Hystrix It. J. Mamm (n.s.) 17 (1) (2006): 5-14

THE RECOVERY OF THE OTTER IN THE CEVENNES (FRANCE): A GIS-BASED MODEL

XAVIER JANSSENS[1,2 a], PIERRE DEFOURNY[1], JEAN DE KERMABON[3] PHILIPPE V. BARET[2]

[1] Department of Environmental Sciences and Land Use Planning - Geomatics - Université catholique de Louvain, Croix du Sud, 2, bte 16, B-1348, Belgium
[2] Biodiversity Research Centre and Unit of Genetics - Université catholique de Louvain, Croix du Sud, 2, bte 14, B-1348, Belgium
[3] Service Scientifique et du Plan, Parc national des Cévennes, 48400 Florac, France
[a] Fax: +32 10 47 88 98; E-mail: defaurny@enge.ucl.ac.be

ABSTRACT - The Eurasian otter (*Lutra lutra*) is an elusive semi-aquatic mammal. Its absence is difficult to prove and censuses can be biased by false-negative observations. A model is proposed to correct this bias by predicting occurrence probabilities where observations are negative. In case of otter signs observation in one place, the probability to find the species in another place is assumed to decrease if the distance between both places increases. This approach is tested on a 15-years otter survey dataset (4,592 data) from the National Cevennes Park (3,200 km^2, France). Four methods are compared, using Euclidian distances, decisional distances, cost-weighted distances and basin analyses. The validation is performed on 61 stretches that were prospected each year in the Cevennes. For these stretches, if observations were negative during a year *A* but positive during the previous and the following year, observations were assumed to be false-negative during this year *A* and compared to predictions given each modelling method. The modelling proves the interest of describing the landscape and defining spatially weighted distances from places where otter is present to predict the species occurrence where its search is unsuccessful. The results highlight that, despite the high mobility of the otter, its distribution is limited by some watershed limits. Hydrographical basins represent a relevant spatial unit to predict the otter occurrence and to analyse its recovery.

Key words: *Lutra lutra,* modelling, false-negative observatons, dispersal path, France

RIASSUNTO - ***L'espansione della Lontra nelle Cevennes (Francia): un modello predittivo basato sul GIS***. La Lontra (*Lutra lutra*) è un mammifero semi-acquatico dal comportamento elusivo e il mancato ritrovamento di segni di presenza non implica necessariamente l'assenza del mustelide dall'area in esame. Viene proposto un modello per stimare la probabilità di presenza della specie quando le osservazioni diano esito negativo, assumendo che, dati dei segni di presenza in un determinato tratto investigato, la probabilità di trovarne di ulteriori in un secondo tratto sia inversamente proporzionale alla distanza intercorrente. L'ipotesi è stata testata utilizzando il dataset (4592 dati) del censimento condotto nel Parco Nazionale delle Cevennes (3200 km^2, Francia) su un periodo di 15 anni.
Sono stati comparati quattro diversi metodi, utilizzando distanze Euclidee, distanze decisionali, costo-distanze e analisi di bacino, e considerando 61 tratti di corsi d'acqua perlustrati annualmente. Per ogni tratto, se in un anno *A* le ricerche davano esito negativo ma negli

anni immediatamente precedente e successivo le osservazioni risultavano positive, i risultati dell'anno *A* venivano considerati falsi-negativi e confrontati con gli esiti di ciascun metodo predittivo. Le simulazioni evidenziano come la morfologia del territorio interposto tra i siti di campionamento positivi e quelli negativi abbia un ruolo importante nel determinare la probabilità di presenza della specie dove le ricerche sono risultate infruttuose. Malgrado l'elevata mobilità della lontra, la sua distribuzione può essere limitata da alcuni spartiacque e i limiti dei bacini idrografici rappresentano un fattore spaziale rilevante per prevedere la distribuzione della specie e analizzarne le possibilità di recupero.

