Risk analysis report of non-native organisms in Belgium

SPW | Éditions

RAPPORTS - ETUDES

Ressources naturelles

Risk analysis of the sika deer

Cervus nippon

(Linnaeus 1758)

Wallonie

Université de Liège

Risk analysis of the sika deer *Cervus nippon* (Linnaeus 1758)

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

[1] Unité de Zoogéographie, Université de Liège

[2] Cellule interdépartementale Espèces invasives, Service Public de Wallonie

Adopted in date of:	11th March 2013
Reviewed by :	Roseline Beudels-Jamar (RBINS), Jim Casaer (INBO) & Alain Licoppe (DEMNA)
Produced by:	Unité de Zoogéogaphie/Université de Liège & Cellule interdépartementale Espèces invasives (CiEi)/DEMNA/DGO3
Commissioned by:	Service Public de Wallonie
Contact person:	etienne.branquart@spw.wallonie.be

This report should be cited as : "Baiwy, E., Schockert, V. & Branquart, E. (2013) Risk analysis of the sika deer, Cervus nippon, Risk analysis report of non-native organisms in Belgium. Cellule interdépartementale sur les Espèces invasives (CiEi), DGO3, SPW / Editions, 38 pages.

Contents

Acknowledgements

The author wishes to thank the reviewers who contributed to this risk analysis with valuable comments and additional references: Roseline Beudels-Jamar (RBINS), Jim Casaer (INBO) & Alain Licoppe (DEMNA). They are also very grateful to Rory Putman for helpful comments and data.

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

[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).

important to realise that this risk assessments exercise is carried out by (an) independent expert(s) 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 (EXPOSURE)

Entry in Belgium	Casual observations of sika deer were reported from different localities in Belgium during recent years but establishment is considered as unlikely so far. The most probable pathway of sika deer entry in Belgium is the accidental/deliberated releases of individuals from deer parks and, secondarily, the natural spread of individuals from neighbouring countries.
Establishment capacity	Providing that enough founder individuals are encountered, the sika deer is likely to establish easily self-sustaining populations in most of Belgium because appropriated climatic conditions, habitats and food are encountered and native natural enemies and diseases are unlikely to affect very much its fitness. High population densities are likely to occur in Kempen and in the Southern part of the country.
Dispersion capacity	The sika deer can easily spread naturally beyond introduction points and has a moderate range expansion capacity (3-5 km per year) providing that suitable wooded habitats are present in the landscape. This rate of expansion is likely to be locally enhanced as a result of human translocation and illegal introduction into the wild.

EFFECT OF ESTABLISHMENT

Environmental impacts	It is very likely that the establishment of sika deer in Belgium will result in an increase of the biomass and density of deer per hectare and will produce strong negative impacts on native vegetation through overgrazing, especially on acidic soils. It could also cause the local decline of native deer species, favour disease transmission to native ungulates and induce extensive hybridization with the red deer*. During irruptive events, a degradation of the conservation status of ecosystems is also expected to occur locally (alteration of vegetation, inhibition of tree regeneration, soil trampling, etc.).

RISK MANAGEMENT

Because of the large distances to be travelled, a natural expansion of sika feral populations from Germany or France is unlikely to cause arrival and establishment in Belgium in the coming years. However, establishment due to escape from private deer parks is much more likely to occur. The prohibition of sika deer importation, trade and holding could therefore be considered as an efficient measure for reducing the risk of entry to an acceptable level. To reach this goal, it is suggested to withdraw the sika deer from the positive list of mammals that are allowed to be hold by private owners in Belgium and to discourage sika deer farming activities. Where deer parks are already present and have to be maintained, escape and establishment risk can be reduced through the adoption of drastic security measures including ear-tagging and systematic sterilization of captive deer combined with an official surveillance system and the obligation to rapidly report any escape.

Those preventive measures have to be preferred over early detection and population control as the sika deer may easily establish feral populations after escape. It is a very discreet animal that is difficult to cull and has the capacity to establish rapidly hybrid populations. So far, no sika population has been extirpated through eradication actions. A successful density control is difficult to achieve and cannot be reached without an intensive coordinated approach involving well trained hunters that support the management goal. A further awareness raising among the hunting community and education on the possible negative consequences of the presence of the species will be essential to reach this purpose.

Résumé

PROBABILITE DE NATURALISATION ET DE DISSEMINATION DANS L'ENVIRONNEMENT

Introduction en Belgique	Des observations ponctuelles de cerfs sika ont été rapportées dans diverses localités belges au cours de ces dernières années mais sa naturalisation reste jusqu'ici considérée comme peu probable. Les vecteurs d'introduction les plus probables en Belgique sont la libération accidentelle ou délibérée d'individus à partir de parcs animaliers et, dans une moindre mesure, sa dispersion naturelle à partir de populations férales établies dans les pays voisins.
Capacité de naturalisation	A condition de rassembler suffisamment d'individus fondateurs, le cerf sika pourrait facilement établir des populations pérennes dans la majeure partie de la Belgique étant donné qu'il peut y trouver des conditions climatiques, des habitats et des ressources alimentaires adaptés à ses besoins. Il est peu probable que sa naturalisation puisse être entravée par des ennemis naturels ou des maladies. Des densités élevées pourraient même être localement observées en Campine et dans le sud du pays.
Capacité de dissémination	Une fois introduit, le cerf sika se disperse facilement et il affiche une capacité d'expansion modérée (de 3 à 5 km par an) lorsqu'il trouve une densité suffisante de milieux forestiers. Cette capacité d'expansion pourrait être localement accrue par le transport et l'introduction illégale d'animaux dans la nature.

EFFETS DE LA NATURALISATION

Impacts environnemen-taux	Il est très probable que l'établissement du cerf sika en Belgique conduise à une augmentation de la densité de cervidés et se traduise par des dommages importants à la flore indigène par le biais du surpâturage, surtout sur les sols acides. Cette naturalisation pourrait aussi entraîner le déclin de cervidés indigènes, favoriser la transmission de maladies aux ongulés et mener à la formation d'une population hybride avec le cerf élaphe* On s'attend aussi à ce que son développement provoque localement une dégradation de l'état de conservation des écosystèmes (altération de la végétation, compaction des sols, etc.).

GESTION DU RISQUE

Etant donné les distances importantes qui devraient être parcourues par le cerf sika à partir de ses populations férales établies en Allemagne ou en France, il est peu probable que cette espèce puisse coloniser la Belgique dans les prochaines années au travers d'un processus naturel d'expansion. Par contre, un établissement lié à l'évasion ou au relâchement d'individus à partir de parcs animaliers est beaucoup plus probable. L'interdiction d'importer, de vendre et de détenir le cerf sika pourrait donc être considérée comme une mesure permettant de réduire le risque d'introduction à un niveau acceptable.

Pour atteindre cet objectif, il est suggéré de retirer le cerf sika de la liste positive des mammifères qui sont autorisés à la détention par des particuliers en Belgique et de décourager les activités d'élevage du cerf sika. Là ou des parcs animaliers existent déjà et doivent être maintenus, le risque d'évasion et d'établissement peut être réduit par l'adoption de mesures de sécurité draconiennes comprenant e.a. le marquage d'oreille et la stérilisation systématique des animaux captifs, combinées à un système de surveillance officiel et à une obligation de notification rapide de toute évasion.

Etant donné que le cerf sika est capable de développer facilement des populations sauvages à partir des individus qui s'échappent, les mesures de prévention doivent être préférées aux mesures de détection précoce et de contrôle des populations. Il s'agit d'un animal très discret, difficile à abattre et qui a la capacité d'établir rapidement des populations hybrides. Un contrôle efficace de la densité est difficile à réaliser et ne sera pas possible sans une approche intensive et coordonnée ainsi que l'implication de chasseurs bien entraînés qui partagent les objectifs de gestion. La sensibilisation des conseils cynégétiques aux nuisances produites par le cerf sika sera essentielle pour atteindre cet objectif.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

Introductie in België	Hoewel er de afgelopen jaren op verschillende plaatsen in België sporadisch sikaherten waargenomen werden, is het tot dusver vrij onwaarschijnlijk dat de soort zich heeft gevestigd. De meest waarschijnlijke introductieweg voor het sikahert in België is het ontsnappen en/of opzettelijk uitzetten van individuen uit hertenparken, gevolgd door de natuurlijke verspreiding van individuen vanuit de buurlanden.
Vestigings-vermogen	Gesteld dat er voldoende individuen ergens aanwezig zijn, is de kans vrij groot dat het sikahert overal in België populaties kan vormen. De klimaatomstandigheden, habitats en het aanwezige voedsel laten toe dat de soort perfect in zijn noden kan voorzien. Bovendien heeft de soort weinig natuurlijke vijanden of ziekten te duchten. Zowel in de Kempen als in het zuiden van het land zouden de populatiedensiteiten hoog kunnen oplopen..
Verspreidings-vermogen	Het sikahert kan zich door natuurlijke dispersie ver buiten de introductiepunten verspreiden; de soort vertoont een eerder matige capaciteit om zijn leefgebied te verruimen (3-5 km per jaar) op voorwaarde dat er geschikte boshabitats in de omgeving aanwezig zijn. De snelheid van expansie kan plaatselijk verhogen door menselijke translocaties en (verboden) introducties in het wild.

EFFECTEN VAN VESTIGING

Milieu-impact	Vestiging van het sikahert in België zal wellicht leiden tot een toename van de biomassa en densiteit aan herten per hectare. Boven bepaalde drempelwaardes kan dit nadelige gevolgen hebben op inheemse vegetaties door overbegrazing, vooral op zure bodems. Verder zou dit ook een plaatselijke reductie van inheemse hertensoorten, overdracht van ziektes op inheemse hoefdieren en hybridisatie met edelhert kunnen veroorzaken. Een populatie-explosie zou plaatselijk ook kunnen leiden tot een verarming van ecosystemen (verandering van de vegetatie en successie, afremmen van de natuurlijke regeneratie van bomen, bodemverdichting, enz.).

RISICOBEHEER

Door de grote afstand is het weinig waarschijnlijk dat het sikahert via natuurlijke expansie van verwilderde populaties vanuit Duitsland of Frankrijk België zal bereiken en er populaties kan vestigen. Ontsnappingen uit hertenparken van particulieren vormen een grotere dreiging. Een verbod op de invoer, verkoop en het houden van sikahert kan dan ook beschouwd worden als een efficiënte maatregel om het risico op introductie tot een aanvaardbaar niveau terug te brengen. Om dit doel te bereiken wordt voorgesteld om het sikahert van de positieflijst zoogdieren die door particulieren in België voor niet-productiedoeleinden mogen worden gehouden te verwijderen en om het fokken van sikaherten te ontmoedigen. Voor reeds bestaande hertenparken moeten drastische veiligheidsmaatregelen het risico op ontsnapping en vestiging terugdringen; die kunnen bestaan in het oormerken en systematisch steriliseren van herten in gevangenschap, gecombineerd met een officieel toezichtsysteem en de onverwijlde meldplicht bij ontsnappingen van dieren.

Preventieve maatregelen dienen de voorkeur te krijgen boven een vroege detectie en populatiecontrole;, Na ontsnapping kunnen zich immers snel populaties van het sikahert vestigen. Het sikahert is een erg schuw dier dat moeilijk te detecteren valt en dat heel snel hybride populaties kan vestigen . Tot dusver is men er nog niet in geslaagd om sikahert populaties volledig uit te roeien . Populaties controleren is een moeilijke opdracht en kan nooit plaatsvinden zonder een intensief gecoördineerde benadering waarbij goed opgeleide jagers betrokken worden die het beheerdoel ondersteunen. Een verdere bewustmaking onder de jagersgemeenschap en het verspreiden van informatie over de mogelijke negatieve gevolgen van de aanwezigheid van de soort zullen absoluut noodzakelijk zijn om dit doel te bereiken.

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: *Cervus nippon* Temminck, 1838
Common name: Sika Deer (GB), Sikahert (NL), Sikahirsch (DE), Cerf Sika (FR)
Taxonomic position: Chordata (Phylum) > Mammalia (Class) > Artiodactyla (Order) > Cervidae (Family).

Note: The sika deer (*Cervus nippon*) is an important member of the native fauna in eastern Asia, and it has been widely introduced into many parts of the world. Although it hybridizes with red deer and wapiti (*Cervus elaphus*), which are their closest relatives, most taxonomists accept that sika constitute a valid species. The species is extremely polytypic with extensive variation in size and colours between populations. How to divide the species in different subspecies is the subject of an ongoing debate. Recent studies of sika deer mitochondrial DNA show that the species is split broadly into a northern and a southern type in the native range. In the south they are relatively small in body size, they are non-migratory and non-winter adapted. In the northern part of their range, conversely, they have larger body size, they use mountainous areas, migrate from low-elevation winter areas to high-elevation summer areas, and are adapted to winter conditions (Mitchell-Jones *et al.* 1999, McCullough 2009).

Animals imported in Europe mainly originated from Asian captive populations, where there is a long tradition of human manipulation through farming, artificial selection and translocation. It is therefore very complex to determine which subspecies was/were introduced in Europe (Groves 2005, Harris 2008, Bartos 2009). Populations established in Europe are polymorphic as they originate from different parts of its native range, Japan acting as the main donor area for Great-Britain (Mitchell-Jones *et al.* 1999, Goodman *et al.* 2001, Diaz *et al.* 2006, Perez-Espona *et al.* 2009).

