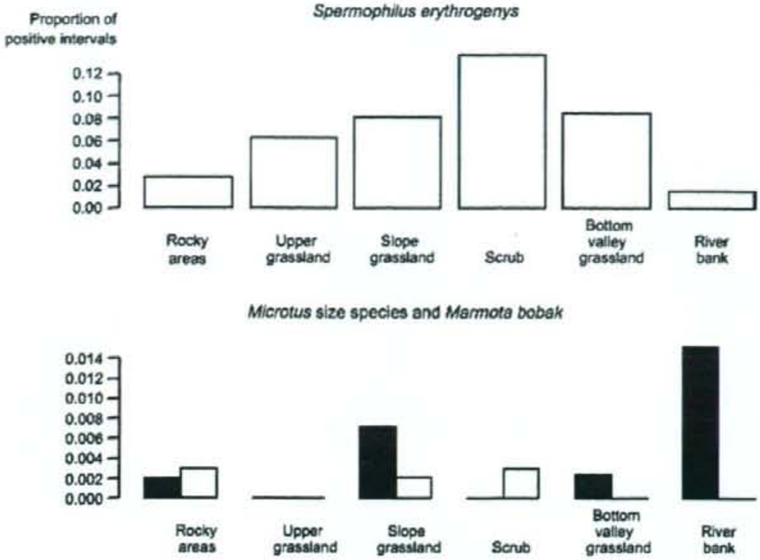

Figure 6 Index distribution of *Spermophilus erythrogenys*, *Microtus* size species (black bars) and *Marmota bobak* (grey bars) along transects in Kokehada.

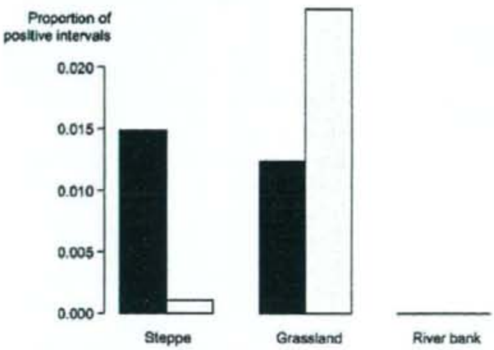

Figure 7 Index distribution of medium size species (*Spermophilus*, *Dipodidae*, etc.) (black bars) and *Microtus* size species (grey bars) along transects in Narenhebuke.

does not take into account possible multi-annual changes of population densities. *Ellobius tancrei* indices were found at frequencies as large as those observed for the subterranean vole species *Arvicola terrestris* during population outbreaks in Europe (Giraudoux et al. 1995, Duhamel et al. 2000). Furthermore, *Microtus obscurus*, a typical grassland species, was found in almost every habitat, except dense forest. Thus, such cyclic species can drastically change assemblage structure over time because populations are limited to optimal habitats at low density and may spill over to any sub-optimal habitat during high density peaks. Delattre et al. (1992), Raoul et al. (2001) and Giraudoux et al. (2008) observed such patterns for *Microtus arvalis* Pallas in Europe, a species similar to *Microtus obscurus* [they are even considered the same species in Wilson and Reeder (2005)]. *Microtus agrestis* is also known to undergo large multi-annual fluctuations of populations in Scotland (Bierman et al. 2006), *Myodes rufocanus* in Hokkaïdo, Japan (Stenseth et al. 1996, Stenseth and Saitoh 1998a,b) and in northeastern China (Xia 1996, Zhang 1996), *Myodes rutilus* in Scandinavia (Haukisalmi et al. 1988), *Microtus oeconomus* in Alaska and northern Siberia (Rausch 1995).

Northern Junggar assemblages

In total, five sites were sampled, although standard trapping could not be carried out everywhere and sampling pressure varied. All sites were situated at a maximum distance of 216 km from each other (Kokehada–Baihaba). In total, five assemblages could be recognised on a regional range: (i) assemblages of cold semi-desert with *Allactaga*, *Stylodipus*, *Meriones*, etc. in Fuhai and Narenhobuke; (ii) assemblages of alpine grassland of two types: (iia) one is a mixed forest landscape, described above at fine grain (Baihaba) with *Ellobius tancrei*, *Microtus obscurus*, *Myodes* sp. etc., (iib): the other with just grassland (Kokehada) with *Spermophilus erythrogenys* (*Marmota bobak* was recorded in the two areas); (iii) assemblages of stream banks and wetlands characterised either by the presence of (iiia) *Microtus oeconomus* (Baihaba, Fuhai) or (iiib) *Microtus gregalis* (Kokehada, Narenhebuke).

