Functional response of species to multiscale landscape structure in a vector-borne disease system

A method to detect critical scale levels favourable to the presence of *Echinococcus multilocularis* in the Doubs, France

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ABSTRACT

The functional response of species to landscape is a recurring issue in landscape ecology. The scale levels favourable to the parasite responsible for a vector-borne disease, alveolar echinococcosis, have been explored in the Doubs department in eastern France. The method consists in maximizing landscape composition's heterogeneity in the environment of infected and non-infected georeferenced samples at various scales. The aim is to identify scale levels at which the positive samples' landscapes are the most specific and differ the most from the landscape in the environment of all samples. Three scales were identified and the distance to the positive samples' composition vectors were computed at each scale. The resulting maps give an insight on areas expected to be prone to host the parasite's life cycle. The landscape composition vectors were also compared between the two sets of data and helped drawing conclusions on landscape elements presumed favourable to the parasite. Subsequent sampling in areas highlighted by this work would help validate the conclusions and confirm the critical scales identified.

KEYWORDS

Landscape ecology, multiscale analysis, spatial epidemiology, risk factors, *Echinococcus multilocularis*

INTRODUCTION

The question of scale is a major issue in landscape ecology. Li and Wu [10] do stress the fact that a distinction should be made between the scale of landscape patterns and the scale to which ecological processes are sensitive. These scales are not necessarily equal and they might even not be linked [17]. It is therefore critical that the scale at which the landscape is described coincides with the process of interest. Observation scale and analysis scale should be clearly understood and stated [9]. The way species use their environment is constrained at various scale levels. Population dynamics, species abundance and biotic and ecological interactions are not only related to one habitat type [13]. It is now the landscape approach that is privileged in most studies [8][11][16]. Landscape context doesn't equally influence species because they have different movement ranges and different spatial strategies. The functional response of species to landscape is the level of perception at which they perceive their environment. Gehring and Swihart [4] explored the influence of habitat fragmentation on mammal predators. Generalist predators such as foxes are more adaptive to fragmented landscapes as they are more mobile [14]. Other species have a smaller movement range and are influenced by local changes. Inter-species relationships and the complexity of prey-predators systems do require a multiscale approach [2][6]. Different scale choices are found in landscape ecology studies. Hansson [7] chose three scale levels in the study of micromammals population dynamics: habitat scale (1 to 10 hectares), landscape scale (a few dozen square kilometres), and regional scale (a few thousand square kilometres). The choice of these scales is based on food

availability factors, predator pressure and climatic factors. In another study of foxes in Germany, radiotracking records were used in the choice of a 2.5 km radius circular analysis zone [12]. In a study of the transmission of a parasite, epidemiological factors have been integrated in the choice of scales [5].

This study aims at characterizing the functional response of species to landscape structure without any *a priori* assumptions on the species behaviour. The influence of landscape on the presence of the parasite *Echinococcus multilocularis* in a vector-borne disease system has been explored. This parasite is responsible for the fatal zoonotic disease alveolar echinococcosis in humans. The life cycle of the parasite is dependent upon two animal vectors. Micromammals such as voles do host the larval form of the parasite and foxes carry its adult form. The main goal of this work was to identify critical scale levels favourable to the presence of *Echinococcus multilocularis* in the Doubs department in eastern France. This area is known as endemic for the parasite and most of French human cases have been diagnosed in the Doubs [5].

MATERIAL AND METHODS

In the study area, a database of 175 georeferenced samples has been constituted and 9 samples revealed the presence of the parasite. A classified image of the study area was derived from IRS remote sensing data and resampled at a 25 m resolution. Landscape contexts were derived around each sample and the composition of these landscapes was recorded. The ratio of each land use class for each sample was expressed as a composition vector [15]. This vector was expressed for each point data P of an image with c land use classes as $X_P = (d_1,d_2,\ldots,dc)$. Manhattan distances were then used to calculate the distance between two composition vectors. A method developed by Foltête and *al.* [3][1] was used to compare the distance between the mean composition vector of all samples and the composition vector of positive samples, at each analysis radius. This index, noted *u*, shows low values when the distance between positive- and all-samples landscape composition vectors is the greatest. It has been computed at radii ranging from 25 to 10000 meters and revealed three scale levels of interest (Figure 1).