In Europe, almost all feral populations of sika are to some degree hybrid with the red deer* (Bartos 2009, Swanson & Putman 2009). The extend of genetic introgression may depend on local hybridization events and circumstances and is therefore unknown in many situations. Information provided hereafter dealing with invasion history, spread capacity and impacts observed in European countries will consequently refer to sika-like hybrids (sika phenotype) rather than true sika (pure sika genotype).

1.2 SHORT DESCRIPTION

Sika deer are designed as small to medium-sized deer, with a height at shoulder of 0.64-1.09 meter (Feldhamer 1980, Nowak 1991). Adult males are on average 8.7% larger than females (Feldhamer 1980, Nowak 1991, Genovesi & Putman 2006). Their summer coat is chestnut or fawn, marked with distinct white spots (Genovesi & Putman 2006). To compare, red deer (*Cervus elaphus*)* are larger (weigh approximately twice as much than sika deer), typically around 30 cm taller at the shoulder (0.75-1.5 meter high at the shoulder), and red males can grow antlers of 12 points or more, while sika male antlers rarely exceed eight points (Sensman 2002, Harris & Yalden 2008, Senn *et al.* 2010).

1.3 ORGANISM DISTRIBUTION

Native range

The native range of *Cervus nippon* is Eastern Asia, and it spreads on South Eastern Siberian up to Vietnam, including far East Russia, China (Manchuria, Formosa-Taiwan), Japan, Korea (Flerov 1952, Feldhamer 1980, Nowak 1991, Pascal *et al.* 2003, Genovesi & Putman 2006). Some subspecies of sika deer are very threatened or possibly extinct (due to habitat loss and hunting, particularly in Vietnam, China, and Korea), some are stable (Taiwan, Russia), while other increase as it is the case in Japan (Harris 2008).

Introduced range

Belgium:	The species is not established in Belgium but casual observations have been reported recently.
Rest of Europe:	Extensive naturalised populations of sika deer are established in Czech Republic, Germany, Ireland and United Kingdom. Small and local populations also occur in Austria, Denmark, Estonia, Finland, France, Lithuania, Hungary, Poland, Switzerland, Ukraine (Harris *et al.* 1995, Mitchell-Jones *et al.* 1999, Pascal *et al.* 2003, Genovesi & Putman 2006, Harris 2008, Pérez-Espona *et al.* 2009, Appolonio *et al.* 2010).
Other continents:	Established in Madagascar, New Zealand, Philippines and the USA (Harris 2008).

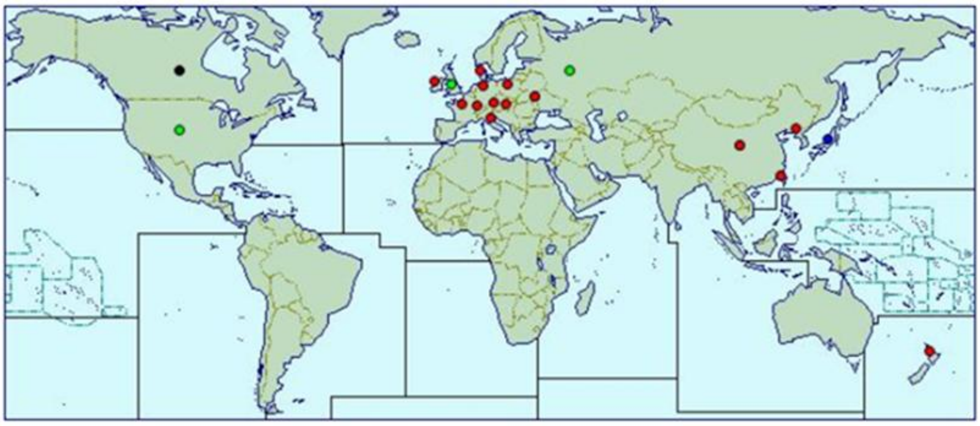

Figure 1: Distribution of the species *Cervus nippon* in the world (Putman 2009).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Sika is a very successful invasive species in Europe that may easily establish in the wild and produce dense feral populations after escaping from parks and enclosures. Detrimental impacts on native vegetation by sika populations are reported through overgrazing both in its native and introduced ranges. Concerns about the consequences of hybridization with the native red deer* have also been frequently raised.

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.

Today, sika deer is not or poorly established in Belgium. Observations in recent years of isolated specimens escaped from captivity have been reported from Bièvre, Bullange, Ciergnon, Saint Ghislain and Zelzate (DEMNA *pers. comm.*, observations.be).

2.1.2 Present status in neighbouring countries

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

Large free-living population of sika deer are established in European countries with very ancient introduction, *i.e.* before 1900 (Czech Republic, Germany, Ireland, Ukraine, United Kingdom), originating both from animal escape and intentional release into the wild (figure 2) (Bartos 2009). Several feral populations derived from deer park animals are established in Germany, quite far away from the Belgian border; the nearest large population (about 2000 individuals) is located in Möhnesee (east of Dortmund), at a distance of 200 kilometres from the border (Eick 1995, Bartos 2009, Lammertsma *et al.* 2012). After introduction of small numbers at multiple locations in Britain and Ireland from 1860 onwards sika have recently increased in population number and range in areas with good forest cover (figure 3) (Perez-Espona *et al.* 2009). The current number of free-ranging sika deer in the UK is estimated to 27,000 individuals (Appolonio *et al.* 2010). Local density may be very high; an average density of 13-24 animals per square kilometre is reported from Scotland, with local densities exceeding 50 animals per square kilometre (Swanson & Putman 2009). The geographic area where sika deer is established in Europe largely overlaps with the distribution range of the red deer, *Cervus elaphus** and the roe deer, *Capreolus capreolus** (Mitchell-Jones *et al.* 1999, Perez-Espona *et al.* 2009).

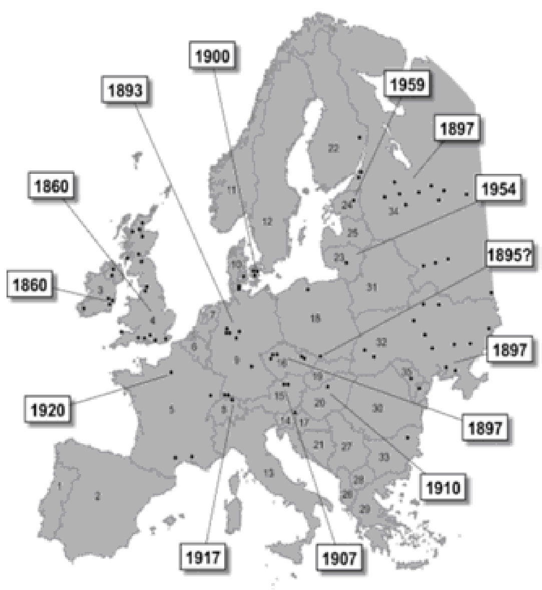

Figure 2 : Distribution of Sika deer in Europe with earliest dates of the first official occurrences (Bartos 2009).

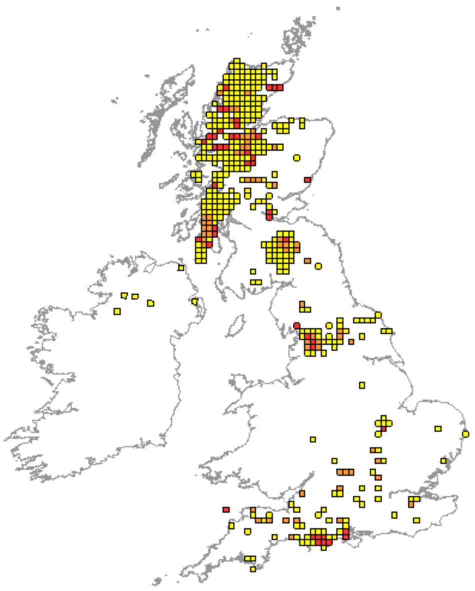

Figure 3 : 10km distribution of Cervus nippon in Great Britain and Ireland (NBN Gateway). Top (red) : 1950-1969, middle (orange) : 1970-1989 and bottom (yellow) : 1990-2009.

In France, feral populations of sika deer are expanding and an increasing number of animals are culled by hunters each year (about 200 specimens in 2011) (Saint-Andrieux & Baboiron 2012). The largest feral populations (> 100 individuals) are located in forested areas near Rambouillet (Ile de France) and Colmar (Haut-Rhin) (Bartos 2009). In addition, an increasing number of small free-living sika deer populations (< 20 individuals) have been reported to establish near Belgium during the last decades, mostly as a result of escape from deer parks. The nearest populations from Belgium are located in the Ardennes and the Nord-Pas-de Calais (Saint Andrieux *et al.* 2009, Hurel 2011).

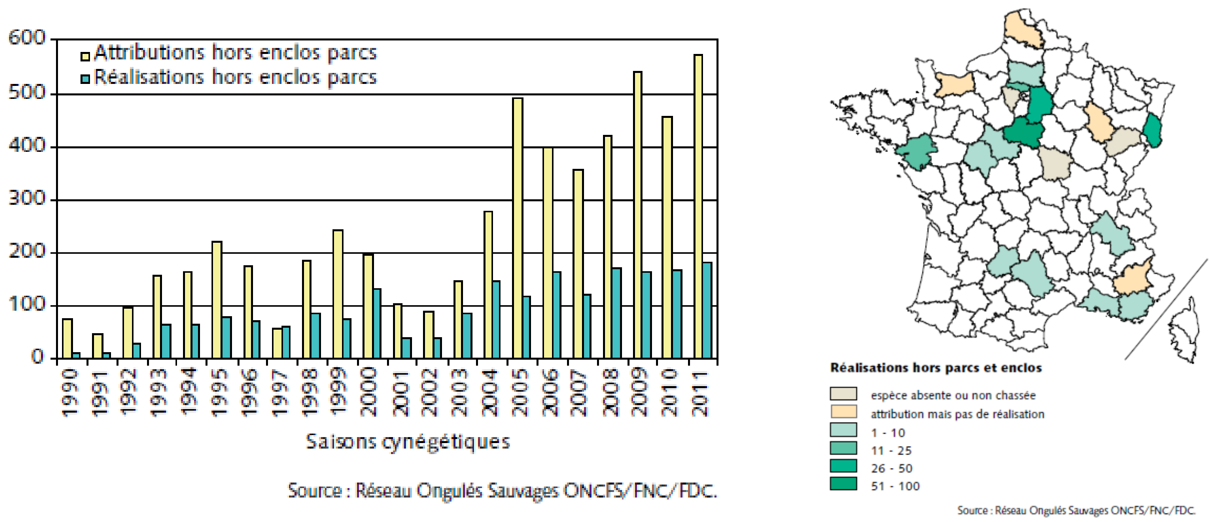

Figure 4 – Evolution of the yearly number of sika deer culled by hunters in France and identification of departments where animals have been shot (from Saint-Andrieux & Baboiron 2012).

Recent casual observations have also been reported from the Netherlands (Hilversum) (www.waarneming.nl) and Luxembourg (S. Célina, comm. pers.). The origin of those specimen is unknown.

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).

Herds of sika deer established in Europe originate either from accidental escapes from deer parks/farms or from deliberate introductions into the wild as a game species (Pascal *et al.* 2003, Genovesi & Putman 2006). Old introductions often originate from intentional releases from deer parks (e.g. in Denmark, Hungary, France, Poland and Switzerland) while **more recent introductions are mainly the result of accidental escapes from captivity** (e.g. enclosures fallen into disrepair or broken by snow) (Bartos 2009, Saint-Andrieux *et al.* 2009). Sika deer is still commonly reared in deer parks in Europe. According to the ISIS (International Species Information System) website, there are 29 zoological gardens in Europe keeping several hundred specimen of various subspecies (listed as: *Cervus nippon, C. n. nippon, C. n. dybowskii, C. n. hortulorum, C. n. pseudoaxis, and C. n. taiouanus*). In addition, the number of deer farms and hobby parks, where captive sika deer breed, is also constantly in growth in Europe; sika found in those parks are frequently intercrossed with red deer, sometimes deliberately for trophy improvement (Bartos 2009). As a consequence, a lot of new small free-ranging populations have been reported and propagule pressure has considerably increased during recent years in Europe (Matuszewski 1988, Eick 1995a, Bartos 2009, Saint-Andrieux *et al.* 2009).

An undetermined number of zoological gardens, deer parks and deer farms are established in Belgium and neighbouring areas, from which escapes may occur. In Belgium for example, sika deer destined to hobby parks as ornamental species have been imported several times from Ireland and Germany ; the largest importation counted more or less 60 animals in 2003 (Audenaerde 2003, pers. comm. in Bartos 2009). On the other hand, this species seems not to be reared in Belgium for meat production. As a result, deer farming should not be considered as a major pathway for introduction in the country.

On top of that, immigrants may also colonise Belgium on the long term from established populations in neighbouring countries, namely from Germany and France where extensive populations already occur and progressively expand.

ENTRY IN BELGIUM

Casual observations of sika deer were reported from different localities in Belgium during recent years but establishment is considered as unlikely so far. The most probable pathway of sika deer entry in Belgium is the accidental/deliberated releases of individuals from deer parks and, secondarily, the natural spread of individuals from neighbouring countries.