However, one can suspect that this list is still incomplete. For instance, other assemblages including *Spermophilus undulatus* Pallas, *Ochotona* sp., *Arvicola terrestris* (reported as *A. amphibius*) have been described in northern Xinjiang (Ma et al. 1987). These authors have also reported *Apodemus sylvaticus*=*uralensis*, *Mus musculus*, *Sicista concolor*=*tianshanica*=*napea* and *Ellobius talpinus*=*tancrei* in the Tarbatagai mountains, a commu-

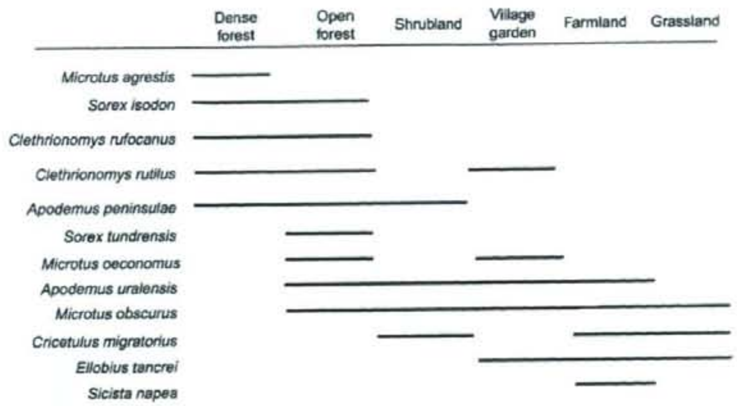

Figure 8 Draft distribution of the main species along the forest-grassland gradient in the Baihaba area.

nity resembling that recorded in Baihaba in the present study.

This highlights the extreme diversity of small mammal assemblages within a regional range in the northern Junggar area. The distribution of these communities and species has never been described at a local scale with standard methods (e.g., linking local habitats and species), nor the transitions between communities on a regional scale. Semi-desert rodent communities have been found in Narenhebuke and Fuhai at very different altitudes and the range of some semi-desert rodents (e.g., *Meriones meridianus*) reached the degraded alpine grasslands of Kokehada pastures where *Marmota bobak* was recorded. *Ellobius tancrei* and *Microtus obscurus* seemed to be the dominant species (in terms of biomass) of the assemblages of the summer pastures of Baihaba in Altai, and *Spermophilus erythrogenys* dominated the assemblage of the Kokehada pastures in the Tarbatagai mountains at the same altitude, where *Marmota bobak* was also present. The origin of such contrasts and diversity is still not clear. Altitudinal gradients from desert to mountain zones are not the only factor that may explain assemblage distribution. Soil conditions which may facilitate or jeopardise digging should also be considered. Precipitation may differ according to aspect and grass production may also be a key factor in small mammal distribution. Overgrazing by sheep, goats and cattle in mountain grassland and the vicinity of the Junggar semi-desert may in part explain the extension of semi-desert species to the Kokehada pastures. Furthermore, the fact that similar habitats, such as grasslands, are dominated by *S. erythrogenys* when others at the same altitude are dominated by *Ellobius talpinus* and *M. obscurus* in the same region is still unexplained.

On a local scale, small mammal assemblages varied at very short distance according to habitat. For instance, in Fuhai, *Microtus oeconomus* was present in wetlands of cultivated areas, within only some hundreds of meters of a typical semi-desert assemblage. This species was also present along small streams in forest and the vicinity of gardens in Baihaba. *Microtus gregalis* was linked to river banks and Alpine cushions close (some metres) to a semi-desert assemblage (Narenhebuke), and to *Spermophilus erythrogenys* populations in mountain grasslands (Kokehada).

