Risk analysis report of non-native organisms in Belgium

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Risk analysis of the fox squirrel *Sciurus niger*

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Risk analysis of the fox squirrel *Sciurus niger*

Evelyne Baiwy[(1)], Vinciane Schockert[(1)] & Etienne Branquart[(2)]

(1) Unité de Recherches zoogéographiques, Université de Liège, B-4000 Liège
(2) Cellule interdépartementale sur les Espèces invasives, Service Public de Wallonie

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Reviewed by :	Sandro Bertolino (University of Turin) & Céline Prévot (DEMNA)
Produced by:	Unité de Recherches zoogéographiques, Université de Liège, B-4000 Liège
Commissioned by:	Service Public de Wallonie
Contact person:	V.Schockert@ulg.ac.be & etienne.branquart@spw.wallonie.be

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Contents

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Etienne Branquart (Cellule Espèces Invasives, Service Public de Wallonie) developed the risk analysis template that was used for this exercise.

The general process of drafting, reviewing and approval of the risk analysis for selected invasive alien species in Belgium was attended by a steering committee, chaired by the Federal Public Service Health, Food chain safety and Environment. RBINS/KBIN was contracted by the Federal Public Service Health, Food chain safety and Environment to perform PRA's for a batch of species. ULg was contracted by Service Public de Wallonie to perform PRA's for a selection of species. INBO and DEMNA performed risk analysis for a number of species as in-kind contribution.

Steering committee members were:

Tim Adriaens	Research Institute for Nature and Forest (INBO)
Olivier Beck	Brussels Environment (BIM)
Roseline Beudels-Jamar	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Etienne Branquart	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Jim Casaer	Research Institute for Nature and Forest (INBO)
Thibaut Delsinne	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Maud Istasse (chair)	Federal Public Service Health, Food chain safety and Environment
René-Marie Lafontaine	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Alice Lejeune	Federal Public Service Health, Food chain safety and Environment
Céline Prévot	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Henri Robert Royal	Belgian Institute of Natural Sciences (RBINS/KBIN)
Vinciane Schockert	Université de Liège (ULg)
Sonia Vanderhoeven	Belgian Biodiversity Platform (BBPF)
Hans Van Gossum	Agency for Nature and Forest (ANB)
Hugo Verreycken	Research Institute for Nature and Forest (INBO)

Rationale and scope of the Belgian risk analysis scheme

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species. It strongly promotes the use of robust and good quality risk assessment to help underpin this approach (COP 6 Decision VI/23). More specifically, when considering trade restrictions for reducing the risk of introduction and spread of a non-native organisms, full and comprehensive risk assessment is required to demonstrate that the proposed measures are adequate and efficient to reduce the risk and that they do not create any disguised barriers to trade. This should be seen in the context of WTO and free trade as a principle in the EU (Baker et al. 2008, Shine et al. 2010, Shrader et al. 2010).

This risk analysis has the specific aim of evaluating whether or not to install trade restrictions for a selection of absent or emerging invasive alien species that may threaten biodiversity in Belgium as a preventive risk management option. It is conducted at the scale of Belgium but results and conclusions could also be relevant for neighbouring areas with similar eco-climatic conditions (e.g. areas included within the Atlantic and the continental biogeographic regions in Europe).

The risk analysis tool that was used here follows a simplified scheme elaborated on the basis of the recommendations provided by the international standard for pest risk analysis for organisms of quarantine concern[1] produced by the secretariat of the International Plant Protection Convention (FAO 2004). This logical scheme adopted in the plant health domain separates the assessment of entry, establishment, spread and impacts. As proposed in the GB non-native species risk assessment scheme, this IPPC standard can be adapted to assess the risk of intentional introductions of non-native species regardless the taxon that may or not be considered as detrimental (Andersen 2004, Baker et al. 2005, Baker et al. 2008, Schrader et al. 2010).

The risk analysis follows a process defined by three stages : (1) the initiation process which involves identifying the organism and its introduction pathways that should be considered for risk analysis in relation to Belgium, (2) the risk assessment stage which includes the categorization of emerging non-native species to determine whether the criteria for a quarantine organism are satisfied and an evaluation of the probability of organism entry, establishment, spread, and of their potential environmental, economic and social consequences and (3) the risk management stage which involves identifying management options for reducing the risks identified at stage 2 to an acceptable level. These are evaluated for efficacy, feasibility and impact in order to select the most appropriate. The risk management section in the current risk analysis should however not been regarded as a full-option management plan, which would require an extra feasibility study including legal, technical and financial considerations. Such thorough study is out of the scope of the produced documents, in which the management is largely limited to identifying needed actions separate from trade restrictions and, where possible, to comment on cost-benefit information if easily available in the literature.

This risk analysis is an advisory document and should be used to help support Belgian decision making. It does not in itself determine government policy, nor does it have any legal status. Neither should it reflect stakeholder consensus. Although the document at hand is of public nature, it is important to realise that this risk assessments exercise is carried out by (an) independent expert(s)

[1] A weed or a pest organism not yet present in the area under assessment, or present but not widely distributed, that is likely to cause economic damages and is proposed for official regulation and control (FAO 2010).

who produces knowledge-based risk assignments sensu Aven (2011). It was completed using a uniform template to ensure that the full range of issues recognised in international standards was addressed.

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted (after Baker et al. 2008):

- *Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based;*
- *The risk assessment deals with potential negative (ecological, economic, social) impacts. It is not meant to consider positive impacts associated with the introduction or presence of a species, nor is the purpose of this assessment to perform a cost-benefit analysis in that respect. The latter elements though would be elements of consideration for any policy decision;*
- *Completed risk assessments are not final and absolute. New scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.*

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD IN BELGIUM (EXPOSURE)

Entry in Belgium	Fox squirrel is likely to be voluntarily imported as a pet animal in Belgium and in neighbouring areas and is therefore at risk of release or escape. It is however unlikely that it will enter in Belgium by the way of natural spread since no feral populations are known in Europe. It is also unlikely that it could be introduced accidentally in Belgium.
Establishment capacity	The fox squirrel is likely to establish easily self-sustaining populations in Belgium and neighbouring areas if introduced because this species has a high invasive capacity and because appropriate climatic conditions, habitats and food resources are encountered.
Dispersion capacity	As with the grey squirrel, the fox squirrel does easily spread in the environment. The dispersal capacity of juvenile away from their natal home range may exceed several tens of kilometers and expansion rates exceeding 3 km/year have been observed in North America. Because of its appeal, the species greatly benefits from human assistance for dispersion, by the way of deliberated or accidental releases in the wild.

EFFECT OF ESTABLISHMENT IN BELGIUM

Environmental impacts	Based on impacts observed in the United States, it is very likely that establishment and spread of *Sciurus niger* in Belgium and neighbouring areas will outcompete the native squirrel species (*Sciurus vulgaris*). It is also likely that it will affect the reproduction of some tree species, enhance the prevalence of some diseases and parasites and favour their transmission to the native fauna.
Socio-economic impacts and ecosystem services	The fox squirrel is very likely to cause moderate to strong socio-economic impacts due to local agricultural and silvicultural damages as well as disease transmission to trees, horses and humans. It is therefore likely to impair forest and orchard provisioning services and affect regulating services as a result of disease transmission.

CONCLUSION FOR RISK ASSESSMENT

The environmental risk score is assessed as high, with a medium level of confidence. It is assumed that the fox squirrel may easily invade Belgium once introduced in the country because its establishment and spread capacities are rather high. Its potential impact on biodiversity is considered as moderate and it also represents a medium risk for agriculture and human health linked to seed/fruit consumption and disease transmission.

CONCLUSION FOR RISK MANAGEMENT

The most likely entry pathway of fox squirrel in Belgium is escape or release from captive breeding. The prohibition of fox squirrel importation, trade and holding could therefore be considered as an efficient measure for reducing the risk of entry to an acceptable level. As a transitional measure, drastic security rules including ear-tagging and systematic sterilization combined with an official surveillance system and the obligation to rapidly report any escape should be imposed for fox squirrels already kept in captivity in zoo.

Those preventive measures have to be preferred over early detection and population control as the fox squirrel may easily establish feral populations after escape. Eradication actions are only possible at the very beginning of the invasion process and are difficult to implement because of species low detection rate at low densities, rapid expansion from the release site when suitable ecological conditions are met and possible strong public opposition towards killing actions.

OTHER AREAS AT RISK IN EUROPE UNDER CURRENT AND FUTURE CLIMATES

The establishment capacity is currently optimal for Atlantic, Black Sea, continental, Mediterranean, pannonian and steppic regions, suboptimal for the alpine areas in Central Europe and inadequate in boreal and alpine areas in Northern Europe. The conclusions of this risk analysis report remain valid for the whole area wherein the species may establish. Climate change may potentially facilitate species establishment in the alpine and boreal bio-geographical regions of Europe as a consequence of the expansion of the distribution of acorn, mast and nut producing trees and an increase in tree functional diversity.

