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ANALYSIS OF LARGE-SCALE RODENTICIDE BAIT CONSUMPTION IN THE SEWERAGE SYSTEM OF THE CITY OF MADRID

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Abstract Urban Pest Management Programs demand spatial information. Madrid City Council has been incorporating Geographical Information Systems (GIS) for the last three decades. As a result, Health Madrid's Vector Control Department (DCV) has improved urban pest management notably. Systematic rat control with rodenticide baits in sewer systems (SS) is a common strategy in urban areas of European Mediterranean cities. Pest Control Operators (PCOs) have placed and regularly checked baits in the sewer manholes of Madrid for more than four decades. Since 2018, bait consumption data has been thoroughly recorded, incorporated into spatial databases and analyzed with GIS. This has led to more efficient Pest Management Program and better praxis. Furthermore, analysis of large-scale rodenticide bait consumption is important because Integrated Pest Management (IPM) principals and risk mitigation of chemical substances have driven recent changes in European legal context, promoting reduction or even suppression of anticoagulant rodenticides, compromising this type of source of information. This manuscript describes how information was collected, processed, analyzes executed, results obtained and main conclusions.

Key words Rodent control, biocide, Geographic Information Systems (GIS), geoprocessing.

INTRODUCTION

As other environmental health fields, in Spain, Pest Management is a legally based competence of municipalities. To reduce negative impacts of pests, municipal agencies usually invest significant economic resources and establish rat surveillance and control programs (Almeida et al. 2013). Health Madrid's DCV performs rodent, almost exclusively Norway rat (*Rattus norvegicus*), control in the public sewer system of the City, as part of the Deratization and **Disinsection Municipal Program**

Considering the huge impact of Norway rats on our societies, it is crucial to design both effective and efficient management programs for this specie (Pascual et al. 2019). Norway rat management, as all pest prevention and control operations, requires the location of pest problems (Bonnefoy et al., 2008; García-Howlett and Cámara, 2009). There is not much scientific literature regarding the factors that affect the distribution of rats within the cities (Feng and Himsworth, 2014), and even less regarding the study of their abundance in urban environments (Himsworth et al., 2014; Langton et al., 2001; Pascual et al., 2019; Tamayo-Uria et al., 2014; Traweger et al., 2006). Thus, bait consumption is a critical source of information regarding rat abundance and distribution.

Systematic rodent control, based on anticoagulant rodenticide baits, has been carried out in the SS of Madrid for over three decades. In 2018, Lokímica was the bidder with the best offer and was awarded the deratization and disinsection service for public spaces in Madrid, including SS. Since then, information from every SS manhole inspection is systematically recorded, generating a large amount of data, which is later introduced, geoprocessed and analyzed with GIS. GIS are tools that permit a technical and scientific based collection, processing and management of data (Bosque-Sendra, 1997). Global Positioning Systems (GPS) and GIS are now essential vector-control tools (Bonnefoy et al., 2008).

All DCV Programs are planned and developed with the help of GIS (Cámara and Tamayo, 2008; Cámara et al., 2012; Tamayo 2013). Prevention strategies implementation, continuous evaluation and vector monitoring are essential parts of IPM programs (Bonnefoy et al., 2008). All of them are dramatically improved by GIS and have proved so in Madrid (Cámara et al., 2012). GIS can manage huge spatial database and can carry out complex spatial data analysis and modelling (Smith et al., 2007), allowing mathematically supported decisions for pest control and prevention operations.

PCOs have historically used bait consumption as an indicator of rodent presence. The aim of recording rat presence at a large-scale, through bait consumption in the SS of a city like Madrid, is to have a better approach to the global situation, concentrate efforts in the areas with more activity and improve efficiency of the Deratization and **Disinsection Municipal Programs**.

This is done through the recording of bait consumption in every manhole or bait station inspection, transferring that information to a spatial database, analyzing with GIS, obtaining activity maps and processing the results critically.

MATERIALS AND METHODS

Madrid's SS counts with over 300,000 manholes. All accessible manholes for PCOs (>90%) are inspected at least once, some on several occasions, every year. Since 2018, with the exception of 2020 due to COVID-19 pandemic, more than 500,000 manholes inspections, and treatments when necessary, are performed per year. SS inspection planning is done at the official neighborhood level (N=131). The total number of inspections carried out in the SS of each neighborhood is based on a five-level ranking, established using citizen complaints and rat activity from the previous years, ranging from one to seven. Some smaller areas with considerable and recurring problems are examined more frequently.

