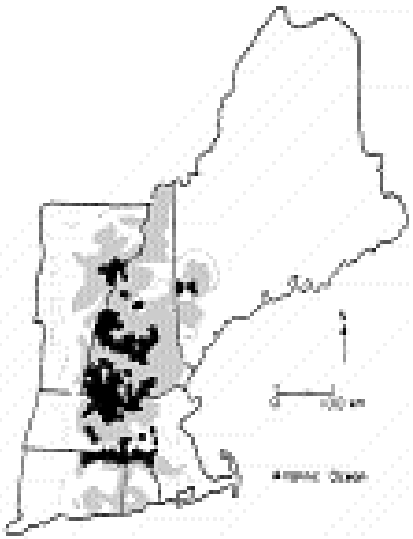
Disturbances

Disturbance regime:
The collection of disturbances occurring in a predefined spatial domain, each characterized by its extent, frequency and scales.

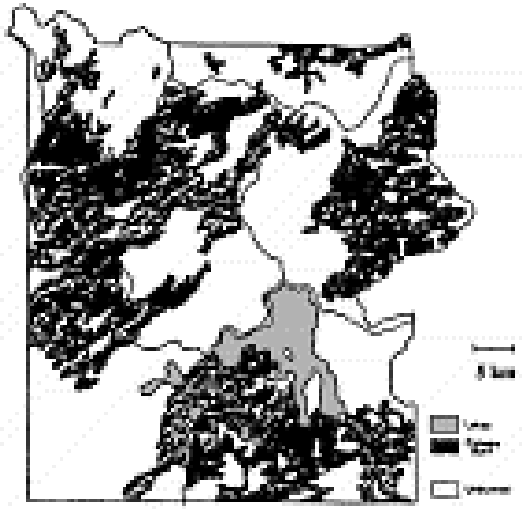
Disturbances: regimes



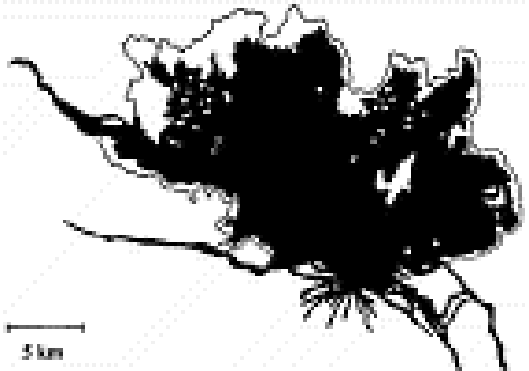
Disturbances: scales



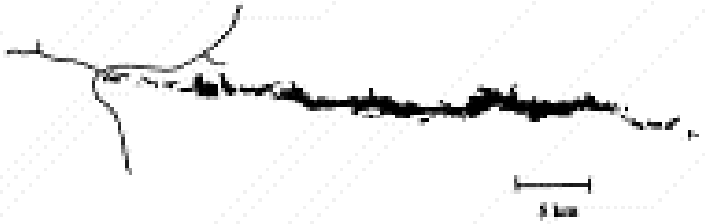
Hurricane (1938 New England)



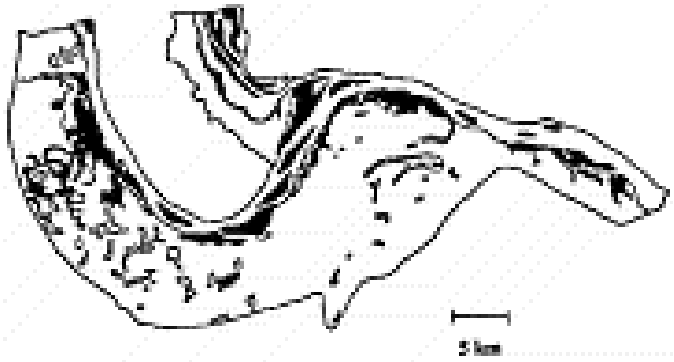
Fire (Yellowstone National Park)



Volcano (Mount St Helens)



Tornado (Tionesta Scenic Area)



Flood (Mississippi River)

Disturbances: types

Wildfires, disease, avalanches, grazing, tree fall, sand relocation….