STAGE 1: INITIATION

Precise the identity of the invasive organism (scientific name, synonyms and common names in Dutch, English, French and German), its taxonomic position and a short morphological description. Present its distribution and pathways of quarantine concern that should be considered for risk analysis in Belgium. A short morphological description can be added if relevant. Specify also the reason(s) why a risk analysis is needed (the emergency of a new invasive organism in Belgium and neighboring areas, the reporting of higher damage caused by a non native organism in Belgium than in its area of origin, or request made to import a new non-native organism in the Belgium).

1.1 ORGANISM IDENTITY

Scientific name : *Sciurus niger* Linnaeus, 1758

Common names : Fox squirrel (GB), Zwarte eekhoorn (NL), Schwarzhörnchen (DE), Écureuil fauve (FR).

Taxonomic position: Chordata (Phylum) > Mammalia (Class) > Rodentia (Order) > Sciuridae (Family).

Note: Sciurus niger is considered of least concern by IUCN red list (Linzey et al. 2008). There are ten subspecies of *S. niger* recognized: *S. n. avicennia*, *S. n. bachmani*, *S. n. cinereus*, *S. n. limitis*, *S. n. ludovicianus*, *S. n. niger*, *S. n. rufiventer*, *S. n. shermani*, *S. n. subauratus, S. n. vulpinus* (Hall 1981). Some of these subspecies are considered as least concern according IUCN, and some have a vulnerable or an endangered conservation status in certain US states (*S. n. avicennia, S. n. cinereus, S. n. niger, S. n. shermani*) because of overhunting and preferred habitat (mature forests) destruction (Koprowski 1994a, Fahey 2001, Guynn *et al.* 2006, Linzey *et al.* 2008).

1.2 SHORT DESCRIPTION

Sciurus niger is a large-sized tree squirrel of about 45-70 cm of total length, 20-33 cm of tail length, and 500-1360 g of weight (Hall 1981, Flyger & Gates 1982). There is no sexual dimorphism (Hall 1981). Some differences in the coat colours (dorsal pelage buff, orange to black, and the venter rufous, white to cinnamon) occur between individuals from the western and northern portions of the United States, the south-eastern United States, and the central United States (Baumgartner 1943a, Moore 1956, Flyger & Gates 1982, Weigl *et al.* 1989, Kiltie 1992).

Fox squirrel is the largest of the North American tree squirrels (Allen 1982); it is larger than western gray squirrel *S. griseus* (350-750 g), eastern gray squirrel *S. carolinensis* (300-750 g), Abert's squirrel *S. aberti* (550-950 g), Douglas squirrel *Tamiasciurus douglasii* (<300g) and our native Eurasian red squirrel *S. vulgaris** (200-400 g) (Woodhouse 1853, Saint-Girons 1973, Ruff & Wilson 1999, Van Der Merwe *et al.* 2005, Koprowski & Doumas 2012).

1.3 ORGANISM DISTRIBUTION

Native range

Sciurus niger is native to eastern and central Unites States (Alabama, Arkansas, , Colorado, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, , South Carolina, South Dakota, Tennessee, Texas, Virginia, West Virginia, Wisconsin and Wyoming) and to very limited areas of adjoining north-eastern Mexico (Coahuila) and southern Canada (Manitoba, Saskatchewan) (Hibbard 1956, Hall 1981, Fitzgerald *et al.* 1994, Koprowski 1994a, Frey & Campbell 1997, Long 2003, Duff & Lawson 2004, Ceballos & Oliva 2005). The gray squirrel (*S. carolinensis*) presents largely the same distribution as *Sciurus niger* in North America but the Fox squirrel has a wider range in the Mid-West while the gray species is present along the Atlantic coast of the United States towards the North, which is not the case for *S. niger*.

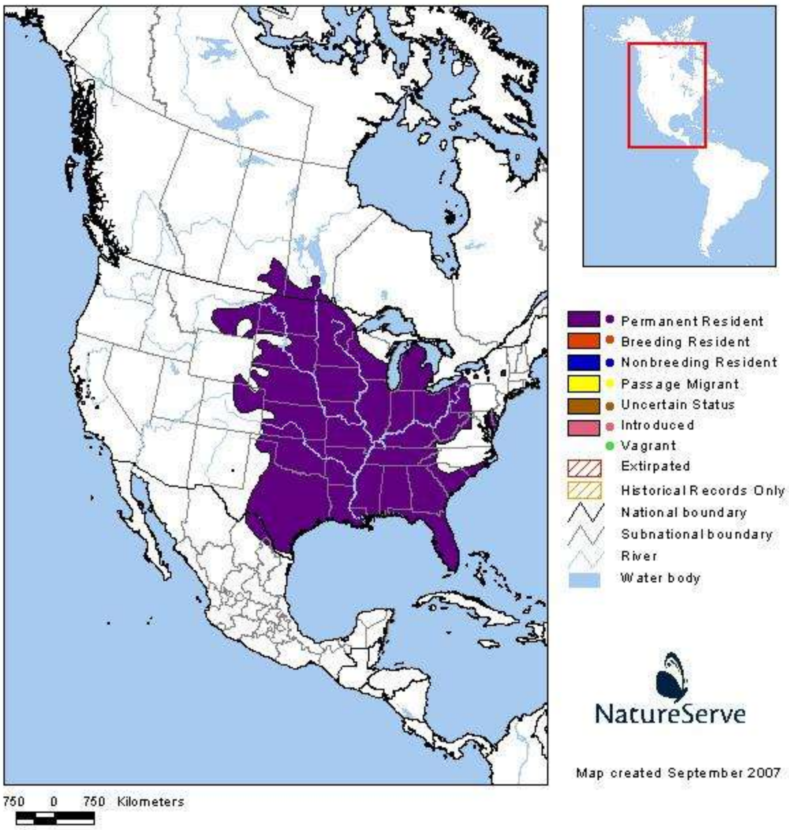

Fig. 1. Native range of *Sciurus niger* (Patterson *et al*. 2003)

Introduced range

Belgium: The species is not established in Belgium.

Rest of Europe: The species is not established in Europe but some isolated individuals were already observed in the Netherlands in 2011, 2012 and 2013 (http://waarneming.nl).

Other continents: The species has been introduced and is established in the western US and Canada: Arizona, British Columbia, California, Colorado, Idaho, Montana, New Mexico, North Dakota, Ontario, Oregon, Texas, Washington (Yocom 1950, Hibbard 1956, Peterson 1966, Hoffman *et al.* 1969, Larrison & Johnson 1981, Jameson & Peeter 1988, Nagorsen 1990, Fitzgerald *et al.* 1994, Frey & Campbell 1997, Verts & Carraway 1998, Long 2003).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Nearly all of 44 introductions occurring in North America resulted in successful establishment of *Sciurus niger* (Bertolino 2009). Even if no established population is reported in Europe and if impacts of fox squirrels are still unknown concerning European flora and fauna, this species seems to have a great establishment capacity, and has therefore a high potential for invasiveness (Palmer *et al.* 2007). Some native squirrel species and environments could be affected by *S. niger* introduction (Palmer *et al.* 2007).

STAGE 2: RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Evidence should be available to support the conclusion that the non-native organism could enter, become established in the wild and spread in Belgium and neighbouring areas. An analysis of each associated pathways from its origin to its establishment in Belgium is required. Organisms intentionally imported maybe maintained in a number of intended sites for an indeterminate period. In this specific case, the risk may arise because of the probability to spread and establish in unintended habitats nearby intended introduction sites.

2.1.1 Present status in Belgium

Specify if the species already occurs in Belgium and if it makes self-sustaining populations in the wild (establishment). Give detail about species abundance and distribution within Belgium when establishment is confirmed together with the size of area suitable for further spread within Belgium.

There is no information about establishment of *S. niger* in Belgium and in the rest of Europe; among the 248 worldwide squirrel introductions, all the 44 recorded ones of *S. niger* occurred in North America (Bertolino 2009, UNEP-WCMC 2010). A single individual has however been regularly observed in a private park near Brussels from December 2014 to February 2015 (see picture). Intensive monitoring is currently ongoing to make sure that no established population is present.

Fig. 2 – Picture of *Sciurus niger* recently reported in La Hulpe through the Belgian early warning system (picture: Rafael Pauwels).

