GIS-MODELLING THE DISTRIBUTION OF *RATTUS NORVEGICUS* IN URBAN AREAS USING NON TOXIC ATTRACTIVE BAITS

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ABSTRACT - GIS supplies a useful way for analysing and modelling spatial distribution of brown rats *Rattus norvegicus* in urban areas, supplying maps that predict the occurrence of rats over larger areas. However, two alternative procedures can be used: landscape-based models, which use habitat variables derived from remote sensing satellites or other thematic maps, and interpolation techniques, which convert point samples of species abundance. The first procedure has been previously applied, while the second has never been used until now. In this study, we valued the effectiveness of the interpolating procedure by modelling the distribution of brown rats in a large urban area of northern Italy. During spring and autumn 2004, we positioned non toxic baits in 119 spots distributed over the whole urbanized area of the city and we generated maps of rat presence/absence for the two seasons. Brown rats were irregularly scattered over the city and concentrated mainly around rivers and ditches, as well in the historic centre, particularly where buildings suffer poor maintenance. Seasonal variation of rat occurrence was also detected. Brown rat occurrence may be reliably predicted by the interpolation procedure, which appeared to be a more efficient approach to rat distribution modelling compared with landscape-based procedures.

Key words: geographic information system, modelling, interpolation techniques, *Rattus norvegicus*, urban areas, NW Italy

RIASSUNTO – *Modelli GIS della distribuzione di* **Rattus norvegicus** *in ambiente urbano con utilizzo di esche non tossiche.* I programmi GIS rappresentano un utile strumento per analizzare e modellizzare la distribuzione del ratto delle chiaviche *Rattus norvegicus* nelle aree urbane, fornendo mappe in grado di predire la presenza di questa specie su vaste aree. A questo scopo possono essere impiegate due procedure alternative: i) modelli basati sul paesaggio, che utilizzano le caratteristiche ambientali desunte da mappe tematiche o immagini satellitari oppure ii) tecniche di interpolazione che convertono insiemi di punti di presenza accertata in stime di abbondanza. Il primo approccio è già stato utilizzato, mentre il secondo non ci risulta essere ancora stato applicato nella gestione del ratto delle chiaviche. In questo studio è valutata l'efficacia del metodo di interpolazione nel predire la distribuzione di questo roditore in una grande area urbana del nord Italia. Nel corso della primavera e dell'autunno 2004, sono state posizionate esche non tossiche in 119 punti distribuiti sull'intera area urbana. I dati così raccolti sono stati utilizzati per generare mappe di presenza/assenza della specie nelle due stagioni di indagine. I ratti delle chiaviche sono risultati irregolarmente distribuiti in città e concentrati principalmente lungo i corsi d'acqua e nel

centro storico soprattutto in presenza di edifici soggetti a scarsa manutenzione. Nel corso dell'indagine sono emerse differenze nella distribuzione fra le due stagioni di ricerca. La presenza del ratto delle chiaviche può effettivamente essere predetta mediante il processo di interpolazione: questo metodo risulta essere più efficiente rispetto a quello basato sull'analisi delle sole caratteristiche ambientali.

INTRODUCTION

The brown rat *Rattus norvegicus* (Berkenhout, 1769) is a commensal rodent, widespread among human settlements, which can cause several problems when at high density, such as damages through gnawing, contamination by faeces and urine, and potential transmission of pathogens (Childs *et al*., 1998)

Consequently, several measures against brown rats are taken world-wide by public administrators, mainly by using different kinds of rodenticides. Recently, a new approach to control rat populations has been increasingly applied, which is based on management of rat environments rather than on the simple use of poisons (Colvin *et al*., 1996; Langton *et al*., 2001; Traweger *et al*., 2006).

Fundamental to any program of rat population control is a thorough understanding of the seasonal variation of rat distribution and land use in order to optimize control actions and monitor their effectiveness. Unfortunately, censusing brown rats is rather difficult and the methods used till now are based on two main strategies: direct trapping (Emlen *et al*., 1949; Yo *et al*., 1987; Cowan and Townsend, 1994) and indirect surveys by means of signs (e.g. bites, tracks or burrows) and habitat cues (Emlen *et al*., 1949; Cowan and Town-

send, 1994; Traweger and Slotta-Bachmayr, 2005). This second approach has supplied more promising results, since it notably reduces costs, is less time consuming and allows the monitoring of larger areas. Moreover, indirect surveys may be applied at the same time as trapping in properly selected small areas (Traweger and Slotta-Bachmayr, 2005; Easterbroock *et al*., 2005)

Geographic Information Systems (GIS) supply a useful way for analysing and modelling the spatial distribution of species. Incorporating spatial and non spatial data, GIS produce maps that predict the probability of detecting the species over a given area. These maps can be used to plan control operations or enhance surveillance by identifying problem areas without direct survey it (Moncayo *et al*., 2000; Browenstein *et al*., 2003; Elnaiem *et al*., 2003; Diuk-Wasser *et al*., 2006).