Disturbances: types

Density independent

Density dependent

- Positive density dependence
- Negative density dependence

Disturbances: types

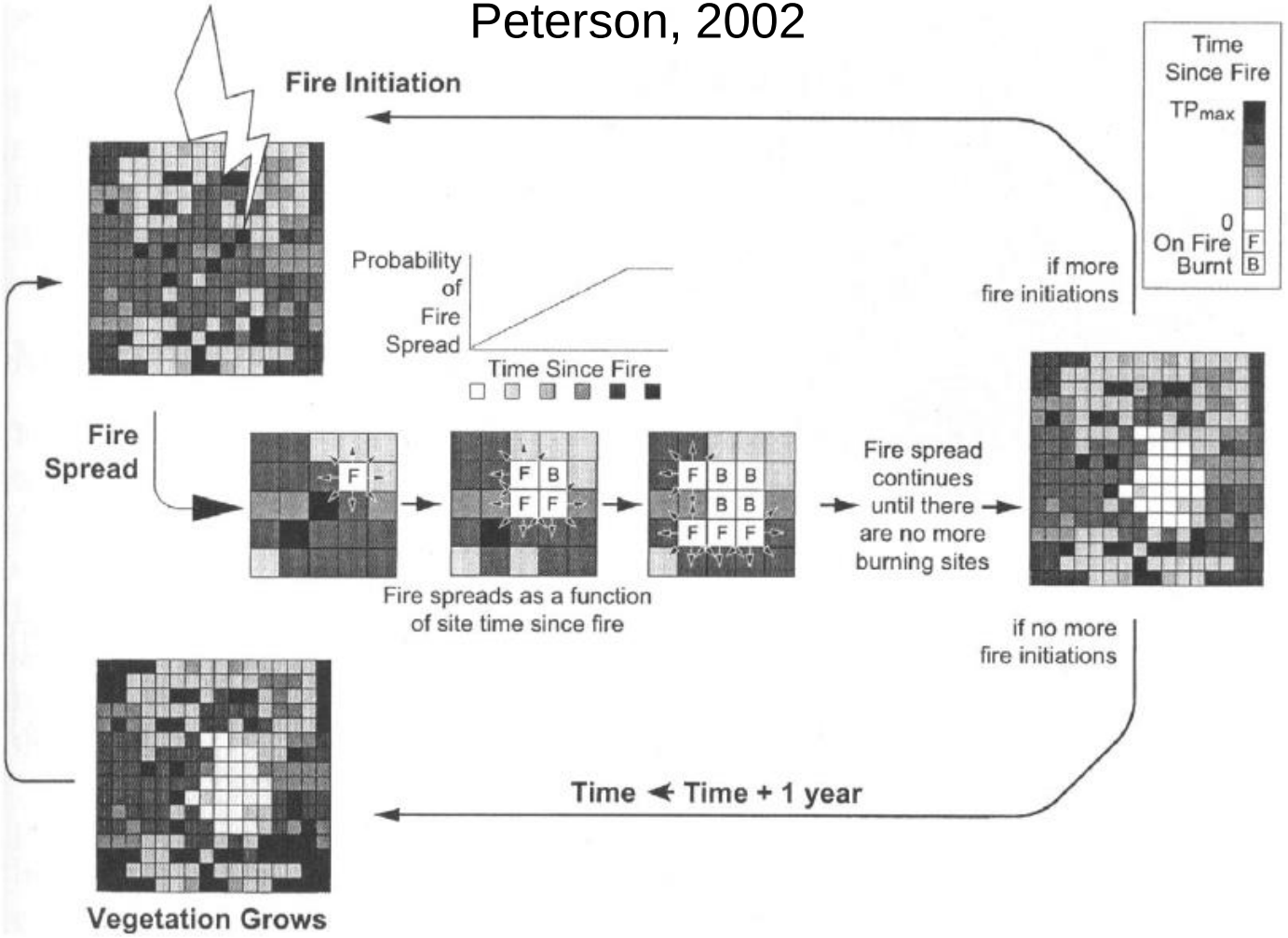
Density independent

Disturbances: types

Density dependent

