

## Distribution and site preferences of the stag beetle, *Lucanus cervus* in Belgium (Coleoptera: Lucanidae)

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### Abstract

Based on the available literature, collections, public surveys and field observations a current and historic distribution map for stag beetle *Lucanus cervus* in Belgium is compiled. The site preferences are analysed by comparing the distribution with habitat, geographic, climatic and soil data. The adults are mainly found in June and July, male sightings peaking before females. The species is present in the Campine, Loam, Condroz, Fagne-Famenne-Calestienne, Ardenne and Lorraine ecoregions. The distribution is limited by soil type and mean temperatures but not by annual rainfall. The soil needs to be deep, well-drained and loamy or sandy and the mean January temperatures should be between 4.0 and 6.1°C. We believe the species declined in the past century but this is only clear for the population in Brabant which was well studied from historic till recent times. The species appears to be no longer present in the region of Antwerp. The preferred habitats are urban areas, forests and forest edges, small landscape elements and parks. The stag beetle prefers steep south exposed slopes. To ensure the protection of this species we recommend active measures in urban areas and appropriate management in more natural habitats.

**Keywords** : Coleoptera, Lucanidae, *Lucanus cervus*, distribution, site preferences, climate, habitat, seasonality, Belgium

### Introduction

The stag beetle *Lucanus cervus* (Linnaeus, 1758) is the largest beetle of our fauna, its larva living from underground woody debris of numerous species of broadleaved trees. The stag beetle has a wide range in Europe from the northern half of Italy, Spain and Greece to the Baltic states and the southern point of Sweden and from the south border of Great Britain to the area near the Ural and the Black Sea (LUCE, 1996). Besides this species four other Lucanidae are found in our country, e.g. *Dorcus parallelipedus* (Linnaeus, 1758), *Platycerus caraboides* (Linnaeus, 1758), *P. caprea* (De Geer, 1774) and *Sinodendron cylindricum* (Linnaeus, 1758).



*Lucanus cervus*, Watermaal-Bosvoorde.

The stag beetle is listed as an appendix II-species of the European Habitat Directive. It was selected, amongst other large, easily recognised invertebrate species as a flag-ship species for insect conservation (LUCE, 1996). The Habitat Directive requires that all countries of the EU bring the listed species to a favourable state of conservation. Each country also has to monitor their distribution and population size. The main goal of protecting a flag-ship species is that while doing so, this will help the conservation of many other species and their habitat. The monitoring allows to have a better insight in the species status and population trends and should lead to better protection measures.

A monitoring is however not evident since populations in NW Europe are often small, only locally present and may be only active during a dozen of warm evenings in June and July (SMITH, 2003; SMIT, 2004). No good bait is known to attract the species from a great distance (KRENN *et al.*, 2002; SPRECHER, 2003). However, because this large species is easily recognised by the public, different countries held a public survey to study its distribution (Great Britain: SMITH (2003), The Netherlands: SMIT (2004)).

MÉLISE (1880) gives the first known overview on Lucanidae in Belgium. DE BORRE (1885a,b; 1886; 1888a,b; 1890; 1891) was intended to bring the distribution data of numerous beetle taxa together, including the stag beetle. This work was further finalized for the Lamellicornia by the book of JANSSENS (1960). A map of the stag beetle distribution was later on published in the atlas of LECLERCQ *et al.* (1973). Since then no detailed and collated information was published on the distribution of this species in Belgium. The authors gathered all available literature and data from collections, public surveys and field observations to compile information on the current and historic distribution. We analysed habitat preference and seasonality and the relation between the distribution and geographic, climatic and soil data.

## Material and Methods

### Distribution

The methods used to collect data of stag beetle in Belgium are: (1) literature and collections; (2) public surveys and (3) field observations.

Literature reports are those of BECKER (1861), BORMANS (1883), DE BORRE (1885a,b; 1886;

1888a,b; 1890; 1891), DECELLE (1982), FÉLIX (1947), FLUYT (2005), FROMONT (1882), GILS (1949), JANSSENS (1960), KERSMAEKERS (1973), MÉLISE (1880), NAVEAU (1992), RADISIC (1974), SLABBAERT (1995), STASSEN (2006), TROUKENS (2008), VAN DEN BERGE (1994) and VERSTRAETEN (1977). The collections of the Royal Belgian Institute of Natural Sciences (KBIN-IRSNB), the Royal Belgian Society of Entomology (SRBE-KBVE), the zoological museums of the Universities of Liège (ULg), Ghent (UG) and Brussels (ULB), the natural history museums of Maastricht and Luxembourg as well as different private collections were looked up. We also used the database of the University of Gembloux (FSAGx), which besides some more recent data, contains most of the records used for the distribution map published in LECLERCQ *et al.* (1973). Furthermore, we had access to the records in the database hosted by Natuurpunt and Natagora ([www.waarnemingen.be](http://www.waarnemingen.be)) and the database hosted by the Walloon public service (<http://biodiversite.wallonie.be/outils/encodage/>).

Enquiries were published by the regional governments in different journals concerned with nature conservation or entomology (for example THOMAES & VANDEKERKHOVE, 2004; KERVYN, 2005; THOMAES *et al.*, 2007; THOMAES, 2008). In Flanders and Brussels announcements were published in local newspapers of towns where old localities were known and flyers were posted by houses in old stag beetle localities. All responses were checked.

Field work was conducted to check doubtful responses, to find out the exact breeding site and to find new localities or more recent records.

Date, place, habitat and circumstances in which the species was found were collated as precisely as possible.

A '<' sign before a year means, without further precision, that it may be any of the years preceding this date, but posterior to 1850. A '>' sign before '1990' means that it concerns one of the years 1991 to 2005, which one exactly is unknown.