2.1.2 Present status in neighbouring countries

Mention here the status of the non-native organism in the neighbouring countries

There are no identified introductions or free-ranging populations of fox squirrel in neighbouring countries (Bertolino 2009, UNEP-WCMC 2010). However, some individuals of *Sciurus niger* were locally observed in the Netherlands (http://waarneming.nl) even if they did not establish populations (pers. com. Wiebe Lammer, cocrdinator of Team Invasieve Exoten - Bureau Risicobeoordeling en Onderzoeksprogrammering (BuRO-Wageningen). In 2011, one individual was observed in winter (January) in Tiel. One and two individuals were re-observed repeatedly in the same place in June-July

2011. But no more observation has been reported in this area during the last two years. Some isolated individuals were observed subsequent years, within a radius of 100 km : one individual in Hilvarenbeek (November 2011), another one in Heelderpeel (April 2012) and one in Venlo (June 2013). The Dutch risk assessment on alien squirrel species (Vilmar and Dekker 2008) assessed that the Netherlands climate and habitats are suitable for establishment and spread of *Sciurus niger*. This explains the current ban on trade and possession of *S. niger* (as well as for *S. carolinensis* and *Callosciurus erythraeus*).

At this time, the species is considered as fragile in Mexico and declining in eastern United States due to habitat loss resulting in a restricted distribution. Since 1967, the Delmarva fox squirrel (*Sciurus niger* subsp*. cinereus*) has even been listed under the Endangered Species Act of the Unites States of America (U.S. Fish & Wildlife Service 1993). On the contrary, *S. niger* is naturally expanding its range in the mid-west states (Ceballos & Oliva 2005, Linzey *et al.* 2008).

2.1.3 Introduction in Belgium

Specify what are the potential international introduction pathways mediated by human, the frequency of introduction and the number of individuals that are likely to be released in Europe and in Belgium. Consider potential for natural colonisation from neighbouring areas where the species is established and compare with the risk of introduction by the human-mediated pathways. In case of plant or animal species kept in captivity, assess risk for organism escape to the wild (unintended habitats).

On a worldwide scale, non-native squirrel introductions peaked from 1900 to 1930, but the phenomenon is still important, with 15–20 new introductions every 10 years. Seven introduced squirrel species are currently established in Europe (Bertolino 2009). The main vector of introduction was the intentional importation of live animals that were either deliberately introduced or escaped from captivity. In the past, the translocation of squirrels into new areas was thought to be appropriate to the public interest and it was accomplished until the 1970s by game and wildlife management agencies also (Davis & Brown, 1988). With the recently increasing awareness about the threat entailed in biological invasions, many national laws and international agreements either ban or discourage new introductions. Nevertheless, animal trade has increased during the last few decades and squirrels are still being sold as pets everywhere. In fact, in recent times the main pathway of squirrel introductions has been connected to private citizens and animal traders who keep animals in captivity, with consequent risk of escape or release them into public estates and parks (Davis & Brown 1988, Westphal *et al.* 2008, Bertolino 2009).

S. niger has been introduced in some US states mostly for the aesthetic novelty and pleasure it brings, or for hunting and trapping opportunities (Davis & Brown 1988, Aprile & Chicco 1999, Long 2003). In America, all introductions of fox squirrels with available dates occurred in the first half of the 20th century (Palmer *et al.* 2007, Bertolino 2009).

Nowadays, no official introduction of *S. niger* in Belgium or in Europe is known (UNEP-WCMC 2010). However, several offers for sale take place on websites, and a fox squirrel trade certainly occurs in Europe as in the world, since individuals (often pair mates) are advertised for sale (more or less 250€) or for exchanges on Austrian, Danish, Dutch, English, Finnish, French, German and Portuguese websites (UNEP-WCMC 2010). In their risk assessment fort the Netherlands, Dijkstra & Dekker (2008) also consider this species as moderately traded or hold by pet traders/private citizens in their country.

ENTRY IN BELGIUM

Fox squirrel is likely to be voluntarily imported as a pet animal in Belgium and in neighbouring areas and is therefore at risk of release or escape. It is however unlikely that it will enter in Belgium by the way of natural spread since no feral populations are known in Europe. It is also unlikely that it could be introduced accidentally in Belgium.

2.1.4 Establishment capacity and endangered area

Provide a short description of life-history and reproduction traits of the organism that should be compared with those of their closest native relatives (A). Specify which are the optimal and limiting climatic (B), habitat (C) and food (D) requirements for organism survival, growth and reproduction both in its native and introduced ranges. When present in Belgium, specify agents (predators, parasites, diseases, etc.) that are likely to control population development (E). For species absent from Belgium, identify the probability for future establishment (F) and the area most suitable for species establishment (endangered area) (G) depending if climatic, habitat and food conditions found in Belgium are considered as optimal, suboptimal or inadequate for the establishment of a reproductively viable population. The endangered area may be the whole country or part of it where ecological factors favour the establishment of the organism (consider the spatial distribution of preferred habitats). For non-native species already established, mention if they are well adapted to the eco-climatic conditions found in Belgium (F), where they easily form self-sustaining populations, and which areas in Belgium are still available for future colonisation (G).

A/ Life-cycle and reproduction

Sciurus niger is rather long lived, the average lifespan under natural conditions being of 5-10 years, with a record of 12.5 years (Koprowski et al. 1988) and captive individuals living up to 15-18 years (Flyger & Gates 1982, Koprowski *et al.* 1988, Koprowski 1994a, Fahey 2001) while the longevity is around 7 to 9 years for the gray squirrel and 5 to 10 years for the red squirrel. For *Sciurus vulgaris**, Wauters & Dhondt (1995) pointed out an average lifespan of 5 ± 2 years old in two populations in North Belgium (where the predation level must be low, some natural predators being absent of these areas).

Sexual maturity may be reached by females at 8 months of age, however the usual reproductive age is over 1.25 years (McCloskey & Vohs 1971, Harnishfeger *et al.* 1978, Koprowski 1994a). Males attain sexual maturity at 10-11 months of age (Fahey 2001). Females red squirrels in North Belgium present an average age of reproduction around 2 years old but may breed since less than 1 year old to 4 years old (Wauters & Dhondt 1995).

The number of young per litter, which ranges from 1 to 7 with on average 2-3, is extremely variable according to years, seasons, food availability... (Nixon & McClain 1969, McCloskey & Vohs 1971, Harnishfeger *et al.* 1978, Weigl *et al.* 1989). In addition, females can exceptionally produce two litters of 2 to 5 young a year (Burton 1991, Fahey 2001). A comparable situation is known for *S. vulgaris* with 1 to 6 offspring per litter, and 1 to 2 litters a year according to food availability (seed-crop size) (Wauters & Lens 1995, Boutin *at al*. 2006; second litter is more common (20-50% of females: Wauters & Lens 1995; Wauters et al. 2001).

B/ Climatic requirements[2]

Globally, *S. niger* tolerates a wide range of climatic conditions; from the tropical monsoon to the continental climate through the tropical wet and dry savanna, steppe, desert, warm temperate climate (Koprowski & Doumas 2012). However, this species prefers a **warm temperate or a continental climate with dry summer** (Koprowski & Doumas 2012). The mean annual temperature has to be between 8 and 23 °C, with a **mean maximum temperature of hottest month comprised between 23 and 41°C**, and a mean minimum temperature of coldest month comprised between -22 and 7°C (Koprowski & Doumas 2012). Concerning the rainfall parameters, a lower limit of 81 mm and an upper limit of 1669 mm for a mean annual rainfall is acceptable (Koprowski & Doumas 2012).

Regarding the climatic needs of *S. niger*, it could likely establish populations in our country. The Invasive Species Compendium (CABI 2013) believes that Belgian climate parameters are suitable for *S. niger*, according to climatic conditions of the native range. The mean temperature of the native range runs from -22°C (mean minimum of coldest month) to 41°C (mean maximum of hottest month) while it is between 0°C to 23°C in Belgium. The mean annual rainfall ranges from 81 to 1669 mm in the native range and from 700 to 1400 mm in Belgium. Moreover, the native range latitudes of *Sciurus niger* are comprised between 26 and 52°N which includes the Belgian latitudes (49-51°N) and calls for a high likelihood of establishment of *Sciurus* niger in Europe (Bertolino 2009). Weather conditions seem to have no influence on survival (Hansen *et al.* 1986).

C/ Habitat preferences[3]

Sciurus niger prefers **open woodland habitats**, mature forest patches even of less than <40 ha, with scattered trees, low percentage of shrub groundcover, forest edges and open understory; optimum tree canopy closure ranges from 20 to 60%. **Squirrel densities are determined by the availability of tree cavities (den sites) and winter food**; they are higher in habitats composed of a high percentage and a good variety of large trees that produce both den sites and winter-storable food such as oaks (*Quercus*), hickories (*Carya*), walnuts (*Juglans*), and pines (*Pinus)* (Allen 1982, Nixon & Hansen 1987, Dueser *et al.* 1988, Weigl *et al.* 1989, Tesky 1993, Linzey *et al.* 2008).