Positive density dependence

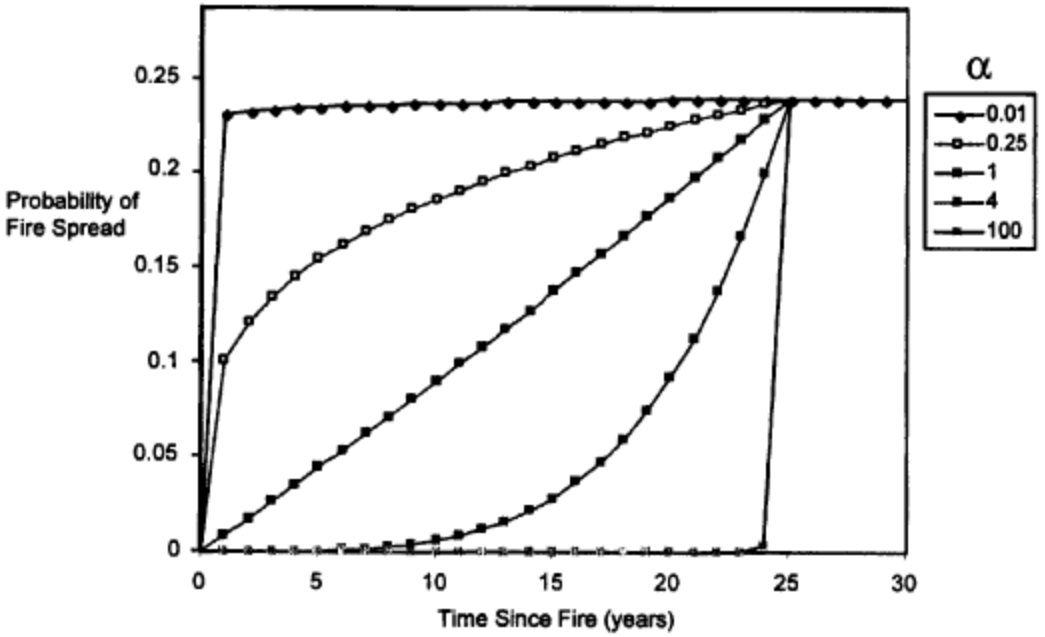
Peterson, 2002

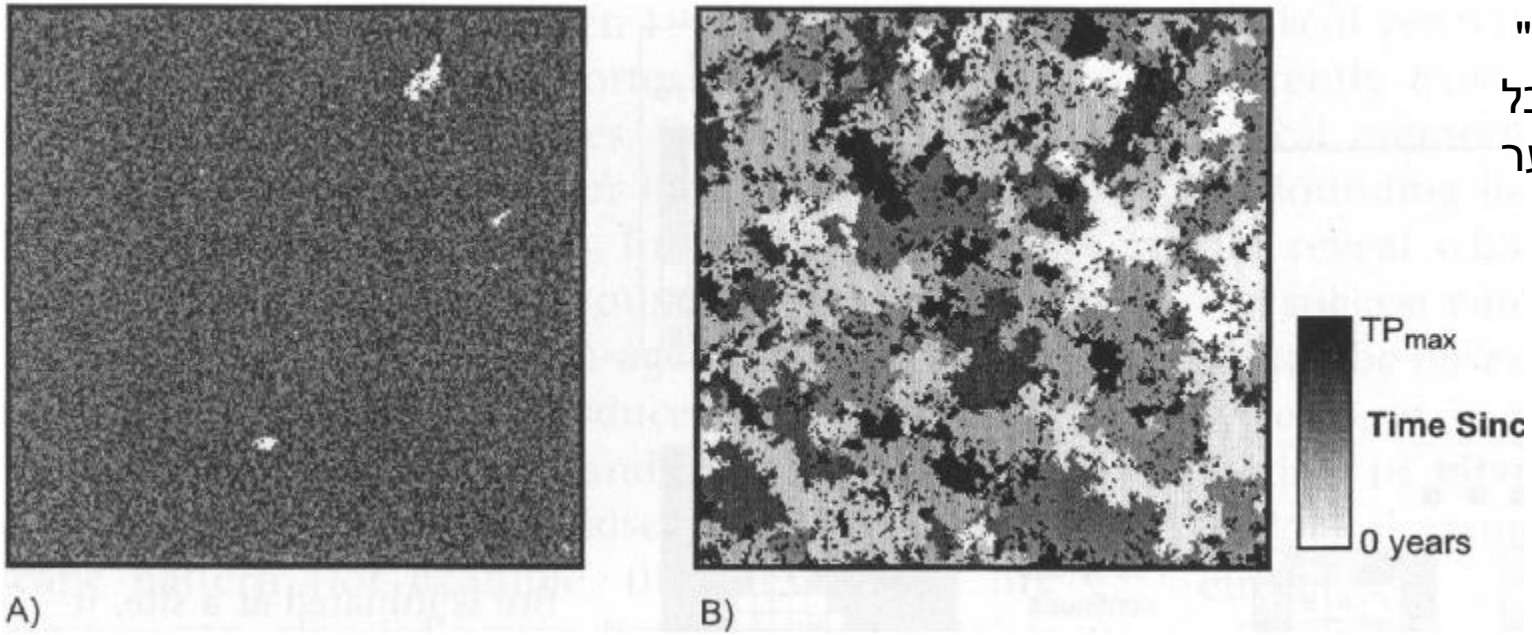


$$\Pr(FireSpread|TSF) = (1 + P_{\max})\left(\frac{TSF}{TP_{\max}}\right)^{\alpha} - 1, \; TSF \leq TP_{\max}$$

