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Cerri, J., Mori, E., Zozzoli, R., Gigliotti, A., Chirco, A., & Bertolino, S. (2020). Managing invasive Siberian chipmunks Eutamias sibiricus in Italy: a matter of attitudes and risk of dispersal. Biological Invasions, 22(2), 603-616.

Managing invasive Siberian chipmunks *Eutamias sibiricus* in Italy: a matter of attitudes towards them and their risk of dispersal

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Running title: Socio-ecological analysis on invasive chipmunk management

Abstract

Eradication of invasive alien species is a form of pest control linked to biodiversity conservation that usually involves killing animals. Squirrels are prominent among invasive alien species in Italy with four species introduced. Three of them are included within the list of alien species of European concern and their eradication and control is recommended. However, their local control is not an easy task, being highly appreciated by the general public. We propose a socio-ecological approach to evaluate the feasibility of eradicating Siberian chipmunks *Eutamias sibiricus* populations. We performed a structured questionnaire to assess the social perception of invasive Siberian chipmunks in urban parks where they occur and to identify groups of visitors who might oppose eradication. We also carried out geographic profiling to test for the spatial expansion of chipmunk populations. Overall, park visitors regarded chipmunks positively and appreciated to see them, but human-chipmunk interactions were still rare. We did not identify any group of visitors with a strong attachment to chipmunks, who might oppose future control programs. Geographic profiling showed that chipmunks in Valeggio sul Mincio are starting to expand outside of their introduction site. Data from questionnaires show that chipmunks eradication, coupled with adequate communication initiatives, might be feasible. Moreover, geographic profiling indicates that time for a rapid removal is running out. Socio-ecological approaches, combining the analysis of structured questionnaires administered to stakeholders and statistical modeling of pest observations, could be a valuable tool to decide the feasibility and the urgency of invasive alien species control.

Keywords: Alien squirrels, eradication, geographic profiling, species control, socio-ecological model.

Introduction

The Siberian chipmunk *Eutamias sibiricus* is a widespread species in Russia and the Far East, which has become invasive in some European countries since the 1960s after its widespread trade as a pet species (Mori et al. 2018a). Chipmunks which escaped from captivity established viable populations in northern Italy and at two urban parks in Rome (Mori et al. 2018a; Loy et al. 2019). The Siberian chipmunk is not a mainstream invader, as the Eastern grey squirrel *Sciurus carolinensis* (Bertolino et al. 2008), but it is considered as an invasive alien species of European concern, being listed within the EU Regulation 1143/2014. Particularly, chipmunks can act as a vector of tick-borne diseases and zoonoses (Pisanu et al. 2010; Marsot et al. 2013; Mori et al. 2018b). The European regulation requires member states to eradicated listed species from their territories when it is still possible and this appear the situation in Italy where the species is still localized with small populations (Benassi and Bertolino 2011; Zozzoli et al. 2018).

Management interventions aimed at containing or removing invasive alien mammals are more feasible when two ideal conditions occur. First, they are more cost-effective and face a higher success rate whenever the target species are still in the early stages of their invasion (Pluess et al. 2014; Bomford and O'Brien 1995; Robertson et al. 2016). Second, eradication initiatives tend to be more feasible when target species have minor interactions with society (McNeely 2001) Attempts to remove iconic alien mammals could result into strong opposition from some stakeholders (Blackburn et al. 2010; Shine and Doody 2011). For instance, a trial eradication of the Eastern grey squirrel (*Sciurus carolinensis*) from Italy attempted in 1990s was stopped by animal right groups who brought the case in front of the court (Bertolino and