This species is found in a wide array of habitat types including deciduous and mixed conifer-deciduous forest habitats, natural or managed forests, plantations and orchards, riparian areas, oak woodlands, agricultural lands, areas with increased hedges, interfaces between forests and prairies, areas with low tree density, urban and periurban areas as town parks (Hoffmann *et al.* 1969, Wolf & Roest 1971, Allen 1982, Littlefield 1984, Nixon & Hansen 1987, Fitzgerald *et al.* 1994, Verts & Carraway 1998, King *et al.* 2010). Fox squirrels sometimes use **human-disturbed woodlands** more than undisturbed areas, because this species lives well in cities, and uses areas with high coverage of

[2] Organism's capacity to establish a self-sustaining population under Atlantic temperate conditions (Cfb Köppen-Geiger climate type) should be considered, with a focus on its potential to survive cold periods during the wintertime (e.g. plant hardiness) and to reproduce taking into account the limited amount of heat available during the summertime.

[3] Including host plant, soil conditions and other abiotic factors where appropriate.

pavements and buildings to survive over winter (Frey & Campbell 1997, Salsbury *et al.* 2004, McCleery *et al.* 2007). With rabbits, deer, opossums, raccoons, pigeons and crows, squirrels represent in North America a portion of the larger and more noticeable animals that maintain flourishing populations in **urban habitats** (Van Der Merwe *et al.* 2005).

As the other squirrel species, fox squirrel uses trees to readily escape predators or rear young (Stoddard 1919, Kantola & Humphrey 1990). The nests, which represent a protection against elements, can be a **tree cavity** (most frequently used in winter) or a stick and leaf construction (called drays, most commonly occupied in warmer months) usually established in large trees (Geeslin 1970, Christisen 1985, Tesky 1993, Koprowski 1994a). The temperature in an occupied nest box in winter may be 25°C warmer than ambient temperature (Havera 1979). Fox squirrels use less than 9 nests annually (Nixon & Hansen 1987).

Seed crop quality especially influences the juvenile survival, and in extremely bad conditions, the adult survival can also be affected (Nixon & McClain 1969, Nixon *et al.* 1975, Hansen *et al.* 1986, Koprowski 1991a). Forest fragmentation, habitat loss (timber harvest, short-rotation pine forestry, conversion of forests for agricultural and structural development), population isolation, and human population growth are the main causes leading to decline of some endangered subspecies of fox squirrels, as for example the Delmarva fox squirrel (*Sciurus niger cinereus*) which remains today in only 10% of its historic range (Taylor 1973, Maryland Forest Park and Wildlife Service 1989, Lance *et al.* 2003, Hilderbrand *et al.* 2007).

S. niger often co-occurs in its distribution area with the eastern gray squirrel *S. carolinensis*. However, in their natural habitats, the last one prefers dense mature hardwood forests with significant undergrowth, contrary to fox squirrels which inhabit **open woodlands with sparse undergrowth** (Allen 1982, Steele & Koprowski 2001).

D/ Food habits[4]

In its native range, *S. niger* eats a wide variety of plant and animal items: tree seeds, fruits, flowers, and buds, agricultural products, fungi (consumed primarily in summer and winter), small quantities of insects (moths, beetles, etc.) and occasionally birds, bird eggs and dead fish. **They heavily feed on mast production** from ≥ 21 species of oak (*Quercus*), 8 species of hickory and pecan (*Carya*), walnut, North American beech (*Fagus grandifolia*), longleaf pine (*Pinus palustris*). Agricultural crops such as corn, soybeans, oats, wheat and fruit crops are also readily consumed (Baumgartner 1939, Bugbee & Riegel 1945, Packard 1956, Nixon *et al.* 1968, Wolf & Roest 1971, Korschgen 1981, Allen 1982, Flyger & Gates 1982, Weigl *et al.* 1989, Shaffer & Baker 1991, Koprowski 1994a).

Food consumption reaches a peak in spring or autumn, but food scarcity can often become limiting in winter (Knee 1983). Thus, as scatterhoarders, fox squirrels dig seed caches, with a recovery rate of 33 to 99% (Cahalane 1942, Stapanian & Smith 1986). As other squirrels, they have strong jaw muscles enabling them to open most seeds and nuts (Steele & Koprowski 2001).

[4] For animal species only.

E/ Control agents

In their native range, under natural conditions, Juvenile mortality is exceptionally high during the first year of life, but is followed by relatively high survival in adults (Steele & Koprowski 2001), which means long before adulthood or the 5-10 years of average lifespan (Fahey 2001). The mean annual adult mortality is generally around 35% (Hansen *et al.* 1986).

In the native range, they have lots of **natural predators** such as timber rattlesnake (*Crotalus horridus*), black rat (*Elaphe obsoleta*) and pine (*Pituophis melanoleucus*) snakes, goshawk (*Acccipiter gentilis*)*, red-tailed (*Buteo jamaicensis*), red-shouldered (*B. lineatus*), rough-legged (*B. lagopus*) and ferruginous rough-legged (*B. regalis*) hawks, great horned owl (*Bubo virginianus*), opossum (*Didelphis virginiana*), American mink (*Neovison vison*), long-tailed weasel (*Mustela frenata*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*)*, gray fox (*Urocyon cinereoargenteus*), bobcat (*Felis rufus*), lynx (*Lynx lynx*)*, wolf (*Canis lupus*)*, coyote (*C. latrans*), domestic dog (*Canis lupus familiaris*)* and cat (*Felis catus*)* (Packard 1956, Flyger & Gates 1982, Weigl *et al.* 1989).

In Great Britain, red foxes (*Vulpes vulpes*)*, pine marten (*Martes martes*)*, sparrowhawks (*Accipiter nisus*)* and tawny owls (*Strix aluco*)* occasionally prey on grey squirrels (*S. carolinensis*) and these predators could potentially also prey on *S. niger* (Genovesi & Bertolino 2006, Sheehy & Lawton 2014).

Concerning diseases and parasites in the native range, the larvae of bot flies (*Cuterebra emasculator*) parasitize squirrels in autumn when the subcutaneous myiases infest 5% of animals in Mississippi. Infections of mange mites (*Notoedres**, *Sarcoptes** and *Cnemidocoptes**) may result in death (Jacobson *et al.* 1979, Jacobson *et al.* 1981, Flyger & Gates 1982, Kazacos *et al.* 1983).

F/ Establishment capacity in Belgium

It appears that *S. niger* presents several characteristics suggesting a great invasiveness capacity; it is abundant in its native range, it takes benefits from human association (human commensal), it is able of securing and ingesting a wide range of food items, it is fast growing (and it is able to establish viable population from small starting populations(< 20 individuals), it has a broad native range, a high genetic variability and a high reproductive potential (sometimes 2 litters a year), it is highly adaptable to different environments (even human-impacted environments), it is highly mobile locally and disperses effectively, it is a habitat generalist, it has the ability to build nests, it is long lived (5-15 years), it is considered as invasive outside its native range (Success rates of introductions appear to be extraordinarily high) (Brown & McGuire 1975, Jameson & Peeter 1988, Koprowski 1994a, Koprowski 1994b, Layne 1997, Aprile & Chicco 1999, Long 2003, Geluso 2004, Palmer *et al.* 2007, Wood *et al.* 2007, Koprowski & Doumas 2012). Moreover, as mentioned above, climatic and habitats requirements seem appropriate for *S. niger* in Belgium.

Squirrels have been introduced worldwide, and have a higher establishment potential (90% of the species and 80.6% of the populations successfully established) than many other vertebrates (means

of respectively 50% and 60%) (Jeschke & Strayer 2005, Bertolino 2009). On a 44 North American introductions of *S. niger*, 37 resulted in an establishment with a large population increase, 2 resulted in an establishment with slight increase, 4 failed and 1 had unknown results (Bertolino 2009).
The likelihood that one pair of *Sciurus* species released in the wild would establish a new population is higher than 50% (The establishment likelihood increases proportionally to the number of individuals released (Bertolino 2009).

G/ Endangered areas in Belgium

This species prefers small patches of open woodland habitats with a great variety of large trees, but can be found in a wide array of different habitat types, natural or urbanized; that means nearly everywhere in the whole Belgium, except maybe in the maritime region and in some areas of dense species-poor forests of Ardenne.