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

Life expectancy of sika deer in captivity is on average 15 to 18 years. Both males and females reach reproductive maturity at 16-18 months (Nowak 1991). Sika deer are polygamous, and a male can have a herd of 12 females during the rutting season. Generally in Europe, sika deer breed during the fall (September to November), and give birth to 1 calf, occasionally 2, between April and June, after a gestation period of approximately 30 weeks; twins are however more frequently observed in nutritious environments. It has a high reproductive rate, with a conception rate of 80-90% and an adult pregnancy rate of 85-100%, with most hinds breeding successfully for the first time as yearlings (Feldhamer 1980, Nowak 1991, Genovesi & Putman 2006, Harris 2008, Onishi *et al.* 2009).

In comparison, the red deer* has a lower fertility rate: its conception rate is approximately 85% and pregnancy rates is 0-80% for yearlings, 30-90% for 2.5 years-old cows, and 50-100% for cows older than 3 years. Calf production typically declines after 7.5 years-old (Peek 2003, Gordon 2004, Innes 2011). Females give also birth to one calf (Hudson *et al.* 1991, Chadwick *et al*. 1996, Wisdom & Cook 2000, Hudson & Haigh 2002, Raedeke *et al.* 2002, Peek 2003).

Sika deer may exhibit **dramatic increase of their populations** following introduction, colonization of new areas or release from harvesting. During the so-called irruptive events, their populations can increase rapidly to reach a **local density exceeding 50 or even 100 individuals per kilometre square**. In its native range, population dynamics is characterized by repeated irruptions and crashes with no associated decline in carrying capacity; peak density is determined by density-dependent resource limitation through interaction with winter climate (Kaji *et al.* 2004, Kaji *et al.* 2009, Uno *et al.* 2009, Kaji *et al.* 2010). After a lag phase expanding over several decades, a strong population increase has also been reported to occur during the last decades in the British Isles, due to a high reproduction rate. There, no clear evidence for any density-dependent reduction in fecundity has been observed with recorded densities up to 35 individuals per square kilometre (Swanson & Putman 2009).

However, some feral populations of sika deer went extinct or remain localised and do not disperse beyond their point of introduction (Austria, Poland and some populations in Great-Britain); this seems to be the case when feral population were established with small numbers of founder individuals and were not hybridised with red deer* (R. Putman, pers. comm.).

B/ Climatic requirements[2]

In its native range, sika deer are mainly found on low-elevation plains and surrounding hills, from the tropical jungles of Vietnam to broad-leaved deciduous forests of Far East Russia and northern Japan. Climate varies from tropical in the south to cold and snowy winters in the north (McCullough 2009). Tropical (A) and warm temperate (C) climates (12° to 46° N) are preferred by sika deer, especially areas where snowfall doesn't exceed 10-20 cm and where snow-free sites remain available (Genovesi & Putman 2006). In Northern Japan, a high mortality of sika fawns is reported during the first winter because their mobility is restricted in the snow and their fat reserves are insufficient to resist to the cold (Takatsuki 2006, Takatsuki 2009a). Long-term warm winters are known to have favoured the recent increase of population size and range expansion in Japan (Miura & Tokida 2009).

The species is widely established in the Cfb climate zone (Köppen-Geiger classification) and in the Atlantic Central, Atlantic North and Continental zones (Metzger classification) in Europe (Genovesi & Putman 2006, Bartos 2009, Swanson & Putman 2009). **The low snowfalls and mild winter temperatures are likely to induce a high survival rate and favour establishment in Western Europe**.

C/ Habitat preferences[3]

In its native range, sika deer inhabits a **wide range of forest types**, with a **preference for early succession stages over mature woodlands**. Like with roe deer (*Capreolus capreolus*) in Europe, it thrives in forests with a mix of different vegetation and succession types. **It is an "edge" species that meets life requirements from different kinds of habitats**; they are equally dependent on forest cover to evade enemies and on open areas with high quality forage. It is also found in prime agricultural and developmental lands for humans, but those habitats are clearly less preferred than forested areas (Nowak 1991, Genovesi & Putman 2006, Smith & Xie 2008, Takatsuki 2009a, Mc Cullough 2009).

---

[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.

In Europe, its preferred habitat is **deciduous or mixed woodlands on acidic soils with dense undergrowth**, including coniferous plantations with clearings or adjacent heath and open ground. In Scotland, commercial conifer forestry is its preferred habitat. However, this species is highly adaptable, which finally allows it to also establish in a variety of open habitats such as estuarine reedbeds, freshwater marshes, grasslands and heathlands, from the sea level up to 1800 meters. Nevertheless it appears to be always dependent on some presence of woodland cover and seems less able to adapt to completely treeless conditions than red deer (Nowak 1991, Mitchell-Jones *et al.* 1999, Harris *et al.* 1995, Genovesi & Putman 2006, Wittenberg *et al.* 2006, Perez-Espona *et al.* 2009, Swanson & Putman 2009, Acevedo *et al.* 2010).

D/ Food habits[4]

In their native range, sika deer are **highly adaptable herbivores and are anatomically adapted to grazing as well as browsing more selectively**; food composition is highly variable and depends on resource availability, vegetation type and climatic conditions. The northern sika deer living in cool temperate zone are grazers feeding predominantly on dwarf bamboos, graminoids and other roughage and poorly digestible foods. The southern deer are dependent on fruits and other more nutritious foods. When facing food shortages, they consume dead leaves, bark, and even underground parts of plants (Hofman 1988 & 1989, Takatsuki 2009a).

As in its native range, diet composition of sika deer in Europe is highly variable according to the site-resources (Feldhamer 1980, Nowak 1991). Their diet is most often constituted of graminoids, forbs, shrubs, twigs, tree foliage, fruits, fungi and agricultural crops without significant reliance on any particular food source (Feldhamer 1980, Genovesi & Putman 2006, Harris 2008, GB Non-Native Species Secretariat 2011).

E/ Control agents

No predator present in Belgium is likely to have a significant impact on the population growth rate of sika deer (e.g. absence of the wolf, *Canis lupus*) (Latham 1999, Perrin *et al.* 2006). It means that densities may rise until very high levels before being possibly limited by the availability of food resources (Putman *et al.* 1996). In some year however, it cannot be excluded that foxes may play a role in limiting population growth rate through predation on calves (O'Donoghue 1991). Successful invasion histories of sika deer in habitats already occupied by other ungulate species in British Isles, Germany and North America show that competition is unlikely to prevent its establishment or even slow down population expansion (Putman & Sharma 1987, Bartos 2009, Feldhamer & Demarais 2009). In European free-ranging populations, sika mortality is largely restricted to non-natural causes such as deliberate culling by man and collision with vehicles (Latham *et al.* 1998, Pérez-Espona *et al*. 2009).

[4] For animal species only.

In Europe, sika deer can be infected by numerous endemic wildlife diseases and parasites like bluetongue virus, foot-and-mouth disease virus, louping I11 virus, malignant catarrhal fever virus, bovine tuberculosis, sarcoptic mange, lungworms *Elaphostrongylus* spp. and *Dictyocaulus* spp., liver fluke and ticks (Reid 1992, Haigh *et al.* 2002, Gortazar *et al.* 2006, Böhm *et al.* 2007, Linden *et al.* 2010). In Poland, Drozdz (1963) found that some sika deer had lost their typical parasites as the Asiatic nematode *Ashworthius sidemi*, but were infected by 12 native deer parasites. Although several of those diseases are often fatal infections among farmed deer, feral sika populations do not seem to suffer very much from them and usually show a high resistance to infection (Böhm *et al.* 2006). **The successful invasion of the British Isles and Central Europe by the sika deer and the good health status of its feral populations suggest that it is only poorly affected by European diseases and parasites.**

F/ Establishment capacity in Belgium

Cervus nippon presents a suite of life-history traits typical of successful invasive deer species such as a large native range with high local abundance, a gregarious behaviour, a wide habitat and diet breadth, a long life span, an early sexual maturity and numerous invasion histories outside its native range (Putman 2009, Fautley 2012). Due to its great adaptability, sika deer has proved to be an extremely successful coloniser of European forest habitats, where it is well established and population number and size are regularly increasing (e.g. Pérez-Espona *et al.* 2009). Woodlands of Belgium provide optimal climatic, habitat and trophic conditions for the establishment of this ungulate, including conifer forest plantations. The good survival rate of isolated escaped sika deer observed in Belgium and neighbouring areas confirms this assertion (Bartos 2009, Swanson & Putman 2009).

G/ Endangered areas in Belgium

All the wooded areas found in Belgium consist in an optimal habitat for the development of the sika deer, where it could form dense populations. The best conditions are likely to be encountered in the Ardenne district as it shows similar eco-climatic conditions (e.g. large areas of conifer plantations on acidic soils) as those found in Scotland, where sika reaches high population densities (Chadwick *et al.* 1996, Acevedo *et al.* 2010). Its establishment capacity by hybridization may also be facilitated in this district thanks to the presence of numerous red deer*. On the other hand, sika deer are likely to be much less abundant in woodland-deprived areas as found in the Brabant, in the Flandrian and in the Maritime districts in Belgium.

Strong impacts due to overgrazing (see impact section) are likely to occur following sika establishment in acidic forest habitats, heathlands and wetlands situated near woodland edges, especially in the Kempen and the Ardenne districts.

The identification of suitable habitat patches for sika in the Netherlands and surrounding countries has been recently performed using the landscape ecology model LARCH, considering that habitat preferences by sika and red* deer are rather similar (Groot Bruinderink *et al*. 2003, Lammertsma *et* *al.* 2012). Four districts were identified as optimal for its establishment in Belgium (figure 5): Kempen, Meuse, Ardenne and Lorraine

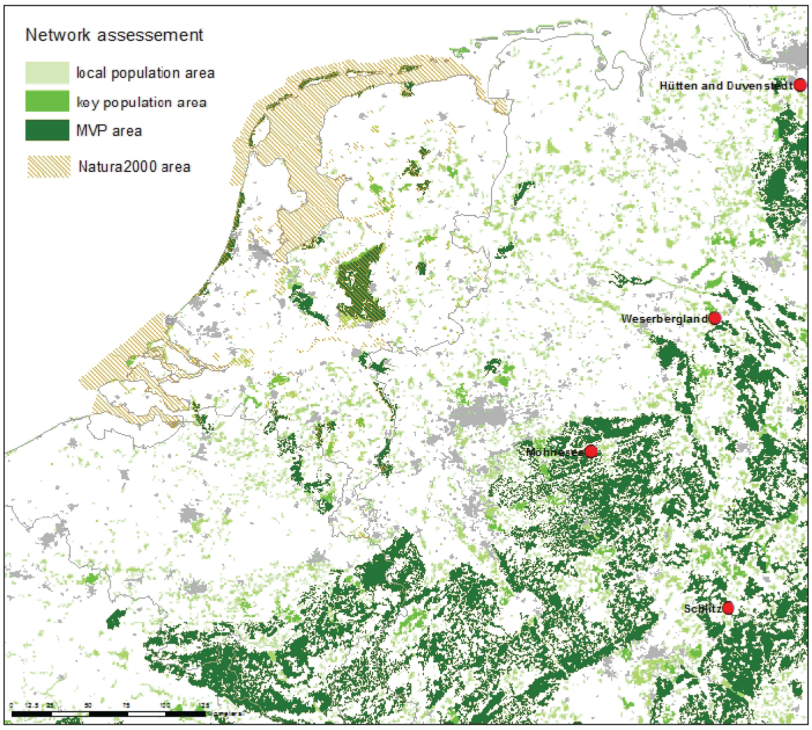

Figure 5: results of habitat suitability analysis for sika deer as calculated by the LARCH model; MVP is minimum viable population (95% probability of survival over a period of 100 years with zero immigration), key population is a large local population in a network that is persistent assuming one immigrant per generation. The red dots indicate established population in Germany (Lammertsma *et al.* 2012).

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	**Environmental conditions for species establishment**[5]
Maritime	Suboptimal
Flandrian	Suboptimal
Brabant	Suboptimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Optimal
Lorraine	Optimal

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

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Providing that enough founder individuals are encountered, the sika deer is likely to establish easily self-sustaining populations in most of Belgium because appropriated climatic conditions, habitats and food are encountered and native natural enemies and diseases are unlikely to affect very much its fitness. High population densities are likely to occur in Kempen and in the Southern part of the country.

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.

A/ Natural spread

Dispersal distances

Sika deer populations have been characterized as rather sedentary in Asia, although some populations perform large-scale seasonal migrations between summer and winter home ranges depending on factors such as the amount and the variability of snowfall and the availability of high quality food. In Hokkaido island, Japan, **migration distance averages 35 kilometres and may exceed 100 km for some individuals**. Moreover, sika deer are excellent swimmers and can travel through 12 kilometres by swimming in the sea. Being migrant or not, sika deer usually exhibit **site fidelity** to seasonal home ranges (Feldhamer 1980, Igota *et al.* 2009).

Sika deer may travel long distances in its introduced range, although no clear seasonal migration pattern has been described. Dispersion is usually initiated by autumn long-distance movements of males. In Japan and USA, movement distances by males ranged from 5 to 30 km. However, in Poland and Russia, **solitary juvenile males have been recorded to travel long distances up to 160 km** before establishing in new areas, sometimes 10 years before hinds were also observed (Matuszewski & Sumin´ski 1984, Bartos 2009, Kalb 2010, Agetsuma *et al.* 2011).