Parole chiave: *Lutra lutra*, modelli, falsi-negativi, vie di dispersione, Francia

INTRODUCTION

Eurasian otters (*Lutra lutra*) are progressively recovering in Europe (Chanin 2003. Reuther 2004; Rosoux and Green 2004). They are used to disperse long distances by streams, i.e. several tens kilometres a night, but they move by land as well, sometimes far from water (Erlinge 1967; Green *et al.*, 1984; Kruuk 1995; Vaisfeld 1996; Ruiz-Olmo *et al.*, 2001; Chanin 2003; White *et al.*, 2003). Some authors assume they use the easiest passes through the hills (Harris 1968; Saavedra 2002). Habitat features that impede otter movements and limit its expansion would be high mountains (above 2000 m), sea, large towns, hyper-pollution (along a stretch of at least 50 km), hydroelectric dams, and important reduction of the river flow (Bouchardy 1986; Ruiz-Olmo *et al.*, 1991; Michelot and Bendelé 1995; Saavedra 2002). Otter costs of moving consequently seem to vary across the landscape, but dispersal across watershed limits stays badly known (Harris 1968; Saavedra 2002).

Most Eurasian otters cannot be observed and counted directly (Kruuk 1995; Ruiz-Olmo *et al.*, 2001). In such context, the survey of their faeces, called spraints, is an appropriate method to study the distribution of their populations, and a broad indicator of their activity patterns and habitat preferences (Mason and Macdonald 1986; Orebda abd Grabadi 1996; Hutchings and White 2000; Reuther *et al.*, 2000). But this indirect census technique is a source of several biases. The absence of spraints does not necessarily mean the absence of otters. 'False negatives' can be a consequence of the inability of surveyors to locate otter signs or can be due to possible otter non-sprainting behaviour (Ruiz-Olmo *et al.*, 2001). Spraint persistence varies between habitat and climate. Spraint density depends on individual behaviour, seasons, food abundance, disturbance or density of animals (Erlinge 1967; Erlinge 1968; Kruuk 1995; Sutherland 1996; Guisan and Zimmermann 2000; Scott *et al.*, 2002; Chanin 2003; Elmeros and Bussenius 2003).

The objective of the present work is to correct the potential false-negative observations that occur in an otter survey. Predictions will first be performed at the stretch level, next, at the basin level. Such method would allow us to analyse and interpret a 15 years-survey

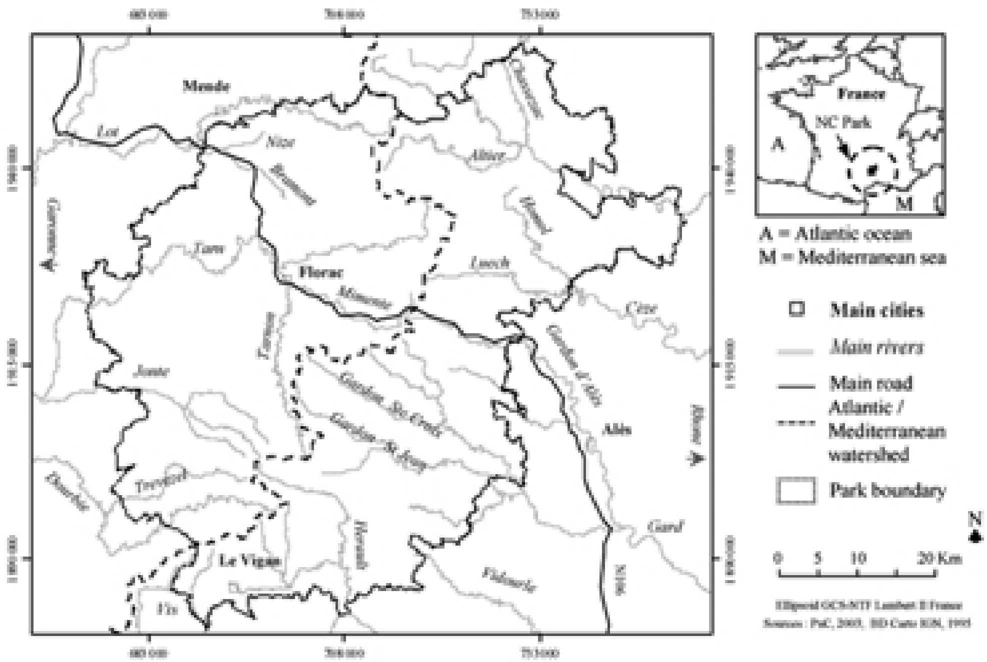

Figure 1 - The National Cevennes Park: location and hydrography.

of otters in the Cevennes, at the front of the recolonisation of the Mediterranean catchment area from the Atlantic one, in France (Fonderflick *et al.*, 1995; Defontaines 1999; Destre *et al.*, 2000).