Genovesi 2003).
Preliminary social impact assessments, integrating social sciences in the debate about invasive alien species (IAS) control (Crowley et al. 2017 a,b), can be highly informative about this second point. For example, surveys based on structured questionnaires can inform managers about public attitudes towards IAS (Lewis et al. 2019), their emotional valence (Larson et al. 2016) or about the existence of peculiar interactions with some social groups (Galbraith et al. 2017). Control intervention targeting iconic IAS which are perceived positively by the general public, are likely to face a fierce and widespread opposition from the society and they should be designed accordingly, with adequate emphasis on communication and institutional commitment, to be effective. Surveys can also tell how much attitudes towards IAS control are polarized, identifying groups who require tailored communication and engagement initiatives (e.g. animal right activists). Again, surveys can also take the form of preference elicitation, asking people to rate competing management options (Cerri et al. 2018) and qualitative inquiries can complement them, explaining the rationale behind this evaluation (Crowley et al. 2018). Finally, preliminary social science inquiries can also provide managers with cues for concrete behavioral interventions targeting problematic interactions between humans and invasive species, like peer pressure or normative expectations (MacKay et al. 2018). Socio-ecological assessments go one step further, by combining information from relevant stakeholders, obtained through qualitative or quantitative methods from the social sciences, with information about the ecology, distribution and population dynamics of target species (Gálvez et al. 2018). Ecological information can also be spatially explicit, as most ecological processes incorporate a geographical dimension (Struebig et al. 2018), and in the case of IAS, their distribution and dispersal around introduction sites might be particularly relevant for socio-ecological assessments.
Eradicating chipmunks from Italy is required under the European and national legal framework, but, to the best of our knowledge, no study was conducted to verify if the species became an iconic presence at its introduction sites, nor to assess the stage of its invasion. Iconicity is particularly important, considering the strong opposition faced by managers aiming to control or eradicate the grey squirrel in this country, even in recent years (Genovesi and Bertolino 2001; Bertolino and Genovesi 2003; Bertolino et al. 2016). Our research aims to fill this gap, by coding a socio-ecological analysis combining spatial data of the species altogether with information from a structured surveys administered to a sample of visitors. We tested whether chipmunks became an iconic species, though structured questionnaire measuring how visitors perceived them. Then, we used existing observations of the species at its introduction sites, to assess, through geographic profiling, the geographical spread of chipmunks over time. Assessing the stage of invasion of an IAS and how citizens perceive the species, are two important aspects that should be considered in planning eradications campaigns. Considering that the perception of a species may be related to its visibility, which in turn depends also on its spread and local density, we think that our approach could be informative to managers.

Materials and methods

Study sites

In this research we focused on the three urban parks where chipmunks established viable populations in Italy. The first one is Sigurtà Garden Park, in Valeggio Sul Mincio, where Korean chipmunks were released in 1978, establishing the largest Italian populations of chipmunks in Italy (Mori et al. 2018a, c; Zozzoli et al. 2018). The latter two areas where two urban parks in Rome, Villa Ada, where chipmunks were introduced at multiple times since the early 1908s and Villa Doria-Pamphilii, where chipmunks were observed for the first time in

2018 (Benassi and Bertolino 2011; Mori et al. 2018d).
This study is based on two separated analyses: a quantitative survey, assessing the perception of chipmunks by visitors at the three urban parks, and a geographic profiling model, to measure the geographical spread of the species around the urban parks.

Survey development, administration and analysis

We surveyed a sample of visitors (n = 248), administering a structured questionnaire measuring their interactions with chipmunks and some psychological drivers of human-chipmunk interactions: attitudes, emotional dispositions, core affect, existence beliefs, social norms and behavioral intention about the presence of chipmunks. Attitudes were measured by means of a Likert scale and they were conceptualized as divided in some beliefs, characterized each one by its strength and the evaluation of its outcome (Manfredo 2008). The attitudinal scale was built up by considering all the potential impacts of a species of ground squirrels living in a park, after a pilot study (Appendix S1). Emotions were measured as emotional disposition (joy, fear, surprise, disgust, interest) and core affect, or the extent respondents would have felt positive or negative at the idea of encountering a chipmunk (Jacobs 2012; Jacobs et al. 2012, 2014; Larson et al. 2016). We measured existence beliefs by asking respondents to rate the importance of chipmunks in the park, both for future generations and *per se* (Frank et al. 2016). We measured social norms about the appropriateness of chipmunk presence in the park, by using three items measuring moral beliefs, empirical and normative expectations, and the willingness to enforce them by reporting the presence of chipmunks to local authorities (Bicchieri 2016). Visitors were also asked whether they had ever heard of chipmunks living in the park and if they had ever seen, fed or touched them. A complete list of the various questions adopted in the questionnaire, altogether with their summary is available in Table 1 and a complete copy of the questionnaire at (https://docs.google.com/forms/d/e/1FAIpQLSelkWacunZsTWDB3Qxy3QCYvfaFKg-hhd9LFmhcLcEZAbyfuA/viewform?usp=sf_link). The questionnaires were administered in Rome in both parks, but the collected data were grouped together as the two parks share the same pool of visitors. The questionnaire was implemented on GoogleForms. Most respondents (93.95%) were recruited on the field and they completed the questionnaire on a tablet. An online version was also administered on some Facebook groups on these urban parks. Questionnaires were confidential and they took approximately 15 minutes to be filled. We assessed the reliability of our attitudinal scale through McDonald's Omega (Dunn et al. 2014) and we tested for construct validity through Confirmatory Factor Analysis (CFA), with a Maximum Likelihood estimator with robust standard errors and a Satorra-Bentler scaled test statistic. Both indicator and latent variables were standardized and all the factor loadings were estimated. We adopted two correlated latent variables reflecting the strength of each beliefs and the evaluation of its outcome, and we also specified some residual correlations between each couple of items describing a specific impact. We selected the best subset of items and the best latent variable structure by comparing models through likelihood-ration testing and some fitness indexes. Attitudes were aggregated into a final score by summing the product of each couple of items (Manfredo 2008).