Expansion rates

In its introduced range, sika deer may exhibit a **rapid range expansion, estimated to 3 to 5 km per year** where a continuous, suitable habitat for colonization is present (e.g. coniferous plantations and woodland corridors) (Ratcliffe 1987, Harris *et al.* 1995, Putman 2000, Ward 2005, Swanson & Putman 2009, Nentwig *et al.* 2010). In Britain and Ireland, **the mean expansion rate of sika deer was about 5-7 % per year** during the last decades (Ward 2005, Ward *et al.* 2008, Carden *et al.* 2011). However, in some areas with fragmented forest landscapes and obstacles to dispersion like roads and urban settlements, spread is relatively slow with long periods of no movement and local density increase before sudden irruption from this source (Putman 2000, Livingstone 2001, Swanson & Putman 2009).

B/ Human assistance

The strong expansion rate and the presence of frequent outlying records of sika (in a patchy way and discontinuous distribution) in Europe suggest that **translocations** and **secondary releases** of animals by man have an important role in its invasion dynamics (Ward 2005, Carden *et al.* 2011). As an example, **a lot of new escapes** from deer parks have been documented from France during the two last decades, leading to a strong increase in the number of free-ranging populations (Saint-Andrieux *et al.* 2009, Hurel 2011).

DISPERSAL CAPACITY

The sika deer can easily spread naturally beyond introduction points and has a moderate range expansion capacity (3-5 km per year) providing that suitable wooded habitats are present in the landscape. This rate of expansion is likely to be locally enhanced as a result of human translocation and illegal introduction into 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.

Detrimental impacts of sika deer are directly linked to over-abundance (see life-cycle and reproduction). Sika population outbreaks have been reported in different parts of their range, causing strong environmental and economic damage that far exceeds the impacts of comparable deer in other parts of the world (McCullough 2009, Putman *et al.* 2011).

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.

A/ Competition

Exotic ungulates have not co-evolved with the indigenous species, and as such may have overlapping niches which result in competition. There is indeed obvious potential for competition between exotic and native deer species in Western Europe as they overlap in habitat preferences and in use of food plants. In addition, ungulate densities in managed forests largely exceed those found in the remnants of natural forests in Europe, up to levels where density-dependent effects are likely to occur (Latham 1999, Swanson & Putman 2009). Two kinds of competition have to be considered here: the resource competition whereby deer compete for food and space, and the interference competition, whereby deer socially interact in a negative way and reduce fitness of another species (Latham 1999).

Concerning resource competition, sika deer are generally described as better competitors for food than native deer species because of their flexibility, their anatomical and behavioural features allowing them to overcome severe environmental conditions and to make supplies of energy with food of poor quality by easily breaking down fibrous food, and their capacity to rapidly exhaust and reduce the quality of feeding resources (Hofmann 1988, Takatsuki 1988, Hofmann 1989, Latham 1999, Bartos 2009, Feldhamer & Demarais 2009). Interference competition occurs as well since sika deer are quite aggressive and intolerant toward other deer species, even larger ones like red deer, and has the capacity to chase them from feeding sites (Hofmann 1988, Takatsuki 1988, Hofmann 1989, Bartos 2009, Feldhamer & Demarais 2009). There is also the possibility of mate competition with red deer* (see the hybridization section) (Swanson & Putman 2009).

Anecdotal observations, correlative studies and spatial segregation suggest that native deer species may decline in forests invaded by sika deer, e.g. roe deer (*Capreolus capreolus*)* in United Kingdom (Danilkin 1996) and Russia (Markovkin 1999), red deer (*Cervus elaphus*)* in Poland (Dzieciolowski 1979), in Germany (Gebhardt 1996) and in the United Kingdom (Chadwick *et al.* 1996, Perez-Espona *et al.* 2009), fallow deer (*Dama dama*) in West Bohemian area, Czech Republic (Bartos 2009) and white-tailed deer (*Odocoileus virginianus*) in Maryland, USA (Keiper 1985, Feldhamer & Demarais 2009).

However, outcompetition of sika by fallow deer has also been reported from Germany (Bartos 2009). In a recent study, Acevedo *et al.* (2010) compared the general favourability values for the occurrence of sika with those of the native roe* and red* deer in Great Britain and concluded that sika are weak competitors and are not expected to displace native species since in areas were they are coincident, sika favourability always remains below that of the native deer.

In fact, **results from the scientific literature are rather contradictory; there is no clear evidence of outcompetition of native ungulates by sika and this has never been unequivocally demonstrated. It cannot be excluded that interspecific interactions may lead to the local decline of native deer species but they seem unlikely to cause large-scale species displacement** (McKelvey 1959, Dzieciolowski 1979, Feldhamer & Armstrong 1993, Chadwick *et al.* 1996, Swanson & Putman 2009).

B/ Herbivory

In its native range, continuous grazing and browsing of sika deer have a marked effect on forest structure and understorey composition. With deer densities between 5 and 20 animals per kilometre square, the forest is characterized by simple vertical structure with poor shrub layer and tree regeneration and a dense herb layer (e.g. dwarf bamboo). At higher densities, deer induce irreversible changes on the vegetation; browsing, bark-stripping and tree decline are commonly observed and large gaps appear within the forest; tall grass drastically decreases to near extinction and is replaced by bare ground areas and plant communities dominated by short grass and unpalatable or invasive plant species. The short grass *Zoysia japonica* is especially favoured in these conditions as it is very resistant to overgrazing, strongly attractive to sika deer and produces deer-dispersed seeds. **Local extinction of endangered plant species has been documented in national parks and nature reserves in Japan due to long-term overpopulation of the sika deer** (Kaji *et al*. 2009 and 2010, Takatsuki 2009a, 2009b, 2009c, Takatsuki & Ito 2009, Akashi *et al*. 2011). Sika is for example responsible of a strong decline of the vegetation diversity in subalpine Betula forests in Central Japan, where it favours the local decline of the vulnerable *Polemonium caeruleum* (subspecies *yezoense*, variety *nipponicum*), a red list plant species (Nagaite 2012).

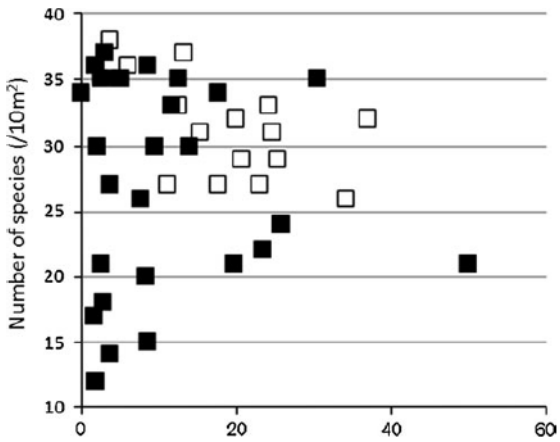

Figure 6 - Relationship between the browsing ratio by the sika deer and the number of plant species in subalpine Betula forests (open squares) and grasslands (solid squares) in Central Japan. After Nagaite 2012.

In Europe, sika deer can reach higher local densities than red deer* and can induce strong vegetation damage due to overgrazing. As observed in its native range, it can cause significant and persistent modification in vegetation structure and composition of semi-natural woodlands, heathlands and wetlands (Diaz *et al.* 2005, Hannaford *et al.* 2006, Genovesi & Putman 2006, Perrin *et al.* 2006, Bartos 2009, Swanson & Putman 2009). Overgrazing by sika deer induces the local decline of numerous plant species in Ireland and United Kingdom, including *Spartina anglica* in salt marshes (Hannaford *et al.* 2006), and many forest plant species like *Ilex aquifolium**, *Hedera helix**, *Lonicera periclymenum**, *Luzula sylvatica**, *Rubus fruticosus**, *Taxus baccata** and *Vaccinium myrtillus** in woodlands. Chronic heavy grazing by sika deer in those habitats inhibits the natural regeneration of most tree species except a few unpalatable species like *Fagus sylvatica** and the alien *Rhododendron ponticum* and favours the canopy dominance of long-lived trees established before the advent of high grazing pressure (Kelly 2002, Stokes *et al.* 2004, Perrin *et al.* 2006 and 2011).

Long-term sika deer exclusion experiments performed in Japan and in United Kingdom showed that fencing rapidly benefits competitive, grazing-sensitive ground flora and tree seedlings, but that total grazing exclusion may result in declines in vegetation diversity in the long-term as it leads to the dominance of a few plant species that gradually outcompete herbaceous woodland specialist species

(Kelly 2000, Nomiya *et al.* 2002, Kumar *et al.* 2006, Mc Evoy *et al.* 2006, Perrin *et al.* 2006 and 2011, Cooper & McCann 2011).

In conclusion, herbivore pressure by sika deer may **affect the future population growth of perennial plants and is known to cause the local extinction of less frequent and vulnerable species while promoting the development of unpalatable species** both in native and introduced ranges. Species disappearance due to browsing by the sika deer can strongly affect the plant species pool, and consequently lead to homogenization of the vegetation. As it is already the case with native deer, this impact is likely to be much more intensive towards the poor vegetation established on acidic soils; however, it is likely to be more drastic due to sika because of the frequent irruptive events in its population dynamics (McCullough 2009, Takatsuki 2009a, Nagaike 2012).

C/ Genetic effects and hybridization

Sika and red* deer can easily interbreed and produce fertile hybrids although they are considered as separate species. First generation hybrids (F1) show traits of both species, while further backcrossed hybrids are much more difficult to identify in the field. Introgression between red* and sika deer has been reported both in the introduced range and in the sika's native range along the Russian-Chinese border (Stokes *et al.* 2004, Bartos 2009, Pérez-Espona *et al.* 2009).

The phenotypic and the genetic outcomes of hybridization between red* and sika deer is quite uncertain; maladaptive sika genes might be introduced to red deer populations, alter their ecology (nutritional ecology for example because of changes in body size and dentition) and cause a reduced fitness (Hulme *et al.* 2009, Senn *et al.* 2010). An additional risk could be that sika deer completely out-compete red deer*, or that the two species **merge in an invasive and vigorous hybrid swarm** which persists indefinitely as a separate entity (Pérez-Espona *et al.* 2009, McDevitt *et al.* 2009, Senn *et al.* 2010).

Hybridization cases have been reported in Europe, both in captivity and in the wild, in Ireland and the United Kingdom (Harrington 1973, Lowe & Gardiner 1975, Ratcliffe *et al.* 1992, Putman & Hunt 1994, Abernethy 1994, Goodman *et al.* 1999, Dıaz *et al.* 2006, Pemberton *et al.* 2006, McDevitt *et al.* 2009, Seen & Pemberton 2009), Czech Republic (Bartos *et al.* 1981, Bartos & Zirovnicky 1981, Zima *et al.* 1990), Germany (Rocholl 1967, Herzog 1987, Gehle *et al.* 1998), Lithuania (Baleisis *et al.* 2002) and France (Pascal *et al.* 2003).

The observations and genetic evidences suggest that hybridization occurs in Europe more generally when sika stags mate with red hinds*, which may occur namely after long-distance dispersal of solitary males joining red deer* herds (Bartos 2009). As cited below, sika deer can disturb red deer* rutting when sika males, extremely aggressive in the rut, attack young red stags *and mate with red hinds* in the presence of red stags* (Matuszewski 1988, Pérez-Espona *et al.* 2009). Actually, early-generation hybrids (as detected by microsatellites) mostly have red deer* mitochondrial DNA, and appear soon after first sika stags were seen in the surrounding area (Goodman *et al.* 1999, Swanson 1999, Livingstone 2001, Pemberton *et al.* 2006, Senn & Pemberton, in press).

Even with increased range overlapping, **interbreeding stays in general a rare event** and the rate of allele introgression is low (10% of individuals hybridized) (Goodman *et al.* 1999, Diaz *et al.* 2006, Pemberton *et al.* 2006, Pérez-Espona *et al.* 2009, Senn & Pemberton 2009, Carden *et al.* 2011). A few examples of extensively hybridized wild populations (hybrid swarms with 45% of individuals hybridized) have however been reported in Ireland and England. Over evolutionary time scales it is difficult to say whether selection will maintain some of the species differences through the formation of a hybrid zone or species reinforcement, but this is unlikely to occur without substantial genotypic and phenotypic introgression. From a practical point of view, **the presence of sika in Europe is likely to alter the ecology and appearance of red deer*** (Goodman *et al.* 1999, Pemberton *et al.* 2006, Pérez-Espona *et al.* 2009, Senn & Pemberton 2009, Senn *et al.* 2010).

D/ Pathogen pollution

All deer species host a wide range of pathogens. The transmission of new diseases and parasites by sika deer and other non-native ungulates is commonly cited by resource managers as a significant concern (Dunn 2009, Feldhamer & Demarais 2009). In addition, the increase in abundance as well as the range expansion of non-native deer species are likely to exacerbate the potential for endemic disease persistence due to the formation of multi-species deer assemblages, which may act as disease reservoirs (Böhm *et al.* 2007).