The data found originated from the 1850 onwards till 2009. To compare the distribution in different periods the data was grouped in three time periods with a similar amount of records. Data were also split up into precisely located data and less precise data (when only town or forest are known). Although our analyses are based on the detailed original data, we have simplified the list of localities presented in the results by

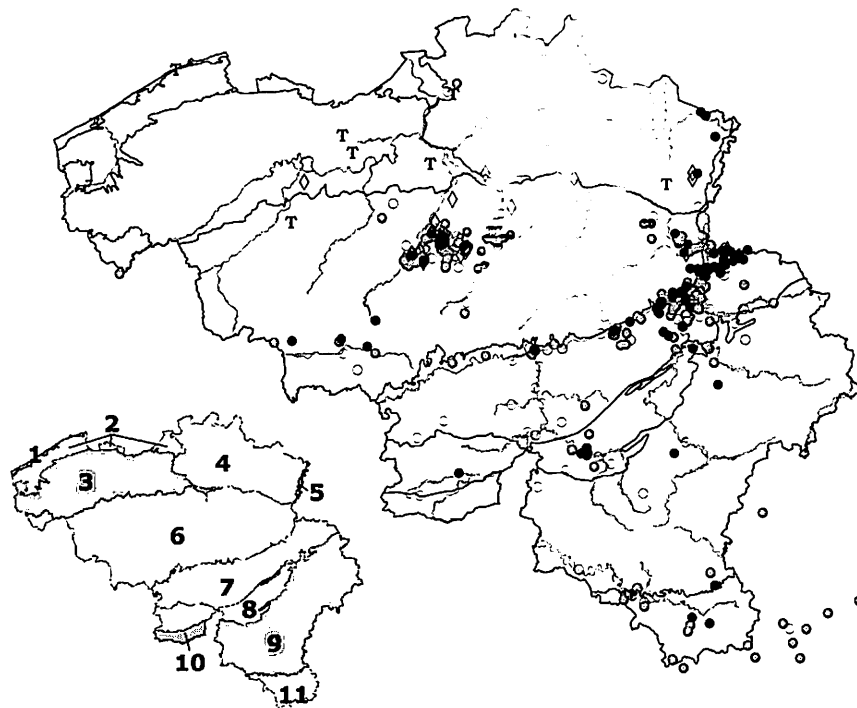


Fig. 1. Historic and current distribution of the stag beetle *Lucanus cervus* in Belgium. Hollow circle: 1850-1949; grey circle: 1950-1999; black circle: 2000-2009; hollow diamond: witnesses; grey T: Transported individual. 1: Dunes; 2: Polders; 3: Sandloam; 4: Campine; 5: Meuse; 6: Loam; 7: Condroz; 8: Fagne-Famenne-Calestienne; 9: Ardenne; 10: Thierache and 11: Lorraine.

naming only the amalgamated cities (known as *fusiegemeenten*, *communes après fusion* or *entités communales*) in which they fall.

#### Climature and altitude

The distribution since 1974 was used as presence/absence data within 5×5 km UTM squares and compared with the altitude, annual rainfall and mean temperatures for these squares (For more information see also MAES *et al.*, 2003; THOMAES *et al.*, 2008). We looked if the presence or absence of the species in certain (parts of) ecoregions could be explained by this data.

#### Habitat

The habitat was looked up and categorised for as much localities as possible. The habitat categories used were: forest edge, forest, small landscape elements (subdivided in hedges, line of trees, wooden bank/sunken lanes, orchard), park, artificial breeding heap, urban (mainly gardens and road verges), open agricultural area and unknown/unclear. The habitat category that was assigned to a locality was based on: (1) the original information of the observation, (2) a visit of the place or (3) aerial photos, topographical maps and other GIS-data. Method 1 was used for

al localities, 2 and 3 only for precisely located places with records after 1973. A single locality could be assigned to different habitat categories. The distribution over the different habitat categories was compared with the present land use categories of Belgium (ADSEI, 2007), omitting the categories water and open natural habitat (dunes, heath and marshes) because of the absence of stag beetle in these habitats. The distribution over the different habitat categories was also subdivided for the Atlantic and Continental zone of Belgium and compared with each other, omitting the category open agricultural area because of the low frequency of the beetle in this habitat type.

The slope exposition was determined for every precisely located place based on topographical maps divided in north oriented, northeast, east, southeast, ..., absence of slope and unknown/unclear. For the places in Flanders and Brussels, their slope inclination was also calculated by using a digital height model (grid cells 20×20m). For all GIS work ArcMap 9.2 was used.

#### Seasonality

The seasonality of the adult beetle was analysed by using all data where at least the month of record was known. We analysed whether seasonality was dependent to the time

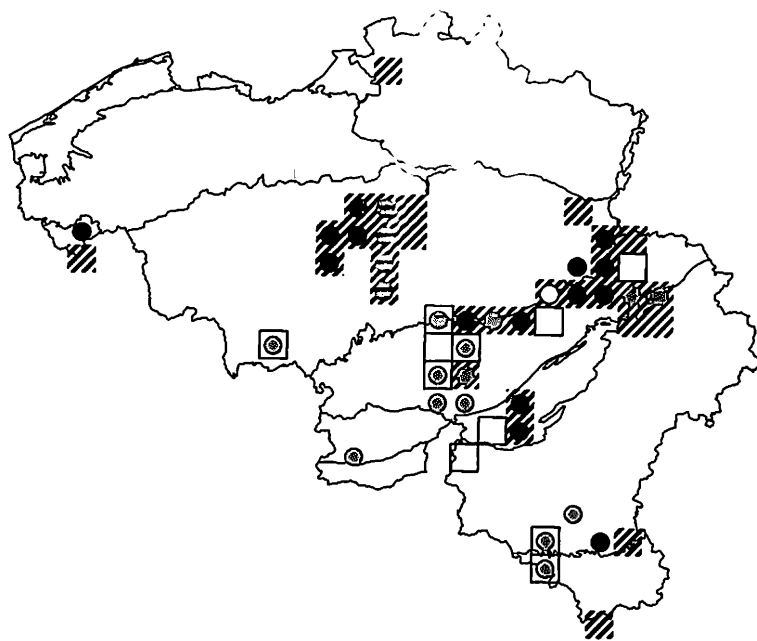


Fig. 2. Comparison between the distribution map of LECLERCQ *et al.* (1973, dots) and the data compiled in this paper (squares) for the same period. White: 1900- 1940; grey: 1940-1950 and black: 1950-1973.

period or ecoregion (grouped by altitude or soil type).

The habitat and seasonality analyses were only conducted on the data available to us in 2008, excluding the data of [www.waarnemingen.be](http://www.waarnemingen.be) and of the Walloon public service as well as of all data from 2009.

## Results

### Distribution: General

A total of 783 stag beetle records in Belgium and 16 from neighbouring areas were collected (Figure 1). The distribution is further described in the text for each ecoregion separately. Splitting the database in 3 different time periods results in 284 records for the period 1850-1949 (100y); 233 records for 1950-1999 (50y) and 276 records for 2000-2009 (6 unknown). This means that during the last 10y a nearly similar amount of records was collated as during the first 100y and during the following 50y.