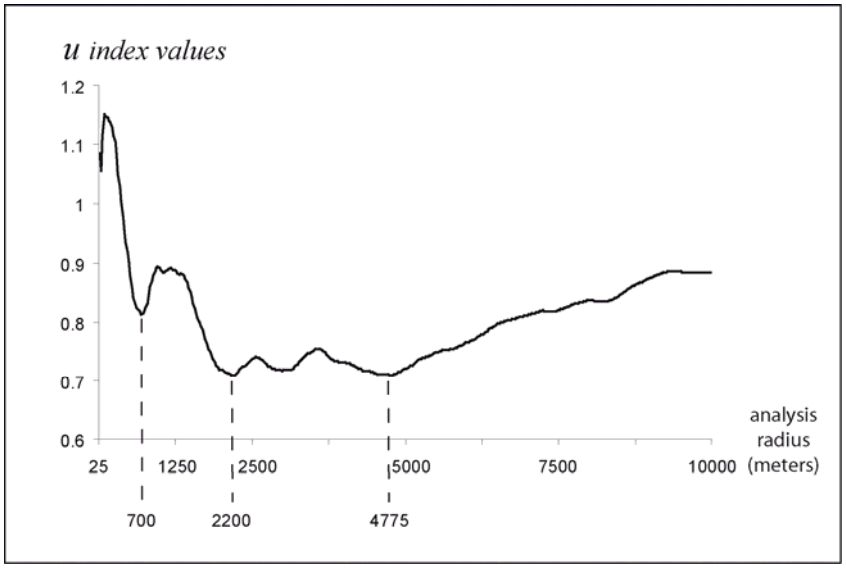

Figure 1: *u* index values. Three minimum values are highlighted.

Landscape proved the most different at radii of 700 m, 2200 m and 4775 m. These scales were selected for subsequent analysis.

RESULTS

At the three scales of analysis, the composition of the landscape has been compared. The first conclusion is that the landscape surrounding positive samples consistently shows a higher ratio of complex patches (abandoned agricultural areas, hedges, forest margins…) which can be interpreted as the expression of the need for species to find both food and shelter. Conversely, cultivated fields do seem repulsive and inappropriate to the development of the parasite's life cycle. This was expected as fields are not optimal habitat for the intermediate hosts because of the disturbances caused by ploughing. Other parameters such as forest do not seem to have an influence on the epidemiological processes. Three maps were computed and illustrate the Manhattan distance of the landscape of each cell of the study area to the mean composition vector of positive samples. At a 700 m radius, forest edges seem to appear significant whereas important uniform agricultural areas do not seem to play a role. At a 2200 m radius, the most complex areas are opposed to the same main field areas. Eventually, at a 4775 m radius, the area of the the first plateau and of the high range of the Jura mountains seem to be of interest. As exposed here, both a precise and spatial description of the specificities of landscapes related to *Echinococcus multilocularis* can be established using these methods. The main interest of this approach lies in the fact that the scale of analysis is expressed by the data and not based on expert knowledge, leaving out potential mistakes in the critical choice of the scale level at which the ecological phenomenon should be observed. Subsequent sampling campaigns could be designed based on these results and used to validate the conclusions of this work.

ACKNOWLEDGMENTS

The authors are grateful to Patrick Giraudoux and Francis Raoul from the Laboratoire de Biologie Environnementale, Déborah Gottschek, Stéphanie Favier and Frantz Catarelli at the ERZ for the coordination of the monitoring survey. Denis Augot, Franck Boué and Anne Thuault at the AFSSA for the samples' analysis work. Financial support from the European EchinoRisk program QLK-2-CT-2001-01995 "Risk assessment and prevention of Alveolar Echinococcosis" and US National Institutes of Health and National Science Foundation "Ecology of infectious diseases" (TWO1565-02).

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