DISTRIBUTION OF *LUCANUS CERVUS* (COLEOPTERA: LUCANIDAE) IN BELGIUM: SURVIVING IN A CHANGING LANDSCAPE

A. THOMAES[1], T. KERVYN[2], O. BECK[3] & R. CAMMAERTS[4]

RÉSUMÉ. — *Distribution de* Lucanus cervus (Coleoptera, Lucanidae) *en Belgique: survivre dans un paysage changeant.* — Le présent article décrit les résultats mettant à jour la distribution passée et actuelle du Lucane cerf-volant en Belgique. Sur la base de ces données une modélisation de la distribution a été effectuée en prenant en compte l'usage des terres et les paramètres climatiques et topographiques afin d'identifier les zones correspondant aux exigences de l'espèce. Les besoins écologiques et en habitat de l'espèce en Belgique sont décrits et discutés.
Mots-clés: Modélisation, régression logistique, écologie, forêt, thermophile

SUMMARY. — This paper describes results updating the former and present distribution of the stag beetle in Belgium. Based on these data, modelling of the distribution was conducted through land use, climatic and topographic parameters in order to identify areas corresponding to the requirements of the species. The habitat and ecological needs of the species in Belgium are described and discussed.
Keywords: Modelling, logistic regression, ecology, forest, thermophile

---

The stag beetle or *Lucanus cervus* is often cited as an indicator of ancient oak forest with ancient trees and large dimensions of dead wood (Tochtermann, 1992). The larva lives on underground woody debris, mostly of oak.

The species got renewed attention because it is listed as an appendix II-species of the Habitat Directive. The stag beetle is selected, amongst other large, easily recognized invertebrate species as flagship species for saproxylic insect conservation (Fig. 1). Protecting flagship species helps a lot of other species or an entire ecosystem. Protection by the Habitat Directive means that all countries of the EU have to start monitoring the distribution and population size of these species. Further active protection is required for species from the appendix II (Luce, 1996).

[1] Research Institute for Nature and Forest (INBO), Gaverstraat 4. B-9500 Geraardsbergen, Belgium. E-mail: arno.thomaes@inbo.be
[2] Direction Générale des Ressources Naturelles et de l'Environnement, Avenue Prince de Liège 15. B-5100 Jambes, Belgium. E-mail: T.Kervyn@mrw.wallonie
[3] Brussels Institute for Management of the Environment (BIM-IBGE), Gulledelle 100. B-1200 Bruxelles, Belgium. E-mail: obe@ibgebim.be
[4] Service de Systématique et d'Ecologie Animales, ULB, F.D. Roosevelt 50, CP 160/13. B-1050 Bruxelles, Belgium. E-mail: rcammaer@ulb.ac.be

Figure 1. — The male stag beetle (left, Photo Arno Thomaes) is more easily recognized than the female (right, Photo Olivier Beck) by the general public.

MATERIAL AND METHODS

The methods used to collect records of stag beetle in Belgium are: (1) literature and collections; (2) advertisements and flyers and (3) field work. In a first phase, historic reports in literature were gathered and beetles in the collections of the Royal Belgian Institute of Natural Sciences (KBIN-IRSNB) and the zoological museums of the Universities of Liège, Ghent and Brussels, as well as in different private collections were looked up.

Secondly, enquiries were published in different journals concerned with nature conservation, amateur entomology and local newspapers in towns where historic localities were known. Flyers were posted to houses nearby historic localities. This kind of public survey is also done in other countries (Great Britain – Smith, 2003, the Netherlands – Smit, 2004) and proves to be a good method for stag beetle. All responses were checked. Many replies proved to be other species, often Rhinoceros beetle (*Oryctes nasicornis*). Finally some field work was conducted, to check some doubtful responses and to find out where the exact breeding site was.

To build a distribution model for the stag beetle in Belgium the actual (1974-2005) and detailed distribution data based on 5*5 km UTM squares was used. Biogeographical regions without stag beetle observations were excluded from the dataset. For the absence data we used the UTM squares that were in biogeographical regions with stag beetle and at least 10 km from any known place with stag beetle (actual or historic). The absence-presence data set was divided into a training set (70%) and a validation set (30%), and this was repeated 10 times. Tree types of 'environmental' data were collected: (1) land use data were derived from the Belgian Corine Land Cover vector map (CEC, 1994), (2) topographic variables were derived from a digital elevation model for Belgium (20 m resolution, National Geographical Institute) and (3) climate point data were made available by the Royal Meteorological Institute of Belgium for the period 1996-2001 (see Maes *et al.*, 2003 for a detailed description of the environmental data).