Comparing our database with the data previously published by JANSSENS (1960) and LECLERCQ *et al.* (1973), we notice that these old literature references are incomplete. In JANSSENS (1960) 54 towns, villages or localities are mentioned (belonging to 35 different amalgamated cities), while in our database 16 other amalgamated cities are found with records dating before 1949 (being the year that the work of JANSSENS (1960) was completed). Thus, Janssens had access to only 69% of the records

currently known for his time. In the atlas of LECLERCQ *et al.* (1973) 1 UTM square is represented for the species being present in Belgium between 1900 and 1940, 16 squares appear for the period 1940-1950 and 17 for 1950-1973. The original database used for the map of LECLERCQ *et al.* (1973) was however not found and UTM data was not included in our database. In our database the result is 11 squares for 1900-1940, 5 for 1940-1950 and 26 for 1950-1973 (Figure 2). There are 15 UTM squares where the species was present, although not mentioned in LECLERCQ *et al.* (1973) but on the other hand there are 7 squares mentioned by LECLERCQ *et al.* (1973) for which we do not know the original records behind it. Most of these squares could probably be produced by the use of different techniques in converting location into squares since there is information of neighbouring squares. For only one square we only have a record from 1880, while it is dated more recent in LECLERCQ *et al.* (1973).

### Transported stag beetles (T) and witnesses (W)

Some of the data was collected by public surveys. Many replies collected in this way proved to be other species by checking photo's, collected material or by interviewing the finder. Often rhinoceros beetle (*Oryctes nasicornis* (Linnaeus, 1758)), lesser stag beetle (*Dorcus parallelipedus*) and even large Carabid and

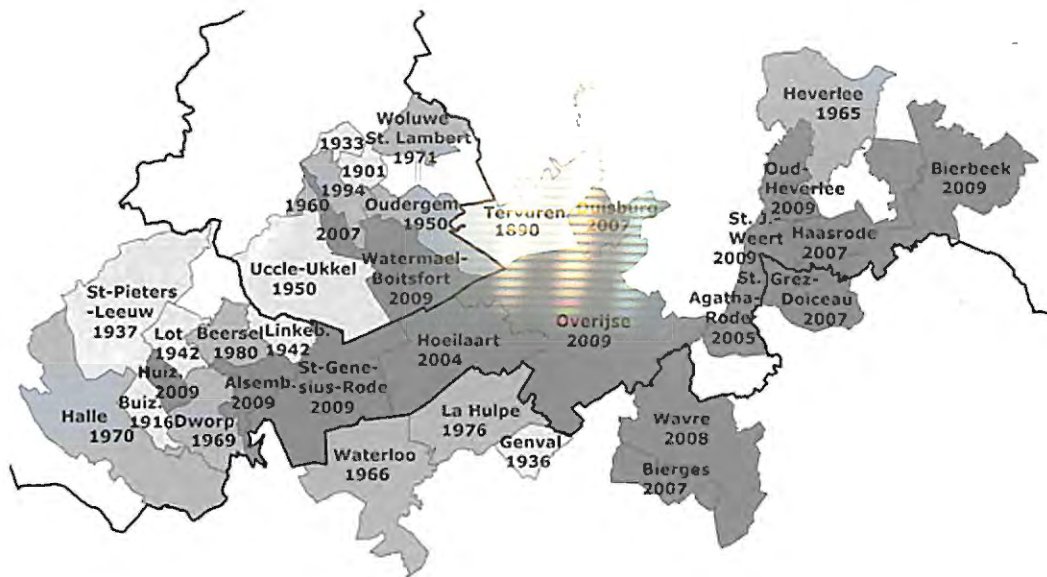


Fig. 3. Last known years of stag beetle observations in the region Halle-Leuven.

Longhorn beetles were wrongly reported as stag beetles. In some occasions the story seemed correct but as long as there was no proof of a correct determination these records stay doubtful and are marked as 'witnesses'.

For six records we assume that the beetles could have been transported over a large distance mainly since there are no other recent records in their surroundings:

- In 1991 one male was found by an entomologist (name unknown) in his garden near the city of Antwerp. Never before or after stag beetles were found in this garden. The beetle had one broken antler. It was found one day after the neighbours arrived back from a vacation in Spain where they had seen stag beetles daily at the camping.
- In august 2002 E. Panis has seen a stag beetle in the city centre of Blankenberge. This person recognised the species since he has seen it before, in France.
- In august 2004 the family Vandebossche found a male stag beetle in their garden in a recently parcelled residential area in Horebeke (TWG-LAMPYRIS, 2005).
- In may 2007 W. De Neef found one male stag beetle in front of his house in Mechelen, near a recently parcelled residential area. A photo from the beetle proofed the determination.
- In august 2008 S. Van Lerberghe saw at least one male stag beetle during several days in her garden in a recently parcelled residential area in Zele ([www.waarnemingen.be](http://www.waarnemingen.be)). The collected beetle proofs the determination.
- In 2009 a female was found in Lokeren by R.

De Vriese one day after his brother came back from camping in the South of France, after having driven non stop all the way. The beetle was found 10m away from the place where the car was parked. A detailed description of the beetle confirmed the determination.

When found in recently parcelled residential areas, we assume that larvae or adults could have been transported with soil or woodchips.

#### Distribution by ecoregion

There are no records from the Polders, Meuse and Thierache ecoregions. For the Dunes and Sandy Loam ecoregions there are only witnesses (W) and transported individuals (T): Blankenberge (T:2002), Horebeke (T:2004), Lokeren (T:2009), Mechelen (T:2007), Merelbeke (W:2005) and Zele (T:2008).

#### • Campine ecoregion

There are 20 records from the Campine ecoregion. This region was probably understudied in the past and also currently. Consequently the number of records in the three time periods are comparable. Current records are from forests on the plateaus along the Meuse. The old records come from Postel (Mol) and the intermediate from the southeast of Limburg and near the city of Antwerp. There are 3 witnesses from the southern river valleys Dijle and Demer. In this ecoregion with sandy soils the species is found mainly within and near forests.

Records of the Campine ecoregion: Antwerpen (<1886, <1949), near Antwerpen (T:1991), Brasschaat (1960), Diest (W:1997, W:2005), Dilsen-

Stokkem (W:2000, 2002), Genk (1975: a male was found at a sawmill but whether it is transported or came from a nearby population is unclear), Keerbergen (W:2003), Kinrooi (2003, 2004), Lanaken (<1891, <1949), Maaseik (2006), Maasmechelen (W:1999) and Mol (1860, 1876, 1877, <1880, <1886, <1952).

