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The spatial distribution of trees outside forests in a large open-field region and its potential impact on habitat connectivity for forest insects

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Abstract: Forest trees are commonly used for ornamental purposes and are thus frequently encountered in non-forest landscapes where they represent an important component of the so-called trees outside forests (TOF). Little is known about the role of these trees in the connectivity between forest patches and their potential impact upon forest organisms' dispersal. We focused on the tree species belonging to genera *Pinus*, *Cedrus* and *Pseudotsuga*, the potential hosts of the pine processionary moth *Thaumetopoea pityocampa*, a common defoliator in the western Mediterranean basin. We carried out an exhaustive inventory of trees in a 22 × 22 km sampling window located in the Beauce region (France) an agricultural territory where landscapes consist of intensively managed open-fields (mainly dedicated to cereal crops). The results showed that host trees suitable for the PPM are much more numerous than expected, and form small patches scattered across the study area. They are mostly ornamental trees planted in populated places such as villages. We conclude that hosts suitable for the PPM are available throughout agricultural landscapes. Various forest pests may benefit from TOF coverage that forms consistent ecological continuities linking forest areas. It appears that forest health should be addressed in a large context, encompassing non-forested areas, either agricultural lands or urbanized territories that play an overlooked role in large-scale spatial dynamics of forest pests and diseases.
Keywords: Trees outside forest, Spatial point pattern, Landscape connectivity, Pine processionary moth

Orman dışında geniş bir açık tarlada yer alan ağaçların uzamsal dağılımı ve orman böceklerinin habitat bağlantıları üzerindeki etkisi

Özet: Orman ağaçları genellikle süs bitkileri olarak kullanılmaktadır ve dolayısıyla orman dışındaki arazilerde sıklıkla karşılaşılmaktadır. Bu ağaçlar söz konusu arazilerde orman dışındaki ağaçların önemli bir bileşenini temsil etmektedir. Bu ağaçların orman parçaları arasındaki bağlantıdaki rolü ve orman canlılarının dağılımı üzerindeki potansiyel etkileri hakkında çok az bilgi mevcuttur. Batı Akdeniz havzasında yaygın olan yaprak zararlısı tür çam kese böceği *Thaumetopoea pityocampa*'nın potansiyel konukçuları olan *Pinus*, *Cedrus* ve *Pseudotsuga* cinsine ait üç türe odaklandık. Yoğun amenajman çalışmaları yapılan açık tarlaların (ağırlıklı olarak tahıl üretimi yapılan) yer aldığı arazilerden oluşan bir tarımsal bölge olan Beauce bölgesinde (Fransa) 22 x 22 km örneklem penceresinde kapsamlı bir ağaç envanteri hazırladık. Çalışmanın sonuçları, çam kese böceği için uygun olan konukçu ağaçların beklenenden daha fazla sayıda olduğunu ve çalışma alanının tamamına yayılmış küçük parçalar oluşturduğunu göstermiştir. Bu ağaçlar ağırlıklı olarak köy gibi yerleşim yerlerinde dikilen süs ağaçlarıdır. Çam kese böceği için uygun konukçu ağaçların tarımsal arazilerin tamamında mevcut olduğu sonucuna vardık. Çeşitli orman zararlıları, orman alanlarıyla bağlantı sağlayan tutarlı ekolojik devamlılıklar teşkil eden orman dışı ağaçların kapladığı alanlardan faydalanabilir. İster tarım arazisi olsun isterse kentsel bölgeler olsun orman dışı alanların, orman zararlıları ve hastalıklarının geniş ölçekli uzamsal dinamiklerinde oynadığı rol göz ardı edilmiştir, dolayısıyla orman sağlığının orman dışı alanları da kapsayacak şekilde daha geniş bir bağlamda değerlendirilmesi gerekmektedir.
Anahtar kelimeler: Orman dışı ağaçlar, Uzaysal nokta deseni, Arazi bağlantısı, Çam kese böceği