First a statistical model was tried with stepwise forward logistic regression to the 10 training sets. The variable that accounted for the largest reduction in deviance was incorporated into the model. Next, all the remaining variables were tested until inclusion was no longer significant. At each step, all previously entered variables were tested for their significance and removed from the model if they were no longer significant. Model efficiency was tested by plotting receiver-operating curves (ROC, Fielding & Bell, 1997). For each model, the area under the curve (AUC) was calculated for the evaluation set within the area and for the complete data set of the other areas. AUC values express model accuracy independent of the threshold used (Fielding & Bell, 1997). Values between 0.5 – 0.7 are considered poor, between 0.7-0.8 acceptable, between 0.8 – 0.9 excellent and > 0.9 outstanding (Hosmer & Lemeshow, 2000).

In the ecological model the used variables were decided taking the ecological behaviour of the beetle into account. Therefore, proportion of urban area, proportion of mixed and deciduous forest, range in altitude (difference between highest and lowest point in the grid cell) and mean temperature were put in this model.

RESULTS

Past and present distribution

A total of 364 stag beetle observations in Belgium were collected. The investigation resulted in a quite complete distribution map of the past and current distribution of the stag beetle (Fig. 2).

The oldest data were mostly obtained from literature and collections and were often not very accurate about the location. In most cases only the village is known. The data from 1974-1990 mostly concern reported observations and collections. The actual data 1990-2005 consist in fieldwork and reported observations.

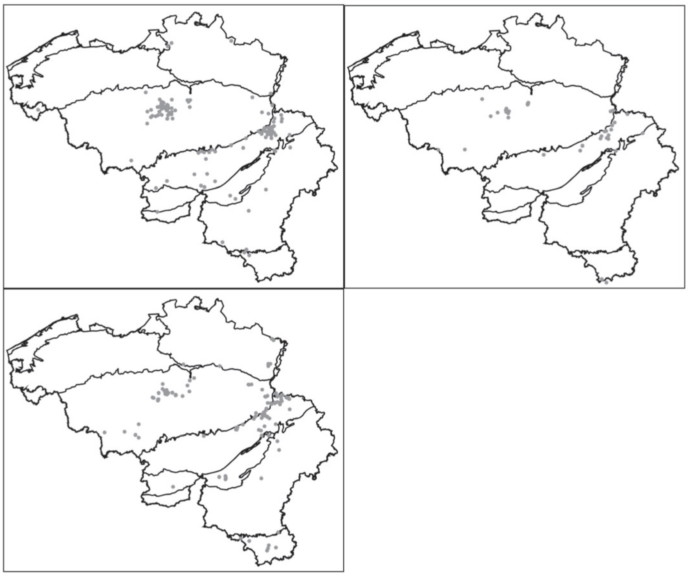

Figure 2. — Distribution of Stag beetle in Belgium. Top left: 1872 to 1973; top right: 1974 to 1990 and bottom left: 1991 to 2005.

For some of the 'historic' stag beetle populations there were no actual records. Other populations appeared to be new, but were probably formerly unrecorded localities. For three biogeographic regions, the dunes, the polders and sandloam plain, in the west of Belgium, there were no records, presumably because of the lack of suitable habitat. These ecoregions, with clay rich soils, are the lowest and most flat part of Belgium.

The stag beetle distribution can further be described by a concentration of records near major towns like Brussels and Liège and a lot of records near river valleys in the low mountainous region (Fig. 2).

A lot of sites were located outside the forest or at the forest edge. Some sites were located at old orchards which have a lot of dead and half-dead standard trees (mainly *Malus sylvestris* and *Prunus* spp.). Other localities were steep afforested slopes, wooden edges, parks and hollow ways. These locations were all found on southern exposed slopes and mainly within the larger range of a greater forest. These habitats were often small remnants of historic forests.

There were also a lot of localities within forest. But on loamy soils, stag beetle was more often found in small habitats nearby the forest. On these soils the coppiced oak forests were converted in the former centuries to high forests, dominated by beech. In these forests dead wood is rare and stands are dense and dark. At the same time, other parts of the forest were claimed for agricultural use and deforested, leaving only small steep forest remnants. In these remnants stag beetle was able to survive. On the other hand, on sandy soils stag beetle was more often found within the forest, but these forests were afforested heath or converted coppice and are now dominated by oak, birch and Scotch pine. This type of forest is more open and the ground is more exposed to sun.