• *Loam ecoregion*

More than half of the records (450) come from this ecoregion. This is mainly explained by the high number of entomologists who studied this species in the ecoregion around Brussels today and in the past. Over the three time periods the amount of records is slightly higher in the last period due to the field studies of the authors. The species is found within this ecoregion in the area between Halle and Leuven, also in and around the valley of the Haine and along the valley of the Meuse. From these three areas both historic and current records are known. The population between Halle and Leuven has been well studied during all time periods and therefore the shrinking distribution of the species can clearly be illustrated here (Fig. 3). From the valley of the Meuse there are records from both parts of the river valley (Loam and Condroz ecoregion). In the Loam ecoregion the records are limited to the area around Liège. Isolated records are from Villers-la-Ville (1968), Asse (1897) and Ternat (1975). In the loam ecoregion the beetle is found mainly in urban areas, but also at the edges or within forest and in small landscape elements, rarely in open areas.

Records of the Loam ecoregion: Asse (1897), Auderghem-Oudergem (<1880, 1882, 1888, 1934, 1942, <1949, 1949, 1950, 2003, W:2004), Bassenge (1980, 1990, >1990, 2002), Beersel (1939, 1940, 1942, 1958, 1969, 1970, W:1980, 1995, W:2000, 2002, 2003, W:2003, 2004, W:2007, 2008, 2009), Beloeil (2003), Bierbeek (2005, 2009), Bruxelles-Brussel (<1880, 1887, 1933, 1949, 1968, 2007), Court-Saint-Etienne (1949), Etterbeek (1887, 1901), Flémalle (1995, 2006 also in Condroz ecoregion), Geer (W:2004), Grâce-Hollogne (1995), Grez-Doiceau (1963, 1972, 2007), Halle (1915, 1916, 1969, 1970, W:1980), Herstal (1998), Hoeilaart (1881, 1886, 1887, 1888, 1891, 194?, 1959, 1985), Horebeke (T:2004), Huldenberg (2005), Ixelles-Elsene (<1880, 1886, 1908, 1910, <1949, 1994), Jurbise (2003), Kortesseem (<1891, <1950, 2002, 2004), La Hulpe (1963, 1965, 1966, <1974, 1975, 1976), La Louvière (1996), Leuven (<1949, 1960, 1965, >1990, W:2003), Liège (1850, <1880, <1889, 1897, 1927, 1931, 1932, 1935, 1938, 1939, 1941, 1942, 1948, <1949, 1950, 1968, >1990, 1999, 2001, 2002, 2008, also in Condroz ecoregion), Linkebeek

(1931, 1936, 1939, 1941, 1942, <1949), Melsbroek (W:2007), Mons (<1880, <1886, 1937, <1949, 1976, 2004), Oud-Heverlee (1965, 1980, 1990, 1997, 2001, 2002, 2004, 2006, W:2003, 2009), Oupeye (2004, also in Condroz ecoregion), Overijse (<1880, 1897, 1909, <1949, 1949, 1960, 1992, 1997, 1999, W:1999, 2000, 2002, 2004-2009, W:2005, W:2006, W:2008, W: 2009), Péruwelz (1990), Riemst (<1949, 1967, 1970, 1972, 1982, 1984, >1990, 1999, 2001, 2007), Rixensart (1936, <1970), Saint-Nicolas (2008, also in Condroz ecoregion), Schaerbeek-Schaarbeek (W: 2004), Seraing (1865, <1880, <1889, <1949, 1985, also in Condroz ecoregion), Sint-Genesius-Rode (<1950, 1960, 1985, W:2003, 2009), Sint-Pieters-Leeuw (1937), Ternat (1975), Tervuren (1890, T: 2002, 2007, two males from Overijse were released in the Tervuren part of the Sonian forest), Tongeren (1993), Uccle-Ukkel (<1880, 1942, <1949, 1950, W:1960), Villers-la-Ville (1968), Waterloo (1963, 1965, 1966, <1974), Watermael-Boitsfort-Watermaal-Bosvoorde (1872, 1874, <1880, 1880, 1881, 1883-1889, 1897, 1899, 1903, 1910, 1912, 1913, 1924, 1925, 1934, 1938, 1945, <1949, 1949, 1955, 1960, 1963-2009 (see also CAMMAERTS in prep.)), Wavre (2007, 2008), Woluwe-Saint-Lambert-Sint-Lambrechts-Woluwe (1971) and Forêt de Soignes-Zoniënwood, but city unknown (1911, 1925, 1949, W:1989, 1998, 2005).

Other records near the Belgium border: Armentières (Fr: <1970).

• *Condroz ecoregion*

There are 245 records from this ecoregion (second most). The species is mainly found around Liège and in the valley of the River Meuse. Other records are from Pays de Herve and the valleys of the Lesse and Eau d'Heure. The number of records in the two first time periods are comparable, there are slightly less recent records. In this loamy ecoregion the species is found at equal times in urban areas, small landscape elements and near and within forests.

Records of the Condroz ecoregion: Amay (2003), Anhée (<1949), Anthisnes (1998, 2002, 2009), Andenne (1940), Ardenne (1940), Beyne-Heusay (1896, 1934, 1937, 1944, 1945, 1961), Blégny (1973), Charleroi (1991), Chaudfontaine (<1889, 1897, 1906, 1917, 1919, 1922, 1923, 1925, 1927, 1934, 1936, 1945, <1949, 1949, 1950, 1976, 1979, 1990, 1995, 2006, W: 2009), Ciney (1988), Dalhem (1907, 1913, 1915, 1921, 1954, 1990, 2002, 2003), Dinant (<1880, <1949), Engis (1985), Esneux (1876, <1889, 1935, 1940, < 1949, 1949, 1950, 1951, 1953, 1954, 1964, 1970, 1978, 1979, 1990, 1995, 1999, 2008, 2009), Flémalle (1968, 1978, 2002, 2006, 2008, 2009 also in Loam ecoregion), Fléron (1945), Floreffe (1932), Froidchapelle (<1886, <1949),

Hastière (1882, <1949), Herve (1932), Huy (1948, 1969, 1976, >1990, 1992, 1994, 1996, 1997, 2004, 2008), Liège (<1889, 1911, 1927, 1929, 1934, 1937, 1941, 1942, 1944, <1949, 1949, <1951, 1974, 1975, 1976, 1987, >1990, 1992, 2001, 2003, also in Loam ecoregion), Modave (<1889, 1900, <1949, 1977), Namur (<1880, 1904, 1907, 1908, 1909, 1911, 1912, <1949, 1970, 1976, 2004), Oupeye (1954, 1991, 2004, also in Loam ecoregion), Saint-Georges-sur-Meuse (1954), Saint-Nicolas (2006, also in Loam ecoregion), Sambreville (1979), Seraing (1862, <1880, <1889, 1912, 1928, <1949, 1969, 1974, 1986, 1987, 1995, also in Loam ecoregion), Sprimont (1997), Theux (1939), Thimister-Clermont (1996), Trooz (1942), Verviers (1941), Visé (1962, 1970, 1979, 2002, 2007-2009), Voeren (1986, 1989, 1993, 1999, W:1999, 2000-2005, 2007-2009), Walcourt (1897) and Yvoir (1922, 1945).

