Risk assessment of Sika deer *Cervus nippon* in the Netherlands

Alterra Report 2295
ISSN 1566-7197

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Commissioned by Invasive Alien Species Team Netherlands Food and Consumer Product Safety Authority

Project code 5239331.01

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Alterra Report 2295

Alterra, part of Wageningen UR
Wageningen, 2012

Abstract

D.R. Lammertsma, G.W.T.A. Groot Bruinderink and A.J. Griffioen, 2012. *Risk assessment of Sika Deer Cervus nippon in the Netherlands*. Wageningen, Alterra, Alterra-Report 2295. 30 blz.; 3 fig.; 6. tab.; 51 ref.

Sika Deer *(Cervus nippon)* is considered an invasive alien species in Europe. They were introduced in the 19th and 20th century in Europe and have established self-sustaining populations in various countries. Main concerns for Sika, without preventive measures taken and without population control, are about damage to forestry (silviculture, timber production), agriculture, Natura 2000 areas, competition with native ungulates and hybridization and introgression with native Red Deer. Risk assessment for Sika Deer in this study was done using two methods assuming no human intervention (no preventive measures, no population control).

Keywords: Sika Deer, Cervus nippon, risk assessment, risk management.

ISSN 1566-7197

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Alterra Report 2295
Wageningen, February 2012

Contents

Summary

Sika deer *(Cervus nippon)* is considered an invasive alien species in Europe. They were introduced in the 19th and 20th century in Europe and have established self-sustaining populations in the UK, Austria, Czech republic, Denmark, Finland, France, Germany, Poland, western Russia and Ukraine. The term 'Invasive alien species' in this project refers to an alien species whose introduction was made possible by human intervention (such as active introduction, or by lifting bio geographical barriers) and spreads beyond the place of introduction and becomes abundant and/or threatens biological diversity.

Sika Deer have no established self-sustaining populations in the Netherlands or Belgium at the moment, although a few Sika Deer are present near 's-Graveland (the Netherlands). A possible pathway from Sika Deer to the Netherlands is dispersal from seven established populations in Germany, especially from the Möhnesee area, which lies approximately 80km as the crow flies from the Dutch border. However, this is not likely to occur given the current control measures (hunting) against Sika Deer in Germany. A second pathway is escape or deliberate release from enclosed parks and deer farms, which was the origin of all of the present European populations.
Main concerns for Sika, without preventive measures taken and without population control, are about damage to forestry (silviculture, timber production), agriculture, Natura 2000 areas, competition with native ungulates and hybridization and introgression with native Red Deer.

Risk assessment for Sika Deer was done using two methods assuming no human intervention (no preventive measures, no population control):
1) ISEIA protocol. Guidelines for environmental impact assessment and list classification for non-native organisms in Belgium. http://ias.biodiversity.be/ias/documents/ISEIA_protocol.pdf
2) Bomford, M., 2003. Risk assessment for the import and keeping of exotic vertebrates in Australia. Bureau of rural sciences, Canberra, Australia. http://affashop.gov.au/product.asp?prodid=12803

1) Sika according to the ISEIA protocol are classified as a category A: 'black list species'.
Sika Deer are not yet naturalized in the Netherlands, but are invasive in other European countries and are on the SEBI 2010 list of 'Worst invasive alien species threatening biodiversity in Europe' (European Environment Agency, 2007). Sika are therefore classified as an 'Alert list species'.
2) Sika according to Bomford are classified as threat category 'extreme'.

As populations in Germany are controlled by hunting and spatial connectivity between these populations and the Netherlands is limited, natural dispersal to the Netherlands is possible but not foreseeable in the immediate future. Several other, sympatric deer species throughout the Netherlands and neighbouring countries increase the chance of an undetected spread of Sika and Sika-Red Deer hybrids. The presence of Sika hybrids may go undetected for a long time, and the presence of Sika hybrids is often disbelieved even by hunters until demonstrated by DNA analysis. Gathering DNA samples (tissue or fresh dung) of Red Deer dispersing into Twente, de Achterhoek and the province of Limburg might yield important information for the start of an eradication campaign, when considered necessary. In order to prevent escape from Sika Deer out of enclosures highly secured premises with low numbers of Sika are needed. Another effective measure would be to keep the numbers of individuals per enclosure low or to not keep the species at all, especially in or near the Veluwe and Oostvaardersplassen where Red Deer occur.
Eradication, the permanent removal of all wild populations by a time-limited campaign, is achievable by heavy culling in parts of the Netherlands where recent settlement occurs or sub-populations remain localised. Once