In the Brussels surroundings, different breeding sites were found inside an open urban area, in the locality of Boitsfort. Most of them are more or less man-made habitats. The rue des Trois Tilleuls, where stag beetle is abundant, is probably their original location. It is a steep slope, which already existed some centuries ago and which is bordered with oaks and other trees. In nearby roads, stag beetles larvae are living in 30-40 cm thick dead stems of Japanese cherries. At a 20 m long school entrance, the larvae live in oak timber used to protect a slope from erosion. At this site, a capture-recapture study enabled to mark 190 males, the expected total being probably 300 during a time span of about one month (more details in Cammaerts, in prep.). Larvae were also found under stem parts of a lime tree.

Modelling

With the exclusion of the three biogeographic regions (the dunes, polders and sandloam plain), the dataset comprise 356 5*5 km UTM squares.

The statistical models from the 10 training sets were acceptable (AUC 0.7 - 0.8) or excellent (AUC 0.8 – 0.9). All models used the same four parameters but not always in the same order:

— proportion of urbanized area,
— proportion of coniferous forest,
— altitude,
— mean temperature.

Some models used a fifth or sixth parameter.

The four parameters always have a positive relation, which means that the higher the parameter the higher the probability to find stag beetles. Some of these parameters have no direct relation with the habitat requirements of the stag beetle, like proportion of coniferous forest and altitude but these parameters were highly correlated to other parameters, other forest types and range in altitude respectively. For this reason ecological models were tried out.

The ecological models from the 10 training sets resulted in even better models, ranging from acceptable (AUC 0.7 - 0.8) to outstanding (AUC > 0,9) models. The different variables had a positive relation. The elevation range had the strongest impact, directly followed by the proportion of mixed and deciduous forest. The other two factors had a rather small impact.

Based on the model a prediction map can be build where each UTM square is given the value of the model (0 till 1). When this value exceeds the breaking value there is a high chance of having stag beetle present or having at least the habitat for it (Fig. 3). Historic localities of stag beetle often lie within areas of high potential in spite of the fact that they were not used to build the model.

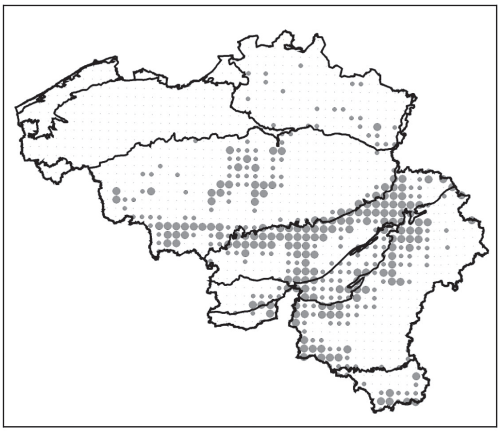

Figure 3. — Prediction map for presence of stag beetle based on the best ecological model (lowest AUC). Large dots have a high chance of stag beetle being present (p>=0.5) and small dots have a medium chance (0.25=<p<0.5).

DISCUSSION AND CONCLUSIONS

Because of the simultaneous requirements of humid dead wood and fast upwarming ground, the stag beetle is not an excellent flagship species for the sole dead wood in forests. The different approaches point out that stag beetle chooses mostly southern exposed and light rich habitat with a warm microclimate. Stag beetle occurs in Belgium in the first place as an indicator of thermophilous areas with fast upwarming grounds. Elements that lead to the general conclusion that stag beetle is a thermophilous species are also found by Whitehead (1993), Pratt (2000), Napier (2003) and Hawes (2004).

Probably forests were the main habitat in the past. These forests however were much more open then the present production forests. Present populations are still found near larger forests because of the small colonization capacity of the species (Rink & Sinsch, 2006, 2007). This makes the species dependent of a continuity of dead wood on one location over historic times. This is the main reason why forest cover is important for explaining the distribution on macroscale.

On a small scale old orchards, broadleaved forest edges and steep afforested slopes (cf. Napier, 2003) form the most important habitat and populations can survive here for long times. These habitats are often remnants of historic larger forests. On the loamy soils, stag beetle is more often found outside the forest. On sandy soils where the ground warms up faster and forests are more open, forest habitat is possibly more important then in the loamy areas.

The distribution pattern of the stag beetle can very easily be explained by a simple model with only a few parameters with clear ecological importance. More complex models with more explaining variables are given in Thomaes *et al.* (2008). Stag beetles occur in squares with lots of forests, urbanization (cf. Pratt 2000; Sprecher-Uebersax, 2003; Hawes, 2004), range in altitude and warm temperature. The forests are discussed above. The three other factors refer to thermophilic character of the species. Urban areas are generally warmer but could also be important for the historic protection of old trees and dead wood as a romantic landscape which started in parks and gardens near cities (cf. Sprecher-Uebersax, 2003). Broad river valleys often combine factors like urbanization, large range in elevation and warm temperature which explains there importance for the species.