In Europe, **sika deer is responsible for the introduction and the transmission of the Asiatic non-specific blood-sucking gastrointestinal nematode (*Ashworthius sidemi*)** to red deer*, roe deer*, fallow deer, maral deer, elk, mouflon, bison and livestock (Drozdz *et al.* 2003, Genovesi & Putman 2006, Böhm *et al.* 2007, Osinska *et al.* 2010, Kowal *et al.* 2012). This parasite is known to be more prevalent, taller in size and present in higher densities than native nematodes that it often displaces (Drozdz *et al.* 2002, Radwan *et al.* 2010). It has a high pathogenicity and is responsible of oedema, hyperaemia, abomasums and duodenum mucosa effusion, chronic diarrhoea, deterioration and death of young animals (Demiaszkiewicz *et al.* 2009). The parasite has not been reported so far in the British Isles. On the contrary, its dispersion is fast and favoured by the good migration capacity of the red deer* in continental Europe (Drodz *et al.* 1998, Demiaszkiewicz *et al*. 2008). It is currently widespread in Central Europe, with usually a high prevalence and a high infection intensity within the populations of native deer (Cleva 1990, Ferte 1991, Ferte *et al.* 2000, Drozdz *et al.* 2003, Demiaszkiewicz *et al*. 2008, Kuzmina *et al*. 2010, Kowal *et al.* 2012). In Poland, this roundworm affects 100 % of the Polish population in the threatened European bison *Bison bonasus* (Drozdz *et al.* 2003, Osinska *et al.* 2010). **The negative impacts of this parasite on native deer and bisons are still difficult to assess. No mass mortality events have been reported so far; however it is very likely that the pathogenicity is high and may lead to fitness decrease and even death of animals** (Ferte *et al.* 2000).

As expressed before (2.1.4, E), a lot of European diseases and parasites of ungulates may infect sika deer and could potentially be amplified by it (reservoir function) and spillback to native deer. Some of them like bovine tuberculosis and sarcoptic mange may even be at threat for wildlife populations.

However, few information is available in the scientific literature about the potential role of sika in this, but **it has clearly the capacity to increase native disease persistence and prevalence due to the formation of overabundant populations** (Böhm *et al.* 2006, Gortazar *et al.* 2006 & 2007, Feldhamer & Demarais 2009, Putman *et al.* 2011).

E/ Effects on ecosystem functions

Due to its gregarious behaviour, grazing and browsing activities by sika strongly modify the structure of forest ecosystems and the natural dynamics of vegetation, both in its native and introduced ranges. The development of shrubs and young trees is strongly inhibited once deer densities exceed a few individuals per square kilometre, which results in forest with a very simplified vertical structure. At densities higher than 20 animals per square kilometre, tree decline is often observed and large gaps appear within the forest, without any tree regeneration (Swanson & Putman 2009, Takatsuki 2009a & 2009c, Akashi *et al.* 2011).

Other kind of impacts on ecosystem functions have been documented like the production of damage due to trampling and soil erosion, both in forests and open habitats (moorlands, upland bogs and salt marshes). Degradation of water quality has been also documented in creeks and streams (Welch *et al.* 2001, Kelly 2002, Genovesi & Putman 2006, Swanson & Putman 2009, Perrin *et al.* 2011). In Japan, even a low density of sika deer in subalpine area has led to the destruction of rhizomes of *Menyanthes trifoliata* growing along channels in mires and in a net decrease of water flow and damage to other marsh plants (Takatsuki 2009a). A potential effect on nitrogen cycle has also been suggested (Hobbs 1996).

At last, the modification of vegetation structure and composition together with soil trampling due to sika deer overabundance is known to cause cascading effects and affect forest animal populations, namely ground-dweller invertebrates, ground- and shrub-nesting birds, small rodents and their predators (Gill 1992, Fuller 2001, Côté *et al.* 2004, Miyashita *et al.* 2004, Gill & Fuller 2007, Takatsuki 2009a, Seki & Koganezawa 2012).

ENVIRONMENTAL IMPACTS

It is very likely that the establishment of sika deer in Belgium will result in an increase of the biomass and density of deer per hectare and will produce strong negative impacts on native vegetation through overgrazing, especially on acidic soils. It could also cause the local decline of native deer species, favour disease transmission to native ungulates and induce extensive hybridization with the red deer*. During irruptive events, a degradation of ecosystems is also expected to occur locally (alteration of vegetation, inhibition of tree regeneration, soil trampling, etc.).

2.2.2 Other impacts

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).

The recent increase of sika population in Japan caused considerable damages. In Hokkaido island for example, agricultural and forest damages increased as the range of sika deer expanded; damage to agricultural crops and forests by sika deer remained at low levels from the mid-1950s through the mid-1970s, but had dramatically increased to nearly 2 million Japanese yen (JPY) by 1990 and to over 5 million JPY by 1996 (Kaji *et al.* 2010) (see figure 7).

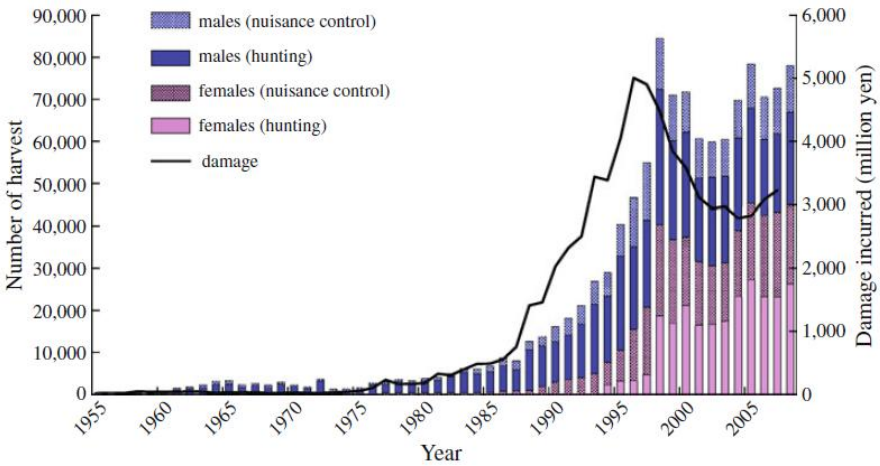

Fig. 7 - Changes in sika deer (*Cervus nippon*) harvest and agriculture/forestry damage occurring between 1957 and 2008 in Hokkaido (after Kaji *et al.* 2010)

So far, agricultural damages were mainly reported from the sika native range. It is known to cause significant damages to pasture and sugar beets in Japan, representing 50% and 12 % of total damage, respectively (Uno *et al.* 2009). Agricultural damages are directly proportional to deer abundance and are more pronounced near forest margins, especially nearby conifer plantation areas wherein little food is available for deer (Sakata *et al.* 2009). Significant damages to arable crops, root crops and grasslands were also reported to occur locally in the British Isles, but without causing a significant economic problem on a regional or a national scale (Perez-Espona *et al.* 2009, Putman *et al.* 2011).

Sika deer may also cause considerable damage to commercial forestry (especially in coniferous plantations) both in its native and introduced ranges that usually exceed those of European ungulates. The economic significance of such damage may be locally very considerable, especially in young plantations. Damages are caused through browsing much as red deer* in similar contexts, that may result in the elimination of tree seedlings and saplings and in the failure of forest regeneration. For example, a formal assessment of the extent of damage caused by sika in commercial forestry in Wicklow, Ireland, showed that between 22% and 76% of newly planted trees were found to have had their leading shoots damaged. Mature trees may also suffer severe damage through bark-stripping in hard winters and "bole-scoring" when sika stags gouge deep vertical grooves into the bole of particular trees during the rut (Lowe 1994, Chadwick *et al.* 1996, Putman & Moore 1998, White & Harris 2002, McCullough 2009, Swanson & Putman 2009, Takatsuki 2009a). A damage to commercial forestry (e.g. elimination of tree regeneration) is likely to occur once deer exceed 4 individuals per kilometer square, a density that sika may easily exceed (Putman *et al.* 2011).

Due to taxonomic proximity of sika deer with domestic livestock (cattle, sheep and goats), they share a considerable number of multihost bacterial, viral and parasitic diseases. Some like bluetongue virus, foot-and-mouth disease virus, malignant catarrhal fever virus or bovine tuberculosis may have a drastic economic impact. Both captive and feral sika populations may act as a reservoir for them, with an increasing risk of persistence and transmission to livestock in overabundance and aggregation situations (Reid 1992, Haigh *et al.* 2002, Böhm *et al.* 2006 & 2007, Gortazar *et al.* 2006 & 2007, Feldhamer & Demarais 2009, Linden *et al.* 2010, Putman *et al.* 2011).

Other kind of economic impacts have been reported, namely collision between deer and motor vehicles and trophy value reduction of hybridized red deer* (Ratcliffe 1989, Chadwick *et al.* 1996, Putman & Moore 1998, Pérez-Espona *et al.* 2009).

Outbreak of sika may also cause extensive indirect costs for the reduction of damages to ecosystems. For example, 2.5 high net fences have been erected over 2,200 km to exclude sika deer from agricultural fields to reduce crop damage on Hokkaido island, which represents a considerable cost (Uno *et al.* 2009). The cost of culling by professional hunters and government agencies to reduce population density may also be very significant (Pérez-Espona *et al.* 2009, Kaji *et al.* 2010, Carden *et al.* 2011).

B/ Social impacts

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

We could expect that sika deer's negative impacts on ecosystem services will affect human wellbeing. The establishment of free-living sika deer populations may induce social impacts through the increase of zoonotic risks (e.g. tick-borne diseases) (Gortazar *et al.* 2006, Böhm *et al.* 2007) and of the risk of deer-vehicle collisions (Langbein & Putman 2006, Pérez-Espona *et al.* 2009). On the other hand, some positive impact may be caused by sika establishment due to appearance of new hunting species; however, there is little or no quantitative information available on the economic value of this (Putman 2009).

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.

An unknown number of sika are kept in captivity today in Belgium (mainly in private hobby parks), from where they are occasionally reported to escape, as also observed in neighbouring countries (see e.g. Perez-Espona *et al.* 2009). **Deliberate releases or accidental escapes from deer parks are considered as the most probable invasion pathways of this species in Belgium.**

Sika entry and establishment in suitable Belgian districts through the expansion of feral populations found in neighbouring countries is another potential route of invasion. The closest large feral populations are located in Möhnesee, Germany, and in Rambouillet, Paris, at a distance exceeding 200 km from the Belgian border (figure 5). A natural colonisation of Belgium is unlikely to occur in the coming years due to the large distance to be travelled, the limited spatial connectivity and the current active control measures performed against sika in Germany and France (Lammertsma *et al.* 2012).

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

To date, a general wildlife management strategy is needed in continental Europe to avoid new sika introductions and to limit population increase where it is already established (Bartos 2009, Senn *et al.* 2010, Carden *et al.* 2011, Keller *et al.* 2011). As advised by Pérez-Espona *et al*. (2009) and Carden *et al.* (2011), both voluntary releases and accidental escapes into new areas should be strongly avoided and avoiding those escapes should be considered as the best option to reduce the environmental and economic risks by this species. **One option to reduce releases and escapes is to restrict importation and holding of sika in deer parks**.

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

In Belgium, the sika deer is not considered as a game species. It can be reared and transported only for meat production or ornamental purposes (see e.g. the royal decree on animal welfare and the regional regulation on environmental permits). Those activities deserve to be strongly limited in the future due to sika's capacity to easily escape from enclosed areas, establish feral populations and cause adverse environmental impacts (Genovesi & Putman 2006, Pemberton *et al.* 2006, Bartos 2009, Pérez-Espona *et al.* 2009). **A withdrawal of the sika deer from the short positive list of mammal species** that are allowed to be hold by private owners in Belgium (Royal Decree of 16th July 2009) is strongly recommended to comply with criteria listed in article 2, §1er, 3° of this regulation. If farming for meat production is considered as a desirable goal, environmental permits should impose strict holding conditions to avoid any animal escape.

While prevention of escapes from deer parks cannot be guaranteed, **the risk of escape and successful establishment may however be reduced through an adequate fencing, the installation of deer parks far away from woodlands, the holding of a low number of individuals per enclosure, the sterilization of captive populations (where possible), the obligation to rapidly report any escape, the frequent inspection of deer parks by public authorities and the preparation of emergency plans to remove escapees** (Carden *et al.* 2011, Lammertsma *et al.* 2012).

The intentional and unlawful releases of sika are the most challenging to detect, monitor and control. In Europe, their frequency is supposed to decrease with time in Europe thanks to legislation, penalties and awareness-raising about the potential consequences of illegal releases (Bartos 2009, Swanson & Putman 2009). Belgian regional nature conservation legislation strictly prohibits intentional release of sika deer into the wild as for other non-native species. In spite of current legal instruments, those events cannot be completely prevented. The use of ear tagging system for importing and holding sika deer and associated penalties when tagged animals are found in the wild could be used as a good incentive to reduce both intentional and accidental releases (Carden *et al.* 2011, Ward & Lees 2011).

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)?

New areas are generally colonized by young sika males, which are often observed roaming together with red deer* and may establish new hybrid populations after mating with red hinds (Bartos 2009). **In many instances detection of those animals might prove practically or economically impossible in large forest areas of Southern Belgium due to their secretive and nocturnal behavior and potential confusions with red deer*. In those conditions, it means that early detection is only possible through the rapid reporting of escapes followed by an active and intensive surveillance program using e.g. trail cameras at bait points** (Pemberton *et al*. 2006, Rowcliffe *et al.* 2008, Pérez-Espona *et al.* 2009, Swanson & Putman 2009). However, detection may be facilitated in the Northern part of the country because of absence of red deer* and the presence of a dense network of field observers (J. Casaer, *pers. comm.*).