METHODS

1. Field survey

A yearly otter survey was performed from 1991 to 2005 by seventy-nine agents and/or naturalists in the mid-mountainous landscape of National Cevennes Park (Fig. 1). Agents or naturalists were assumed to be reliable in searching otter signs. The survey consisted in a search of the spraints along 356 stretches of 300 m riverbanks on one side. The stretches were dependent on accessibility and selected so that most of the permanent streams, i.e. about 1000 km, could be prospected throughout the Park. They were about 5 to 10 kilometres away from each other. The survey was mainly performed during winter (68%) because the vegetation wintering made the researches easier and because sprainting activity was higher than during other seasons, as observed in northern and central Europe (Mason and Macdonald 1986; Macdonald and Mason 1987; Kruuk 1995). Researches were delayed in case of floods. Despite rigorous and enthusiastic fieldwork, the surveys were not perfectly systematic. Lack of patrol effort during some years along a lot of stretches was evident. Lack of signs observations in areas where otters should be present was frequent as well.

2. Modelling methods to correct false-negatives at the stretch level

We tested the appropriateness of different modelling assumptions in predicting otter occurrence along stretches where the observation was negative. If the presence of an otter spraint was observed along a stretch, the probability *P* that the species occurs along another stretch was assumed to decrease as the distance *D* between both stretches increases. A Gauss distribution ($P=exp[-D^2/2s^2]$) was considered to model this relation. The variance of the distribution *s* was fixed to 15 in order to obtain a probability of otter occurrence lower than 0.01 in case of distance longer than 50 km, i.e. a maximal home range size (e.g. Chanin 2003). Probabilities of occurrence were calculated from all positive otter sign observations in the whole study area as the union of all probabilities that the species occurs given each distance. ArcGis 8.3 geographical information system (GIS) and Matlab 6 software were used to implement otter-dedicated algorithms.

Three kinds of distance were compared (Janssens X. *et al.*, unpublished data): (1) Euclidian distance, assuming that the landscape doesn't affect otter movements; (2) decisional distance, based on the hypothesis that otter occurrence depends on random individual decisions when crossing confluences (Le Boulengé *et al.*, 1996); (3) cost-weighted distance, which supposes a cost of moving increasing with the slopes and the absence of water. High mountains, pollution or large urbanized areas, which are not present in the Cevennes, were not considered in these models.

The validation was performed on 61 stretches that were prospected each year in the Cevennes. For these stretches, if observations were negative during a year *A* but positive during the previous and the following year, observations were assumed to be false-negative during this year *A*. This supposed the presence of resident otters occupying their home range for extended periods (Broyer and Erome 1982; Chanin 2003). If observations were negative during a year *A* and negative as well during the previous and/or the following year, observations were assumed to be true-negative during this year *A*. Observations assumed to be false- or true-negative were compared to predictions given each modelling method. A prediction was defined as an occurrence with a probability *P* higher or equals to 0.5. Error rates were estimated for each modelling by the proportion of predicted absence in case of observation assumed to be false-negative and predicted presence in case of observation assumed to be true-negative.

3. Prediction of otter occurrence at the basin level

After working at the stretch level, we analysed the data at the scale of basins, i.e. hydrographical catchment areas occupied by 25 to 100 km of permanent rivers (mean = 60 km, SD=25, N=19). Basins encompassed from 1 to 42 stretches (mean number = 12, SD=11). For each basin, we predicted otter occurrence if at least two observations were positive for otter spraint. Given the recolonisation context, if several observations were positive in a basin during a year and missing for this same basin the year after, otter was assumed to be present in this basin during both years. If observations were missing in a basin one years *A* and if several observations were only negative during several years before and after this year *A*, otter was assumed to be absent from this basin during the whole time interval.