Recently, Traweger and Slotta-Bachmayr (2005) have modelled rat distribution within the city of Salzburg (Austria), showing that the integration of information on building features, waterways, and compost heaps may reliably predict the probability of rat occurrence. The map generated by the GIS was proved to be useful for planning brown rat management in the entire city area. However, in this case a landscape-based approach was used to

elaborate the spatial map of rat occurrence, rather than an interpolation technique using rat abundance from direct sampling in small areas. Maps based on indirect cues have the main limitation of describing in a quite static way the rat population within a city, since they do not allow the assessment of either rat movements within the area or the seasonal variation of land use by rats. From the point of view of management, these models do not allow the monitoring of short time response to control actions by brown rats.

In this paper, we modelled the brown rat distribution in an urban area using an interpolation procedure, gathering information concerning rat occurrence by non toxic attractive baits. In order to test if this approach could allow the monitoring of seasonal variation in rat distribution, we compared maps of rat occurrence in spring and autumn generated with the same sampling procedure.

STUDY AREA

The study was carried out in the city of Moncalieri, NW Italy (45°00'N, 7°40'E). The climate is continental (average temperature 1.5 °C in winter and 24 °C in summer) and precipitation ranges from 60 to 80 cm/year. The overall population is 54,500 people. Architectural features of buildings are bricks and roof tiles generally before World War II in the centre and glass and reinforced concrete in the suburbs. Three main rivers (Po, Chisone and Sangone) cross the urban area, and several ditches and drains run across farmland surrounding the city. The monitored area included the whole urbanized area of Moncalieri and the farmland within a radius of nearly 1 km around the city.

METHODS

1. Rat monitoring

Rats were censused in spring and autumn 2004, by positioning attractive baits at 119 spots in both seasons, opportunistically distributed over the whole urbanized area of the city of Moncalieri. We preferred to use this sampling design rather than a more conventional standardized method (such as for example grid sampling), as our specific objective was to maximize the probability of rats detection, not to evaluate the effect of different habitats on rat distribution. Considering that the feeding preferences of brown rats do not differ among different colonies (Cagnin *et al.*, 1978), attractive baits were placed in all suitable habitats, such as the main parks of the city, along the three main rivers, along the most important ditches and drains, near skips, within manholes, and large deserted buildings in the suburbs. Baits were prepared using Detex Blox (Bell Laboratories), which are 20 g non-toxic blocks of cereals covered by a thick layer of paraffin to be resistant to moisture, normally available on sale for non-lethal monitoring of rodents. The advantages of this kind of bait is that it is highly palatable to rats, hard enough to preserve traces of rat incisors, and highly resistant conditions outside (under shrubs or within cavities and manholes) and can be retrieved up to 10 days after without damage. The absence of a toxin allows monitoring of rats without killing them, preventing non natural local changes in rodent density. In each sampling spot one to three baits were fixed using metal wires and spots were marked by a coloured plastic band to be easily recognised at the end of the sampling period. The spring census was carried out between 23 and 29 March, and the autumn census between 1 and 7 December. Overall, 135 baits were used in both censuses (8 spots having two baits and two spots three in both censuses). At each spot,

baits were retrieved six days after they were set, and incisor traces recorded. Spots with baits not eaten or with evident traces of slugs were considered free from rats.

2. GIS-modelling

Geographic coordinates of all 119 spots were collected by a GPS (Garmin eTrex) and mapped on a 1:5000 vectorial map of the city of Moncalieri using a GIS (ArcGis 8.0). We used a Kernel smoothing (700 m of radius) based on the 119 spots to obtain a map representing spot density to evaluate the sampling effort over the urbanized area of the city of Moncalieri (Fig. 1). The portions of the study area within the line representing 1 spot per hectare were considered reliably monitored; the area outside this line was also analysed, but the results of

following interpolation have to be regarded with caution. We used the reverse square method on the presence/absence of rats within sampling spots to obtain a map of rat presence/absence for spring and autumn and for the two sampling period combined by overlapping the two seasonal maps. We used the McNemar pair-matched test to check for differences between spring and autumn distribution of rats within the city of Moncalieri.