At higher densities, sika deer can be detected, and populations estimated, indirectly by a routine monitoring of damages (on forestry, agriculture and/or conservation habitats) and a correct damage attribution to responsible species by a sure impact assessment methodology (Putman 2009, Putman & Watson 2009).

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

The main population management means for sika deer is possible by coordinated shooting (Genovesi & Putman 2006, Pérez-Espona *et al.* 2009). An efficient alternative could also be individual captures by traps or devices (Genovesi & Putman 2006).

As young sika males disperse first, **a selective culling of these pioneering stags should be a good recommendation to avoid range expansion of sika deer** from those regions where the species is present in established local populations (Bartos 2009, McDevitt *et al.* 2009, Pérez-Espona *et al.* 2009, Swanson & Putman 2009). **However, sika is usually considered as very hard to cull because of high alertness, preference for dense forest habitats and propensity to change its behaviour in response to culling pressure** (Bartos 2009, Pérez-Espona *et al.* 2009, Senn *et al.* 2010).

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

A great vigilance and a selective culling are required in areas where habitat overlaps occur between sika and other deer species, as red deer for example. In the contrary, culling actions designed to reduce sika populations may certainly impact non-targeted ungulates (Pérez-Espona *et al.* 2009).

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

Local control and eradication efforts of sika have to be deployed at the beginning of invasion before the species starts to spread; the feasibility of extirpation is usually considered as very low when they are already abundant in an area. Although it is known that heavy culling of sika may lead to a strong reduction of their local density, **no example of successful sika eradication has been found in the scientific literature and this goal is often considered as extremely difficult to reach** (Genovesi 2005, Wittenberg *et al.* 2006, Pérez-Espona *et al*. 2009, Swanson & Putman 2009).

However, early eradication seems to be a reasonable goal to achieve in some conditions, e.g. in areas deprived of red deer. Examples of eradication of red deer in Flanders show that quick response may result in quick eradication when willingness is present (J. Casaer, *pers. comm*.).

Sika is neither a protected species or a game species in Belgium. In Wallonia, culling by hunters, private owners and foresters is allowed during the whole year, providing that a hunting permit is

hold (see e.g. the ministerial guideline n°2688 on the control of non-native animal species in Wallonia).

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

If extirpation is not possible, the population should be managed as far as possible to avoid further damage to forestry and other valued habitats and to contain it away from red deer* populations. **However, hunting of sika deer where extensive populations are found both in native and introduced ranges has proved to be largely insufficient to avoid further expansion towards suitable habitats and to reduce population densities, despite considerable efforts directed towards this objective.** Better results may however be achieved through a strong coordination of culling actions undertaken by professional or recreational hunters (Pérez-Espona *et al.* 2009, Kaji *et al.* 2010, Carden *et al.* 2011, Putman com. pers.)

Some mitigation techniques have been tested to exclude sika deer from vulnerable areas like chemical repellents, ultrasounds, exploders, pyrotechnics or spotlights. However, those techniques do not produce effective results. Chemical and immunocontraceptive methods are on the way to be explored to control fertility (Genovesi & Putman 2006).

Abernethy, K. (1994) The establishment of a hybrid zone between red and sika deer (genus Cervus). Mol. Ecol. 3:551–562.

Acevedo, P., Ward, A.I., Real, R., Smith, G.C. (2010) Assessing biogeographical relationships of ecologically related species using favourability functions: a case study on British deer. Diversity and Distributions, 16, 515-528.

Agetsuma, N., Agetuma-Yanagihara, Y. & Takafumi, H. (2011) Autumn long-distance movements of male Japanese Sika deer Cervus nippon yesoensis in Western Hokkaido, Japan. Eurasian Journal of Forest Research, 14, pp. 13-19.

Akashi, N., Unno, A. & Terazawa, K. (2011) Effects of deer abundance on broad-leaved tree seedling establishment in the understory of Abies sacchalinensis plantations. Journal of forest research 16: 500-508.

Apollonio, M., Andersen, R. and Putman, R. 2010 European Ungulates and their management in the 21ste Century. Cambridge University Press. Pp 578 – 579.

Baleisis, R., Bluzma, P. & Balciauskas, L. (2002) Lietuvos kanopiniai zverys. Akstis. (Lithuania.)

Bartos, L., Hyanek, J. & Zirovnicky´, J. (1981) Hybridisation between red and sika deer. I. Craniological analysis. Zool. Anz. Jena 207, 260–270.

Bartos, L. & Zirovnicky , J. (1981) Hybridisation between red and sika deer. II. Phenotype analysis. Zool. Anz. Jena 207, 271–287.

Bartos, L. (2009) Sika deer in continental Europe. In: McCullough *et al.* (Eds), Sika deer: biology and management of native and introduced populations, Springer Japan: 573-594.

Böhm, M., White, P.C.L., Daniels, M.J., Munro, A.C.R. & Hutchings, M.R. (2006) The health of wild red and sika deer in Scotland: An analysis of key endoparasites and recommendations for monitoring disease. The Veterinary Journal 171: 287–294.

Böhm, M., White, P.C.L., Chambers, J., Smith, L. & Hutchings, M.R. (2007) Wild deer as a source of infection for livestock and humans in the UK. Vet. J. 174, 260–276.

Cailmail, F. (1988) Frankreich: Forêt de la Harth, Haut-Rhin, Gatter Salzlecke. Pages 5.2-F-2/1–5 In E. Eick, J. A. Willett, R. König and K.-H. Schulze-Schwefe, editors. Sika, Cervus nippon Temminck, 1838. Internationale Arbeitsgemeinschaft Sikawild, Möhnesee-Körbecke, Germany.

Carden, R.F., Carlin, C.M., Marnell, F., McElholm, D., Hetherington, J. & Gammell, M.P. (2011) Distribution and range expansion of deer in Ireland. Mammal Review, 41: 313–325

Chadwick, A.H., Ratcliffe, P.R. & Abernethy, K. (1996) Sika deer in Scotland: density, population size, habitat use and fertility some comparisons with red deer. Scott. For. 50, 8–16.

Cleva, D. (1990) Incidence du parasitisme sur l'état sanitaire et la condition physique du Chevreuil (Capreolus capreolus) dans quatre départements de l'ouest de la France. Th. Doct. Vét., Nantes, 167.

Cook, J.G. (2002) Nutrition and food. In: Toweill, Dale E.; Thomas, Jack Ward, eds. North American elk: ecology and management. Washington, DC: Smithsonian Institution Press: 259-350.

Cooper, A. & McCann, T. (2011) Cattle exclosure and vegetation dynamics in an ancient, Irish wet oakwood. Plant Ecol. 212, 79–90.

Côté, S.D., Rooney, T.P., Tremblay, J.P., Dussault, C. & Waller, D.M. () Ecological impacts of deer overabundance. Annu. Rev. Ecol. Evol. Syst. 35:113–47Danilkin, A. A. (1996) Siberian and European roe deer. Chapman & Hall, London, United Kingdom.

Demiaszkiewicz, A.W., Lachowicz, J. & Osin´ska, B. (2009) Ashworthius sidemi (Nematoda, Trichostrongylidae) in wild ruminants in Białowie_za Forest. Polish Journal of Veterinary Sciences 12: 385–388.

Demiaszkiewicz, A. W., Lachowicz, J. & Osinska, B. (2008) Determination of limits of ashworthiosis foci in eastern and southern Poland. Wiadomości Parazytologiczne, Vol. 54, No. 3, pp. 217-219.

Dıaz, A., Hughes, S., Putman, R., Mogg, R. & Bond, J.M. (2006) A genetic study of sika (Cervus nippon) in the New Forest and in the Purbeck region, southern England: is there evidence of recent or past hybridization with red deer (Cervus elaphus)? J. Zool. 207, 227–235.

Drozdz, J. (1963) Helmintofauna zaaklimatyzowanego w Polsce jelenia sika (Cervus nippon). Wiad Parazytol, 9:133–138.

Drozdz, J., Demiaszkiewicz, A.W., Lachowicz, J. (2002) Kształtowanie sie˛ fauny nicieni_zoładkowojelitowych wolno zyja˛cych _zubrow w Puszczy Białowieskiej w cia˛gu ostatnich 17 lat (1984–2001). Wiadomos´ci Parazytologiczne 48 : 375–381.

Drozdz, J., Demiaszkiewicz, A.W. & Lachowicz, J. (2003) Expansion of the Asiatic parasite Ashworthius sidemi (Nematoda, Trichostrongylidae) in wild ruminants in Polish territory. Parasitol Res 89:94–97.

Dunn, A.M. (2009) Parasites and Biological Invasions. In Webster, J.P. Advances in Parasitology, Burlington: Academic Press, Vol. 68, pp. 161-184.

Dzieciolowski, R. (1979) Structure and spatial organisation of deer populations. Acta Theriologica, 24:3-21.

Eick, E. (1995) A history of naturalisation. Pages 9.1–9.14 In E. Eick, R. König and J. Willett, editors. Sika, Cervus nippon Temminck, 1838. Volume I. Second Edition. International Sika Society, Möhnesee, Germany.

Eick, E. (1995a) Austria. Pages 30.1–30.2 in E. Eick, R. König and J. Willett, editors. Sika, Cervus nippon Temminck, 1838. Volume I, Second Edition, International Sika Society, Möhnesee, Germany.

Fautley, R., Coulson, T. & Savolainen, V. (2012) A comparative analysis of the factors promoting deer invasion. Biol Invasions 14:2271–2281.

Feldhamer, G. A. (1980) Mammalian Species: Cervus nippon. Volume One The American Society of Mammalogists, New York City.

Feldhamer, G.A. & Armstrong, W.E. (1993) Interspecific competition between four exotic species and native artiodactyls in the United States. In: Transaction of the North American Wildlife and Natural Resources Conference, 468-478.

Feldamer, G.A. & Demarais, S. (2009) Free-ranging and confined sika deer in North America: current status, biology and management. In: McCullough, D.R. , Takastsuki, S. & Kaji, K. (Eds), Sika deer: biology and management of native and introduced populations, Springer, pp. 615-641.

Ferte, H. (1991) Contribution à la connaissance de l'helmintofaune du Chevreuil (Capreolus capreolus) et des autres cervidés. Th. Doct. Université de Reims, 114p.

Ferte, H., Cleva, D., Depaquit, J., Gobert, S. & Leger, N. (2000) Status and origin of Haemonchinae (Nematoda: Trichostrongylidae) in deer: a survey conducted in France from 1985 to 1998. Parasitol Res, n°86, 582-587.

Flerov, K.K. (1952) Musk Deer and Deer. The Academy of Sciences of the USSR, Moscow.

Flerov, K. K. (1952a) Fauna SSSR. Tom 1 (2) Kabargi i oleni. Izdatelstvo Akademii Nauk SSSR, Moskva (Academy of Science of the USSR Publishers), Leningrad, USSR. (In Russian.)

Fuller, R.J. (2001) Responses of woodland birds to increasing numbers of deer: a review of evidence and mechanisms. Forestry 74: 289-298.

Fuller, R.J. & Gill, R.M.A. (2001) Ecological impacts of deer in woodland. Forestry 74(3): 189-192.

GB Non-Native Species Secretariat (2011) GB non-native organism assessment scheme : *Cervus nippon*, Sika deer. Available online at : https://secure.fera.defra.gov.uk/nonnativespecies/downloadDocument.cfm?id=384

Gebhardt, H. (1996) Ecological and economic consequences of introductions of exotic wildlife(birds and mammals) in Germany. Wildlife Biology 2: 205-211.

Gehle, T. & Herzog, S. (1998) Is there evidence for hybridisation between red deer and sika deer in Germany? Pages 121–123 in Z. Zomborszky, editor. 4th International Deer Biology Congress, June 30-July 4, 1998, Final Program - Abstracts. Pannon Agricultural University, Faculty of Animal Science, Kaposvar, Hungary.

Geist, V. (1999) Deer of the World: Their Evolution, Behaviour, and Ecology. Swan Hill Press, Shrewsbury, England.

Genovesi, P. (2005) Eradications of invasive alien species in Europe: a review. Biological Invasions 7: 127–133.

Genovesi, P. & Putman, R. (2006). Cervus nippon, species factsheet In: DAISIE Delivering Alien Invasive Species Inventories for Europe www.europe-aliens.org (accessed 03.2010).

Gill, R.M.A. (1992) A review of damage by mammals in north temperate forest: 1. Deer. Forestry 65(2): 145-169.Gill, R.M.A. & Fuller, R.J. (2007) The effects of deer browsing on woodland structure and songbirds in lowland Britain. Ibis 149: 119-127.

Goodman, S. J., Tamate, H. B., Wilson, R., Nagata, J., Tatsuzawa, S., Swanson, G. M., Pemberton, J. M. & McCullough, D. R. (2001) Bottlenecks, drift and differentiation: The population structure and demographic history of sika deer (Cervus nippon) in the Japanese archipelago. Molecular Ecology 10: 1357–1370.