RESULTS

1. Actual observations

A total of 4,592 visits were performed during 15 years along 82 to 238 stretches each year (mean = 129, SD=51). Spraints were first observed in the Lot and Tarn basins, i.e. in the Atlantic basin, around 1991 (Fig. 2, a). A recovery movement was observed along a NW-SE axis (Fig. 2, d, g, h), but poten-

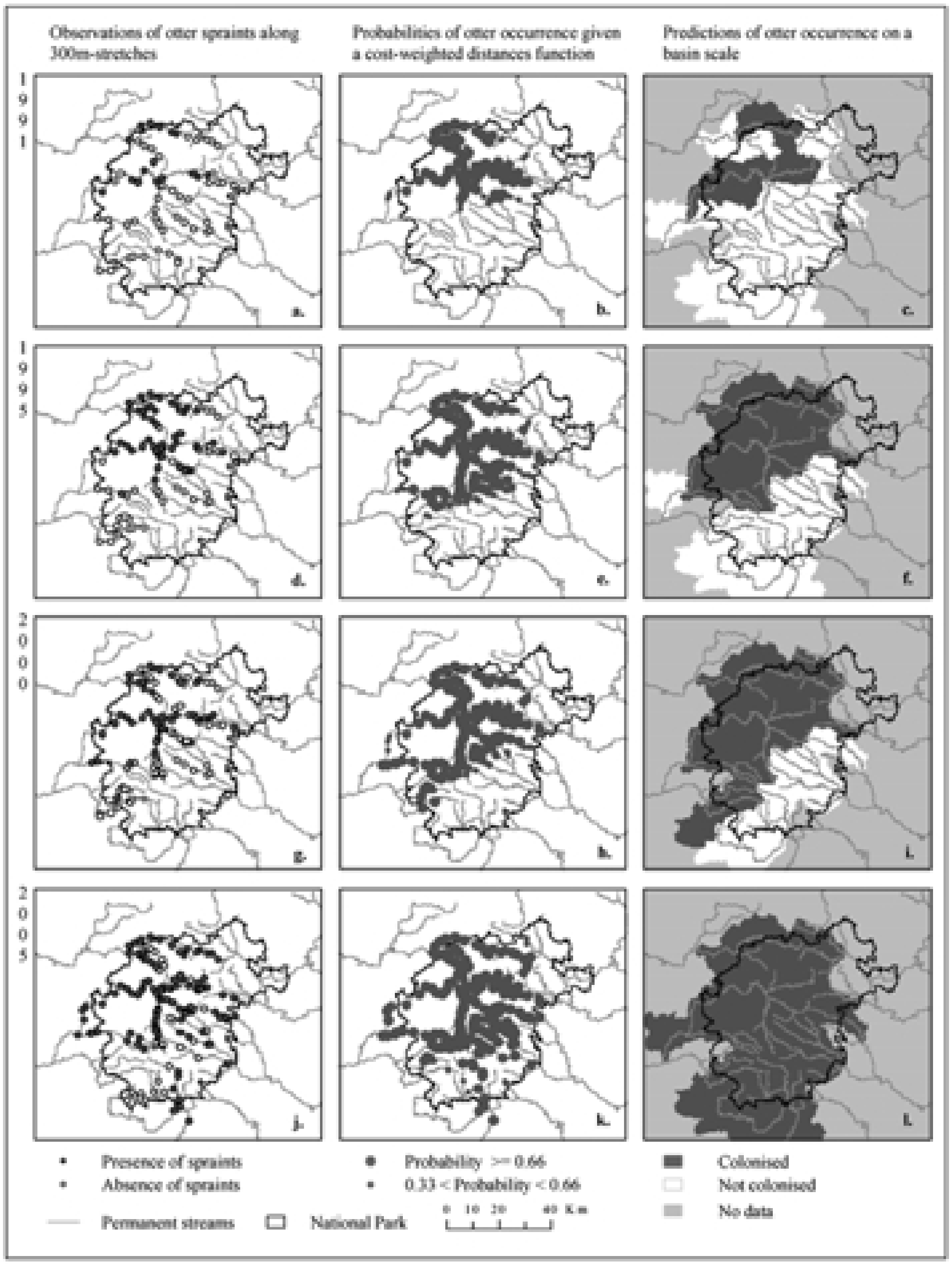

Figure 2 - Otter recovery in the Cevennes from 1991 to 2005. Comparisons between observations (a, d, g, j), results from one method of prediction at the stretch level (b, e, h, k), and results from prediction at the basin level (c, f, i, l).

tial false-negatives and the lack of visit along some rivers some years prevent us from knowing the date of first otter occurrence in each river. A lot of negative observations that are probably false, given positive observations along the same stretches during previous and following year, occurred upstream along the rivers. The observation of spraints along each main stream of the studied area in 2005 proves that habitat is favorable for otters.