We segmented respondents on the basis of their attitudes, emotional dispositions, core affect and their moral, empirical and normative expectations about the presence of chipmunks in the park. Segmentation aimed to identify clusters of respondents who strongly supported chipmunk presence and could oppose their eradication. For example, by highlighting respondents who scored remarkably high in their attitudes, core affect or moral beliefs about chipmunks, cluster analysis can reveal the existence of groups of visitors who regarded chipmunks as an iconic species. Previous experience with grey squirrel control in Italy,

especially in urban areas, shows that these groups are often those who start boycotting control programs (Bertolino et al. 2016). We tested for the presence of clusters in the data through the Hopkins index and we compared k-means, hierarchical and k-medoid cluster analysis (Kassambara et al. 2017), to assess which one clustered observation the best.

We carried out Generalized Linear Modeling (GLM) to highlight differences in the two areas, in terms of attitudes scores, core affect, existence beliefs and moral, empirical and normative expectations about the presence of chipmunks in the park. Given the skewed distribution of the response variables, we fit eight GLMs with a Gamma distribution of the error and an identify link function. To compare the two study areas, we used a dummy variable indicating the location where respondents were sampled. To control for the effect of belief saliency, we included another dummy variable indicating whether respondents had already encountered chipmunks before the study. Finally, we introduced an interaction term between the two predictors. We did not carry out model selection, as GLMs were used to compare the two sampling sites only. Predictors were evaluated in terms of their p-value and the value of their coefficient. We inspected model residuals to see whether assumptions of GLMs were respected. Further details are shown in the reproducible software code (S2).

Geographic profiling

We tested for chipmunk expansion around their introduction sites by means of geographic profiling (GP), a powerful approach to measure spatial tendencies and to reconstruct spatially-explicit dynamics. GP is common in criminology, where the spatial locations of crimes are used to calculate the probability of occurrence of the offender's residence for each point over a certain geographical area. GP outperforms classical measures of spatial tendency, and many ecologists found it good for tracing back the origin of individuals that could move across space (Raine et al. 2008; Martin et al. 2009; Faulkner et al. 2015, 2016). We adopted a Bayesian GP algorithm (Verity et al. 2014), requiring only the specification of a distribution parameter, indicating a plausible maximum extent to which individuals could move. Based on available evidence indicating that chipmunks usually disperse within a few hundred meters from their birthplace (Marmet et al. 2009, 2011), we opted for a dispersal parameter of 1 km. We used available observations (Benassi and Bertolino 2011; Zozzoli et al. 2018; Di Febbraro et al. 2019) collected in Villa Ada, from 2011 to 2014 (n=26), and in Valeggio sul Mincio, from 1997 to 2018 (n=87), as the input for the GP algorithm. We did not use observations from Villa Doria-Pamphilii as the park is embedded in an urbanized matrix, which prevents chipmunks from dispersing around. It is important to note that we were not interested to identify where chipmunks were released, but to reconstruct a probabilistic profile for the origin of the observations: the inspection of its shape told us whether observed chipmunks came from disjoint hotspots, related to source areas in good habitats, as expected for an expanding invasive alien species, or from a single one, like in the case of a species which is not expanding. Statistical analyses were carried out with the statistical software R (R Core Team 2018) and a detailed information about statistical analysis, altogether with a reproducible software code is available in the Supplementary Information (S2).