$$\Pr(FireSpread|TSF) = P_{\max} \quad , TSF > TP_{\max}$$

Peterson, 2002





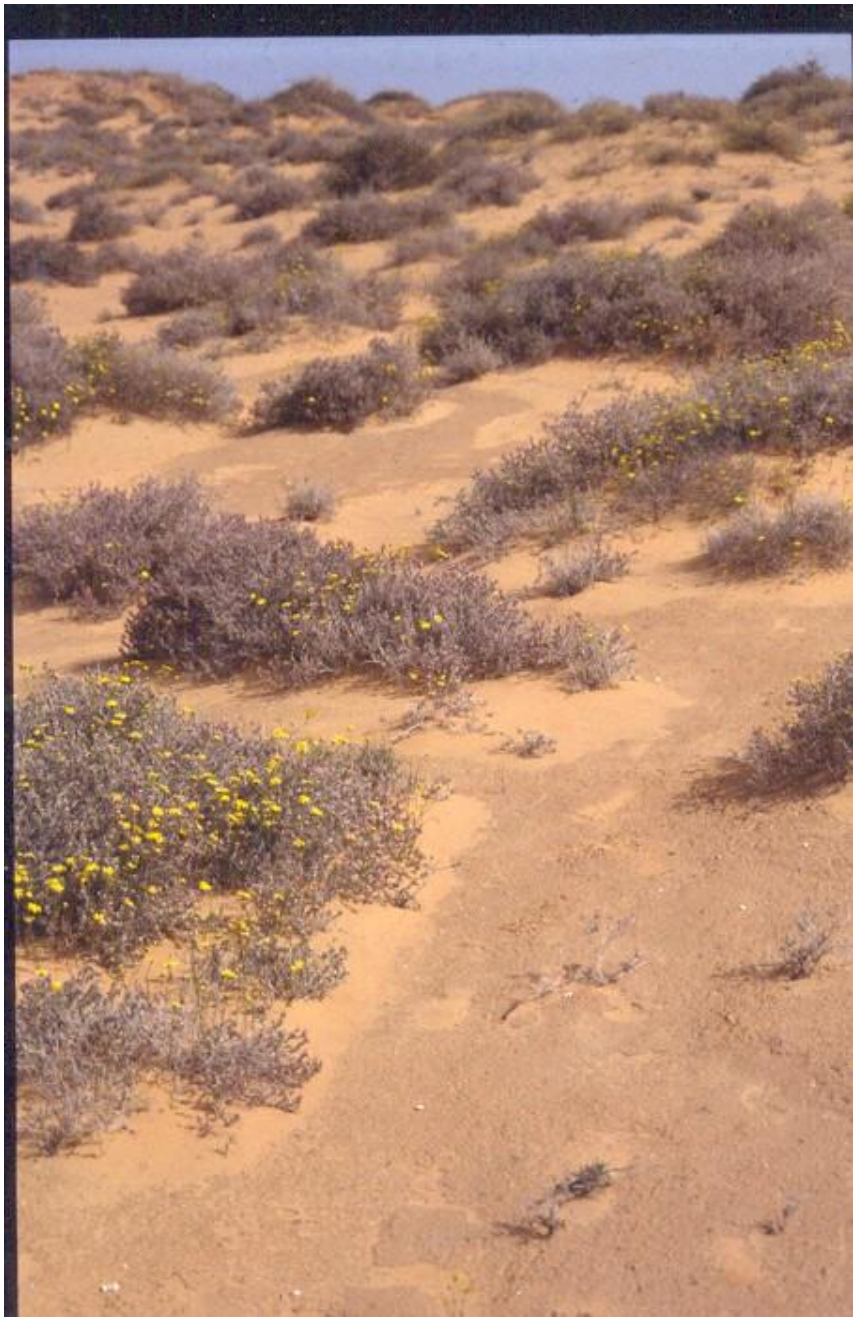
לאחר 300 "שנות" סימולציה מתקבל דגם מרחבי ביער