2. Predictions at the stretch level

Among the three modelling methods we compared (Janssens H. *et al.*, unpublished data), the use of cost-weighted distances yields the lowest error rate, i.e. 33%. Results from this method are consequently illustrated in Fig. 2 (b, e, h, k). Probabilities of otter occurrence were estimated for all survey stretches in case of negative and missing data. Cost-weighted distance function is in accordance with the observations, except along some eastern rivers where it predicts otter occurrence several years before the first sign observation (e.g. Altier and Gardons rivers; Fig. 2 e). The use of Euclidian distances predicts otter presence everywhere in the Cevennes Park from 1991, which was not observed at all by means of spraints. Its error rate is 56%. The use of decisional distances predicts occurrence at long swimming distances in basins with few confluences, e.g. in gorges, but it doesn't correct observations assumed to be false-negative in small spited tributaries. Its error rate is 43%.

3. Predictions at the basin level

On a basin scale, otter colonisation process can be mapped without ambiguity (Fig. 2, c, f, i, l). The absence of otters in basins was concluded after 7 to 74 negative observations, which probabilistically reduces the risk of a false prediction of otter absence. First observations in the Mediterranean basin were performed along the Luech and Altier rivers, in 1992 and 1994 respectively, while otter occurred along the Tarnon and Mimente rivers from 1992 and along the Jonte river from 1995 (Fig. 2, f). The species recovered the Dourbie river from 1997 to 1999 (Fig. 2, i) and the Herault and Gardons basins in 2002 and 2005 respectively (Fig. 2, l).

DISCUSSION

As performed in the Cevennes, an otter survey along stretches of 300 m is inadequate to conclude otter absence. Mason and Macdonald (1991) observed that only 80% of stretches where otter is present are found positive with such a survey distance.

None of our three methods at the stretch level do perfectly correct false negatives in our data. Each of them overestimate otter occurrence. Their validation is incomplete with non-systematic time series and they need complex GIS algorithms and subjective parameters adjustments. Predicting otter occurrence given Euclidian distance from positive stretches is incorrect because individuals travel preferentially in rivers, which meander (Saavedra 2002; Williams *et al.*, 2002). The use of decisional distance is inappropriate for the crossing of watershed limits and it is probably too restrictive for the otter that forages several tributaries of a basin in a few days (Rosoux and Green 2004). Our cost-weighted distance function highlights the part played by not too steep watershed limits in otter dispersal, but tends to overestimate the crossing of some limits (e.g. Tarnon/Gardons, Fig. 2, e).

Basins of several tens kilometres long seem to be more appropriate spatial unit to analyse otter occurrence and recovery from non-systematic surveys. Individual movements are not confined to short stretches of rivers and predictions on a basin scale reflect more realistically the dispersal and settlement process (Ruiz-Olmo *et al*., 1991; Ruiz-Olmo *et al.*, 2001). Otters should have easily crossed the watershed limits between the Tarn and Luech rivers and between Lot and Altier rivers, shaped by gently sloping areas (Defontaines 1999). They dispersed by swimming from the Tarn to the Tarnon Rivers and followed the Tarn to progressively reach the rivers Jonte in 1995 and Dourbie in 1997. Dispersers next recolonised the Herault basin from 2002 and the Gardons between 2004 and 2005 (Fig. 2, c, f, i, l; Fig. 3).