Results

Respondents had generally positive emotions towards chipmunks. Moreover, they generally agreed with the idea that the presence of chipmunks in the park was important for future generations and that it was important to have chipmunks living in the park even if one does not see them. Finally, most respondents deemed right and common for chipmunks to live in urban parks (Table 1). However, most respondents were not aware of the presence of

chipmunks in the park where they were interviewed and about half of them had never observed these animals before. The proportion of respondents who had fed (14.6%) or touched (6.3%) chipmunks were even lower. Moreover, 14.11% of respondents reported to have observed chipmunks, despite they were not aware of their presence (Figure 1).

CFA and McDonald's Omega did not support an overall attitudinal construct, but they identified two separate groups of beliefs. The first one included items about the impact of chipmunks over the quality of recreation at the park: increasing the aesthetic appeal of the park, attracting new visitors and making visitors more prone to visit the park again. The second group included the potential impacts of chipmunks over human health: rummaging garbage from bins, transmitting disease to humans and to visitors' dogs (Table 2; Table 3).

Hierarchical cluster analysis with Euclidean distance and a complete link indicated the presence of a small segment of respondents, characterized by negative attitudes about chipmunk impacts over human health, fear and disgust towards chipmunks (Figure 2). The two sites differed only in respondents' score about the positive impact of chipmunks over the recreational experience, with Rome having slightly higher scores. Visitors in Rome also agreed slightly more with the idea that most people deemed appropriate for chipmunks to live in urban parks in Italy (Figure 3; Table 4).

Geographic profiling showed that invasive chipmunks disperse less than 500 m from the place where they are born. Chipmunk observations in Rome come from a single source, whereas observations in Valeggio sul Mincio are likely to have involved individuals coming from two distinct spatial cores (Figure 4). One of these two cores was found to be outside of the boundaries of the urban park where the species was introduced.

Discussion

Overall, these findings indicate that visitors regard chipmunks positively. Apart from a small cluster of respondents, most of them have positive emotions towards chipmunks, deem appropriate the fact that they live in an urban park and value their presence as something having an intrinsic value. However, this positive perception probably stems from a more general, favorable, disposition towards the presence of wildlife at urban areas. Respondents do not have a coherent system of attitudes about the presence of chipmunks, probably because their real interactions were limited: attitudes are shaped and reinforced by our everyday experience with a certain issue, that make it salient for ourselves (Heberlein 2012; Manfredo 2008). On the other hand, visitors had stable beliefs about those impacts of chipmunks that could affect their recreational experience at the park, as well as fears about those impacts that could undermine hygiene. These two sub-dimensions probably indicate that visitors' beliefs are embedded in broader belief networks encompassing different, and more salient, topics (Nilsson 2014). For example, our respondents could have stable belief networks diseases, and they could have tied to them some of their beliefs about chipmunks. Framing experiments, where participants are primed to think about some precise topics and where the effect of this priming over beliefs is measured (Chong and Druckman 2007) might be a valuable tool to better investigate how human-wildlife interactions are embedded into broader nomological networks, and influenced by beliefs about relevant social issues. Framing experiments could also be used to test for attitude certainty and strength (Howe and Krosnick 2017, Rucker et al. 2011).

The idea that respondents' attitudes were not grounded into experience is reinforced by the limited interactions between visitors and chipmunks: approximately, only half visitors observed chipmunks in the park, 15% of them fed chipmunks and only about 6% of them reported to have touched a chipmunk. Moreover, some visitors who observed chipmunks were not aware of their stable presence in the park: our questionnaire was arguably the first time they were introduced to this aspect. These superficial interactions are also reflected by the low

differences between the two areas. Respondents in Rome and in Valeggio sul Mincio had similar scores for almost all the psychological antecedents of their interactions with chipmunks. They showed minor differences only in their beliefs about the impact of chipmunks over the recreational experience, and in their normative beliefs about the presence of chipmunks in an urban green area. Moreover, hierarchical cluster analysis did not divide respondents into meaningful segments, on the basis of their attitudes, emotions, existence values and social norms towards chipmunks and it did not identify any group of strong supporters of chipmunks. We only noticed a small cluster of visitors, concerned about the potential impacts of chipmunks over human health and holding negative emotions (fear, disgust) towards chipmunks. These visitors might be people who are scared or disgusted by rodents and concerned about their impact over hygiene, two aspects that are often related and characterize some individuals (Davey et al. 2008, Curtis et al. 2004, Prokop and Fančovičová 2010).