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	**Environmental conditions for species establishment**[5]
Maritime	Suboptimal (except in urban parks)
Flandrian	Optimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Optimal (with some suboptimal areas)
Lorraine	Optimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

The fox squirrel is likely to easily establish self-sustaining populations in Belgium and neighbouring areas if introduced because this species has a high invasive capacity and because appropriate climatic conditions, habitats and food resources are encountered.

2.1.5 Dispersion capacity

Specify what is the rate of dispersal once the species is released or disperses into a new area. When available, data on mean expansion rate in introduced territories can be specified. For natural dispersion, provide information about frequency and range of long-distance movements (i.e. species capacity to colonise remote areas) and potential barriers for spread, both in native and in introduced areas, and specify if the species is considered as rather sedentary or mobile. For human-assisted dispersion, specify the likelihood and the frequency of intentional and accidental movements, considering especially the transport to areas from which the species may easily colonise unintended habitats with a high conservation value.

[5] For each district, choose one of the following options : optimal, suboptimal or inadequate.

A/ Natural spread

Home range

Males have larger home ranges (from 1.54 to 42.8 ha) than females (from 0.85 to 17.2 ha), the largest ones occurring in the south-eastern US (Geeslin 1970, Adams 1976, Hilliard 1979, Benson 1980, Weigl *et al.* 1989, Kantola & Humphrey 1990). Adults may defend an exclusive core area thereby limiting immigration, but territoriality is not evidenced and home range overlaps are frequent (Allen 1943, Havera & Nixon 1978, Benson 1980, Kantola & Humphrey 1990). Fox squirrels are gregarious only at the breeding season when females are in oestrus, but generally they don't stay together in non-breeding season (Fahey 2001).

Their densities vary from 0.04–0.12 individuals/ha in the south-eastern US to 1.0–12 individuals/ha in the mid-west (Baumgartner 1943b, Moore 1957, Koprowski 1985, Nixon & Hansen 1987, Kantola & Humphrey 1990). Some population densities of 25 individuals per hectare have been recorded but they are uncommon (Burt & Grossenheider 1976, Linzey *et al.* 2008).

Dispersal distance

There is a dispersal peak in autumn, when juveniles (and sometimes many adults too) move from their natal nests to find a new home range, males moving further than females (Allen 1943, Baumgartner 1943b, Koprowski 1985). Small scale migrations are observed, but rarely mass migrations (Schorger 1949). This species is able to spread over long distances, from both natural and introduced populations; the longest dispersal movement recorded is of 64 km (Allen 1943, King *et al.* 2010).

Expansion rate

S. niger is expanding its range westward in the central United States (Koprowski & Doumas 2012). To spread, it uses riparian corridors, riverine corridors of cottonwoods, fencerows of osage orange (Maclura pomifera), agricultural areas, urbanized areas (human-made constructions such as bridges or utility cables), newly cultivated areas with deciduous trees while some squirrels even cross waterways (Packard 1956, Wright & Weber 1979, Knapp & Swenson 1986, Jameson & Peeter 1988, Fitzgerald *et al.* 1994, Layne 1997, Geluso 2004, King *et al.* 2010). An estimated expanding rate of 0.44 to 3.44 km/year has been reported in Los Angeles county (King *et al.* 2010). This rate is comparable to the 0.22 km/year to 3.26-km/year rate of range expansion shown by the eastern gray squirrel *S. carolinensis* in Vancouver, British Columbia, Canada (Gonzales 1998) and 7.7 km/year for the same species introduced in Great Britain (Lloyd 1983).

Although adult fox squirrels can move for more than 1 km (0.62 miles) on occasion (Sheperd and Swihart 1995) most dispersal involves juveniles and subadults (Koprowski 1996; Nixon et al. 1974, 1986) during April and May or July through October as the young of the year and yearlings set out in search of a new home range (Thompson 1978). In Kansas, Koprowski (1996) found dispersal distances varying from 0.14 km to 3.5 km (0.09- 2.17 miles) for female and male fox squirrels respectively while the record movement for a fox squirrel is 64 km (39.9 miles) (Allen 1943). Individuals have also been known to return home from a distance of 4.5 km (2.8 miles) after experimental displacement (Hungerford and Wilder 1941). Perceptual range, i.e. the maximum distance from which an animal can perceive the presence of remote landscape elements such as patches of habitat, is 400 m, higher than in the invasive grey squirrel (300 m) (Zollner 2000).

B/ Human assistance

In addition to natural spread, to extend its range, *S. niger* may benefit from human assistance for introduction in several areas (UNEP-WCMC 2010). Moreover, intentional translocations have occurred in its native range to restore declining populations of some subspecies in certain parts of the US (Dawson *et al.* 2008).

DISPERSAL CAPACITY

As with the grey squirrel, the fox squirrel does easily spread in the environment. The dispersal capacity of juvenile away from their natal home range may exceed several tens of kilometers and expansion rates exceeding 3 km/year have been observed in North America. Because of its appeal, the species greatly benefits from human assistance for dispersion, by the way of deliberated or accidental releases in the wild.

2.2 EFFECTS OF ESTABLISHMENT

Consider the potential of the non-native organism to cause direct and indirect environmental, economic and social damage as a result of establishment. Information should be obtained from areas where the pest occurs naturally or has been introduced, preferably within Belgium and neighbouring areas or in other areas with similar eco-climatic conditions. Compare this information with the situation in the risk analysis area. Invasion histories concerning comparable organisms can usefully be considered. The magnitude of those effects should be also compared with those caused by their closest native relatives.

2.2.1 Environmental impacts

Specify if competition, predation (or herbivory), pathogen pollution and genetic effects is likely to cause a strong, widespread and persistent decline of the populations of native species and if those mechanisms are likely to affect common or threatened species. Document also the effects (intensity, frequency and persistency) the non-native species may have on habitat peculiarities and ecosystem functions, including physical modification of the habitat, change to nutrient cycling and availability, alteration of natural successions and disruption of trophic and mutualistic interactions. Specify what kind of ecosystems are especially at risk.

As no introductions of *Sciurus niger* are documented in Europe, the potential impacts of this species on native European fauna and flora are unknown, so the following environmental impacts are only based on the problems detected in its native range and other American recipient areas, thus mainly the United States. The same logic will be applied for the economic and social impacts.

A/ Competition

Invasive *S. niger* is generally considered as a potential threat to other American squirrel species such as the western gray squirrel (*S. griseus*), the eastern gray squirrel (*S. carolinensis*), the Douglas squirrel (*Tamiasciurus douglasii*) and the Abert's squirrel (*S. aberti*) because of **resource competition** (Ingles 1947, Robinson & McTaggart-Cowan 1954, Link 2004, Linders & Stinson 2007). Native squirrel species have declined because of outcompetition by *S. niger* in the region of Portland-Vancouver while in urban areas of Washington, fox squirrels have outcompeted native squirrels (Aubudon Society of Portland 2010, King County Biodiversity 2010). In the Black Forest of Colorado, the Abert's squirrel (*S. aberti*) suffered a population decline due to monopolization of resources by introduced *S. niger* (Littlefield 1984, Fitzgerald *et al.* 1994). On the other hand, by field manipulations (removal of female fox squirrels), Brown & Batzli (1985) have shown that local densities of sympatric fox and gray squirrels do not depend on a particular competition due to agonistic interactions but on food availability.

However, the coexistence or the population decline between native and invasive squirrel species highly depends on the environment quality (Van Der Merwe *et al.* 2005). Habitat overlap often occurs between *S. niger* and the eastern gray squirrel *S. carolinensis* (Armitage & Harris 1982). These two species are ecologically very similar: they have the same food preferences (nuts, insects, fungi, fruits, buds, flowers and bark) and use the same types of shelters (Smith & Follmer 1972, Korschgen 1981, Steele & Koprowski 2001). **Fox squirrel females displace gray squirrel ones from concentrated food sources during the breeding season but they can cohabit because the second ones are more efficient to find food**. As a confirmation, removal of *S. niger* females leads to only slight shifts in space use by eastern gray squirrel females (Brown & Batzli 1985a , Brown & Batzli 1985b). In fact, fox and gray squirrel coexistence is facilitated by a trade-off between managing the cost of predation and foraging efficiently (Van Der Merwe *et al.* 2005), environmental conditions sometimes favouring one of the species and vice versa. For example, the urban changes could possibly influence a direct competition between both species (Sexton 1990). In the suburb of Oak Park, the current trend shows an extension of gray squirrel distribution and a decrease of fox squirrel distribution because in areas of high food availability and low predator (cats and dogs) densities, gray squirrels are able to outcompete fox squirrels (Van Der Merwe *et al.* 2005).