Which path did the otters follow to reach the Mediterranean basins in the South of the park, separated from the northern basins by steep sloping watershed limits? A unique hypothetical process is suggested for the recovery of the Herault basins: the crossing of the watershed limit from the Dourbie basins (Fig. 3). Following small tributaries, an otter would cover less than 500 m of land between these both basins. We propose three hypothetical paths of colonisation of the Gardons: either from the North, i.e. through the Tarnon or Mimente watershed limits (Fig. 3, path *a*), either from the Luech River by swimming via the Rhone River (Fig. 3, path *b*), either from the Southwest, i.e. through the Herault watershed limits (Fig. 3, path *c*). To assess all paths, we compare the distances they suppose that otters would have covered to reach each basin (km) with the time interval it passed before the basins were actually colonised (years). Distances are estimated from the centroid of the basins of origin, i.e. the upper Tarn basin, to the centroid of 8 colonised basins. The time interval began in 1991, when the first otter survey in the Cevennes was performed.

Comparisons (Fig. 3) highlight that the distances covered on our hypothetical paths, including paths *a*, *b* or *c*, explain respectively 56, 89 or 99 % of the variance of the observed colonisation time. Since the beginning of otter survey in Cevennes, it passed 14 years before otters were observed in Gardons basins. Path *a* suggests the crossing of only one narrow watershed limit, which doesn’t explain such long time interval. Path *b* proposes that otters crossed a gently sloping watershed limit and next swam downstream and finally upstream along a curve of more than 250 km long. This should be easy for otter individuals, but researches made by naturalists (pers. comm.) along this potential long swimming path didn’t result in the observation of otter signs. Path *c* finally assumes that otters crossed two sharp sloping watershed limits. Despite this