Disturbances: types

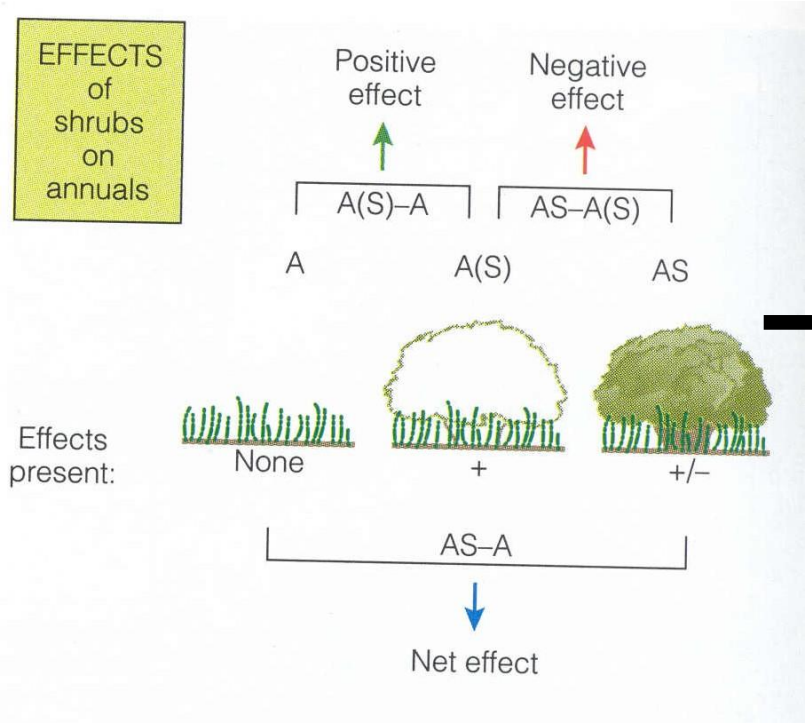
Density dependent

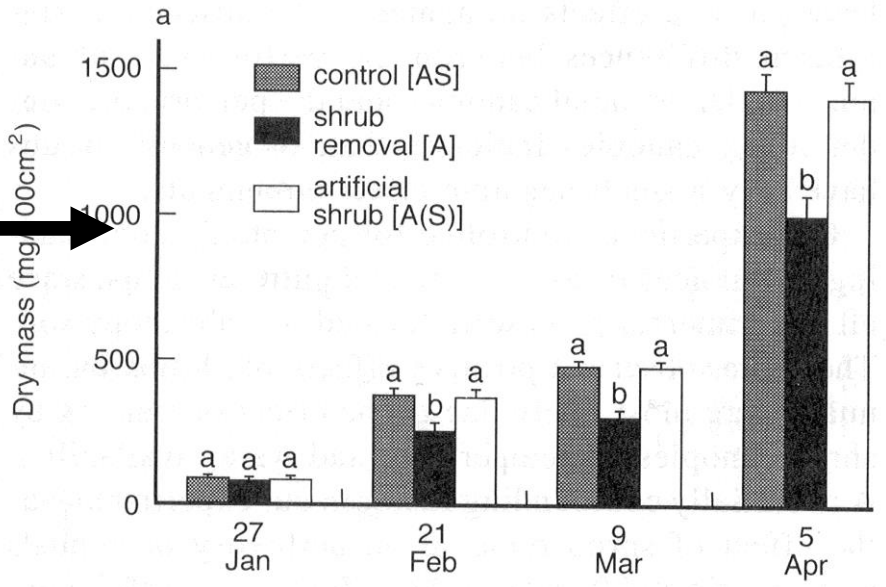
Negative density dependence

Competition - Facilitation



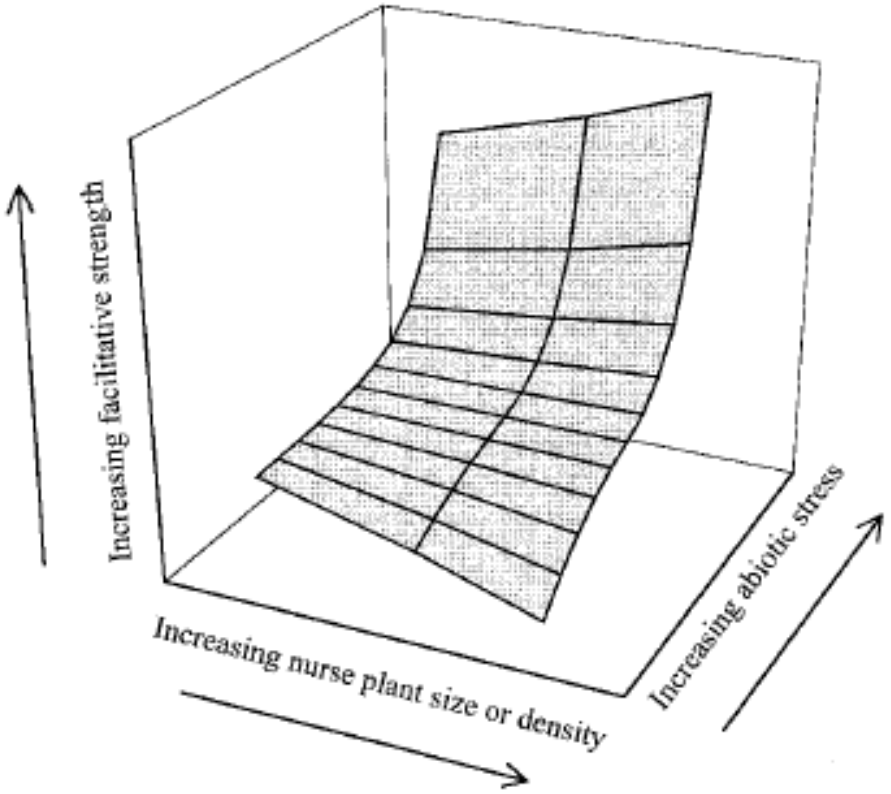
Competition - Facilitation





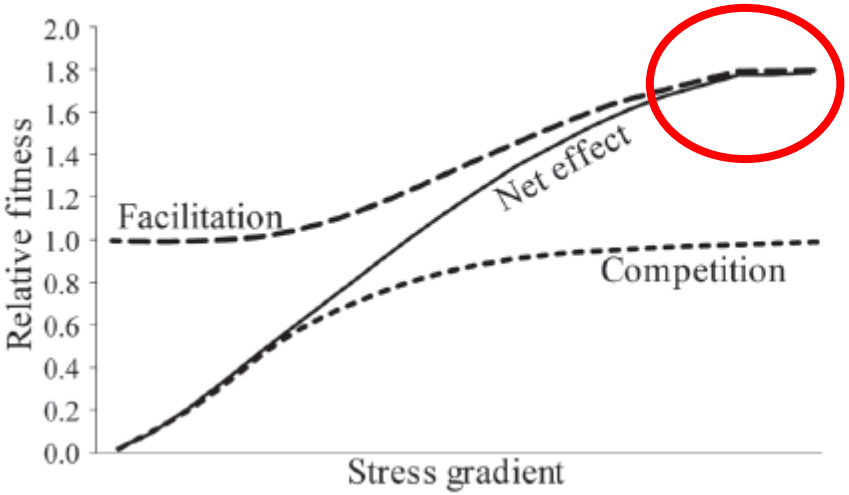
Holzapfel and Mahall 1999