Concerning what happens in Europe, in some areas, the American gray squirrel *S. carolinensis* has been introduced many times (particularly in Great Britain) and is responsible to drive the native European red squirrel *Sciurus vulgaris* to extinction by both competitive exclusion and squirrel poxvirus transmission (Gurnell *et al.* 2004b). The effect of an additional introduction of *S. niger* is questionable but a synergy between invasive species may exist. In the Netherlands, where free-ranging populations of *S. carolinensis* do not exist, a recent report considers the risk of large-scale displacement of native *S. vulgaris* by *S. niger* as potentially significant (Landbouw natuur en voedselkwaliteit 2009).

B/ Predation/herbivory

Through its feeding behavior, *S. niger* (as other squirrel species) **could possibly cause negative impacts on breeding birds**, however relevant evidences or impact levels of such predation have not been found in literature.

As in other tree squirrels species, *S. niger* influences significantly seed fates, tree demography and forest structure and composition. It acts both as a **seed predator** and a **seed disperser** (e.g. in oak, pine and walnut trees), across its native and introduced ranges. In pine forests of South-Eastern USA, the fox squirrel can have a devastating impact on seed crops (> 90%) through the consumption of flowers and seeds. Few studies have rigorously monitored seed losses in temperate deciduous tree forests but existing data suggest that predation rates are highly variable between years and may be less significant here than in conifer forests. However, tree squirrel impact on seed fate may be quite strong on some tree species like white oaks due to embryo excision and seed killing. This behaviour allows squirrels to store what is otherwise highly perishable food for up to 6 months. As a general principle, tree squirrel's impact is likely to be much more severe on tree species that doesn't have evolved seed protective measures (Burt & Grossenheider 1976, Koprowski 1994a, Steele *et al.* 2001, Steele *et al.* 2005, Steele 2008).

Bark-stripping due to *S. niger* is occasional (especially during times of food scarcity). It can affect different tree species like elms (*Ulmus sp*.) in Texas (Montgomery & Matlack 2010) and in Kansas (Packard 1956), cottonwood (*Populus sp*.) in Colorado (Yeager 1959), buckeye (*Aesculus glabra*) in Illinois (Havera *et al.* 1976). So far, the importance of damages is not well estimated but looks much less intensive than those produced by other tree squirrels (Palmer *et al.* 2007, Bertolino 2009). Montgomery & Matlack (2010) noticed that the elm bark was stripped by fox squirrels on branches of 2 to 8 cm of diameter and touched the entire circumference of the sections of branch. No bark stripping occurred on larger branches and trunks which might advocate for low levels of damages. In spring, the bark stripping stopped while tree buds were eaten.

It should be stressed, however, that the introduced Eastern grey squirrel is responsible for severe damage to the timber industry and forests in Great Britain and Ireland (Williams et al. 2010), although in its native range and even in Italy where the species is introduced, damages are limited (Kenward 1989).

C/ Genetic effects and hybridization

Hybridization of *Sciurus niger* with congeners is not known but probably non-existent, and even if fox squirrel males sometimes follow gray squirrel females in oestrus, copulation is not attempted (Moore 1968, Gurnell 1987, Koprowski 1991b).

D/ Pathogen pollution

Numerous diseases and parasites can be carried out and transmitted by the fox squirrel (see table 1), most of which already occur in Europe; co-introduction of new diseases or parasites is however not excluded (McCloskey & Vohs 1971, Flyger & Gates 1982, Krauss et al. 2003, Sukow et al. 2012).

Prevalence of West Nile virus, parasitic worms and ecto-parasites is often rather high within fox squirrel populations; on the contrary, prevalence of rabies, plague, and encephalitis is usually low. The establishment of populations of *S. niger* in Europe is likely to increase the prevalence of some of the listed diseases but the level of risk and the exact outcome for native species are difficult to predict (Weaver *et al.* 1997, Treml *et al.* 2002, Krauss *et al.* 2003, Walsh 2005, Suckow *et al.* 2012).

The raccoon roundworm (*Baylisascaris procyonis*) can also infect *S. niger* as an intermediate host, like in Indiana and California (Samuel 2001). Most of the time, the infection leads to squirrel death but the dead host can especially be infecting for scavenging carnivores, which could also be at risk in Europe due to the presence of the invasive *Procyon lotor*.

Table 1 – Main diseases and parasites carried out by the fox squirrel. Different types of diseases are listed: virus, bacteria (bact.), fungi, endo- (endo.) and ecto-parasites (ecto.). Disease prevalence in North America is specified when information is available. After: (1) Cappuci et al. 1972, (2) Kirkwood 1931, (3) Leitheser 2013, (4) Root et al. 2006, (5) Salked et al. 2008, (6) Samuel 2001, (7) Treml et al. 2002, (8) Walsh 2005 and (9) Weaver et al. 1997.

Disease name	Scientific name	Type	Zoonotic	Prevalence	References
Rabies	-	Virus	Y	Rare	(1), (3)
West Nile Virus	-	Virus	Y	Frequent	(3), (4)
Squirrel fibromatosis	-	Virus	N	-	(3)
California encephalitis	-	Virus	Y	-	(3)
Western equine encephalitis	-	Virus	Y	-	(9)
St Louis encephalitis	-	Virus	Y	Rare	(3)
Tularemia	*Francisella tularensis*	Bact.	Y	Rare	(2), (3)
Plague	*Yersinia pestis*	Bact.	Y	Rare	(3), (8)
Leptospirosis	*Leptospira grippotyphosa*	Bact.	Y	-	(7)
Lyme disease	*Borrelia burgdorferi*	Bact.	Y	Rare	(5)
Dermatophytosis	*Sporothrix schenckii*	Fungi	Y	-	(3)
Squirrel bot fly	*Cuterebra emasculator*	Endo.	N	-	(3)
Raccoon roundworm	*Baylisascaris procyonis*	Endo.	Y	Frequent	(6)
Acanthocepala worm	*Moniliformis clarki*	Endo.	Y	Rare	(3)
Tape worm	*Raillietina bakeri*	Endo.	N	-	(3)
Parasitic roundworms	*Strongyloides robustus, Heligmodendrium hassalli*	Endo.	N	Frequent	(3)
Squirrel flea	*Orchopeas howardii*	Ecto.	-	Frequent	(3)
Lice	Several species	Ecto.	-	Frequent	(3)
Ticks	*Amblyomma americanum, Ixodes scapularis*	Ecto.	-	Frequent	(3)
Mites	*Atricholaelaps sigmodoni, Androlaelaps casalis*	Ecto.	-	Frequent	(3)

E/ Effects on ecosystem functions

Sciurus niger is a scatterhoarder burying seeds (nuts) to have food stocks during winter (Koprowski 1994a). Fox squirrel plays a role of seed disperser, particularly in open grasslands where it facilitates natural succession from grassland to forest (Stapanian & Smith 1986, Cahalane 1942). Even if a small part of seed caches may sometimes remain forgotten by *S. niger* (1 to 67 %) these seeds may sprout where hidden, thus fox squirrel partly shapes the forest composition (Cahalane 1942, Stapanian & Smith 1984). Its consumption of tree seeds may also have an impact on forest structure and composition (see above).

ENVIRONMENTAL IMPACTS

Based on impacts observed in the United States, it is very likely that the establishment and spread of *Sciurus niger* in Belgium and neighbouring areas will outcompete the native squirrel species (*Sciurus vulgaris*). It is also likely that it will affect the reproduction of some tree species, enhance the prevalence of some diseases and parasites and favour their transmission to the native fauna.

2.2.2 Other impacts and ecosystem services

A/ Economic impacts

Describe the expected or observed direct costs of the introduced species on sectorial activities (e.g. damages to crops, forests, livestock, aquaculture, tourism or infrastructures).

Fox squirrels are responsible of crop damages, but generally only at a local scale. They may cause problems by feeding on corn, pecan, English walnut, avocado, orange and strawberry crops but losses are normally moderate (Wolf & Roest 1971, Burt & Grossenheider 1976, Flyger & Gates 1982, Gurnell 1987, Koprowski 1994a, King *et al*. 2010). However, in some areas, they were added to agricultural pest lists due to stronger damages, e.g. in pecan orchards (Salmon *et al.* 2005, Frey *et al.* 2013).

They are also considered as nuisance species because of their raiding for food in gardens, and on bird food during winter (Fahey 2001). Electric cables can also be damaged because fox squirrels use them as routes of travel and this may sometimes cause power outages (Koprowski 1994a, Fahey 2001, Bertolino 2009). Some damage to gardens, buildings, irrigation systems and phone lines have also been reported (Jackson 1994, Koprowski 1994a, Salmon *et al.* 2005).