1. Introduction

Forest trees are commonly used for ornamental purposes and are thus frequently encountered in non-forest landscapes where they represent an important component of the so-called trees outside forests (TOF). TOF are defined as "trees on land not defined as forest and other wooded land" (Kleinn, 2000). There is a growing recognition that TOF provide various valuable benefits and services such as their contribution to biodiversity conservation or their recreational value in urban and peri-urban landscapes (Manning et al., 2006; Roy et al., 2012). Nevertheless, TOFs may also play a key-role in pest dissemination and expansion by creating ecological continuities between forest patches. This phenomenon may be of importance since urban areas are major points of entry for invasive species

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whilst urban forests and TOF connect these areas to natural or planted forests. Ludicrously, TOF role as element of ecological continuities with regard to forest pest dispersal has not received much attention so far, possibly because they are generally absent from forest inventories. The present study was designed to finely assess the spatial distribution of TOF across agricultural landscapes and to determine if they constitute ecological continuities for a forest insect, the pine processionary moth (PPM) *Thaumetopoea pityocampa.* The PPM is one of the main defoliating forest pests in the Mediterranean area. Recent studies showed that its range is currently expanding northward due to climate warming. This recent expansion did not appear to be affected by the presence of very large open-field areas such as the Beauce region one of France's most productive agricultural areas, where trees are considered relictual. We designed a field survey with the aim of mapping all the TOF that could be suitable host for the PPM and evaluating their impact in terms of ecological continuities with regard to the pest dispersal.

2. Material and methods

2.1. Study site and field sampling

The survey was carried out in a 22 × 22 km = 484 km^2 area located in the north of the Centre region of France (Figure 1). The landscape mostly comprised wide arable lands (cereal) (Rousselet et al., 2013). All TOF belonging to the genera *Pinus*, *Cedrus* and *Pseudotsuga* were considered as potential hosts of the PPM and are thereafter referred to as HTOF. We conducted an exhaustive sampling by visiting all carriageable paths and roads in autumn and winter 2009–2010, a period during which sighting and identification of PPM host trees (coniferous species) is easier because deciduous trees have lost their leaves. We observed and geolocalized every individual or small group of host trees (single trees, linear groups of trees, trees in linear features or along roads and small woodlands). Observation was done from the public space by eye and with binoculars when necessary.

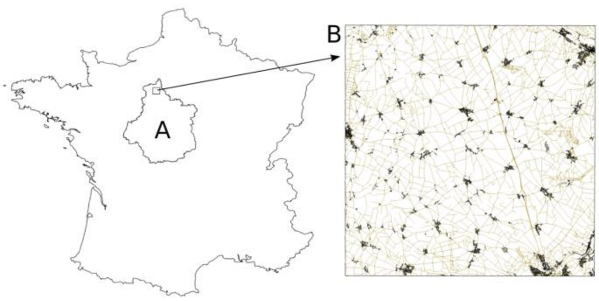

Figure 1. Sampling plot. A. The survey was carried out in the Région Centre in France. B. The sampling plot consisted in a 22 × 22 km window where an exhaustive inventory of HTOF was performed. The landscape mostly comprised wide arable lands (cereal) with scattered villages. The figure illustration shows the distribution of the buildings and the roads in the sampling area

2.2. Data analyses

The field data formed a spatial point pattern. We performed exploratory analysis using the Ripley's reduced second moment function K(r) (Ripley, 1981). A test based on 1000 simulations of complete spatial randomness (CSR) was carried out in order to discriminate between random, aggregated and regular point patterns.

A map of HTOF density was derived from the kernel smoothed intensity function of the observed point pattern (Diggle, 2003) and expressed in tree per ha. All computations were carried out using the R language (R Core Team, 2014) and the R package spatstat (Baddeley and Turner, 2005).