Other records near the Belgium border: Eysden (NL:1998).

#### • *Fagne-Famenne-Calestienne ecoregion*

From this ecoregion 16 records are brought together. The species is found mainly in the valley of the Lesse, while other records come from the valley of the Viroin, Ourthe and Amblève. Half (8) of the records come from the last time period, so the species has probably been overlooked in the past. For this ecoregion there are only four localities for which we know that the species was found within (2) or near (2) the forest.

Records of the Fagne-Famenne-Calestienne ecoregion: Aywaille (1973, 1976), Beauraing (1906), Chimay (<1886, <1949, also in the Ardenne ecoregion), Comblain-au-Pont (2003), Couvin (2001), Houyet (>1990, 2003, 2004, 2006) and Rochefort (1947, <1949, 1963, 1966, 2003, 2004, 2007).

#### • *Ardenne ecoregion*

There are 23 records from this ecoregion. The species is only found at the borders of this ecoregion in the river valleys of the Semois, Ourthe, Amblève and Vesdre. The number of records in the two first time periods are comparable, but more recent records are limited. For this ecoregion there are only six localities for which we know that the species was found within (3) or near (3) the forest.

Records of the Ardenne ecoregion: Bouillon (1886, <1949), Chimay (1937, <1949, also in the Fagne-Famenne-Calestienne ecoregion), Chiny (1903, 1908, also in Lorraine ecoregion), Florenville (1902, also in Lorraine ecoregion), La Roche-en-Ardenne (<1949, 2004), Léglise (1950, 1955), Lierneux (2003), Limbourg (1980), Saint-Hubert (<1880,

<1949), Spa (<1889, <1949, 1949) and Stoumont (1992, 1993).

Other records near the Belgium border (region of Gesling in Luxembourg): Biwer-Wecker (Lx:1973) and Wiltz (Lx:<1951).

#### • *Lorraine ecoregion*

There are 26 records from this ecoregion (wherefrom 13 from Luxembourg and France). The species is found in valleys of the Semois and Ton. The records come mainly from the end of the second time period, most of the records (9) are from 1990 onwards. Also in this ecoregion with calcareous loam soils the species is found near (4) and within (5) forests.

Records of the Lorraine ecoregion: Attert (2003), Chiny (1878, <1949, 1995, also in Ardenne), Etalle (2003), Florenville (1902, >1990, also in Ardenne ecoregion), Rouvroy (1970, 1975), Saint-Léger (2002) and Virton (1990, 1995, 1998, 1999).

Other records near the Belgium border (regions of Gutland in Luxembourg and Lorraine in France): Bertrange (Lx: 19??), Bettembourg (Lx:1963), Buré-la-Forge (Fr:1970, 1975), Differdange (Lx: 19??), Echternach (Lx:1911), Hostert (Lx:<1951), Leudelage (Lx:<1951), Luxembourg-Ville (Lx:1963), Mamer (Lx:<1951) and Pétange (Lx:1955, 1977).

### Climate and altitude

The mean January temperatures in Belgium vary from 2.5 to 6.6°C while stag beetles are mainly found in areas with mean January temperatures between 4.0-6.1°C (Fig. 4). For the mean July temperatures a similar but less pronounced relation is found. Mean July temperatures vary from 19.6 to 23.6°C and stag beetles are found mainly in areas with temperatures above 21.2°C. There is no upper boundary found for the summer temperature. Both winter and summer temperature strongly correlate with the altitude. The number of days with frost give very similar results as mean January temperatures (39 to 98 days of frost in Belgium and 48 to 85 days of frost in areas with stag beetles).

The presence of the species in Belgium seems not to be linked with the amount of rainfall (Fig. 5, see also THOMAES *et al.*, 2008). In Belgium the species is found mainly in the area with 800-900mm/y, but is also present in the areas with the highest rainfall (1200-1400mm/y, Valley of the Semois).

The species is found on altitudes between 2m (Antwerpen) and 446m (Saint-Hubert), but dominantly at 30-150m.

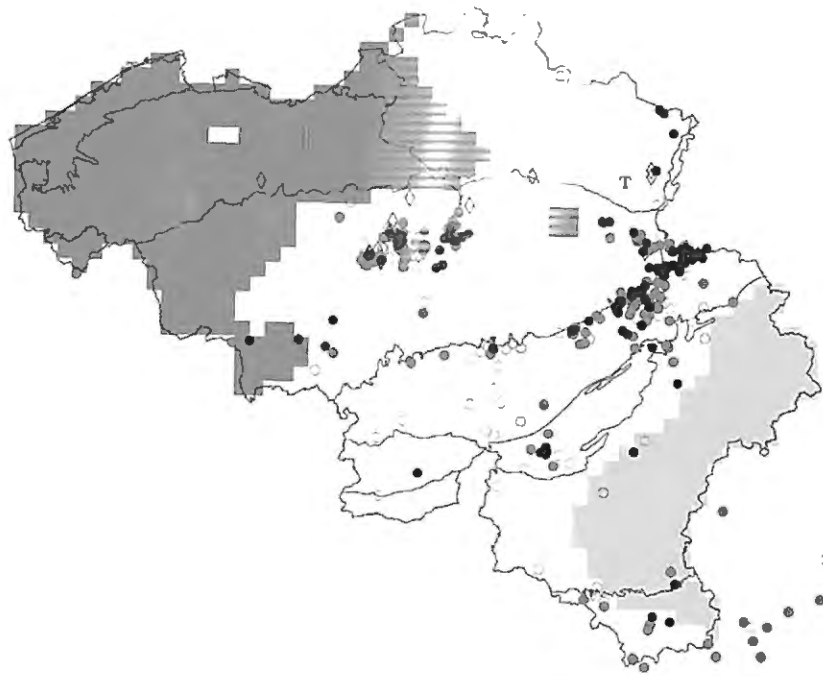


Fig. 4. Historic and current distribution of the stag beetle in Belgium (see Fig. 1) compared with the area of mean January temperatures lower than 4°C (light grey) and above 6,1°C (dark grey).