Rat activity inspections consist in opening accessible (under premises of occupational safety) lids of every SS manhole, general observation of the situation from a pest perspective, checking the baiting point (a sounding cord fixed to the wall with rodenticide bait hanging 10-15 cm from the floor) and replenishing if necessary. Toxic baits are standard cereal based 100 gr blocks, manufactured specifically for sewer conditions. In the summer of 2018, due to reclassification of rodenticide toxicology in the European Unión, the block model was changed. The concentration of bromadiolone, active ingredient, was reduced from 0.005% to 0.0025%. Also, after performing a specific study it was decided to slightly vary the block composition, with the purpose of improving appetite although losing some residuality. In the second half of 2019 bromadiolone was replaced by brodifacoum as a good practice to avoid resistance to anticoagulants.

In every inspection, data is recorded systematically and regarding the rodent bait consumption, classified as: total, partial, null or not evaluable. Total (T), when all the blocks are consumed totally and there is evidence that rats are involved (gnawing marks either on the cord or on the block rod). Partial (P), when the blocks are not consumed entirely, and rat gnawing marks are visible. Null (N), when blocks are visible and there is no evidence of rodent activity. Not evaluable (NE), when blocks are not present and there is no evidence of rat activity or they cannot be examined.

Information is transferred to a spatial database, so that every SS Manhole is linked to the street section it is located in. Street sections are defined by street names and official neighborhood limits. Therefore, they are the minimum representative geographical unit and can be grouped into larger scales, such as the different official administrative levels (districts, neighborhoods and streets). Different temporal levels (months, weeks and days) can also be analyzed since the day of inspection is also recorded. Spatial databases can be incorporated into GIS where more complex analysis can be achieved. Madrid City Council has a normalized street map that is accessible in its Open Data Portal (datos.madrid.es), as well as its administrative boundaries and can all be loaded into GIS. Having intersected Madrid's normalized street map with the official neighborhood limits and then joint the bait consumption per street section database in GIS allowed geographical representation of rat activity.

Data Analysis

In order to obtain an activity indicator (AI), for each street section the percentage of rat presence was calculated as the sum of inspections with consumption (total or partial) divided by the total reviewed manholes:

AI =100 x Nº manhole insp. with consumption (T+P) / Nº of valid insp. (T+P+N)

AI were calculated per street section, complete streets, neighborhoods and districts per year (). To compare the results in all the street sections of Madrid, it is necessary to group the data annually, since some sections only receive one visit per year.

RESULTS AND DISCUSSION

Global activity (AI) in the SS of Madrid from 2018 to 2021 was 38,3. Meaning that more than a third of the manhole inspections have had rat presence at some moment during the Study period. AI, street sections with some activity (AI>0) and street sections with full activity (AI=100) per year are available in the following table:

Table with the Global Activity (Ai) in the SS of Madrid				
YEAR	**2018**	**2019**	**2020**	**2021**
AI (%)	**44.5**	**34.6**	**35.5**	**38.5**
Sections AI>0 (%)	**93.1**	**91.6**	**93.5**	**94.1**
Sections AI=100 (%)	**5.6**	**4.5**	**2.0**	**2.8**

Results from 2020 and 2021 must consider the impact of the COVID-19 pandemic in urban pest management (reduction in resources available for rodent control, changes in rat behavior, social awareness, etc.).
The results have been mapped, classifying the AI of the sections in five categories based on quintiles, from very low to very high, with the purpose of facilitating interpretation. Figure 1 and 2 are examples of the resulting maps, adjusted to a specific area in the northwest of the city in order to make them understandable due to the level of detail and scale necessary. In 2018 the first and last quintiles, the fifth part of the street sections with less and most activity respectively, corresponded to those with less than 22% of activity and more than 67%. In 2019 those figures changed to 15% and 50%. In 2020 it was 18% and 50%, respectively. And, finally, in 2021 it was 20% and 55% the first and last quintiles.