Taken together, these three points are important for the future management of chipmunks in the study area. Attitudes are an antecedent of human behavior and often a good barometer to forecast an eventual opposition to the management of invasive native (Manfredo 2008) and introduced wildlife (Sharp et al. 2011). As visitors do not have stable attitudes and no segments of highly motivated visitors exist, it is reasonable to say that an eradication campaign would not face any strong opposition from local visitors. Chipmunks at the two sites do not seem to be an iconic species yet like the grey squirrel in many urban parks if the UK (Dunn et al. 2018). Their interactions with visitors, especially those creating emotional bindings, like feeding, are still limited. However, considered that respondents regard chipmunks favorably and that they value their presence as a legacy for the younger generations, we believe that eradication initiatives should be coupled with an adequate communication strategy, to avoid polarization and the 'backfire effect'. Considered that respondents from the two sites did not show any particular difference, communication actions might be similar between Rome and Valeggio sul Mincio.

Animal right groups at the national level have their own agenda regarding wildlife management, and usually they tend to oppose eradications (Bertolino et al. 2016). Our study was focused on visitors of the parks, and did not target these groups. In any case, any eradication project should consider possible opposition from these groups, learning from previous experiences and planning an effective communication campaign (Bertolino et al. 2016).

Future studies adopting scenario analysis techniques (e.g. factorial surveys, Auspurg and Hinz 2014) would be important to provide more nuanced insights about the acceptability of various management options for the species. Notably, factorial surveys would enable to combine scenario analysis with the inspection of respondent's stable traits, such as wildlife value orientations (Manfredo et al. 2009), which might be highly informative about the acceptability of management options by the most polarized stakeholders, such as animal rights activists.

According to the GP, chipmunks are slowly expanding outside the Sigurtà Garden Park, i.e. their introduction site in Valeggio sul Mincio. There are two issues connected with this slow spatial trend. The first one is the fact that it is an expansion; then, we also expect chipmunks to continue their expansion outside of the park. This perspective is not encouraging, because Valeggio sul Mincio is surrounded by a countryside environment and cultivations, that might promote chipmunk dispersal at the landscape scale (Mori et al. 2018c) and maybe even their role as a pest species damaging crops, in the near future. Considered that chipmunks are still distributed over a relatively small area, but there are large areas in Italy suitable for the species (Di Febbraro et al. 2016, 2019), we recommend their quick removal, as it will be easy and cost-effective. Then, we also recommend their removal, in the near future, because this expansion is not fast. Although this might sound positive, because rapidly dispersing IAS are traditionally problematic to control, a slow rate of expansion would imply that chipmunk population might

further increase in their densities within the parks. This is likely to increase their visibility and their interaction with visitors as well, ultimately raising their level of iconicity. Therefore, although chipmunks cannot be defined an iconic species yet, a slow dispersal coupled with their reproductive potential, could make them achieve this status in the near future, decreasing the social feasibility of their eradication. Another advantage of rapid intervention is the availability of different alternatives for the removal of few animals, including non-lethal methods, which can be accepted by animal right activists (Scapin et al. 2019).

Conclusions

In this research, we showed how spatially-explicit data about a biological invasion and survey data on its social perception may inform decision makers about potential feasibility and urgency of management actions. Geographic profiling can be used not only to identify introduction or to locate dens of invasive pests, but also to signal the emergence of source-sink systems. Both these systems indicate the end of an early invasion stage and the spatial expansion of the invasive alien species, often due to their numerical increase, which can make management actions, including eradication and numerical or spatial control, too hard and too expensive. Moreover, structured surveys could inform conservationists about the interactions between stakeholders and biological invaders, altogether with their social perception.

Our findings indicated that visitors still have limited interactions with invasive chipmunks in Italian urban parks where they have been released. They do not have stable attitudes, and there seems not to be any visitor group who regard chipmunks as an iconic species. Perspectives about chipmunks are positive, but probably weak. At the same time, chipmunks are currently expanding their range outside their introduction site in northern Italy.

We deem that initiatives aimed at removing chipmunks are still feasible, if properly planned with adequate consultation and communication, and urgent. We feel that animal right groups may represent important stakeholders in Italy and, if not properly involved, they may hinder any action against this introduced species (e.g. Bertuzzi 2019). However, postponing management interventions could complicate and limit the potential success of future eradications, both for the spatial spread of the species in one of the two areas and for the risk of change in visitors' attitude due to a greater confidence with chipmunks that have become more abundant.