Goodman, S., Barton, N., Swanson, G., Abernethy, K. & Pemberton, J. (1999) Introgression through rare hybridization: a genetic study of a hybrid zone between red and sika deer (Genus Cervus) in Argyll, Scotland. Genetics 152:355–371.

Gordon, I.R. (2004) Reproductive technologies in farm animals. Library of congress cataloging in publication data, Cromwell Press, UK, Trowbridge.

Gortazar, C., Vicente, J., Samper, S., Garrido, J.M., Fernández-De-Mera, I.G., Gavín, P. *et al.* (2005) Molecular characterization of Mycobacterium tuberculosis complex isolates from wild ungulates in south-central Spain. Veterinary Research 36: 43–52.

Gortazar, C., Acevedo, P., Ruiz-Fons, F. & Vicente, J. (2006) Disease risks and overabundance of game species. Eur. J. Widl. Res. 52: 81-87.

Gortazar, C., Ferroglio, E., Höfle, U., Frölich, K. & Vicente, J. (2007) Diseases shared between wildlife and livestock: a European perspective. Eur. J. Widl. Res. 53: 241-526.

Groot Bruinderink, G.W.T.A., van der Sluis, T., Lammertsma, Opdam, P. & Pouwels, R. (2003) Designing a coherent ecological network for large mammals in Northwestern Europe. Conservation Biology 17: 549-557.

Groves, C. (2006) The genus Cervus in eastern Eurasia. European Journal of Wildlife Research 52:14-22.

Guofeng, L., Runping, G., Ruijuan, Z. & Yongguang, Y. (2009) PP-015 Sika deer as a new source of human infection by brucella. International Journal of Infectious Diseases, Volume 13, Supplement 1, Page S54.

Haigh, J.C., Mackintosh, C., Griffin, F. (2002) Viral, parasitic and prion diseases of farmed deer and bison. Revue Scientifique et Technique de l’Office International des Epizooties 21: 219−248.

Hannaford, J., Pinn, E.H. & Diaz, A. (2006) The impact of sika deer grazing on the vegetation and infauna of Arne saltmarsh. Marine Pollution Bulletin 53: 56–62

Harrington, R. (1973) Hybridisation among deer and its implications for conservation. Ir. For. J. 30, 64–78.

Harrington, R. (1979) Some aspects of the biology and taxonomy of the deer of the County Wicklow region, Ireland. Ph.D. Thesis, National University of Ireland, Dublin, Ireland.

Harris, R.B. (2008) Cervus nippon. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. www.iucnredlist.org (accessed 03.2012).

Harris, S. & Yalden, D.W. (2008) Mammals of the British Isles. The Mammal Society, 4th edn., Southampton.

Harris, S., Morris, P., Wray, S. & Yalden, D. (1995) A review of British mammals: population estimates and conservation status of British mammals other than cetaceans.

Heptner, V.G., Nasimovitch, A.A. & Banikov, A.G. (1961) Mlekopitayushtchie Sovetskogo soyuza. Tom pervyy. Parnokopytnye i neparnokopytnye. Gosudarstvennoe izdatel’stvo ‘Vysshaya shkola’, Moskva. (In Russian.)

Herzog, S. (1987) Mechanisms of karyotype evolution in Cervus nippon Temminck. Caryologia 40:347–353.

Hobbs, N.T. (1996) Modification of ecosystems by ungulates. Journal of Wildlife Management 60, 695–713.

Hofmann, R. R. (1988) Morphological classification of sika deer within the comparative, morphophysiological system of ruminant feeding types. Pages 6.2/1–8 In E. Eick, J. A. Willett, R. König and K.-H. Schulze-Schwefe, editors. Sika, Cervus nippon Temminck, 1838. Internationale Arbeitsgemeinschaft Sikawild, Möhnesee-Körbecke, Germany.

Hofmann, R. R. (1989) Evolutionary steps of ecophysiological adaptation and diversification of ruminants: A comparative view of their digestive system. Oecologia 78:443–457.

Holt, R.D., Dobson, A.P., Begon, M., Bowers, R.G. & Schauber, E.M. (2003) Parasite establishment in host communities. Ecology Letters 6: 837–842.

Hudson, R.J., Kozak, H.M., Adamczewski, J.Z. & Olsen, C.D. (1991) Reproductive performance of farmed wapiti (Cervus elaphus nelsoni). Small Ruminant Research. 4: 19-28.

Hudson, R.J. & Haigh, J.C. (2002) Physical and physiological adaptations. In: Toweill, Dale E.; Thomas, Jack Ward, eds. North American elk: ecology and management. Washington, DC: Smithsonian Institution Press: 199-258.

Hulme, P.E., Roy, D.B., Cunha, T. & Larsson, T.-B. (2009) A pan-European Inventory of Alien Species: Rationale, Implementation and Implications for Managing Biological Invasions In DAISIE, Handbook of Alien Species in Europe, 1. Springer Science + Business Media B.V, p1-14.

Hurel, P. (2011). Les espèces exotiques envahissantes animales du Nord-Est de la France: inventaire, évaluation, hiérarchisation et plan d'actions. Rapport de stage Master Environnement et Aménagement, Université Paul Verlaine, Metz.

Igota, H., Sakuragi, M. & Uno, H. (2009) Seasonal migration of sika deer in Hokkaido Island, Japan. In: McCullough, D.R. , Takastsuki, S. & Kaji, K. (Eds), Sika deer: biology and management of native and introduced populations, Springer, pp. 251-272.

Innes, R.J. (2011) Cervus elaphus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/ (accessed on 04.2012).

Johnson, M., Mackintosh, C.G., Labes, R.E., Taylor, M.J. & Wharton, D.A. (2003) Dictyocaulus species: a cross infection between cattle and red deer. New Zealand Veterinary Journal 51: 93–98.

Kaji, K, Okada, H., Matsuda, H. Yamanaka, M.& Yabe, T (2004) Irruption of a colonizing sika deer population. J. Wildlife Management 68(4):889–899.

Kaji, K, Takahashi, H., Okada, H., Kohira, M. & Yamanaka, M. (2009) Irruptive behavior of sika deer. In: McCullough, D.R. , Takastsuki, S. & Kaji, K. (Eds), Sika deer: biology and management of native and introduced populations, Springer, pp. 421-435.

Kaji, K., Saitoh, T., Uno, H., Matsuda, H. & Yamamura, K. (2010) Adaptive management of sika deer populations in Hokkaido, Japan: theory and practice. Population Ecology 52 (3): 373-387.Kisanuki, H., Nakasu, M., Nakai, A. & Yurugi, Y. (2008) Predicting the population dynamics of three understory broad-leaved evergreen species under the influence of Sika deer in primary and secondary forests of mid-western Japan. J For Res, 13:52–58.

Kalb, D.M. (2010) Spatial ecology and survival of subadult male sika deer on Maryland's eastern shore. Thesis University of Delaware.

Keiper, R.R. (1985) Are sika deer responsible for the decline of white-tailed deer on the Assateague Island Maryland? Wildl. Soc. Bull. 13, 144±146.

Keller, R.P., Geist, J., Jeschke, J.M. & Kühn, I. (2011) Invasive species in Europe: ecology, status, and Policy. Environmental Sciences Europe, Springer open.

Kelly, D.L. (2000) Charting diversity in a Killarney oakwood: levels of resolution in floristic recording, and the effects of fencing and felling. In: Rushton, B.S. (Ed.), Biodiversity: The Irish Dimension. Royal Irish Academy, Dublin, pp. 76–96.

Kelly, D.L. (2002) The regeneration of Quercus petraea (sessile oak) in southwest Ireland: a 25-year experimental study. Forest Ecology and Management 166: 207-226

Kettunen, M., Genovesi, P., Gollasch, S., Pagad, S., Starfinger, U. ten Brink, P. & Shine, C. (2008) Technical support to EU strategy on invasive species (IAS) - Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission). Institute for European Environmental Policy (IEEP), Brussels, Belgium. 44 pp. + Annexes.

Kotrla, B., Kotrly, A. & Kozdon, O. (1976) Studies on the specifity of the nematode Ashworthius sidemi Schulz, 1933. Acta Vet Brno 45:123–126.

Kowal, J., Nosal, P., Bonczar, Z. & Wajdzik, M. (2012) Parasites of captive fallow deer (Dama dama L.) from southern Poland with special emphasis on Ashworthius sidemi. Annals of Parasitology, 58(1): 23–26.

Kumar, S., Takeda, A. & Shibata, E. (2006) Effects of 13-year fencing on browsing by sika deer on seedlings on Mt. Ohdaigahara, central Japan. J For Res, 11:337–342.

Kuzmina, T.A., Kharchenko, V.A. & Malega, A.M. (2010) Helminth fauna of roe deer (Capreolus capreolus) in Ukraine: biodiversity and parasite community. Vestnik zoologii, 44(1): 12–19.

Lammertsma, D.R., Groot Bruinderink, G.W.T.A. & Griffioen, A.J. (2012) Risk assessment of sika deer *Cervus nippon* in the Netherlands. Alterra Report 2295, Wageningen, 30 pages.

Langbein, J. & Putman, R.J. (2006) National deer-vehicle collisions project, Scotland (2003–2005). Report to the Scottish Executive.

Latham, J. (1999) Interspecific interactions of ungulates in European forests: an overview. Forest Ecology and Management 120: 13-21

Latham, J., Fairweather, A. & Staines, B.W. (1998) How effective is culling for controlling deer populations in forestry plantations? In: Goldspink, C.R., King, S., Putman, R.J. (Eds), Population Ecology, Management and Welfare of Deer, Manchester Metropolitan University, Manchester, UK, pp. 73±78.

Linden, A., Grégoire, F., Nahayo, A., Hanrez, D., Mousset, B., Massart, L., De Leeuw, I., Vandemeulebroucke, E., Vandenbussche, F. & De Clercq, K. (2010) Bluetongue virus in wild deer, Belgium, 2005–8. Emerging Infectious Diseases 16: 833–836.

Livingstone, S.R. (2001) The application of GIS to the spread of introduced Japanese sika deer (Cervus nippon) in Scotland. M.Res. Thesis, University of Edinburgh.

Lovari, S., Herrero, J., Conroy, J., Maran, T., Giannatos, G., Stubbe, M., Aulagnier, S., Jdeidi, T., Masseti, M., Nader, I., de Smet, K. & Cuzin, F. (2008) Cervus elaphus. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. www.iucnredlist.org (accessed 04.2012).

Lowe, V.P.W. & Gardiner, A.S. (1975) Hybridisation between red deer and sika deer, with reference to stocks in north-west England. J. Zool. 177, 553–566.

Lowe, R. (1994) Deer Management: developing the requirements for the establishment of diverse coniferous and broadleaf forests. Unpublished Report, Coilte, Bray, Co. Wicklow.

Maak, R.K. (1859) Puteshestvie po Amuru, sovershenoe v 1855 godu. Saint-Petersburg. (In Russian.)

Markovkin, L. (1999) The sika deer of Lazovsky reserve and surronding areas of the Russian Far East. Almanac Russki Ostrov, Valdivostock, Russia.

Matuszewski, G. (1988) Polen. Pages 5.2-PL/1–9 In E. Eick, J. A. Willett, R. König and K.-H. Schulze-Schwefe, editors. Sika, Cervus nippon Temminck, 1838. Internationale Arbeitsgemeinschaft Sikawild, Möhnesee-Körbecke, Germany.

Matuszewski, G. & Sumin´ski, P. (1984) Sika deer in Poland. Deer 6:74–75.

Maurin H. & Haffner P. (1995) Inventaire de la Faune de France. Nathan & Muséum National d'Histoire Naturelle Paris : 416 pp.

Mayle, B. (1999) Managing Deer in the Countryside, Practice Note No. 6. Forestry Commission, Edinburgh.

McCullough, D.R. (2009) Introduction. In: McCullough, D.R. , Takastsuki, S. & Kaji, K. (Eds), Sika deer: biology and management of native and introduced populations, Springer, pp. 1-10.

McDevitt, A.D., Edwards, C.J. Toole, P.O., O'Sullivan, P., O'Reillva, C.O. & Cardene, R.F. (2009) Genetic structure of, and hybridisation between, red (Cervus elaphus) and sika (Cervus nippon) deer in Ireland. Mamm. biol. 74: 263–273.

McEvoy, P.M., Flexen, M. & McAdam, J.H. (2006) The effects of livestock grazing on ground flora in broadleaf woodlands in Northern Ireland. For. Ecol. Manage. 225, 39–50.

McKelvey, P.J. (1959) Animal damage in North Island protection forests. New Zealand Science Review, 17:28-34.

Miyashita, T., Takada, M. & Shimazaki, A. (2004) Indirect effects of herbivory by deer reduce abundance and species richness of web spiders. Ecoscience 11: 74–79.

Nagaike, T. (2012) Effects of browsing by sika deer (Cervus nippon) on subalpine vegetation at Mt. Kita, central Japan. Ecol Res, 27: 467–473.

Nentwig, W., Kühnel, E. & Bacher, S. (2010) A Generic Impact-Scoring System Applied to Alien Mammals in Europe. Conservation Biology, 24: 302–311

Nomiya, H., Suzuki, W., Kanazashi, T., Shibata, M., Tanaka, H. & Nakashizuka, T. (2002) The response of forest floor vegetation and tree regeneration to deer exclusion and disturbance in a riparian deciduous forest, central Japan. Plant Ecology 164: 263–276.