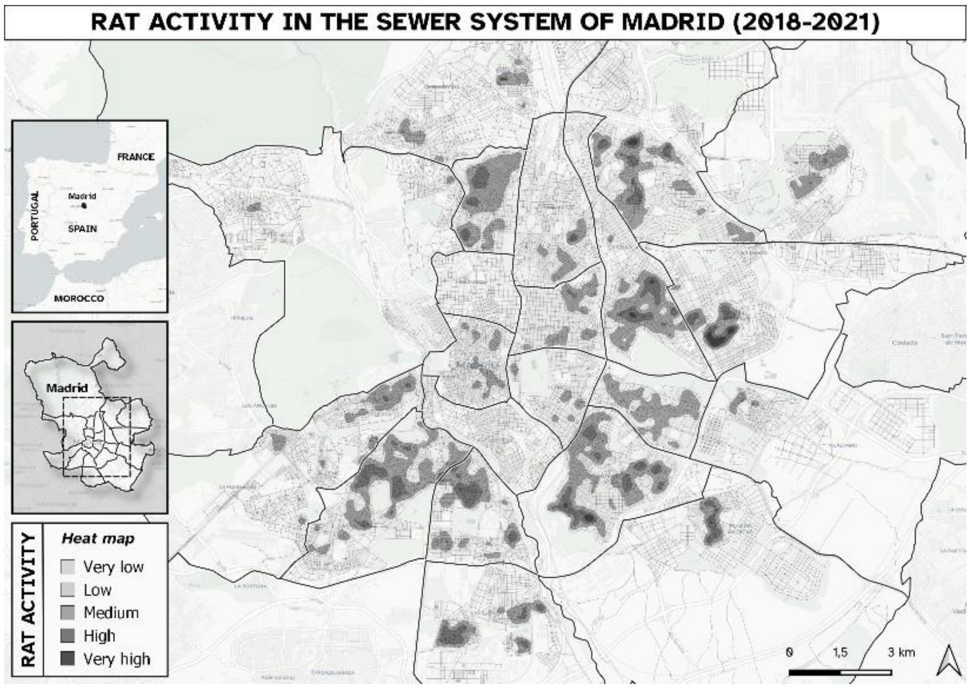
Results confirm that rat activity in the SS of Madrid was clearly reduced in 2019 (versus 2018) but that in later years it has stabilized with a slow increase. Differences in tendencies are probably due to raise in more than 200,000 manhole inspections from 2017 to 2018, showing results in 2019. These results suggest that systematical baiting in SS to control rat population is an effective method, however the impact is limited and efficiency of this measure requires further studies.

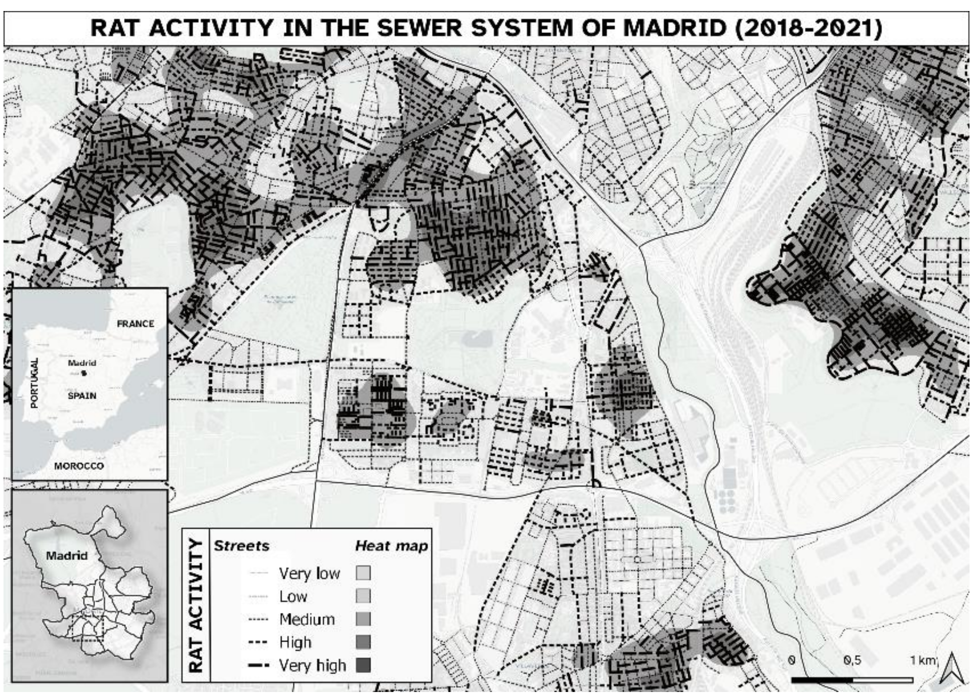
The number of verified citizen complaints increased by 50%, from 1,592 in 2018 to 2,394 in 2019. In 2020, there were 2,585, 8% increase; and, finally in 2021, there were 2,869, 11% increase compared to the previous year. DCV, as many other municipal pest control agencies, has historically used citizen complaints as their main management indicator. A recent study in Barcelona revealed that the number of complaints about rats was highly correlated to the human population density but poorly related to the bait consumption and rat capture estimators of activity (Pascual et al., 2019). The results of this study corroborate this affirmation. Although, at the end of 2018 the City Council included pest complaints in its new Madrid Intelligent Technological Platform, MiNT, easing the process for citizens and thus partially responsible of the increase.