the spread of Sika is too advanced this approach to contain the population will not be effective. Once widespread populations in the Netherlands do exist, the only option will be to maintain low population density in colonized area and to prevent the spread of Sika into new areas. Methods available to control populations and minimize their impact are culling, contraception and exclusion of deer by the use of fences.

1 Introduction

Sika Deer *(Cervus nippon)* is considered an invasive alien species in Europe. They were introduced in the 19th and 20th century in Europe (UK, Austria, Czech republic, Denmark, Finland, France, Germany, Poland, western Russia, Ukraine). The term 'Invasive alien species' in this project refers to an alien species whose introduction was made possible by human intervention (such as active introduction, or by lifting bio geographical barriers), spreads beyond the place of introduction and becomes abundant and threatens biological diversity. This report contains a risk analysis on Sika Deer for the Netherlands.

Sika Deer (*Cervus nippon* Temminck, 1838)

Class:	Mammalia
Order:	Artiodactyla
Family:	Cervidae
Subfamily:	Cervinae

Original distribution and subspecies
Sika originate from China, Japan, Korea, Taiwan, Russia and Vietnam (Wilson and Mittermeier, 2011). Traditional taxonomy considers at least ten subspecies, whose validity is questionable.

China
C. n. sichuanicus, C.n. kopschi, C. n. grassianus, C. n. mandarinus, C. n. mantschuricus

Japan
C.n. yesoensis, C.n.centralis, C.n. nippon,.

Korea
C.n. mantschuricus

Taiwan
C.n. taiouanus

Vietnam
C.n. pseudaxis

Russia
C. n. mantschuricus

Risk analysis
Important aspect of the risk analysis is the possible impact of this exotic species on Dutch biodiversity, the economy and public and animal health. This report consists of two elements: risk assessment and risk management.

Risk assessment

Risk assessment is done assuming no human intervention (no preventive measures, no population control) considering:

A. Probability of entry
   1. Distribution of Sika Deer in the Netherlands and neighbouring countries
   2. Pathways

B. Probability of establishment
   1. Habitat suitability analysis of the Netherlands

C. Possible rate of spread (natural or induced by humans)

D. Risk areas
   1. Colonisation of high conservation value habitats (Natura 2000)

E. Impact
   1. Possible consequences for biodiversity, economy and public health

F. Risk assessment score

Ad E: Biodiversity impact includes: ecosystem destabilisation, reduced biodiversity, loss of habitats. Economic impact includes agricultural productivity, damage costs. Public health includes injuries to people.

Risk management

A. Prevention
   1. What methods are available to prevent settlement in the Netherlands

B. Elimination
   1. What methods are available to eradicate Sika Deer in the Netherlands

C. Control
   1. What methods are available to control populations and minimize impact in the Netherlands

2 Method

Calculating risk assessment scores for Sika Deer was done using two methods:
1) ISEIA protocol. Guidelines for environmental impact assessment and list classification for non-native organisms in Belgium. http://ias.biodiversity.be/ias/documents/ISEIA_protocol.pdf
2) Bomford, M., 2003. Risk assessment for the import and keeping of exotic vertebrates in Australia. Bureau of rural sciences, Canberra, Australia. http://affashop.gov.au/product.asp?prodid=12803

Method 1
The ISEIA protocol focusses on documented invasion histories in previously invaded areas in western Europe and allocates species in the following categories:
1) Category A (black list): includes species with a high environmental risk
2) Category B (watch list): includes species with a moderate environmental risk on the basis of current knowledge
3) Category C (low environmental risk): includes other non-native species that are not considered as a threat for native biodiversity and ecosystems

Scoring system
A three point scale is selected for the assessment. Providing that sufficient information exists the following scores are used:
1) L = low score=1
2) M = medium score=2
3) H = High score=3

When the parameter is only poorly documented in the literature or is based on expert judgment and field observations the score is adapted to:
1) Unlikely score=1
2) Likely score=2

When no information is available:
1) DD = deficient data, no score

The global ISEIA score is the sum of four impact scores: Invasiveness, Colonisation of high conservation value habitats (Natura 2000), Adverse impact on native species, Alteration of ecosystem functions. Allocations by total score are: 11-12 points (A black list), 9-10 points B (watch list), 4-8 points C (low environmental risk).