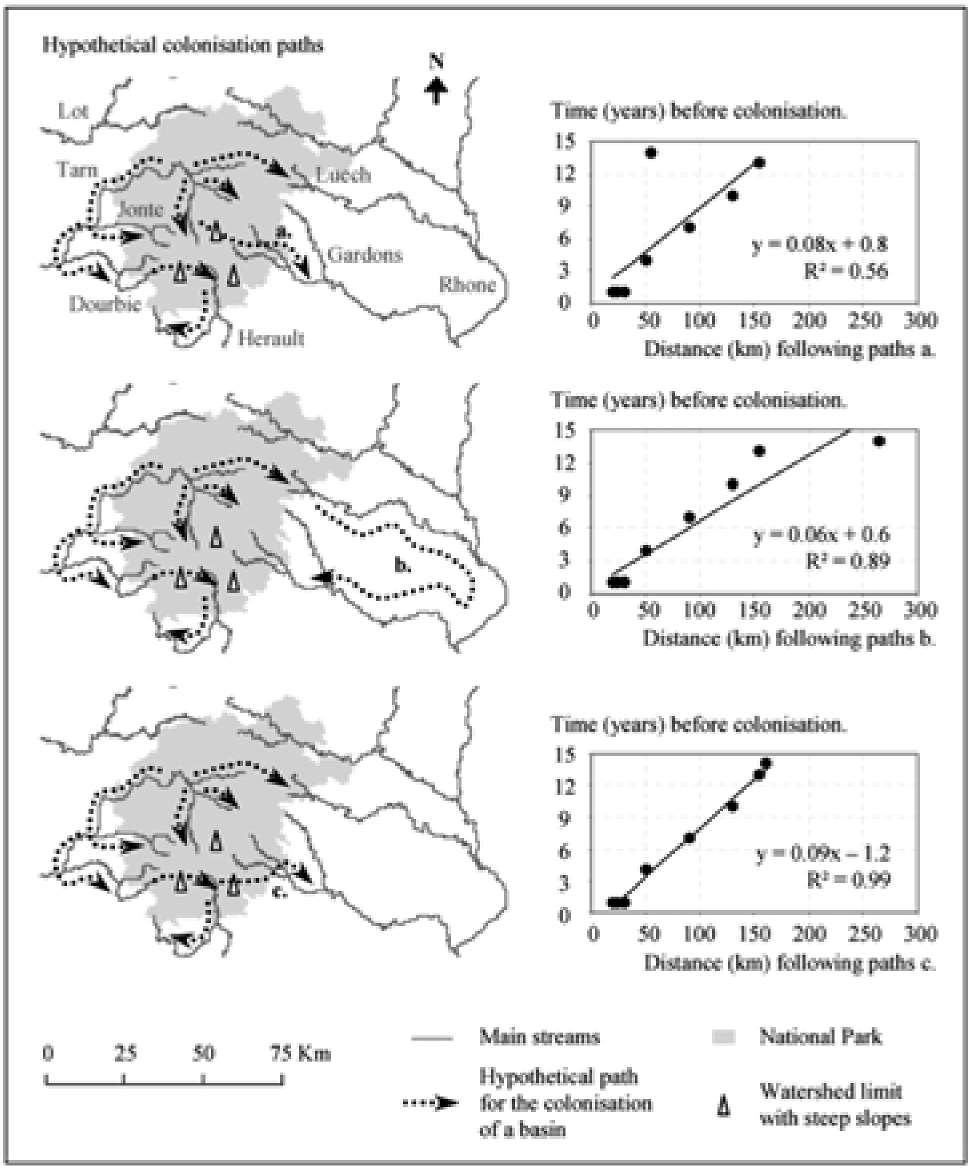

Figure 3 - Left: Hypothetical colonisation paths, including variable paths (a, b and c) towards Gardons basin. Right: Comparison between the distance that otters would have covered to reach basins following each path (km) and the time before basins were actually colonised (years).

hypothesis seems less probable for a water-linked species like otter, its rate of recovery of about 11 km a year is comparable to the otter recolonisation in other regions, e.g. 10 km a year in the North of the Massif Central (Bouchardy 1986; Rosoux *et al.*, 1999) or in Denmark (Christensen H., unpublished data). Further studies, e.g. genetic ones, could validate this last hypothesis.

In conclusion, watershed limits are landscape features that impede otter movements and dispersal. The 'cost of moving' they induce is complex to model and validate, especially with incomplete and biased survey datasets. In such context, the prediction of otter occurrence on the scale of basins occupied by 25-100 km of permanent rivers can bring more relevant information to analyse its distribution than on a more local scale.

ACKNOWLEDGMENTS

We gratefully acknowledge the National Cevennes Park agents, P. Baffie (Fisheries Council, CSP), the ALEPE (Association Lozérienne pour l'Etude et la Protection de l'Environnement), the CISM (Institut de Calcul Intensif et de Stockage de Masse) and Eric Le Boulengé (Ecology and Biogeography Unit) of the UCL (Université Catholique de Louvain). The National Fund for Scientific Research (Belgium) funded this work through a 'research fellow' grant (mandat d'aspirant FNRS) to X.J.

REFERENCES

Bouchardy C. 1986. La loutre. Sang de la Terre, Mondeville , France, 174 pp.

Broyer J. and Erome G. 1982. Eléments d'écologie de la loutre (*Lutra lutra* L.): Premières données bibliographiques. *Bièvre*, 4(1): 33-58**.**

Chanin P.R.F. 2003. Ecology of the European Otter. Conserving Natura 2000 Rivers Ecology Series No. 10. English Nature, Peterborough, 67 pp.

Defontaines P. 1999. Répartition de la loutre - *Lutra lutra* L.- dans le sud-est du Massif central. *Bièvre*, 16: 13-26.

Destre R., d'Andurain P., Fonderflick J. and Parayre C. 2000. Faune sauvage de Lozère. Les Vertébrés. Association Lozérienne pour l'Etude et de Protection de l'Environnement, Balsiège, France, 256 pp.

Elmeros M. and Bussenius N. 2003. Influence of selection of bank side on the standard method for otter surveys. *IUCN Otter Specialist Group Bulletin*, 19: 67-74.

Erlinge S. 1967. Home range of the otter *Lutra lutra* L. *Oikos*, 18: 186-209.

Erlinge S. 1968. Territoriality of the otter *Lutra lutra* L. *Oikos*, 19: 81-98.

Fonderflick J., de Kermabon J., Libois R., Baffie P. and Tournebize T., 1995. Evolution récente du statut de la loutre dans le Parc National des Cévennes. *Cahier d'Ethologie*, 15(2-3-4): 233-238.

Green J., Green R. and Jefferies D.J. 1984. A radio-tracking survey of otters *Lutra lutra* on Perthshire river system. *Lutra*, 27: 85-145.

Guisan A. and Zimmermann N. E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling*, 135: 147-186.