3. Results and discussion

A total of 3831 HTOF were recorded corresponding to 0.078 occurrences per ha. The observed point pattern is shown in Figure 2. HTOF appeared to be distributed in the form of small patches scattered across the sampling window. The Ripley’s K function (Figure 3) indicated a patchy distribution with Ripley’s K index well above the 97.5% quantile computed from the CSR simulations. The map derived from the kernel smoothed intensity is given in Figure 4. It strongly conveyed the spatial distribution of HTOF patches. Small patches of HTOF are scattered across the whole survey window and comparing Fig 1B, Figure 2 and Figure 4 indicated that HTOF were located close to buildings. Our results clearly indicated that HTOF were distributed in the form of small spatial aggregates. These structures appeared to be associated with the buildings where people plant ornamental trees. Although this pattern is not surprising, the virtue of our survey is to provide a quantitative overview of the phenomenon. Interestingly, there were patches of HTOF scattered throughout the study plot and the consequence in terms of PPM dispersal is very important. Even in an open-field agricultural landscape, ornamental trees form a dense network of small patches covering fairly homogeneously the whole area. Such network thus constitutes an important element of ecological continuity with regard to the PPM as well as other forest pests, either vertebrate, invertebrate or plant disease. More research is needed to explore the potential implications of these findings in terms of management. These could imply recommendations regarding the ornamental species to be used and ultimately policies. The idea that emerges is that forest health should be addressed in a large context encompassing non-forested areas, either agricultural lands or urbanized territories because they play an overlooked role in large-scale spatial dynamics of forest pests and diseases.

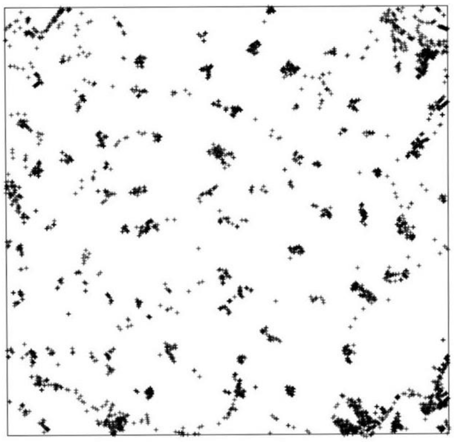

Figure 2. Observed spatial point pattern of HTOF in the Beauce region. A total of 3831 trees were georeferenced

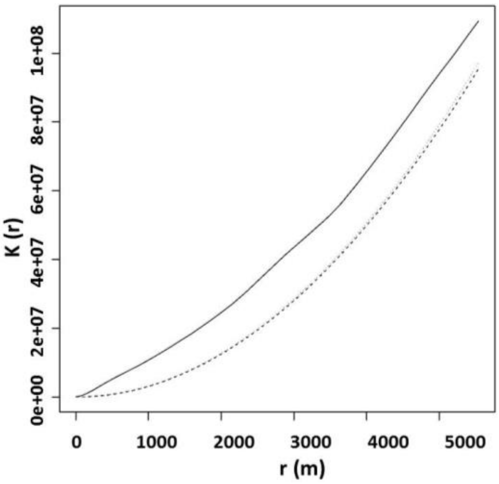

Figure 3. Ripley's K function for the observed HTOF. Dotted and dashed lines stand for 97.5% and 2.5% envelopes corresponding to complete spatial random point patterns

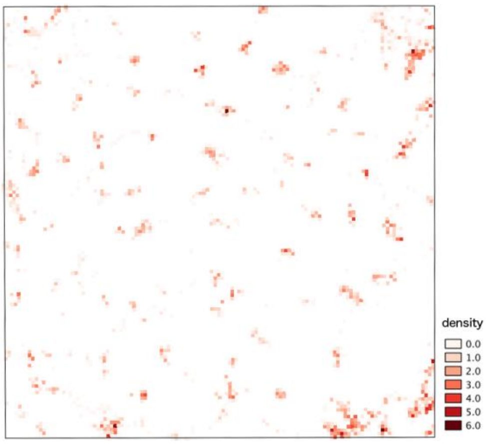

Figure 4. Kernel smoothed density for HTOF. The values are expressed in number of HTOF per ha

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