Method 2
The following factors are assessed (Table 1). Climate matching analysis was excluded from the risk assessment because Sika Deer is thriving around Europe.

Table 1
Risk factors and min-max scores.

Factor	
A1.	Risk to people from individual escapees (0 - 2)
A2.	Risk to public safety from individual captive animals (0 - 2)
Stage A	**Risk to public safety from captive or released individuals: A = A1 + A2 (0 - 4)**
B1.	Degree of climate match between species overseas range and the Netherlands (1 - 6)
B2.	Exotic population established overseas (0 - 4)
B3.	Taxonomic Class (0 -1)
B4.	Non-migratory behaviour (0 - 1)
B5.	Diet (0 - 1)
B6.	Lives in disturbed habitat (0 - 1)
B.	**Establishment risk score: B = B1 + B2 + B3 + B4 + B5 + B6 (1 - 14)**
C1.	Taxonomic group (0 - 4)
C2.	Overseas range size (0 - 2)
C3.	Diet and feeding (0 - 3)
C4.	Competition with native fauna for tree hollows (0 - 2)
C5.	Overseas environmental pest status (0 - 3)
C6.	Climate match to areas with susceptible native species or communities (0 - 5)
C7.	Overseas primary production pest status (0 - 3)
C8.	Climate match to susceptible primary production (0 - 5)
C9.	Spread disease (1 - 2)
C10.	Harm to property (0 - 3)
C11.	Harm to people (0 - 5)
C.	**Pest risk score for birds, mammals, reptiles and amphibians:** **C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 (1 - 37)**

To assign the species to a VPC (Vertebrate Pest Committee) Threat category, the scores from Table 1 are used as the basis for the following decision process.

Risk to public safety posed by captive or released individuals (A)
A = 0 not dangerous
A = 1 moderately dangerous
A = 2 highly dangerous

Risk of establishing a wild population (B)
For birds and mammals:
B < 7 low establishment risk
B = 7 - 8 moderate establishment risk
B = 9 - 10 high establishment risk
B > 10 extreme establishment risk

Risk of becoming a pest following establishment (C)
C < 9 low pest risk
C = 9 - 14 moderate pest risk
C = 15 - 19 high pest risk
C > 19 extreme pest risk

VPC Threat Category

A species' VPC Threat Category is determined from the various combinations of its three risk scores (Table 2).

Table 2

VPC Threat Categories, based on risk posed by captive or released individuals (A), establishment risk (B) and pest risk (C).

Establishment risk[1] (B)	**Pest risk[1] (C)**	**Risk posed by individual escapees (A)**	**VPC Threat Category**
Extreme	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
High	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Moderate	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Moderate	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Moderate	Moderate	Highly Dangerous	Serious
Moderate	Moderate	Moderately Dangerous or Not Dangerous	Moderate
Moderate	Low	Highly Dangerous	Serious
Moderate	Low	Moderately Dangerous or Not Dangerous	Moderate
Low	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Low	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Low	Moderate	Highly Dangerous	Serious
Low	Moderate	Moderately Dangerous or Not Dangerous	Moderate
Low	Low	Highly Dangerous	Serious
Low	Low	Moderately Dangerous	Moderate
Low	Low	Not Dangerous	Low

1 'Establishment Risk' is referred to as the 'Establishment Likelihood' and 'Pest Risk' is referred to as the 'Establishment Consequences' by the Vertebrate Pests Committee.

Data used for the risk analysis were obtained from a literature scan. In order to analyze habitat suitability and connectivity between existing populations of Sika in neighbouring countries we used the LARCH landscape ecology model (Groot Bruinderink et al., 2003).