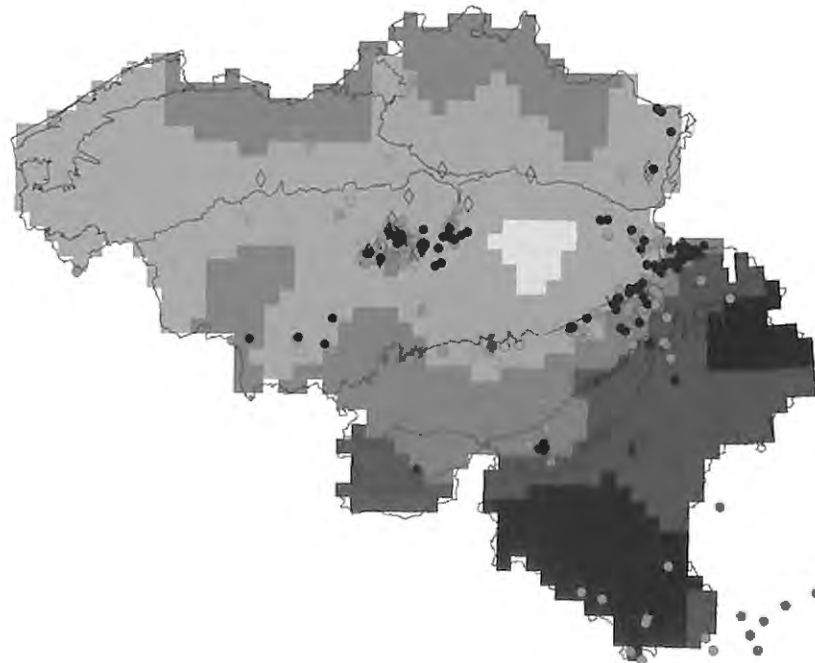


Fig. 5. Historic and current distribution of the stag beetle in Belgium (see Fig. 1) compared with total amount of annual rainfall. From light to dark grey: 751-800 mm/y; 801-900 mm/y; 901-1000 mm/y; 1001-1200 mm/y and 1201-1394 mm/y.



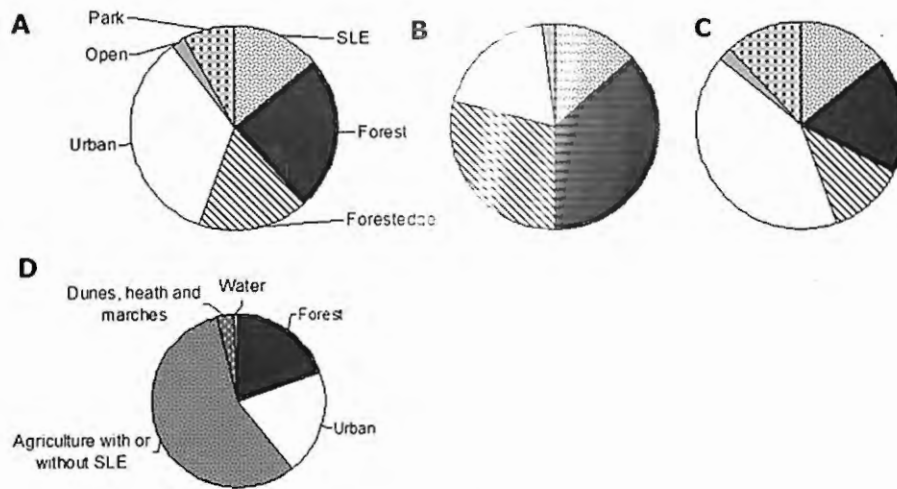


Fig. 6. Habitat of the locations where the stag beetle is found in Belgium (A; n=160), in the Atlantic (B, n=108) and the Continental (C, n=52) zones of Belgium, compared with the land use categories in Belgium (D, ADSEI, 2007). SLE: Small landscape element.

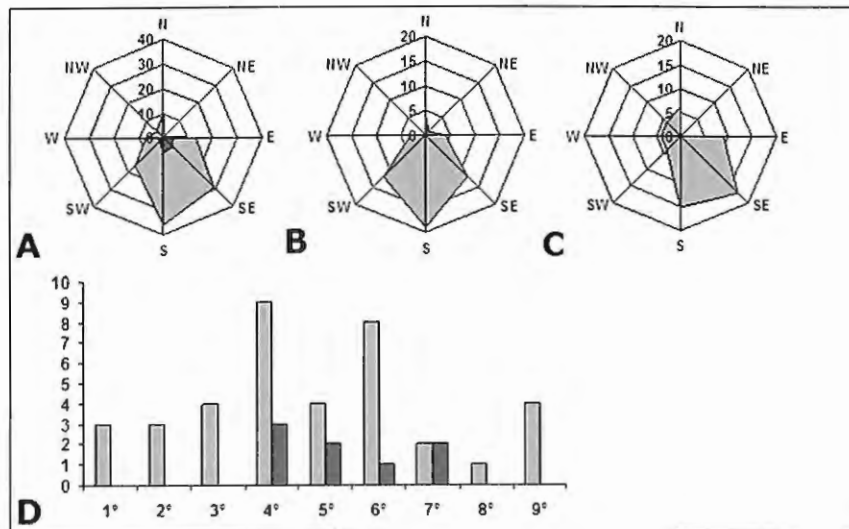


Fig. 7. Slope orientation (A-C) and inclination (D) of stag beetle localities (light grey) and breeding sites (dark grey) in Belgium (A; n=116; 20), the Atlantic (B, n=55) and Continental (C, n=59) part of Belgium and Flanders and Brussels (D; n=38; 8).

### Habitat

The habitat of 132 stag beetle localities in Belgium could be defined with 160 types of habitats found in total (Fig. 6). The main habitat used was urban, followed by forest, forest edge, small landscape element and park. The habitat selection was significantly different ( $\chi^2$ -test:  $p < 0.01$ ) from the whole of the habitats present in Belgium (ADSEI, 2007). Urban and forest are the most overrepresented categories, while open agricultural areas is least represented in the stag beetle habitat. The results were significantly

different between the Atlantic (Campine and Loam ecoregion) and Continental zone (all ecoregions south east of Sambre-Meuse) in Belgium ( $\chi^2$ -test:  $p < 0.01$ ): the habitat used in the Atlantic zone was very similar with the habitats used in the whole of Belgium, while in the Continental zone, forest and forest edge became the most important habitat.

