RECONSTRUCTION AND RECOGNITION OF SPATIAL PATTERNS FROM SPARSE DATA IN THE PROBLEM OF BIOLOGICAL INVASION

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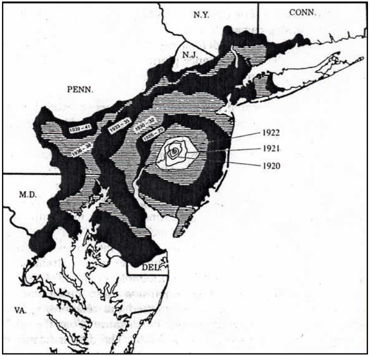
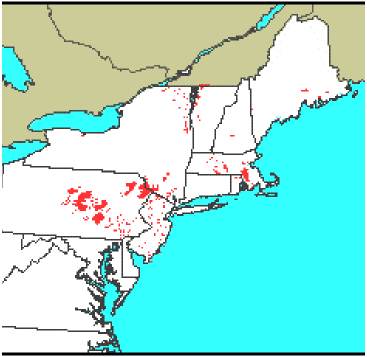
Biological invasion

The term biological invasion refers to a variety of phenomena arising as a result of introduction and proliferation of alien (or ‘exotic’) species.

Spatial patterns of biological invasion





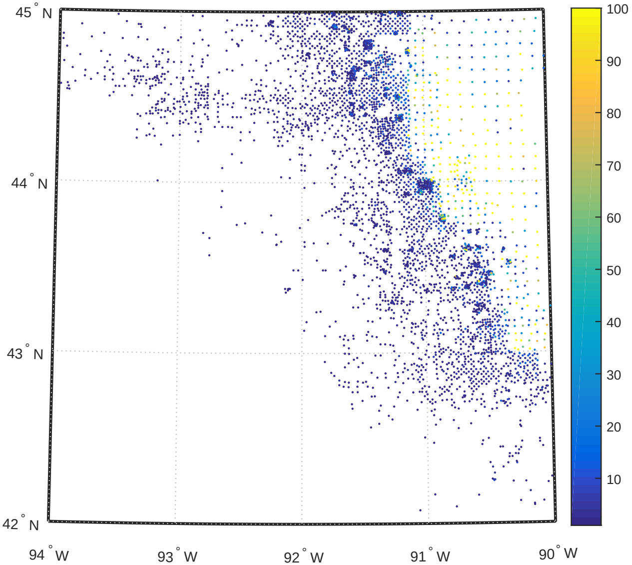
Invasion of Japanese beetle
(*Popillia japonica*)
in the United States
2-D traveling front

Invasion of Gypsy moth
(*Lymantria dispar*)
in the United States
Patchy invasion

One important question is...

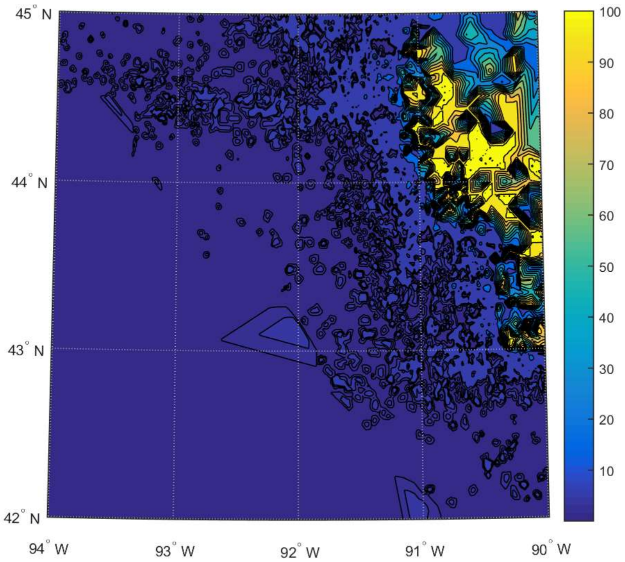
How far are spatial patterns sensitive to parameters of the monitoring protocol?