B/ Social impacts

Describe the expected or observed effects of the introduced species on human health and well-being, recreation activities and aesthetic values

Under experimental conditions, the fox squirrel has been identified as a potential vector of the oak wilt fungus *Ceratocystis fagacearum.* This fungus may kill trees in ornamental and production plantations; it is known to be especially detrimental in urban areas. The exact role of the squirrel in fungus epidemiology is however unknown (Himelick & Curl 1955, CABI & OEPP 2011).

S. niger could also play a reservoir function for two zoonotic diseases transmitted by mosquitoes and currently absent from Belgium, i.e. the West Nile Virus and Western Equine Encephalitis; both viruses may strongly affect human and horse health. It has been also involved in the transmission of tularemia an other zoonotic diseases to humans in North America due to its capacity to thrive in urban areas (Root 2006, CFSPH 2008, Leitheiser 2013).

Squirrels are often released in or near urban areas such as parks, where they could benefit from supplementary feeding by humans and become an aesthetic value, making removal more complicated (Anonymous 2013).

C/ Impacts on ecosystem services

Describe the expected or observed positive and negative effects of the introduced species on ecosystem services. Please consider as far as possible provisioning, regulation and cultural services

The fox squirrel may moderately affect the provisioning of wood and fruits in forested and orchard areas due to seed consumption. This service may be further jeopardized in case of transmission of the oak wilt disease (see above).

It also plays a role in regulating services through seed dispersion, the positive or negative consequence of which is difficult to assess. It may influence e.g. ecological successions in extensive areas along wood margins.

D/ Socio-economic benefits

Describe the known socio-economic benefits derived from the use of the introduced species

There is no real socio-economic benefit derived from the use of the fox squirrel as a pet species in Belgium as holding possibilities are already limited by the animal welfare regulation (Royal Decree of 16th July 2009). However, it may be rarely hold as a pet in other European countries (Dijkstra & Dekker 2008, UNEP-WCMC 2010).

OTHER IMPACTS AND ECOSYSTEM SERVICES

The fox squirrel is very likely to cause moderate to strong socio-economic impacts due to local agricultural and silvicultural damages as well as disease transmission to trees, horses and humans. It is therefore likely to impair forest and orchard provisioning services and affect regulating services as a result of disease transmission.

2.3 SUMMARY, RISK SCORING AND CONFIDENCE LEVEL

Provide the environmental risk score based on the default options of the online version of the Harmonia+ protocol, together with level of confidence for each individual module.

The information provided in this report is used to calculate the species's environmental risk score based on the default scoring of the Harmonia+ protocol (D'hondt et al. 2015) (table 2). **This risk score is assessed as high, with a medium level of confidence**. It is assumed that the fox squirrel may easily invade Belgium once introduced in the country because its establishment and spread capacities are rather high. Its potential impact on biodiversity is assessed as moderate.

Table 2 - Environmental risk for *Sciurus niger* assessed at the Belgian scale using the Harmonia+ protocol (D'hondt *et al.* 2015).

Module	Score	Level of risk*	Level of confidence
Introduction	0.33	Low	High
Establishment	1.00	Very high	High
Spread	0.63	High	Medium
Environmental impact	0.54	Medium	Medium
ENVIRONMENTAL RISK	0.32	HIGH	MEDIUM

* five risk categories are defined from the *Harmonia*+ scoring in each module, considering 20th, 40th, 60th and 80th percentiles of the frequency distribution generated by 10 000 random simulations as class boundaries (D'hondt *et al.* 2015).

STAGE 3 : RISK MANAGEMENT

The decision to be made in the risk management process will be based on the information collected during the two preceding stages, e.g. reason for initiating the process, estimation of probability of introduction and evaluation of potential consequences of introduction in Belgium. If the risk is found to be unacceptable, then possible preventive and control actions should be identified to mitigate the impact of the non-native organism and reduce the risk below an acceptable level. Specify the efficiency of potential measures for risk reduction.

3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM

The relative importance of intentional and unintentional introduction pathways mediated by human activities should be compared with the natural spread of the organism. Make use e.g. of information used to answer to question 2.1.3.

The most probable pathway of entry and establishment of *Sciurus niger* in Belgium could be due to deliberate releases of individuals in the wild by people who bought them on websites or in pet shops (Dijkstra & Dekker 2008, UNEP-WCMC 2010). Since feral populations do not exist in Europe, the entry in Belgium by a natural spread from neighbouring countries is not expected (Bertolino 2009, UNEP-WCMC 2010).

3.2 PREVENTIVE ACTIONS

Which preventive measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially (i) the restrictions on importation and trade and (ii) the use of specific holding conditions and effect of prohibition of organism introduction into the wild.

(i) Prohibition of organism importation, trade and holding

There are no official trade statistics concerning *Sciurus niger* in Europe, only an Internet survey to estimate the trade and demand for this species as pet (UNEP-WCMC 2010). As a precautionary approach, Bertolino (2009) advises the ban of all squirrels from pet trade but it is not legitimate to adopt a general position concerning all squirrel species when we do not have enough evidences about their specific impacts. At least, we could recommend to ban the trade and importation of *Sciurus niger* according the risk assessment performed. In November 2009, due to isolated observations of *S. niger*, the Netherlands banned the trade and possession of fox squirrel (with two other squirrel species) under the Flora and Fauna Act, but this interdiction may take some time to come into force (Landbouw natuur en voedselkwaliteit 2009, Staatsbosbeheer 2009).

In Belgium, fox squirrel holding possibilities are already limited nowadays as this species is not included in the short positive list of mammal species established in the framework of the animal welfare regulation (Royal Decree of 16th July 2009).

In the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), in the periodic revision of the Annexes, the European Union adopted also the inclusion of three invasive or potentially invasive alien pet species of squirrels, including *Sciurus niger* (UNEP/CBD/AHTEG-IAS 2011), as advised by Bertolino & Lurz (2013).

(ii) Use of specific holding conditions and effect of prohibition of organism introduction into the wild

Squirrels imported by the way of pet markets, private citizens and zoos are at risk of releases or escapes from captivity (Bertolino 2009). Use of stricter rules on importation and possession is thus the most desirable approach to prevent unwanted introductions in the wild, followed by eradication actions or long-term containment or control (Shine *et al.* 2008, Bertolino 2009).

3.3 CONTROL AND ERADICATION ACTIONS

Which management measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially the following questions.

(i) Can the species be easily detected at early stages of invasion (early detection)?

Fox squirrels are diurnal (and often abundant when established), so this facilitates their observation (Van Der Merwe *et al.* 2005). Some nest boxes for fox squirrel, which attract individuals looking for temporary shelters or building long term nests, can be used to (i) detect the presence or monitor the range expansion in the colonizing process of new areas (ii) evaluate the success of an eradication effort (Brown & McGuire 1975, Koprowski & Doumas 2012). Photo traps, hair tubes and snares collecting hairs can also be helpful to determine the presence of fox squirrels in areas possibly threatened by colonization by neighbouring population spread (Gurnell *et al.* 2004a, S. Bertolino personal communication). Finally, some transect surveys can be realized in forests in or near sites of introduction to determine fox squirrel densities and distributions (Brown & McGuire 1975, Koprowski *et al.* 2005, Koprowski *et al.* 2006).

(ii) Are they some best practices available for organism local eradication?

S. niger is reported to be often classified among pest species, and can be legally killed without a hunting license or permit in some parts of the United States (Link 2004, Salmon *et al.* 2005). Several kinds of traps and shooting can be used to control existing populations (Jackson 1994, Link 2004, Salmon *et al.* 2005).

In the native range, live-traps placed near large trees are used (with bait as peanuts, peanut butter, corn, sunflower seeds or nuts) to catch problematic squirrel individuals and release them several kilometers away (Flyger & Gates 1982) which would not be a solution in European countries (necessary removal of individuals). Pre-baiting for several days may increase trap success as well as trap use in winter and spring (Baumgartner 1940, Brown & Batzli 1985a, Koprowski 1985). In Europe, because of the presence of *Sciurus vulgaris*, it is advised to check the traps twice a day to avoid excessive stress or death of native animals (S. Bertolino, personal communication).

Chemical repellents and sound frightening were tested but have apparently little success (Salmon *et al.* 2005). To prevent social impacts on humans, some repellents exist to keep away fox squirrels from holes in wooden walls and roof shingles, such as paradichlorobenzene or naphthalene under moth ball or crystal forms (Koprowski 1994a). Moreover, methyl nonyl ketone crystals and paradichlorobenzene are used to repel fox squirrels from garden and property borders, but their effectiveness is questionable (Jackson 1983). Gnawing of plant stems or tree bark may be reduced with the application of tetramethylthiuram disulfide (Koprowski 1994a).

However, there have been no widespread efforts to eradicate *S. niger* from areas where it has been introduced (Koprowski & Doumas 2012).