3 Risk assessment

3.1 Probability of entry

3.1.1 Distribution in the Netherlands and neighbouring countries

In Europe Sika were introduced (e.g. from Japan, China, Vietnam, Korea or 'unknown') into enclosures (deer parks, zoos, private collections) from which they subsequently escaped or were released, in most cases at the end of the 19th and the beginning of the 20th century. In all following European countries the species now is established: Austria, Czech Republic, Denmark, France, Hungary, Ireland, Poland, Switzerland, Ukraine, western Russia, United Kingdom and Germany (Bartos, 2009; Perez-Espona et al., 2009; Figure 1). Very likely subspecies from the source countries interbred, so no longer a single subspecies can be distinguished. Sika Deer also can hybridise with Red Deer and introgression (the fertile hybrid can backcross with either parent species) may occur.

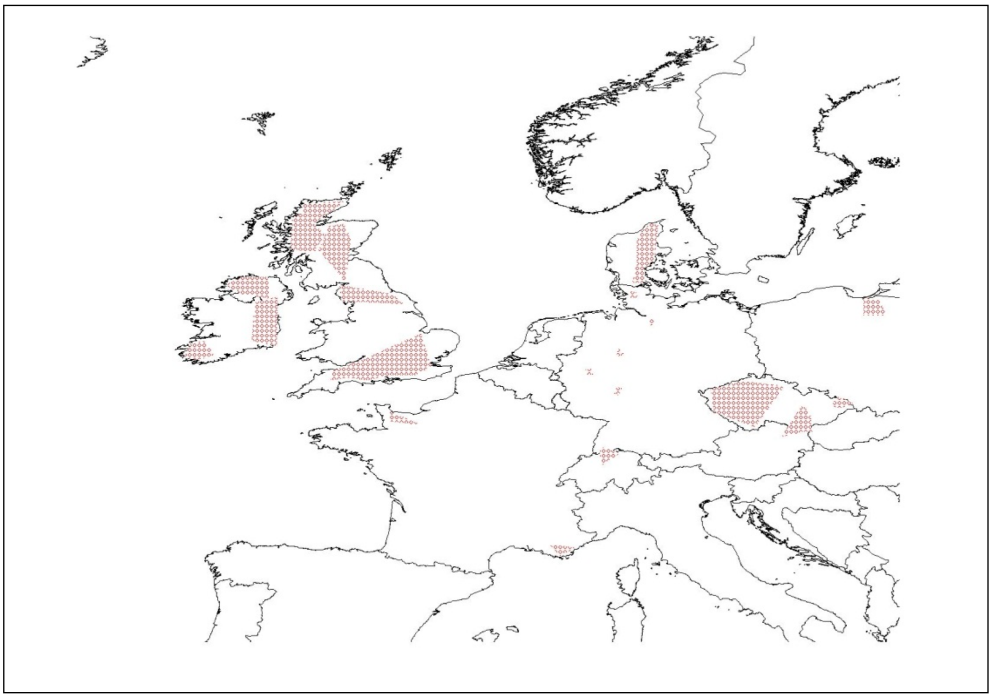

Figure 1
Approximate distribution of Sika Deer in Europe.

Germany has seven established populations. Estimated numbers in Germany in 2005 was 1500 Sika (Bartos, 2009). Glücksburg north of Ostangeln harbours a population of 25 Sika Deer, Hochrhein near Waldshut and the Swiss border 350, Hütten and Duvenstedt mountains 70, Möhnesee east of Dortmund 800, Ostangeln and Schwansen close to the Danish border 150, Schlitz 35 (probably extinct) and Weserbergland southwest of Hannover 70. The largest population of Sika Deer in Germany where first introduced in 1893 in an enclosure of 800 ha near Neuhaus, Möhnesee. Sika escaped in 1936 when the fence was broken by snow and started spreading from 1945 onwards. Populations of Hochrhein and Ostangelen, Schwansen formed during World War II after fences broke down. Hütten and Duvenstedt mountains formed after 1965. In Schlitz Sika appeared in the wild after 1960. The most recently established population is the one in Glücksburg where Sika escaped in the winter of 1978/79 after heavy snow. Numbers given by Bartos appear to be an underestimate. Each year between 2001-2008 on average 400-700 Sika are culled or found dead in the Möhnesee area (http://nrw.nabu.de/themen/jagd/weiteresaeugetiere/07264.html). This indicates that numbers are higher than mentioned by Bartos (2009). An irruptive population in Japan increased by 20% on a yearly basis between 1986 to 1998 (Kaji et al., 2004). In order for the hunting bag to be stable this means that population size in the Möhnesee area amounts to 2000-3500 Sika. The Hochrhein population has a stable hunting bag of 446 Sika/year (Elliger et al., 2011). The population therefore can be estimated at 2230 deer.