Example: data on Gypsy moth invasion

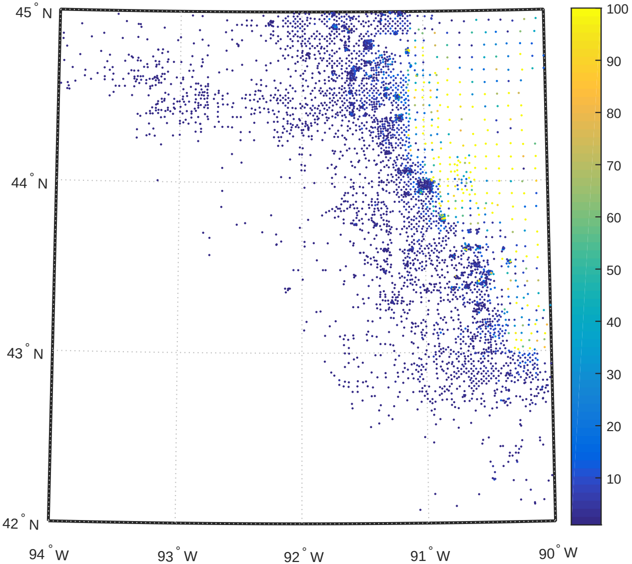


by courtesy of Andrew Liebhold

Spatial pattern of Gypsy moth invasion

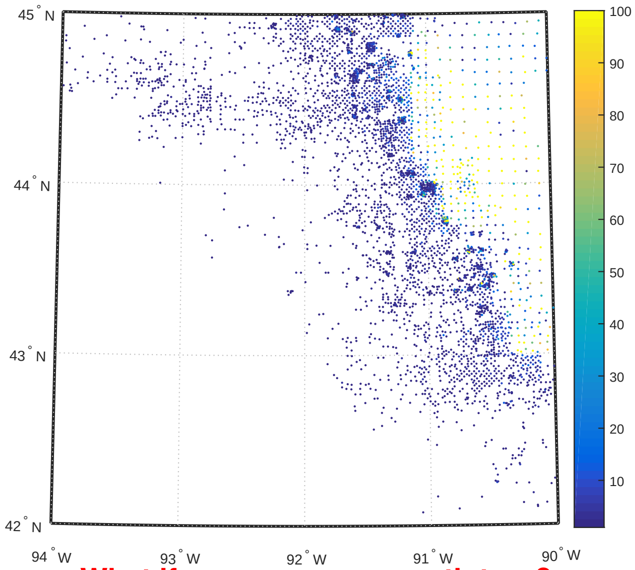


Data on Gypsy moth invasion



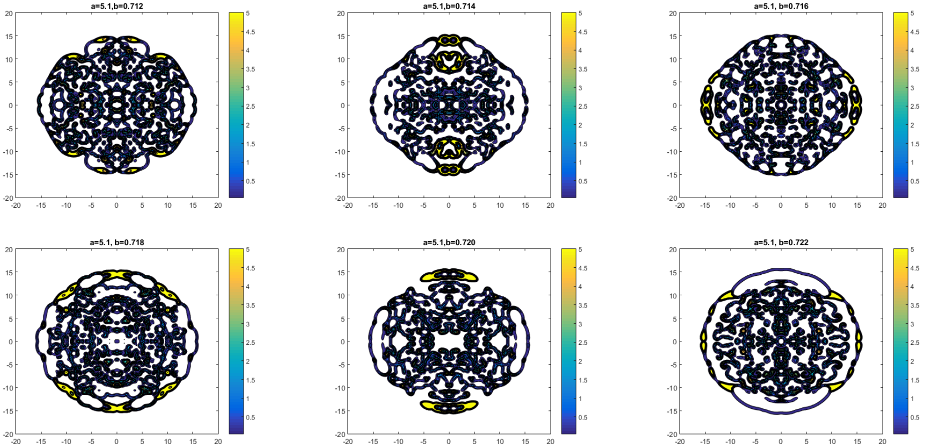
What if we ignore traps with low trap counts?

Data on Gypsy moth invasion



What if we remove every *n*th trap?

Simulation of spatial patterns



The number of objects

- We use the Image Processing Toolbox in MATLAB to count number n of separate objects (patches) in the spatial density distribution.

- Binary presence/absence maps are defined as

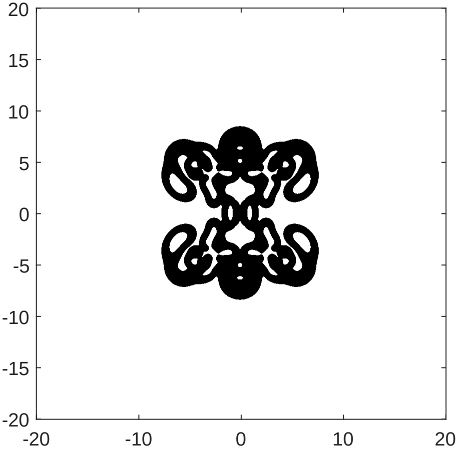
$$\hat{u}(x,y) = 1 \quad \text{for} \quad u(x,y) > C, \quad \hat{u}(x,y) = 0 \quad \text{for} \quad u(x,y) \leq C.$$

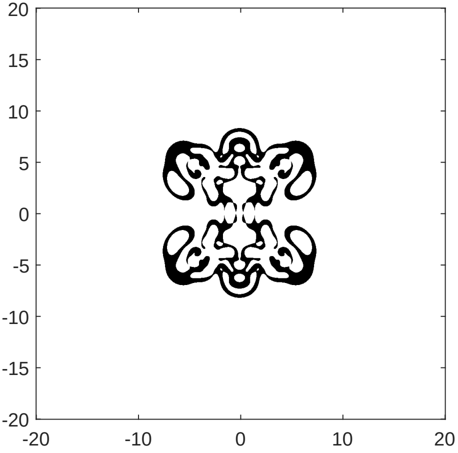
- We ignore a complex topological structure of the spatial density distribution within any sub-domain of the non-zero density with a closed boundary (e.g. density patterns behind a continuous front)

Continuous front spatial pattern counts as a single object. Patchy pattern counts as several objects.