RESULTS

Only 85.7% of sampling spots supplied data during the spring survey, since in 17 spots baits were removed or completely destroyed (see details in Table 1). Overall rats were detected in 55 spots (53.9%) and based on the sample
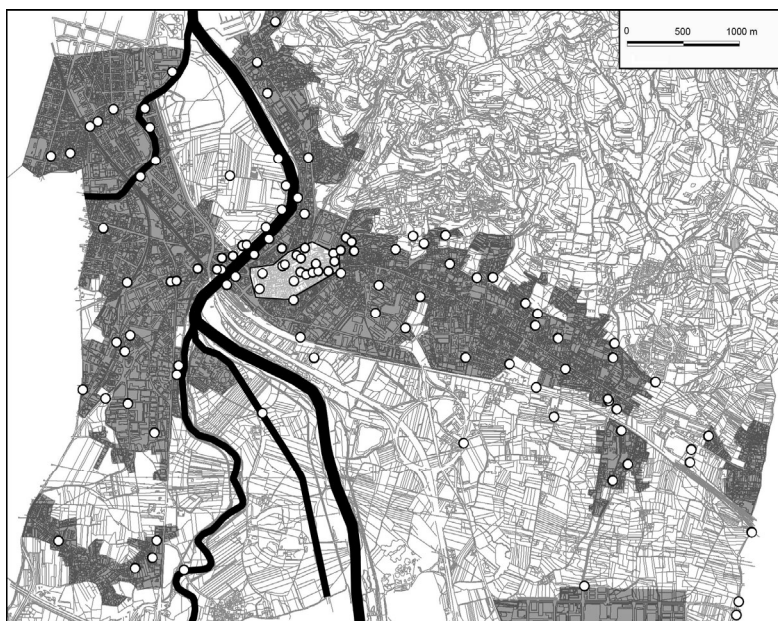

Figure 1 - Distribution of the 119 sites in the city of Moncalieri where brown rats were censused by non toxic attractive baits. Historical centre and suburban areas are marked in light and dark grey respectively; black lines represent the main rivers.

Table 1 - Use by rats of 119 baits set in spring and autumn.

	Spring N (%)	Autumn N (%)
Consumed baits	55 (53.9)	34 (30.1)
Non-consumed baits	47 (46.1)	79 (69.9)
Total of data collected	102 (85.7)	113 (95.0)
Baits removed or destroyed	17 (14.3)	6 (5.0)

Table 2 - Use by rats of 98 baits set in the same sites in spring and autumn.

Baits	N (%)
Consumed in both seasons	25 (38.5)
Non-consumed in both seasons	40 (61.5)
Unchanged outcome	65 (66.3)
Consumed only in spring	26 (76.5)
Consumed only in autumn	7 (23.5)
Changed outcome	33 (33.7)

of spots surveyed in both seasons (N = 98, 82.3% of the spots), presence of rats decreased significantly from spring (52%) to autumn (32.7%; McNemar exact test = 9.82, d.f. = 1, P = 0.002) (Table 2). The 25 sites where the presence of brown rats was detected in both seasons of the survey were located in the proximity of water, near skips of rubbish, within crumbling buildings or in deserted industrial sheds.

Sampling density ranged from 0-1 spots/ha in farmland and outer suburbs of the city up to more than 10 spots/ha in the inner parts of the historical centre and along the banks of the River Po. If we assumed that baits recruited brown rats from nearly one hectare, the line corresponding to 1 spots/ha comprised nearly all the urbanized area and most of the farmland surrounding the suburbs of the city (see black lines in Figs 2, 3, 4).

The map of presence/absence of rats during spring (Fig. 2) showed that rats principally inhabited the historic centre, the two banks of the River Po and the southernmost and easternmost portions of the city. As suggested by previous analyses, the map elaborated on the basis of the autumn survey (Fig. 3) showed a considerable reduction of the areas used by rats, even though the areas with the highest probability of rat occurrence where nearly the same as in spring.