Acknowledgements

The "U.O. Manutenzione e Valorizzazione del Verde Urbano" office of the Municipality of Roma provided us with permits to set the survey within urban parks in Rome. Authors would like to thank Davide Sogliani, who kindly helped in the fieldwork, Rocco Tiberti for recommendations, and Giulia Benassi, who provided them with data from previous surveys about chipmunk presence in Rome. Two anonymous reviewers provided us with useful comments, which improved our MS.

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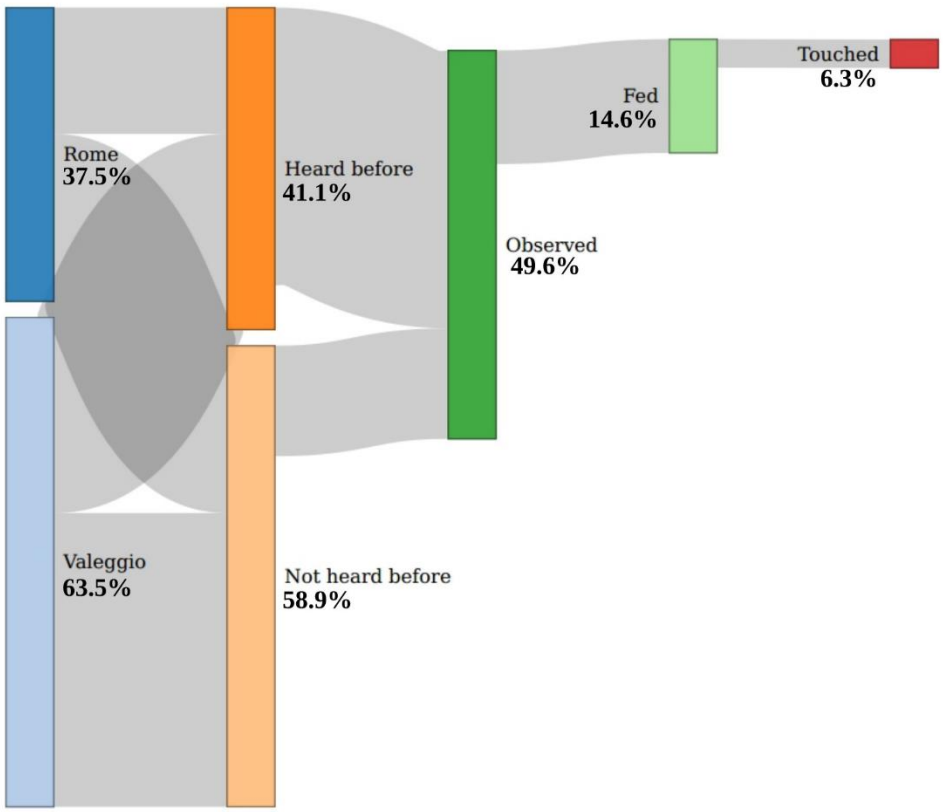

Figure 1. Sankey plot about visitor-chipmunk interactions: proportion of visitors who had heard of, observed, fed and touched chipmunks before our study.