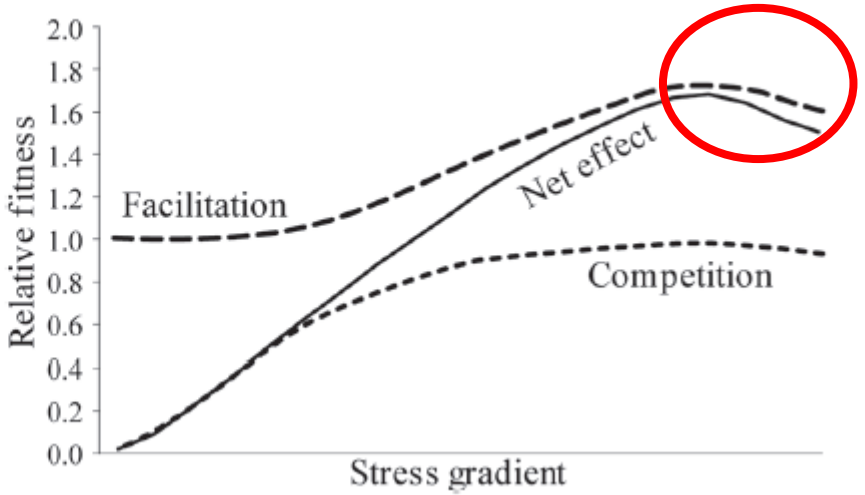
Competition - Facilitation



Bertness and Callaway (1994, 1996)
Callway and Walker (1997)

Competition - Facilitation





Spatial pattern formation most likely results from the interactions between local scale (self-organizing) processes and large scale (exogenous) processes.