The habitat found in urban areas were trees and tree stumps in gardens and road verges, besides numerous breeding sites in railway sleepers and wooden planks which were used to

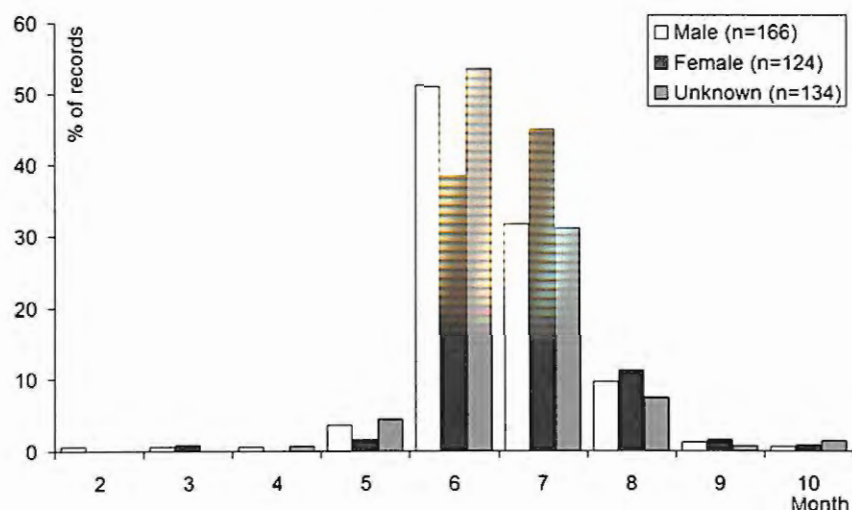


Fig. 8. Periodicity of the Belgian records for the stag beetle separated in male, females and records for which the sex was not noted.

cover steep slopes (in gardens). The forest areas where the stag beetle was present tended to be more open forests.

The slope orientation and inclination are presented in Fig. 7 and based on 116 stag beetle localities in Belgium. 70% of the points lie on a slope with southwest (SW), south (S) or southeast (SE) orientation. From the 38 localities in Flanders and Brussels 70% are located on a slope between SW and SE with an inclination of  $\geq 4^\circ$  while these slopes are only covering 0.7% of the surface of Flanders and Brussels.

### Seasonality

When looking to the seasonality the adult beetles are found mainly in May-August (Fig. 8). A few earlier and later records are most likely related to beetles which were dug up accidentally. Fifty percent of the males were found in June and 30% in July while 40% of the females were found in June and 45% in July. This seasonality is independent for the time period and ecoregion (grouped by altitude or soil type).

## Discussion and Conclusions

### Distribution and soil

The stag beetle was found to be absent in the Dunes, Sandy Loam, Polders, Meuse and Thierache ecoregions. It is present in all other ecoregions. The stag beetle distribution shows to be concentrated in broad river valleys and near major towns like Brussels and Liège (as for foreign countries, see DUTREIX, 1974; NAPIER, 2003; SPRECHER, 2003; SMITH, 2003), in the

Loam plateau and in the low mountainous region.

The soil type explains why some (parts of) ecoregions are unsuitable for the species (see also THOMAES *et al.*, 2008). This accounts for the dry and pure sandy soils of the Dunes, the heavy clay soils of the Polders and wet clay soils of large parts of the Ardenne and Thierache. When the species is present, it is on well-drained loamy (Loam, Condroz and Fagne-Famenne-Calestienne ecoregion) or sandy soils (Campine ecoregion). In the Lorraine ecoregion stag beetles were only found along river valleys where well-drained loamy and sandy soils are found. However, the reason for their absence on the plateaus may be that the latter are agriculture land. Also in Great Britain the soil is found to be an important factor in explaining the distribution. There, the species is found in deep, well-drained soils of loam, sand or gravel, while clay and chalk are avoided (PERCY *et al.*, 1999; PRATT, 2000; NAPIER, 2003; HAWES, 2005). The distribution is there also found to follow river valleys, especially in areas with less suitable soil (NAPIER, 2003; HAWES, 2005).

### Climate and altitude

The fact that the species is absent in the centre of the Ardenne and the northeast of the Lorraine ecoregion could be explained by the lower temperatures. The species is rarely found in the area with mean January temperatures below  $4.0^\circ\text{C}$  (Fig. 4). This area is also characterised by low July temperatures (below  $21.2^\circ\text{C}$ ) and a high number of days with frost (above 85). Since soil and different climatic parameters strongly

correlate it is difficult to conclude which factor limits the distribution of the species. In Great Britain 16.5°C is found as the mean July isotherm and 5°C as the mean January isotherm (HAWES, 2005) to explain the distribution. Especially this last one is very close to our result. Other studies relate the British distribution with the high accumulated day degrees (PERCY *et al.*, 1999). But the species has its northern boundary in the south of Sweden where the mean January temperatures are below 0°C. A reasonable ecological explanation for this boundary could be that cold winters are a limiting factor for the development of the underground larvae.

The absence in the Sandy Loam ecoregion might be explained by the high mean January temperatures (above 6.1°C) and the limited number of days with frost (below 48). The species is also known to be absent in other areas with a strong Atlantic influence (with mild winter temperatures) like in the UK (SMITH, 2003), Northeast of France (MUSEUM NATIONAL D'HISTOIRE NATURELLE, 2008) and the Netherlands (SMIT, 2004). However, how this sensitivity for mild winters should be interpreted ecologically is less clear especially since the species not only prefers urban habitats which also have warmer winters, but is very common in European regions with a mild climate such as southern France. The low forest index and lack of slopes was found to be an other possible reason for the absence of the species in the Sandy Loam ecoregion (THOMAES *et al.*, 2008).

In contrast with PERCY *et al.* (1999) and PRATT (2000) the presence of the species in Belgium seems not to be linked with the amount of rainfall (see also THOMAES *et al.*, 2008). PERCY *et al.* (1999) and PRATT (2000) found the species only present in areas with low rainfall (<690mm/y in Great Britain and <900mm/y in Sussex respectively). In Belgium, the species is found mainly in areas with 800-900mm/y, but it is even present in the areas with the highest rainfall (1200-1400mm/y).