Conclusions

Many small mammal communities co-exist in the northern Junggar Basin (China) over a range of 20,000 km^2, and they form a mosaic of assemblages whose composition dramatically varies over space. Considering this complexity, species distribution and assemblage description should be undertaken on at least two scales:

- at a local scale of some square kilometres, the aim would be to standardise observation and describe the relationships between species and habitats at fine grain. Here, the study undertaken in Baihaba was of this type, but due to the short time span of the study it failed to address the issue of multi-annual variations of small mammal populations. However, the time dimension may be essential to understand processes governing the ecological system locally;
- on a regional scale of some ten thousands of square kilometres, the target would be to standardise observations and describe the transitions between communities at a coarse grain and understand the factors responsible for changes in the composition of assemblage mosaics and the species turnover, given the fact that, over this range, similar habitats can harbour different assemblages.

Some years ago this type of study would have be more difficult to undertake due to lack of an easy-to-use spatial reference system. The increasing availability of global positioning system tools (GPS) and satellite data (digital elevation models, multispectral imaging, etc.) should help to guide small mammal studies on a regional scale. They would be essential not only for understanding the basic ecology of small mammals in this area, but also to provide a baseline to understand the effect of environmental variables on small mammal population time-space distribution, to predict where population outbreaks are likely and to estimate the risk of infectious disease transmission from small mammal reservoirs.

Acknowledgements

We would like to acknowledge Professors Yang Wen Guang vice-president of the Xinjiang Medical University, Wang Yun Hai and Wen Hao for their dedicated support to this work, to Drs. Karine Bardonnet and Tamotsu Kanazawa for their help in the field. We are grateful to the two anonymous referees who helped to improve the manuscript. Financial support from the European Union (TS3-CT94-0270), the French-Chinese Programme of Advanced Research (PRA E95-01), the Rotary International through the Rotary Club of Dijon, the Conseil général de Haute-Saône, the French Ministère de la Jeunesse et des sports (Défi Jeune) and the US National Institutes of Health and National Science Foundation (EID TW001565-05) from the Fogarty International Centre are acknowledged.

References

Allen, G.M. 1940. The mammals of China and Mongolia. American Museum of Natural History, New York. 620 pp.

Aubry, J. 1950. Deux piéges pour la capture de petits rongeurs vivants. Mammalia 14: 174–177.

Bierman, S.M., J.P. Fairbairn, S.J. Petty, D.A. Elston, D. Tidhar and X. Lambin. 2006. Changes over time in the spatiotemporal dynamics of cyclic populations of field voles (*Microtus agrestis* L.). Am. Nat. 167: 583–590.

Bjornstad, O., R. Ims and X. Lambin. 1999. Spatial population dynamics: analyzing patterns and processes of population synchrony. Trends Ecol. Evol. 14: 427–432.

Chessel, D., A.B. Dufour and J. Thioulouse. 2004. The ade4 package-I: one-table methods. R News 4: 5–10.

Corbet, G.B. 1978. The mammals of the Palearctic region: a taxonomic review. British Museum (Natural History), Cornell University Press, London. pp. 314.

Delattre, P., P. Giraudoux, J. Baudry, D. Truchetet, P. Musard, M. Toussaint, P. Stahl, M.L. Poule, M. Artois, J.P. Damange and J.P. Quere. 1992. Land use patterns and types of common vole (*Microtus arvalis*) population kinetics. Agric. Ecosyst. Environ. 39: 153–169.

Delattre, P., B. De Sousa, E. Fichet, J.P. Quéré and P. Giraudoux. 1999. Vole outbreaks in a landscape context: evidence from a six year study of *Microtus arvalis*. Landscape Ecol. 14: 401–412.

Duhamel, R., J.P. Quéré, P. Delattre and P. Giraudoux. 2000. Landscape effects on the population dynamics of the fossorial form of the water vole (Arvicola terrestris sherman). Landscape Ecol. 15: 89–98.

Giraudoux, P. 2007. Pgirmess: data analysis in ecology. R Foundation for Statistical Computing, http://www.R-project.org. Accessed 30.08.07.