The cumulative map (Fig. 4) summarized rat occurrence in the city, confirming the seasonal results. By con-
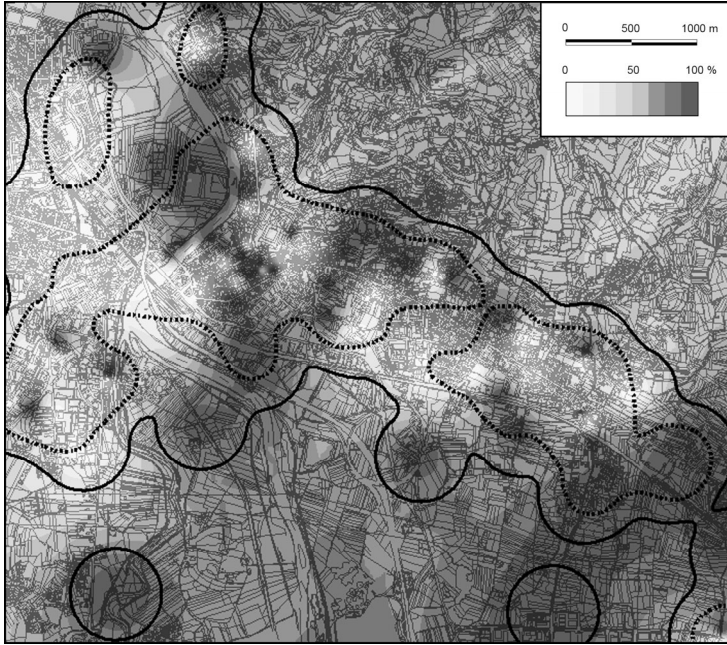
Figure 2 - Occurrence of brown rats within the city of Moncalieri during spring. Full and dashed black lines correspond to sampling efforts higher than 1 spots/ha and 5 spots/ha.

trast, rats were not detected in all the parts of Moncalieri characterized by modern buildings, i.e. all the districts in the westernmost areas of the city.

DISCUSSION

Two main approaches may be used to model spatial distribution of pest species in order to produce continuous surface maps predicting the probability of their occurrence. Landscape-based models use habitat variables derived from remote sensing satellites or other thematic maps as predictors of species occurrence (Moncayo *et al*., 2000; Browenstein *et al*., 2003; Elnaiem *et al*., 2003; Diuk-Wasser *et al*., 2006), while interpolation techniques convert point samples of species abundance to

estimate species abundance in areas not directly surveyed (Jeffery *et al*., 2002; Nansen *et al*., 2003; Ryan *et al*., 2004; Cocu *et al*., 2005). Both those approaches can be applied for modelling the distribution of brown rats, and actually Traweger and Slotta-Bachmayr (2005) showed that the landscape-based approach can be used effectively to predict rat occurrence in the city of Salzburg. However, the landscape-based modelling approach might not be the most appropriate for brown rat occurrence, since it is most effective for pest species which use few specific and well recognizable habitats for breeding, e.g. the mosquito vectors of the West Nile virus (Diuk-Wasser *et al*., 2006). Brown rats are not limited to specific landscape variables and have been
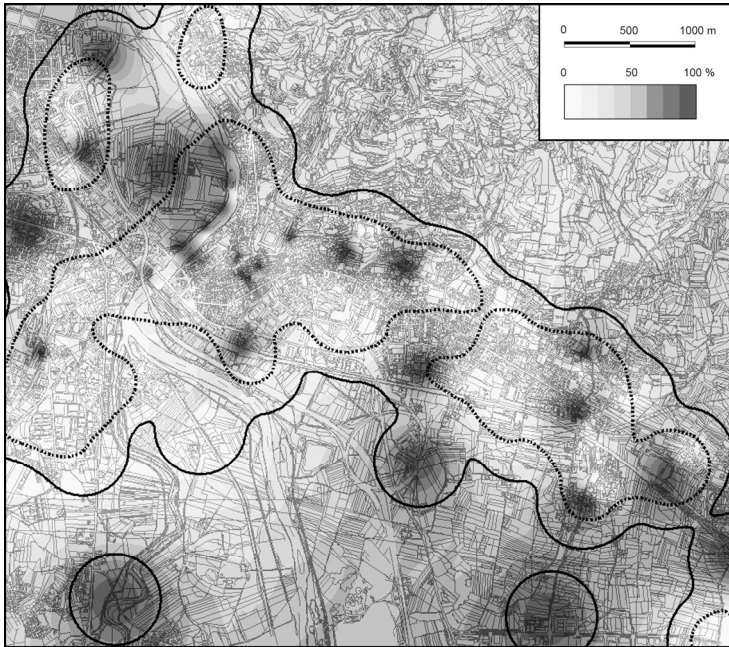
Figure 3 - Occurrence of brown rats within the city of Moncalieri during autumn. Full and dashed black lines as in figure 2.
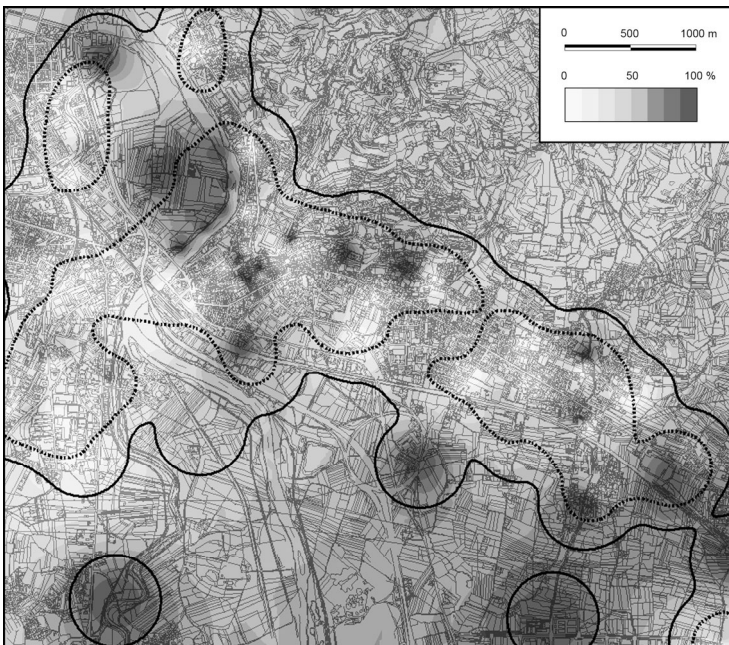