In Great Britain, *S. carolinensis* has been subject to wide control and eradication methods such as trapping, shooting and poisoning (Dagnall *et al.* 1998, Palmer *et al.* 2007). Although a high number of gray squirrels killed, the hunting program was ended because squirrel populations had not been reduced to a manageable level, the problem is even suggested to have grown worse despite the effort (Sheail 1999, Palmer *et al.* 2007). However, it is not known if the removal of so many individuals has slowed their population expansion (Palmer *et al.* 2007). The poisoning program, even though believed to be more efficient for squirrel control, has been confronted with pressure from animal right groups (Dagnall *et al.* 1998, Sheail 1999).

(iii) Do eradication and control actions cause undesirable consequences on non-target species and on ecosystem services?

No undesirable consequence on other species or ecosystem services has been found in literature sources as no real eradication efforts have been done to eliminate *Sciurus niger*. But we may consider that if trapping efforts had to be done to remove free-ranging *S. niger* in Europe, it would be necessary to take into account the presence of *S. vulgaris* in the wild checking the traps twice a day to avoid excessive stress or death of native animals.

For the same reason, and because other non-target protected species could suffer from it, it is obvious that poisoning should be avoided to control any introduced fox squirrel population unless with the use of selective device in countries where this is allowed.

(iv) Could the species be effectively eradicated at early stage of invasion?

As already mentioned, there have been no significant efforts to eradicate *S. niger* from areas where it has been introduced (Koprowski & Doumas 2012). However, populations can survive to a hunting loss of less than 40%, while only immigration would allow a population to sustain with an 80% loss (Nixon *et al.* 1974, Nixon *et al.* 1975). Thus, theoretically, if a collective effort between regions or countries is well coordinated, it seems possible to eradicate the problematic fox squirrel populations, especially at early stage of invasion, since few immigration from other populations is possible.

(v) If widely widespread, can the species be easily contained in a given area or limited under an acceptable population level?

Free-ranging fox squirrel populations are difficult and costly to control, and management actions are rarely successful when populations are already widespread (Koprowski & Doumas 2012). Several methods may be attempted to reduce fox squirrel numbers, such as shooting, poisoning (where allowed in Europe and taking into account risks for non-target species), trapping, manipulation of the physical environment (by managing forests), and surgical sterilization (Dagnall *et al.* 1998; Anonymous 2013). Some capture-mark-recapture or indirect methods may be useful to monitor population densities (Nixon *et al.* 1984, Koprowski 1985, Hansen *et al.* 1986).

CONCLUSION OF THE RISK MANAGEMENT SECTION

The most likely entry pathway of fox squirrel in Belgium is escape or release from captive breeding. The prohibition of fox squirrel importation, trade and holding could therefore be considered as an efficient measure for reducing the risk of entry to an acceptable level. As a transitional measure, drastic security rules including ear-tagging and systematic sterilization combined with an official surveillance system and the obligation to rapidly report any escape should be imposed for fox squirrels already kept in captivity.

Those preventive measures have to be preferred over early detection and population control as the fox squirrel may easily establish feral populations after escape. Eradication actions are only possible at the very beginning of the invasion process and are difficult to implement because of species low detection rate at low densities, rapid expansion from the release site when suitable ecological conditions are met and possible strong public opposition towards killing actions.

STAGE 4 : IDENTIFICATION OF AREAS AT RISK IN EUROPE UNDER CURRENT AND FUTURE CLIMATES

In North America, the geographic distribution of the fox squirrel closely matches those of temperate oceanic, temperate continental and subtropical humid forests; it is less frequently observed in mountain systems and avoids conifer-dominated boreal forests (Allen 1982, Tesky 1993, Patterson et al. 2003). When transposing this to the European forest types, one may consider that its establishment capacity is currently optimal for Atlantic, Black Sea, continental, Mediterranean, pannonian and steppic regions, suboptimal for the alpine areas in Central Europe and inadequate in boreal and alpine areas in Northern Europe (see figure 2). It is not excluded that the species may also establish in some forest ecosystems of the Baltic countries as they include temperate elements and broadleaved trees although included in the boreal bio-geographic area as defined by the European Environmental Agency.

Climate change may potentially facilitate the establishment of *S. niger* in the alpine and boreal bio-geographical regions of Europe as a consequence of the expansion of the distribution of acorn, mast and nut producing trees and an increase in tree functional diversity in those areas (Allen 1982, Nixon & Hansen 1987, Thuillier *et al.* 2006, Lindner *et al.* 2010).

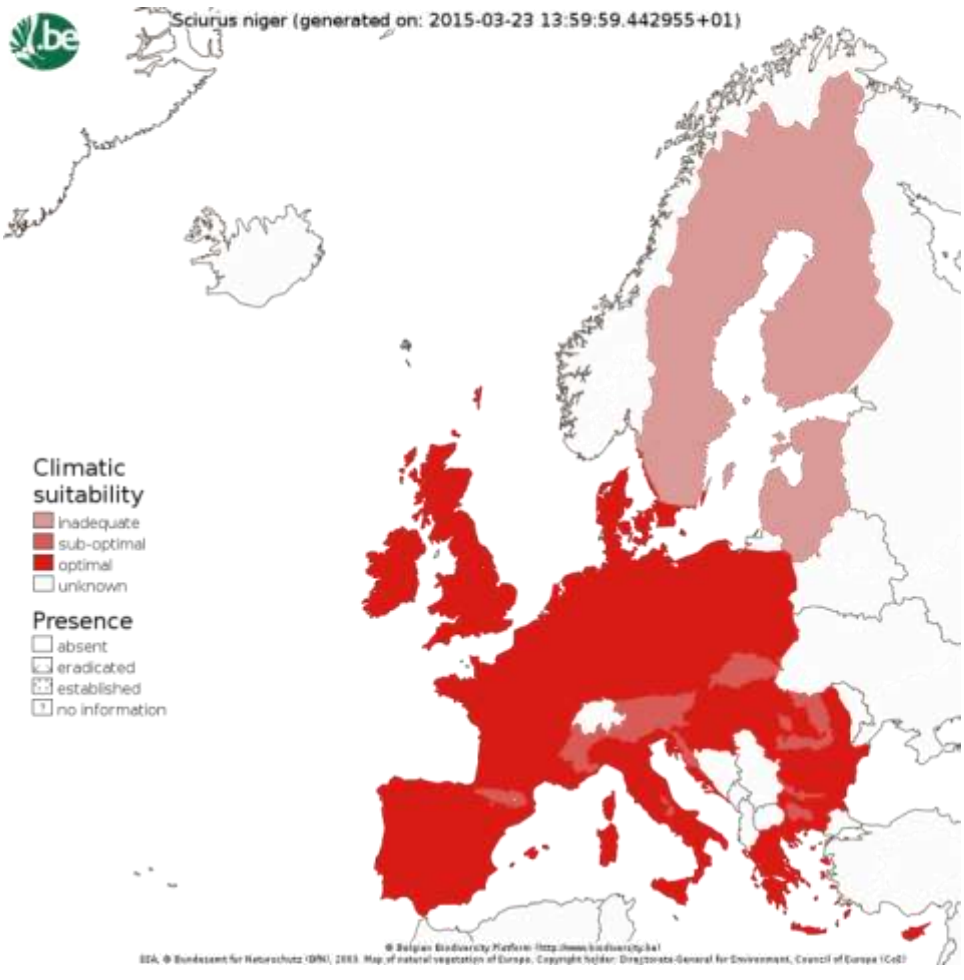

Figure 2 - Identification of the bio-geographic regions at risk for the establishment of *S. niger* in Europe based on eco-climatic preferences extrapolated from distribution in its native range.

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Espèces invasives

La CiEi est chargée depuis novembre 2009 de coordonner les actions visant à limiter les dommages causés par les espèces invasives en Wallonie. Ses activités se fondent sur l'engagement du Gouvernement wallon à prévenir l'installation de nouvelles espèces invasives et de lutter contre celles dont la prolifération pose problème

http://biodiversite.wallonie.be/invasives
Email : invasives@spw.wallonie.be

DIRECTION GÉNÉRALE OPÉRATIONNELLE DE L'AGRICULTURE, DES RESSOURCES NATURELLES ET DE L'ENVIRONNEMENT
Département de l'Etude du Milieu naturel et agricole
Direction de la Nature et de l'Eau
Avenue de la Faculté, 22
5030 GEMBLOUX
BELGIQUE
Tél. : + 32 81 620 420 – Fax : + 32 81 615 727
http://biodiversite.wallonie.be
http://environnement.wallonie.be
http://agriculture.wallonie.be

SPW n° vert : 0800 11 901 – Internet : www.wallonie.be