Nowak, R. M. (1991) Walker's Mammals of the World. Johns Hopkins University Press, Baltimore fifth edition, volume two.

O'Donoghue, A. (1991) Growth, reproduction and survival in a feral population of Japanese sika deer (*Cervus nippon*). PhD thesis, University College, Dublin, Ireland.

Onishi, N., et al. (2009) Reproduction of female sika deer in Japan, with special reference ot Kinkazan Island, Northern Japan. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 101-112.

Osińska, B., Demiaszkiewicz, A.W. & Lachowicz, J. (2010) Pathological lesions in European bison (Bison bonasus) with infestation by Ashworthius sidemi (Nematoda, Trichostrongylidae). Pol J Vet Sci. 13(1):63-7.

Pascal, M., Lorvelec, O., Vigne, J.D., Keith, P. & Clergeau, P. (2003) Évolution holocène de la faune de Vertébrés de France : invasions et disparitions. Institut National de la Recherche Agronomique, Centre National de la Recherche Scientifique, Muséum National d'Histoire Naturelle. Rapport au Ministère de l'Écologie et du Développement Durable (Direction de la Nature et des Paysages), Paris, France. Version définitive du 10 juillet 2003 : 381 pages.

Peek, J.M. (2003) Wapiti (Cervus elaphus). In: Feldhamer, George A.; Thompson, Bruce C.; Chapman, Joseph A., eds. Wild mammals of North America: Biology, management, and conservation, 2nd ed. Baltimore, MD: The Johns Hopkins University Press: 877-888.

Pemberton, J., Swanson, G., Barton, N., Livingstone, S. & Senn, H. (2006) Hybridisation between red and sika deer in Scotland. Deer 13, 22–26.

Pérez-Espona, S., Pemberton, J.M. & Putman, R. (2009) Red and sika deer in the British Isles, current management issues and management policy. Mamm. biol. 74: 247–262.

Perrin, P.M., Kelly, D.L. & Mitchell, F.J.G. (2006) Long-term deer exclusion in yew-wood and oakwood habitats in southwest Ireland: Natural regeneration and stand dynamics. Forest Ecology and Management 236: 356–367.

Perrin, P.M., Mitchell, F.J.G. & Kelly, D.L. (2011) Long-term deer exclusion in yew-wood and oakwood habitats in southwest Ireland: changes in ground flora and species diversity. Forest Ecology and Management 262: 2328–2337.

Przhevalski, N.M. (1870) Puteshestvie v Ussuriiskom krae v 1868–1869. Saint Petersburg. (In Russian.)

Purser, P., Wilson, F. & Carden, R. (2010) Deer and Forestry in Ireland: A Review of Current Status and Management Requirements. Commissioned report prepared for the Woodlands of Ireland (Coillearnacha Dúchasacha) Steering Committee, Dublin, Ireland.

Putman, R.J. (2000) Sika Deer. British Deer Society/Mammal Society.

Putman, R. (2009) Cervus nippon (Sika) datasheet (On-line) In: CAB International 2012 - Invasive Species Compendium. http://www.cabi.org/isc/ (accessed on 04.2012).

Putman, R.J. & Hunt, E. (1994) Hybridisation between red and sika deer in Britain. Deer 9, 104–110.

Putman, R.J. & Moore, N.P. (1998) Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. Mammal Rev. 28, 141–164.

Putman, R.J. & Watson, P. (2009) Developing an impact assessment methodology for use beyond the site scale. Report for the National Trust, England.

Putman, R.J., Langbein, J., Hewison, A.J.M. & Sharma, S.K. (1996) Relative roles of density-dependent and density-independent factors in population dynamics of British deer. Mammal. Rev. 26: 81-101.

Putman, R.J., Langbein, J., Green, P. & Watson, P. (2011) Identifying threshold densities for wild deer in the UK above which negative impacts may occur. Mammal Rev. 41 (3): 175–196.

Radwan, J., Demiaszkiewicz, A.W., Kowalczyk, R., Lachowicz, J., Kawałko, A., Wojcik, J.M., Pyziel, A.M. & Babik, W. (2010) An evaluation of two potential risk factors, MHC diversity and host density, for infection by an invasive nematode Ashworthius sidemi in endangered European bison (Bison bonasus). Biological Conservation, 143: 2049–2053.

Raedeke, K.J., Millspaugh, J.J., Clark, P.E. (2002) Population characteristics. In: Toweill, Dale E.; Thomas, Jack Ward, eds. North American elk: ecology and management. Washington, DC: Smithsonian Institution Press: 449-492.

Ratcliffe, P.R. (1987) Distribution and current status of sika deer (Cervus nippon) in Great Britain. Mammal Rev. 17: 37–58.

Ratcliffe, P.R. (1989) The control of red and sika deer populations in commercial forests. In: Putman, R.J. (Ed.), Mammals as Pests. Chapman & Hall, London, pp. 98–115.

Ratcliffe, P.R. (1991) Sika deer In: Corbet, G.B., Harris, S. (Eds.), The Handbook of British Mammals. Blackwell Scientific Publications, Oxford, pp. 504–508.

Ratcliffe, P.R., Peace, A.J., Hewison, A.J.M., Hunt, E.J. & Chadwick, A.H. (1992) The origins and characterization of Japanese sika deer populations on Great Britain. In: Maruyama, N., *et al.* (Eds.), Wildlife Conservation: Present Trends and Perspectives for the 21st Century. Proceedings of the International Symposium on Wildlife Conservation in Tsukuba and Yokohama, August 21–25, 1990. Japan Wildlife Research Centre, Yushima, Bunkyo-ku, Tokyo, pp. 185–190.

Reed, D.H. & Frankham, R. (2003) Correlation between fitness and genetic diversity. Conserv Biol 17: 230–237.

Reid, H.W. (1992) The biology of a fatal herpesvirus infection of deer (malignant catarrhal fever). In: Brown, R.D. (Ed.), Biology of Deer. Springer Verlag, Berlin, pp. 93−100.

Rocholl, W. (1967) Gebt 'grünes Licht' fur Sika-Wild. Wild und Hund 134–137. (In German.)

Rowcliffe, J.M., Field, J., Turvey, S.T. & Carbone, C. (2008) Estimating animal density using camera traps without the need for individual recognition. Journal of Applied Ecology 45: 1228-1236.

Rutter, S.M. & Langbein J. (2005) Quantifying the damage wild deer cause to agricultural crops and pastures. Contract Report VC0327 to the Department of the Environment, Food and Agriculture (DEFRA).

Sakata, H., Hamasaki, S.I. & Mitsuhashi, H. (2009) The management of sika deer populations in Hyogo prefecture, Japan. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 437–452.

Saint-Andrieux, C., Pfaff, E. & Guibert, B. (2009) Le daim et le cerf sika en France: nouvel inventaire. Faune sauvage 285: 10-15.

Saint-Andrieux, C. & Barboiron, A. (2012) Tableaux de chasse ongulés sauvages, saison 2011-2012. Supplément Faune Sauvage n°296.

Scott, D., Welch, D., Thurlow, M. & Elston, D.A. (2000) Regeneration of Pinus sylvestris in a natural pinewood in NE Scotland following reduction in grazing by Cervus elaphus. Forest Ecology and Management 130 : 199±211.

Scottish Natural Heritage (1994) Red deer and the natural heritage: SNH policy paper, SNH Publications and Graphics.

Senn, H.V., Swanson, G.M., Goodman, S.J., Barton, N.H. & Pemberton, J.M. (2010) Phenotypic correlates of hybridisation between red and sika deer (genus Cervus). Journal of Animal Ecology Volume 79, Issue 2, pages 414–425.

Seki, Y. & Koganezawa, M. (2012) Does sika deer overabundance exert cascading effects on the raccoon dog population. Journal of Forest Research ***

Senn, H.V. & Pemberton, J.M. (2009) Variable extent of hybridization between invasive sika (Cervus nippon) and native red deer (C. elaphus) in a small geographical area. Molecular Ecology, 18: 862–876.

Senseman, R. (2002) Cervus elaphus (On-line), Animal Diversity Web. http://animaldiversity.ummz.umich.edu/site/accounts/information/Cervus_elaphus.html (accessed on 04.2010)

Smith, A. & Xie, Y. (2008) The Mammals of China. Princeton University Press, Princeton, New Jersey.

Société national de protection de la nature et d'acclimatation de France (1961) La terre et la vie. Vol 108-109, pp43.

Sokolov, I. I. (1959) Fauna SSSR. Mlekopitayushtchie. Kopytnye zveri (Otryad Perissodactyla i Artiodactyla). Izdatel'stvo Akademii nauk SSSR, Moskva, Leningrad. (In Russian.)

Stokes, K., O'Neill, K. & McDonald, R.A. (2004) Invasive species in Ireland. Unpublished report to Environment & Heritage Service and National Parks & Wildlife Service. Quercus, Queens University Belfast, Belfast.

Swanson, G.M. (1999) The genetic and phenotypic consequences of translocations of deer (Genus Cervus) in Scotland. Ph.D. Thesis, University of Edinburgh, UK.

Swanson, G.M. & Putman, R. (2009) Sika deer in the British Isles. In: McCullough DR, Takatsuki S, Kaji K (eds) Sika Deer: Biology and Management of Native and Introduced Populations, 595–614. Springer, Tokyo, Japan.

Takahashi, H. & Kaji, K. (2001) Fallen leaves and unpalatable plants as alternative foods for sika deer under food limitation. Ecological Research 16, 257–262.

Takatsuki, S. (1988) The weight contributions of stomach compartments of sika deer. Journal of Wildlife Management 52:313–316.

Takatsuki, S. (2006) Ecological History of Deer. University of Tokyo Press (in Japanese).

Takatsuki, S. (2009a) Effects of sika deer on vegetation in Japan: A review. Biological Conservation 142 : 1922–1929.

Takatsuki, S. (2009b) Geographical variations in food habits of sika deer: the northern grazer vs. the southern browser. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 231–237.

Takatsuki, S. (2009c) What is "natural" vegetation? A reconsideration of herbivory by wild ungulates. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 231–237.

Takatsuki, S. & Ito, T.Y. (2009) Plants and plant communities on Kinkazan Island, northern Japan, in relation to sika deer herbivory. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 125–143.

Theodorou, K. & Couvet, D. (2006) On the expected relationship between inbreeding, fitness, and extinction. Genet Sel Evol 38: 371–387.

Uno, H., Kaji, K. & Tamada, K. (2009) Sika deer population irruptions and their management on Hokkaido island, Japan. In: McCullough, D.R., Takatsuki, S., Kaji, K. (Eds.), Sika Deer: Biology and Management of Native and Introduced Populations, pp. 405–419.

Vavruneˇk, J. & Wolf, R. (1977) Chov jelení zvˇeˇre v Západocˇeském kraji. Sborník veˇdeckého lesnického ústavu VŠZ v Praze 20:97–115. (In Czech.)

Ward, A.I. (2005) Expanding ranges of wild and feral deer in Great Britain. Mammal Rev, Volume 35, No. 2, 165–173.

Ward, A., Etherington, T. & Ewald, J. (2008) Five years of change. Deer 14, 17–20.

Ward, A.I., Lees, K. (2011) Analysis of cost of preventing establishment in Scotland of muntjac deer (Muntiacus spp.). Scottish Natural Heritage, Commissioned Report No. 457.

Welch, D. *et al.* (2001) An audit of species in Scotland. Scottish Natural Heritage Review 139, 225 pp.

White, P.C.L. & Harris, S. (2002) Economic and environmental cost of alien vertebrate species in Britain. In: D. Pimentel (Ed), Biological Invasions: economic and environmental cost of alilen plant, animal and microbe species, CRC Press, pp. 113-150.

Wisdom, M.J. & Cook, J.G. (2000) North American elk. In: Demarais, Stephen; Krausman, Paul R., eds. Ecology and management of large animals in North America. Upper Saddle River, NJ: Prentice Hall: 694-735.

Wittenberg, R., Kenis, M., Hänggi, A., Gassman, A. & Weber, E. (2006) Invasive alien species in Switzerland, An inventory of alien species and their threat to biodiversity and economy in Switzerland. Federal Office for the Environment, Bern.

Wolf, R. & Vavruneˇk, J. (1975–1976) Sika východní Cervus nippon Temm v Západních Cˇechách. Sborník Veˇdeckého Lesnického Ústavu VŠZ v Praze 18–19:185–199. (In Czech.)

Wotchikowsky, U. (2009) Distribution and management of ungulates in Germany. In: Apollonio, M., Andersen, R., Putman, R.J. (Eds.), European Ungulates and their Management in the 21st century. Cambridge University Press (in press).

Wotchikowsky, U. (2010) Ungulates and their management in Germany. In:Apollonio M, Andersen R, Putman R (eds) European Ungulates and Their Management in the 21st Century, 201–222. Cambridge University Press, Cambridge, UK.

Zima, J., Kozena, I. & Hubalek, Z. (1990) Non-metrical cranial divergence between Cervus elaphus, C. nippon nippon and C. nippon hortulorum. Acta Sci. Nat. Brno. 24, 1–41.

Cellule interdepartementale
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 81 626 420 – 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