Modeling and evaluating human-mediated dispersal mechanisms at landscape scale: a study of road network and invasion parameters for Lasius neglectus ants invasive species

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Abstract:
Modeling and evaluating human-mediated dispersal mechanisms at landscape scale: a study of road network and invasion parameters for *Lasius neglectus* ants invasive species

Jérôme Gippet[1], Charles Rocabert[2], Serge Fenet[2], Adeline Dumet[1], Bernard Kaufmann[1]

[1] Université de Lyon, CNRS, Université Lyon 1, LEHNA, UMR5203, F-69622, France
[2] Université de Lyon, CNRS, Université Lyon 1, LIRIS, UMR5205, F-69622, France

1 Context

Biological invasions are considered, right after climate and land use changes, to be one of the principal causes of biodiversity erosion. This phenomenon is related to global change, since climate and land use modifications affect environmental conditions, and are partly responsible for the introduction and proliferation of exotic species into new environments. Furthermore, human-mediated dispersal acts as a dispersal vector for many exotic species, both at the introduction and secondary spread stages. On the one hand, introduction stage is a consequence of human-mediated long distance dispersal, due to human activities (and especially commercial exchanges), and is known to happen at large spatial scales (continental or global scales). On the other hand, secondary spread occurs at smaller spatial and time scales (like landscape scale) and can be provided by natural and human-mediated dispersal mechanisms ([2]), once the introduction had brought the exotic species into a novel environment, and after it has succeeded in establishing itself (i.e. survive and reproduce). Few works have pointed out the role of these second stages in small-scale invasive species spread. And yet, a lot of invasive species are susceptible to be partly or completely dispersed by local human processes happening at local spatial and time scales (materials transportation, for example) ([2]). The lack of consideration for this potential important mode of dispersal seems to be the consequence of multiple factors:

- human-mediated dispersal is generally considered as a long distance dispersal process, more responsible for invasive species introduction than for secondary spread,
- it is difficult to qualify and quantify this mode of dispersal because of the multiplicity of potentially involved human activities being its vector,
- for a given organism that can disperse naturally, it is complicated to distinguish between natural and human-mediated dispersal, as they may occur at similar scale.

2 Questionning

Even though a range of methodologies are available for describing population spread by natural dispersal ([4]), only few models have been developed to describe and predict human-mediated dispersal consequences at reduced scale. When focusing on this small scale spreading process, the two main current approaches exhibit several limitations and biases. On one side, pure gravity models ([1]) do not consider the movement rates of organisms themselves and are based on forces of attraction between an origin and a destination. They neglect the impact of environment topology, and lead to unrealistic

spreading process by only reflecting indirect relationships between external activity rate (like human activity, for example) and invasive spread. On the other side, infection models ([5]) rely on the estimation of the number of dispersal events by year, the distance of the jump and its direction, which lead to more precise and realistic outcomes. However, these models also rely on strong expert knowledge and the availability of a well-documented literature about the studied species, which can be an hindrance when the targeted species is less known. One could summarize the drawbacks of the existing approaches :

- none of them take into account neither the orientation and the assymetry of human means of transportation, nor the topology of the road infrastructure that will allow the spreading,
- they rely solely on expert knowledge rather than also taking into account up-to-date population sampling.

As a consequence, we argue that basing estimation of human-mediated dispersal parameters only on distances between invaded localities and neglecting the topology of the transport infrastructure can lead to overestimated distances and underestimated number of transportation events, especially when the information used is presence only ([5],[3]). Thus, we advocate that in order to understand how human-mediated dispersal acts at the landscape scale and how it can be responsible for invasive species spread, we must first combine socio-economical and geographical data to provide good estimation of frequencies and distances of material transportations through landscape, and then estimate human-mediated dispersal parameters directly from invasion data (such as landscape distribution data) using a computer modeling/simulation approach. This process especially takes advantage of the growing availability of databases and distributional data concerning the targeted species.

3 Methods and results

In this paper, we study the spreading pattern of *Lasius neglectus*, an invasive ant species originated from Anatoly, which invaded Europe in the last decades and which is currently present in the Rhône valley, in France. This species do not perform mating flights, and its spreading is solely ensured by the transport of soil materials (during road works, for example) in which individuals are present. We present a numerical model enabling the estimation of multiple human-mediated dispersal parameters, based on ground-truth sampling and minimizing a priori. The first step of this work has been to build a model of the landscape-level spreading process taking explicitely into account the topology of the road network able to support invasion trajectories. Then, initializing our model with sampling data gathered in the field, we localized the most probable sites of introduction, the number of jump events, as well as parameters of jump distances linked to the road network. Our model is also able to compute presence probability map, and can be used to calibrate sampling campaigns, explore invasion scenarios, and more generally perform invasion spreading previsions. In a longer term, and on the condition of available ground-truth data samples, it could be applied to all the species that can be disseminated at local to regional scales by human activities through road network.

References

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