Sika Deer have no established self-sustaining populations in the Netherlands or Belgium at the moment (Bartos, 2009). However, from 2005 onwards Sika Deer are spotted in one area in the Netherlands. In total 18 observations were made near ‘s-Graveland (www.waarneming.nl). Based on photo’s at least one male and one female are present. In Belgium one observation of two individuals was made in Les Marionville (Saint-Ghislain) in November 2011 (www.waarnemingen.be).

3.1.2 Pathways

The most likely pathway for Sika Deer and Sika-Red Deer hybrids is natural dispersal from the populations in Germany (Figure 2). Dispersal from established populations at the Möhnesee, Weserbergland and Hütten and Duvenstedt area is most likely to occur. The Möhnesee population is closest to the Dutch border (approximately 80km as the crow flies), but connectivity is rather low. Colonisation by dispersal of young adult (subadult male) Sika is possible, but seems unlikely in the immediate future considering the fact that German populations are actively controlled by hunting.

A second pathway is escape or deliberate release from enclosed parks and deer farms, which was the origin of all of the present European populations (Bartos, 2009; Perez-Espona et al., 2009). In the Netherlands, Sika are kept in Zooparc Overloon and Safaripark Beekse Bergen (http://www.nvddierentuinen.nl/dierzoeker/ , http://www.isis.org/Pages/findanimals.aspx). Available information on the occurrence in private Zoo’s however is fragmentary and constantly changing (Bartos, 2009). In the Netherlands several smaller parks keep Sika (for instance Dierenpark Ten Kate, Nieuwleusen; Zie-Zoo, Volkel; Uilen-dierenpark 'de Paay', Beesd; Van Blankendaell Park, Tuitjenhorn). The few observed Sika Deer near ‘s Graveland most likely originate from captivity.

In Belgium Sika are distributed over several hobby parks (Bartos, 2009). The probability of release or escape cannot be quantified. The probability is determined mainly by the conditions under which species are kept, natural disasters, and any economic or social benefit perceived to be attached to their release (Bomford, 2003). However, given the current populations and observations of Sika Deer in European nature it is clear that incidental release or escape does occur, also in the Netherlands.