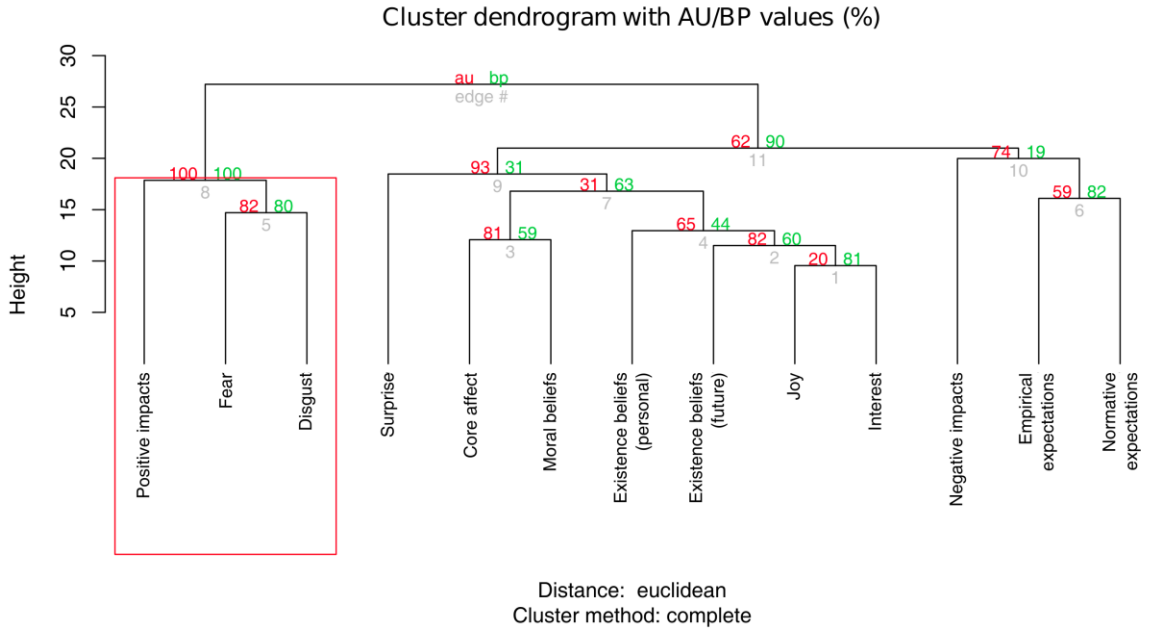

Figure 2. Dendrogram of the hierarchical cluster analysis.