Harris C.J. 1968. Otters. A study of the Recent Lutrinae. Weidenfeld and Nicolson, London, 397 pp.

Hutchings M.R. and White P.C.L. 2000. Mustelid scent-marking in managed ecosystems: implications for population management. *Mammal Review*, 30(3-4): 157-169.

Kruuk H. 1995. Wild Otters. Predation and Populations. Oxford University Press, Oxford, 290 pp.

Le Boulengé E., Legendre P., delaCourt C., Le Boulengé-Nguyen P. and Languy

M. 1996. Microgeographic morphological differentiation in muskrats. *Journal of Mammalogy*, 77(3): 684-701.

Macdonald S.M. and Mason C.F. 1987. Seasonal marking in an otter population. *Acta Theriologica*, 32: 449-469.

Mason C. F. and Macdonald S. M., 1986. Otters ecology and conservation. Cambridge University Press, Cambridge, 235 pp.

Mason C. F. and Macdonald S. M. 1991. Assessment of otter (*Lutra lutra*) survey methods using spraints - Proceedings V International Otter Colloquium. *Habitat*, 6: 167-169.

Michelot J.L. and Bendelé R. 1995. Statut de la loutre dans le bassin du Rhône et le département de l'Ardèche. *Cahier d'Ethologie*, 15(2-3-4): 223-232.

Prenda J. and Granado C.A. 1996. The relative influence of riparian habitat structure and fish availability on otter *Lutra lutra* L - sprainting activity in a small Mediterranean catchment. *Biological Conservation*, 76(1): 9-15.

Reuther C. 2004. On the way towards an Otter Habitat Network Europe (OHNE). Method and Results of an Area Assessment on the European and the German Level. *Habitat*, 15. pages?

Reuther C., Dolch D., Green R., Jahrl J., Jefferies D.J., Krekemeyer A., Kucerova M., Madsen A.B., Romanowski J., Roche K., Ruiz-Olmo J., Teubner J. and Trindade A. 2000. Surveying and monitoring distribution and population trends of the Eurasian otter (*Lutra lutra*). Guidelines and evaluation of the Standard Method for surveys as recommended by the European section of the IUCN/SSC. Otter Specialist Group. *Habitat*, 12: 1-148.

Rosoux R. and Green J. 2004. La loutre. Paris, 96 pp.

Rosoux R., Libois R. and de Bellefroid M. 1999. Rapport d'expertise: Programme de conservation de la loutre d'Europe dans la Réserve de Biosphère de Trebon (République Tchèque). Conseil de l'Europe, Strasbourg.

Ruiz-Olmo J., Jimenez J. and Lacomba I. 1991. Length of hydrographical basins and population viability of the otter in rivers in Eastern Spain. *Habitat*, 6: 255-258.

Ruiz-Olmo J., Saavedra D. and Jimenez J. 2001. Testing the surveys and visual and track censuses of Eurasian otters (*Lutra lutra*). *Journal of Zoology*, London, 253: 359-369.

Saavedra D. 2002. PhD thesis: Reintroduction of the Eurasian otter (*Lutra lutra*) in Muga and Fluvia basins (North-Eastern Spain): viability, development, monitoring and trends of the new population. Departament de Ciències Ambientals, Universitat de Girona, Spain, 217 pp.

Scott M.J., Heglund P.J. and Morrison M.L. 2002. Predicting species occurrences. Issues of accuracy and scale. Island Press, Washington, 868 pp.

Sutherland W.J. 1996. Ecological census techniques - A handbook. Cambridge University Press, Cambridge, 352 pp.

Vaisfeld M.A. 1996. The river otter in the European North of Russia. Council of Europe Publishing, Leeuwarden, 114 pp.

White P.C.L., McClean C.J. and Woodroffe G.L. 2003. Factors affecting the success of an otter (*Lutra lutra*) reinforcement programme, as identified by post-translocation monitoring. *Biological Conservation*, 112(3): 363-371.

Williams T.M., Ben David M., Noren S., Rutishauer M., Macdonald K. and Heyward W. 2002. Running energetics of the North American river otter: do short legs necessarily reduce efficiency on land? *Comparative Biochemistry and Physiology* A, 133: 203-212.