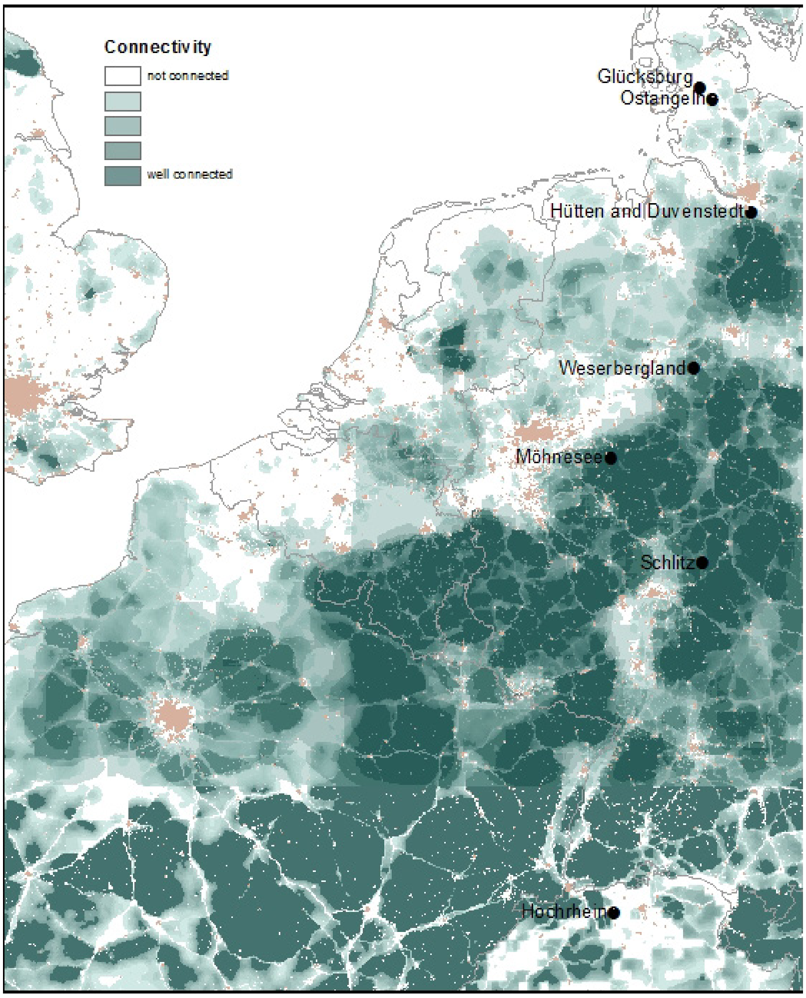

Figure 2
Spatial connectivity for Sika and hybrid Sika-Red Deer habitat as calculated by the landscape ecology model LARCH (Groot Bruinderink et al., 2003).

3.2 Probability of establishment

Climate and habitat
In Asia the species currently inhabits areas with either a steppe, a warm terrestrial or a snow climate (> 40 cm is limiting; Wilson and Mittermeier, 2011). Principal habitats are managed and natural forests, plantations and orchards, grasslands (grazing systems) and riverbanks. Sika will adapt to live in many habitats, including mixed woods and moorland, estuarine reed beds, provided some cover is available (Perez-Espona et al., 2009). Sika, like Red Deer, are intermediate grazers (Hofman, 1985; Henk et al., 1988), well adapted to grazing on pastures, and can digest coarser (more fibrous) vegetation such as heather, conifer needles and deciduous tree leaves. Diet is quite similar to Red and Fallow Deer. They are sympatric with other native deer species in Europe like Roe, Red and Fallow Deer. Competition with these species did not prevent settlement in other European countries such as the UK, Germany and the Czech Republic and Sika can even outcompete native ungulates (Bartos, 2009). Therefore it is plausible that Sika and hybrid Sika-Red Deer can occupy the same habitats in the Netherlands as Red Deer can. Habitat suitability analysis was therefore performed using Red Deer modeling data (Groot Bruinderink et al., 2003). Figure 3 gives an indication of the suitable habitat patches in the Netherlands and surrounding countries. Settlement at the moment is possible due to the

presence of an adult male and female near 's-Graveland. The location is near to a key and MVP population area on the Utrechtse Heuvelrug. When offspring is viable the probability of establishment in this area is high. Viability of the population however will depend on the occurrence of inbreeding depression (Laikre, 1999; Liberg et al., 2005).