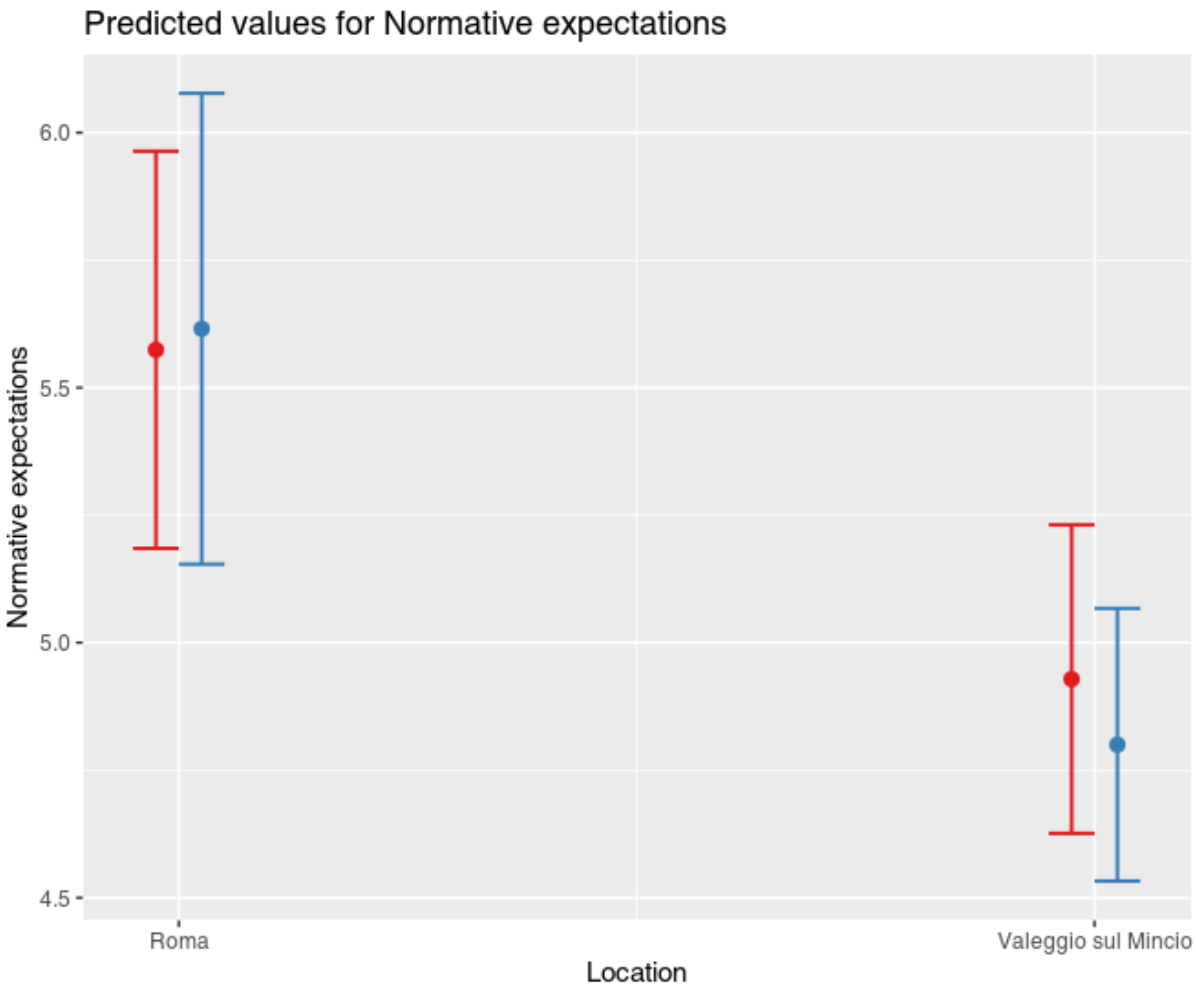

Figure 3. Marginal effects of the GLMs: differences in normative expectations between the two areas. Comparison between respondents who had never had an interaction with chipmunks (left) and those who did (right);

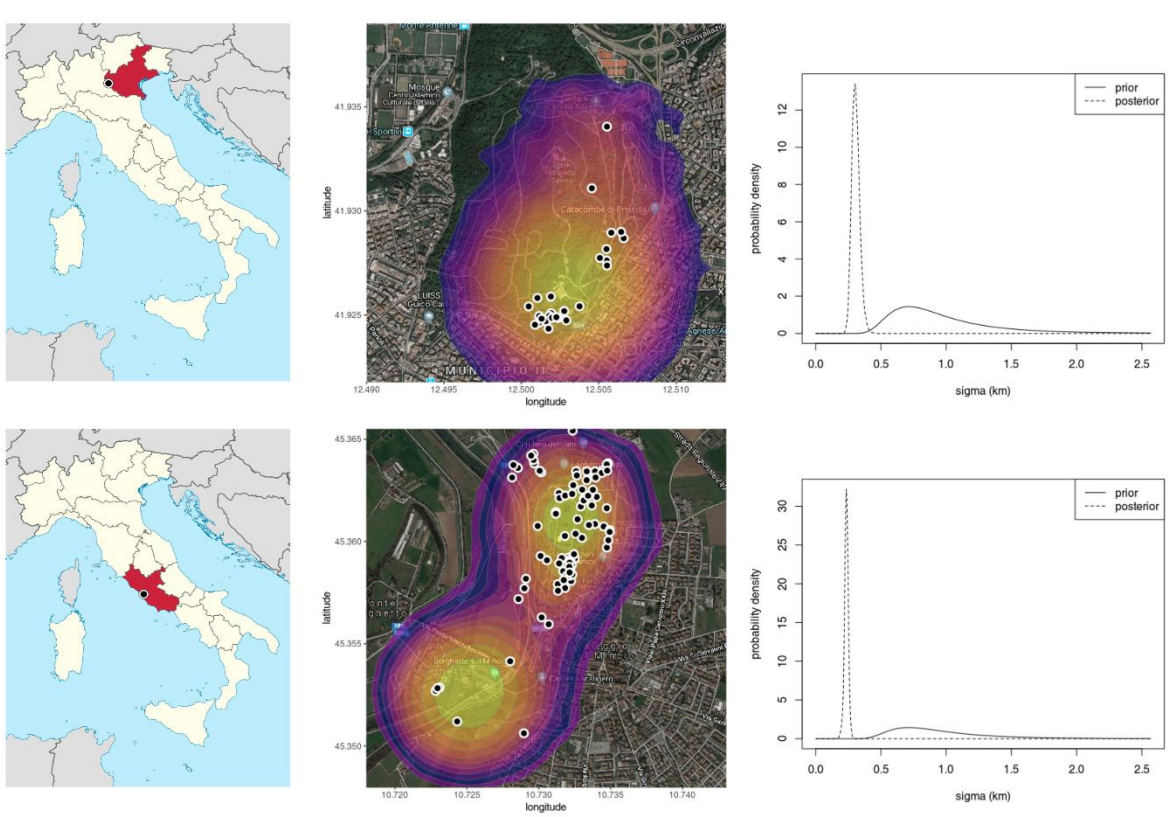

Figure 4. Location of the three study sites (left), heat-map with the posterior probabilities of the origins of observed chipmunks (center, coordinates with EPSG:3857) and posterior probability of the dispersal parameter (right).