Old orchards, broadleaved forest edges and steep afforested slopes where stag beetles are still present, disappear because of agriculture and forestry intensification and urbanization. In the meantime there is more attention for getting more open forests with more dead wood. A challenging question is whether the stag beetle will be able to recolonize these nearby forests while its present habitats are disappearing (Fig. 4). Therefore monitoring and active protection of the species (cf. Mendez, 2002) is needed.

Figure 4. — An experiment in which oak timber with larvae from the school in Boitfort is moved to a nearby park to see if transplanting is possible (Photo Olivier Beck).

ACKNOWLEDGEMENTS

Authors are grateful towards all the volunteers and local observers who kindly forwarded their observations; and to the Royal Belgian Institute of Natural Sciences (KBIN-IRSNB), the zoological museums of the Universities of Liège, Ghent and Brussels for providing specimens and data from their collections.

REFERENCES

CEC (1994). — *CORINE Land Cover technical guide.* European Commission, Luxemburg.

FIELDING, A.H. & BELL, J.F. (1997). — A review of methods for the assessment of prediction errors in conservation presence/absence models. *Envir. Cons.*, 24: 38-49.

HAWES, C.J. (2004). — The Stag beetle *Lucanus cervus* (L.) (Coleoptera: Lucanidae) in the County of Suffolk (England): Distribution and Monitoring. *Proceedings of the 3rd Symposium and Workshop on the Conservation of Saproxylic Beetles (07th-11th July 2004) Riga, Latvia*: 51-67.

HOSMER, D.W. & LEMESHOW, S. (2000). — *Applied logistic regression*. Wiley, New York.

LUCE, J.-M. (1996). — *Lucanus cervus* (Linnaeus, 1758). Pp 53-58 *in*: P.J. van Helsdingen, L. Willemse & M.C.D. Speight (eds). *Background information on invertebrates of the Habitat Directive and the Bern Convention*. Council of Europe Publishing, Strasbourg.

MAES, D., GILBERT, M., TITEUX, N., GOFFART, P. & DENNIS, R.L.H. (2003). — Prediction of butterfly diversity hotspots in Belgium: a comparison of statistically-focused and land use-focused models. *J. Biogeogr.*, 30: 1907-1920.

MENDEZ, M. (2002). — Conservation of *Lucanus cervus* in Spain: an amateur's perspective. *Proc. 2nd pan-European conference on Saproxylic Beetles, Royal Holloway, University of London, June 2002*: 6-8.

NAPIER, D. (2003). — *The Great Stag Hunt: Methods and findings of the 1998 National Stag Beetle Survey*. People's Trust for Endangered species, London.

PRATT, C.R. (2000). — An investigation into the status history of the stag beetle *Lucanus cervus* (Linnaeus) (Lucanidae) in Sussex. *Coleopterist*, 9: 75-90.

RINK, M. & SINSCH, U. (2006). — Habitatpräferenzen des Hirshkäfers *Lucanus cervus* (Linnaeus, 1758) in der Kulturlandschaft - eine methodenkritische Analyse (Coleoptera: Lucanidae). *Entom. Zeitschr.*, 116: 228-234.

RINK, M. & SINSCH, U. (2007). — Radio-telemetric monitoring of dispersing stag beetles: implications for conservation. *J. Zool.*, 272: 235-243.

SMIT, J. (2004). — *Inhaalslag verspreidingsonderzoek Vliegend hert*. Stichting European Invertebrate Survey Nederland, Leiden.

SMITH, M.N. (2003). — *National Stag Beetle Survey 2002*. People's Trust for Endangered species, London.

SPRECHER-UEBERSAX, E. (2003). — The status of *Lucanus cervus* in Switzerland. *Proc. 3rd pan-European conference on Saproxylic Beetles*: 1-3.

TOCHTERMANN, E. (1992). — Das "Spessartmodell" heute. Neue biologische Fakten and Problematik der Hirschkäferförderung. *Allg. Forst Zeitschr.,* 47: 308-311.

WHITEHEAD, P.F. (1993). — *Lucanus cervus* (L.) (Coleoptera: Lucanidae) in Worcestershire with a hypothesis for its distribution. *Entomologist's monthly magazine*, 129: 206.

THOMAES, A., KERVYN, T. & MAES, D. (2008). — Applying species distribution modelling for the conservation of the threatened saproxylic Stag Beetle (*Lucanus cervus*). *Biol. Cons.*, 141: 1400-1410