Figure 4 - Map of rat occurrence generated by overlapping the spring and autumn maps. Full and dashed black lines as in figure 2.

shown to efficiently adapt themselves to various types of habitats (Telle, 1966; Becker, 1973; Lore and Schultz, 1989; Traweger *et al*., 2006). Some landscape variables used by brown rats - such as water ways, deserted buildings or skips of rubbish - are quite rough predictors because they are assumed to be attractive for rats *a priori*, irrespective of their actual occurrence. Moreover, some other variables, such as skips or building condition, might prevent researchers testing the effectiveness of such variable in shaping management action involving such variables on the spatial distribution of rats. Therefore, interpolation techniques based on direct sampling would be a better approach to modelling brown rat occurrence, despite the difficult of trapping, since they include precise knowledge about the relationship between habitat variables and rat occurrence.

In the present study we have tested the effectiveness of the interpolation modelling approach to rat occurrence in a large urban area. Since all areas where rats had been repeatedly seen by citizens fall into the portion of the maps with the highest probability of rat occurrence, and in several occasions we directly observed rats while eating bait during surveys, we can suggest that sampling by non toxic baits is an effective and reliable method for gaining data for GIS modelling.

Our three maps of distribution show that brown rats are irregularly scattered over the city, being more frequent along watercourses and where buildings suffer poor maintenance. The overlapping of spring and autumn maps allowed the setting of the areas where

rats show the highest site-fidelity, which probably correspond to the main stable colonies. All these findings confirm that rats in urban areas are correlated with deserted buildings and disposal of anthropogenic waste (Telle, 1966; Becker, 1973; Lore and Schultz, 1989; Traweger *et al*., 2006).

An important result of this study was the marked variation of the distribution pattern of brown rats between spring and autumn. Since maps were generated using the same sampling procedure (i.e. the same number of baits was placed in the same sites in both seasons over the same time period), we can reasonably exclude the suggestion that differences between the two seasons might be due to sampling errors or different sampling efforts. Thus, the difference in rat occurrence between spring and autumn maps has to be related to seasonal differences in brown rat activity. Two main mutually non-exclusive hypotheses may explain the observed difference: i) breeding activity peaks during spring and rats move over large areas to look for partners belonging to other colonies, or ii) brown rats reduce mobility during autumn according to the lower food demand following the end of the breeding period. The monitoring of brown rats over time periods longer that a single year, together with direct trapping of individuals, would supply useful information to ascertain the causes of the decrease of rat occurrence during autumn.

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