Giraudoux, P., B. Pradier, P. Delattre, S. Deblay, D. Salvi and R. Defaut. 1995. Estimation of water vole abundance by using surface indices. Acta Theriol. 40: 77–96.

Giraudoux, P., J.P. Quere, P. Delattre, G. Bao, X. Wang, D. Shi, D. Vuitton and P.S. Craig. 1998. Distribution of small mammals along a deforestation gradient in south Gansu, China. Acta Theriol. 43: 349–362.

Giraudoux, P., D. Pleydell, F. Raoul, J.P. Quéré, Q. Wang, Y. Yang, D. Vuitton, J. Qiu, W. Yang and P.S. Craig. 2006. Transmission ecology of *Echinococcus multilocularis*: what are the ranges of parasite stability among various host communities in China? Parasitol. Int. 55: 237–246.

Giraudoux, P., D. Pleydell, F. Raoul, A. Vaniscotte and P.S. Craig. 2008. Why multidisciplinary and multiscale are essential in infectious disease ecology: the *Echinococcus multilocularis* case. Trop. Med. Health 35: 293–299.

Gotelli, N.J. and R.K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4: 379–391.

Gratz, N.G. 1994. Rodents as carrier of disease. In: (A.P. Buckle and R.H. Smith, eds) Rodent pests and their control. CAB International, Wallingford, Oxon. pp. 85–108.

Gromov, I.M. and M.A. Erbajeva. 1995. The mammals of Russia. Russian Academy of Sciences, St. Petersburg. pp. 520.

Halik, M., N. Ohtaishi, A. Abudukadir and E. Hayashida. 1999. Characteristics of mammalian fauna and its distribution in the Kanas National Nature Reserve in Xinjiang Altai, China. In: (M. Cheni and I. Sheydhidin, eds) Modern research in high technology. Japan Silk Road Club, Tokyo. pp. 118–124.

Hansson, L. 2002. Rodent dynamics, population regulation and predation in changeable landscapes: importance for *Echinococcus* transmission. In: (P.S. Craig and Z. Pawlowski, eds) Cestode Zoonoses: echinococcosis and cysticercosis. An emergent and global problem. IOS Press, Amsterdam. pp. 267–285.

Hansson, L. and H. Henttonen. 1988. Rodent dynamics as community processes. Trends Ecol. Evol. 3: 195–200.

Haukisalmi, V., H. Henttonen and F. Tenora. 1988. Population dynamics of common and rare helminths in cyclic vole populations. J. Anim. Ecol. 57: 807–825.

Hoffmann, R.S. 1987. A review of systematics and distribution of Chinese red-toothed shrews (Mammalia, Soricinae). Acta Theriol. Sinica 7: 100–139.

Huitu, O., K. Norrdahl and E. Korpimäki. 2004. Competition, predation and interspecific synchrony in cyclic small mammal communities. Ecography 27: 197–206.

Lidicker, W.Z. 2000. A food web/landscape interaction model for microtine rodent density cycles. Oikos 91: 435–445.

Lu, P. and S. Yan. 1989. Xinjiang forest. People Press, Urumqi, China. pp. 577.

Ma, Y. 1981. The geographical distribution of rodents in northern Xinjiang. Acta Zool. Sinica 27: 180–188.

Ma, Y., F.G. Wang, S.K. Jin and S.H. Li. 1987. Glires (rodents and lagomorphs) of Northern Xinjiang and their zoogeographical distribution. Science Press, Academia Sinica, Beijing. pp. 247.

Michelat, D. and P. Giraudoux. 2006. Synchrony between small mammal population dynamics in marshes and adjacent grassland in a landscape of the Jura plateau, France: a ten year investigation. Acta Theriol. 51: 155–162.

Musser, G.G., E.M. Brothers, M.D. Carleton and R. Hutterer. 1996. Taxonomy and distributional records of oriental and European *Apodemus*, with a review of the *Apodemus-Sylvaemus* problem. Bonner Zool. Beit. 46: 143–190.

Quéré, J.P., F. Raoul, P. Giraudoux and P. Delattre. 2000. An index method applicable at landscape scale to estimate relative population densities of the common vole (*Microtus arvalis*). Rev. Ecol. (Terre Vie) 55: 25–32.