What if we ignore traps with low trap counts?

A continuous front pattern is transformed into a patchy distribution consisting of 6 disconnected patches as threshold density *C* is increased.

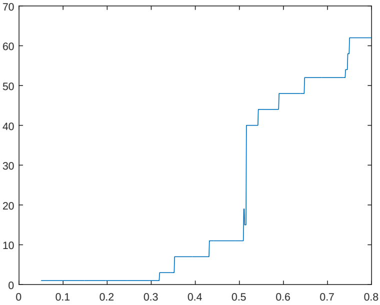


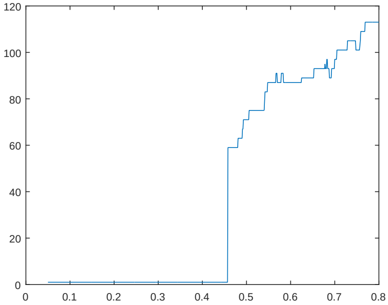


What if we ignore traps with low trap counts?

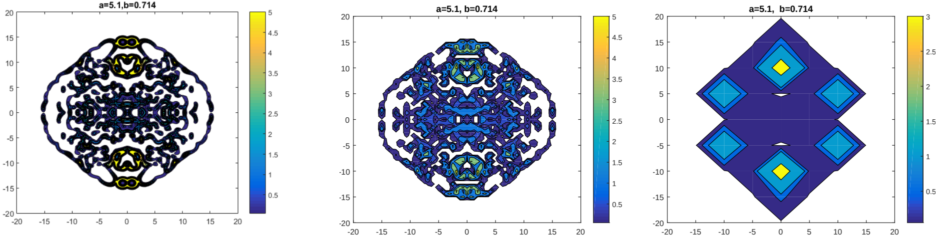
The number of objects as a function of threshold density C for two continuous front distributions.

The biologically meaningful maximum threshold value is $C \sim 0.1$.





What if we remove every *n*th trap?

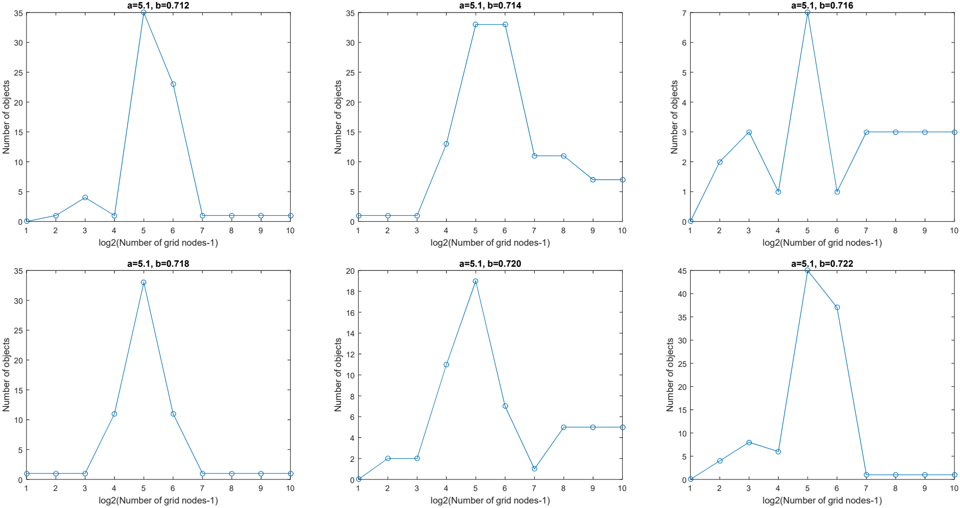


Spatial pattern reconstruction on coarse ($N = 65$) and very coarse ($N = 9$) grids, where N is the number of grid nodes at each direction.

The original patchy spatial distribution has been obtained on a fine grid with $N = 1025$.

The population density values are taken at every 16th node and 128th node of the original grid to simulate the density distribution on the coarse grid and the very coarse grid respectively.

What if we remove every *n*th trap?



The number of objects as a function of the number of grid points in a sampling grid used to reconstruct the visual image of spatial pattern.

Conclusions

- Investigation of the invasion model has confirmed that patchy invasion is not a byproduct of a poor monitoring protocol. 'Similar looking' patchy and continuous front spatial distributions are not similar at all!
- Future work will be focused on real-life ecological data to check whether continuous front and patchy spatial patterns remain robust to the factors that can affect the results of monitoring.
- The formal definition of 'patch' used in our work should be revisited to take into account requirements to the monitoring and control routine.
- Future study is required to identify the factors transforming the spatial pattern of invasive spread.

THANK YOU!