Other issues should be regarded before discarding citizen complaints as a rat activity indicator and establishing conclusions about discrepancies with bait consumption tendencies in SS. First, as expressed in Materials and Methods, bait blocks were modified in summer of 2018 and although there is no basis for significant variation of results it may have contributed to some extent. Second, the interaction between sewer and surface rat subpopulations is controversial because of the lack of correlation between the dynamics of both subpopulations (e.g. Barnett and Bathard, 1953; Channon et al., 2000; Mughini-Gras et al., 2012). Citizen complaints, due to proximity, will probably be more influenced by activity of rats in surface rather than in the SS. Because of recent legal restrictions in rodenticide use, there is a tendency to increase the use of non-toxic baits in baiting stations, maybe tending to delay control results in surface populations and leading to an increase in activity. Third, variations in environmental factors (waste management and cleaning service, management of green areas, maintenance and construction of buildings, etc.), climate change and effects of globalization should also be considered. Pest management in heterogenous urban areas involves many factors, all source of information should be considered and reviewed meticulously.

In 2019 planning of inspection and control efforts where not only based on neighborhoods with higher amount of citizen complaints but also on the amount of sections where consumption is highest. Most probably also promoting reduction in bait consumption.

Before further analysis are made, there is one aspect to remark: in neighborhoods with very few inspections of some street sections, with unusual high consumption, will highlight and may divert attention from neighborhoods with higher global activity but due to more inspections lower accumulated consumption.





Figures 1, 2. Activity of Rattus norvegicus in sewer system of Madrid, Spain.

CONCLUSIONS

Urban environment are very complex scenarios where the access to spatial data and environmental information is crucial (Gerin, 2003 and Kanevsky, 2008). Currently the access to novel technologies makes it mandatory for all pest operators to implement systematic information recording and analysis platforms, these should count either with GIS capabilities or the capacity to easily transfer data to them. Big cities can generate huge amounts of data that can prove very valuable to understand pest dynamics and behaviors, or evaluate management strategies, but they are complex and heterogenous landscapes. Performing scientific studies in such urban areas is full of challenges and unpredictable situations.

Bait consumption is a critical source of information to estimate rat activity. Rodenticide bait blocks have been used for rat population control in SS for decades, with scarcely any study of global results in cities conducted (Channon et al. 2000; Mughini-Gras et al. 2012). In the current legal context of Europe, promoting reduction of anticoagulant rodenticide baits use and future scenarios of prohibition, large studies of bait consumption in urban areas are a great and critical source of information for future management strategies.

Repeatedly baiting the SS with rodenticide blocks does not follow IPM principals and therefore should be replaced as the standardized control strategy, independently of actual or future legal contexts. Reduction of food, water and harborage should always be the essential target of pest management. But rodent surveillance and control in SS is necessary. Alternative control methods must be validated before prohibiting toxic baits based on anticoagulants and until other options, both technical and economically assumable, are available we believe rodenticide baits should be accessible for PCOs. Notably in regions with limited economical resources and mild or hot climates where the lack of regular control actions could lead to rat populations growth and increase Public Health risks.

DCV will follow recording bait consumption and other information that can help understand rat ethology and as evidenced improve SS rat management. Further analysis must be performed, including specific correlation statistics with environmental factors, citizen complaints, socioeconomic variables, etc. Publishing and spreading the results of studies on urban pests is crucial.

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