R Development Core Team. 2007. R: a language and environment for statistical computing. R Foundation for Statistical Computing, http://www.R-project.org. Accessed 30.08.07.

Raoul, F., R. Defaut, D. Michelat, M. Montadert, D. Pépin, J.P. Quéré, B. Tissot, P. Delattre and P. Giraudoux. 2001. Landscape effects on the populations dynamics of small mammal communities: a preliminary analysis of prey-resource variations. Rev. Ecol. (Terre Vie) 56: 339–352.

Raoul, F., J.P. Quéré, D. Rieffel, N. Bernard, K. Takahashi, R. Scheifler, A. Ito, Q. Wang, J. Qiu, W. Yang, P.S. Craig and P. Giraudoux. 2006. Distribution of small mammals in a pastoral landscape of the Tibetan plateaus (Western Sichuan, China) and relationship with grazing practices. Mammalia 42: 214–225.

Rausch, R.L. 1995. Life-cycle patterns and geographic distribution of *Echinococcus* species. In: (R.C.A. Thomson and A.J. Lymbery, eds) *Echinococcus* and hydatid disease. CAB International, Wallingford, Oxon. pp. 89–134.

Shenbrot, G.I. and B.R. Krasnov. 2005. An atlas of the geographic distribution of the arvicoline rodents of the world (Rodentia, Muridae: Arvicolinae). Pensoft Publishers, Sophia. pp. 336.

Siegel, S. and N.J.J. Castellan. 1988. Non parametric statistics for the behavioral sciences. McGraw-Hill International Editions, New York. pp. 399.

Stenseth, N.C. and T. Saitoh, eds. 1998a. The population ecology of the vole *Clethrionomys rufocanus*. Japanese Society of Population Ecology, Kyoto. pp. 158.

Stenseth, N.C. and T. Saitoh. 1998b. So, what do we know and what do we need to know about the population ecology of the vole *Clethrionomys rufocanus*? Res. Popul. Ecol. 40: 123–125.

Stenseth, N.C., O.N. Bjornstad and T. Saitoh. 1996. A gradient from stable to cyclic populations of *Clethrionomys rufocanus* in Hokkaido, Japan. Proc. R. Soc. London B 263: 1117–1126.

Wang, S.B. and G.Y. Yang. 1983. Rodent fauna of Xinjiang. Xinjiang People's Publishing House, Urumqi. pp. 223.

Wang, Y.H., M.T. Rogan, D.A. Vuitton, H. Wen, B. Bartholomot, C. Macpherson, P. Zhou, X. Ding, X. Zhang, J. Luo, H. Xiong, Y. Fu, A. McVie, P. Giraudoux, W. Yang and P.S. Craig. 2001. Cystic echinococcosis in semi-nomadic pastoral communities in north-west China. Trans. R. Soc. Trop. Med. Hyg. 95: 153–158.

Wilson, D.E. and D.M. Reeder. 2005. Mammal species of the world. Johns Hopkins University Press, Baltimore, MD. pp. 1207.

Wust-Saucy, A.G. 1998. Polymorphisme génétique et phylogéographie du Campagnol terrestre Arvicola terrestris. Université de Lausanne, Lausanne, Suisse. pp. 118.

Xia, W.P. 1996. Rodent-like pest control and ecological equilibrium. In: (Z.W. Wang and Z.B. Zhang, eds) Theory and practice of rodent pest management. Science Press, Beijing. pp. 2–18.

Zhang, Y.Z. 1997. Distribution of mammalian species in China. China Forestry Publishing House, Beijing. pp. 280.

Zhang, Z.B. 1996. Population fluctuation and regulation of small mammals. In: (Z.W. Wang and Z.B. Zhang, eds) Theory and practice of rodent pest management. Science Press, Beijing. pp. 145–165.

Zhao, G.Z. 1996. Rodent pest control and plant protection. In: (Z.W. Wang and Z.B. Zhang, eds) Theory and practice of rodent pest management. Science Press, Beijing. pp. 19–37.

Zhu, S.K. and A.G. Chen. 1993. The ecology features and detects of *Mus musculus*. Science Press, Beijing. pp. 339.