For the county Sussex, PRATT (2000) found that 66% of the stag beetle records came from altitudes of less than 30m (25% of the area) which he explained by climatic differences. The species was found up to 150m while the highest point is 240m high. In Belgium the species is mainly found on higher altitudes and the highest record is at 446m while the highest point in Belgium is 694m. Despite the fact that the altitudes differ, presumably a similar climatic relation explains the pattern.

### Distribution: Trend

When we compared the current map of the historic distribution with previously published ones, we noticed that the latter were incomplete. Therefore we should be aware that our current map also is likely to be incomplete despite we probably have put more effort than before in compiling it and despite new technologies (online databases, e-mail, public surveys) give a more easy access to data.

When looking to the data it could be concluded that some populations appear to be new (because only recent data are available), but we assume that it is more likely that their localities were formerly unrecorded. The species is limited in its colonisation capacity (< 700m/generation, RINK & SINSCH (2007)), excluding a colonisation theory.

Since the data is far from complete it is difficult to reveal a trend in the Belgian stag beetle population. The data was split up in three time periods with equal number of records but in our opinion the total amount of records is not linked to a possible trend, but rather to the intensity with which the species was studied and to the difficulty to retrieve data from the older periods.

Different people have witnessed to us that the species was locally rather common till the 50' and declined in the 60' and 70' of the previous century, and finally became rare or absent. However these witnesses are often only related to one breeding site.

When looking at the decrease or increase of the beetle's distribution, we find a decrease in the area of Antwerp, in the western edge of the population in Brabant (Fig. 3) and possibly in the lower parts of the Lesse, Vesdre and Semois valleys. The species appears to be extinct in the province of Antwerp since it was no longer found after 1960 in the surroundings of Antwerp (Brasschaat) and Mol. In the Netherlands the species disappeared in the adjacent region in Breda and along the river IJssel at the end of the 19<sup>th</sup> century (HUIJBREGTS, 2002). Only for Brabant we are convinced that the data can illustrate the decline of the species distribution during the sixties and seventies of the previous century since the species was there sufficiently studied from historic till present times. It is unclear whether this trend was similar in other Belgian regions.

## Habitat

In contrast to the main idea that the stag beetle is a forest species, we can conclude that it lives mostly outside the forests or at their edge. These habitats are for example located in old orchards with dead wood. Other habitats are steep afforested slopes, wooden edges, parks and sunken lanes (for other countries see SMITH, 2003; SMIT, 2004; FREMLIN, 2009). The habitat needs to be at least half open (cf. SMITH, 2003) and dead wood can be provided by railway sleepers (cf. PRATT, 2000; SMIT, 2004) or other artificial pieces of dead wood. Like in the UK (PERCY *et al.*, 1999; SMITH, 2003) most Belgian stag beetle localities are found in urban areas, however these results may be biased by a higher presence of observers. Using the habitat of each recorded locality instead of that of each recorded specimen (like in PERCY *et al.*, 1999; SMITH, 2003) partly counteract this bias since in urban environment localities tend to have more records than localities with less observers.

Strangely, the sites where stag beetles are found are often near a large forest despite that the species is not found inside it. There are for example only a limited number of records for the Sonian forest (6 since the '80) while breeding sites exist today in the nearby surroundings, in Sint-Genesius-Rode, Beersel, Watermael-Boitsfort-Watermaal-Bosvoorde and Overijse. These few forest records could even be explained by dispersal from the neighbouring breeding sites. It seems probable that the species was not overlooked inside the Sonian and Meerdaal forests because these forests were investigated at different times by the authors and by BERGMANS (2009) and also because the fact that *Prionus coriaceus* (Linnaeus, 1758), a Longhorn beetle with a similar nocturnal activity has been frequently recorded there. We assume that the absence (or rarity) of the species in many forests can be explained by their management. The species needs a soil that receives enough sunshine to warm up for the development of the larvae (PRATT, 2000; NAPIER, 2003). If clear-cut areas are immediately planted with trees, the soil no longer receives the needed sunshine and doesn't warm up effectively. It is for example remarkable that records from this species found within forests often come from more open forests. On sandy soils stag beetles are more often found within the forest, but on loamy soils they are more often found outside the forest. This is presumably because sand warms up faster than loam and because forests on sand are dominated

by oak, birch and Scotch pine, which allows more light to reach the soil than does a beech forest.

## Seasonality

The seasonality found for Belgium is comparable with that in Great Britain. In Belgium the species is found generally between May and August. The first males are found in May, the peak being at the end of June (50% in Belgium, 66% in SMITH, 2003; 63% in PERCY *et al.*, 1999). In July they are clearly less abundant and the last ones are found in August. The first females are also present in May, but they peak later than the males, at the end of June till the beginning of July (45% in July in Belgium, 44% in July in SMITH, 2003; 53% in June in PERCY *et al.*, 1999). They are still to be found in August, rarely in September. The seasonality of the species does not differ by ecoregion or between Belgium and Great Britain (by comparing with PERCY *et al.*, 1999; NAPIER, 2003; SMITH, 2003; FREMLIN, 2009).

## Protection

Concerning the status of this species we conclude that it is unclear whether the species is declining in number. However, it is certain that at least in some areas it declined in distribution.

The population of Brabant and presumably also the population in the Meuse valley are vulnerable since they are mainly found in urban areas and therefore, their durability depends on the management of limited areas. The owners of private gardens with stag beetles are often unaware of their presence and populations may be unknowingly ruled out by the destruction of their habitat. For these urban populations active protection measures (informing owners, building artificial wood-piles, translocating threatened populations...) are needed.

For other populations proper management of the known sites and surroundings can probably ensure their continuity by creating half open habitat and sufficient broadleaved dead wood. Small landscape elements should therefore be (partly) coppiced, with wood pieces being left at the site. To ensure the presence of the species in and near forest, parts could be left unmanaged and light rich borders and gaps with suitable dead wood could be created. Clear cut areas could be left unplanted for a while (for example 10y) or planted with a large distance between the trees (for example 10×10m).

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### Question of the authors

The authors are still interested in any facts on the stag beetles in Belgium and would be grateful if you could provide them with any information. Because of scientific interest and to improve the protection of this species we would like to encourage you to look for stag beetles at places where they are no longer recorded. It is less useful to put effort in looking for the beetle at places where it is currently known from. The first author is also working on a genetic research on this species: any dead stag beetle found in any country is therefore welcome.

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