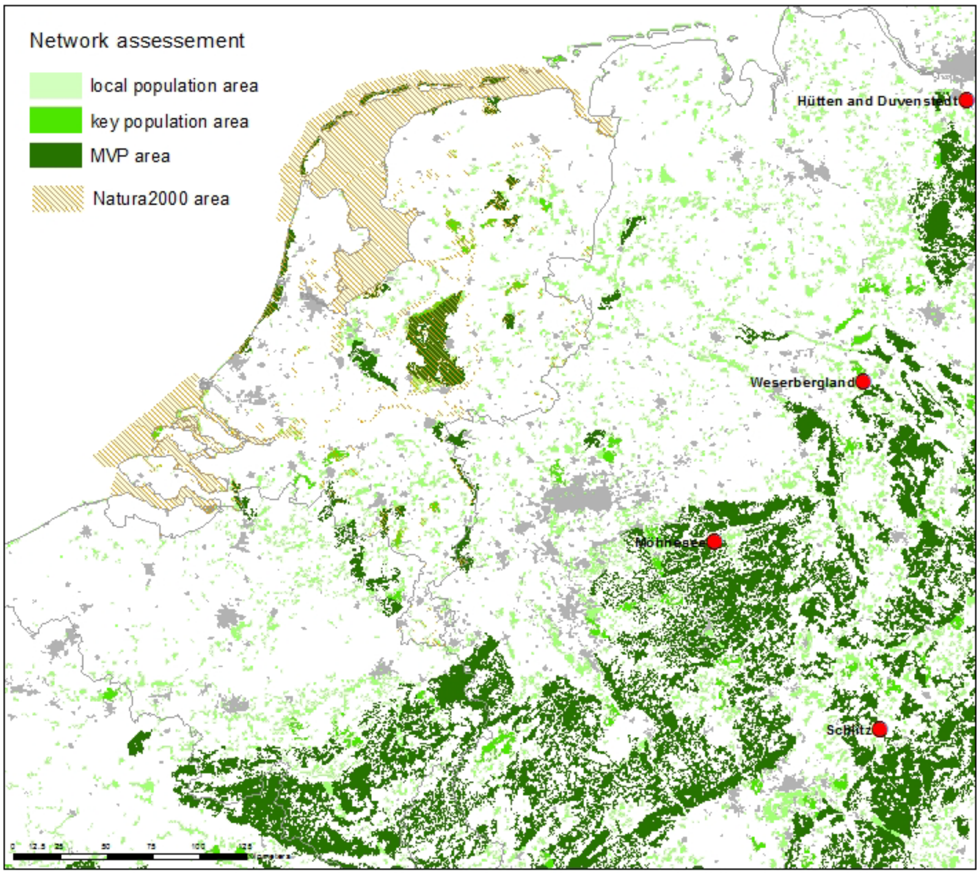

Figure 3
Network assessment for Sika and hybrid Sika-Red Deer as calculated by landscape ecology model LARCH (Groot Bruinderink et al., 2003). MVP is minimum viable population (95% probability of survival over a period of 100 years with zero immigration), Key population is a large local population in a network that is persistent assuming one immigrant per generation.

3.3 Possible rate of spread

Range expansion in Ireland and the UK varies between 4.6-7.3% per year (Perez-Espona et al., 2009; Carden et al., 2011; Ward, 2005). Natural spread may at first not be very fast as Sika are not territorial and are socially fairly tolerant, even at high densities (Kaji et al., 2004; Bartos, 2009), but young males are likely to make longer dispersal movements (Senn and Pemberton, 2009). Sika can migrate long distances up to 80-160 km/year (Bartos, 2009). In their native range in Japan seasonal migration distances of 7-101 km/year were recorded by radio tracking 57 deer (Igota et al., 2004). Mean dispersal distance by yearling males (N=120) was 7.7km with distance and direction being random (Kalb, 2010). Considering the rate of spread theoretically Sika can reach the Netherlands within ten years. In practice when considering the spatial connectivity between the German populations and the eastern border of the Netherlands (see 3.1.2) and the general control of the population by hunting in Germany, it seems likely that spontaneous colonisation will not take place in the immediate future. Colonisation by hybrid Sika-Red Deer however remains possible (see 3.5) as they are often not detected by hunters.

3.4 Risk areas

Possible colonisation of high conservation value habitats (Natura 2000 areas) is presented in Figure 2. Considering the impact Sika in high densities can have on these habitats (see 3.5) the following areas could be threatened if Sika establish a minimum viable population by dispersal, escape or release:

- Duinen Schiermonnikoog
- Lauwersmeer
- Duinen Ameland
- Waddenzee (kust)
- Duinen Vlieland
- Duinen en lage land Texel
- Schoorlse duinen
- Noordhollands duinreservaat
- Kennemerland-Zuid
- Meijendel & Berkheide
- Brabantse Wal
- Oostvaardersplassen
- Fochteloërveen
- Drents-Friese Wold & Leggelderveld
- Dwingelderveld
- Veluwe
- Sallandse Heuvelrug
- Maasduinen
- Kempenland-West
- Leenderbos, Grootte Heide & de Plateaux
- Meinweg
- Swalmdal
- St. Jansberg
- Bruuk

3.5 Impact

Main concerns in Europe are about damage by Sika Deer to forestry and hybridization with native Red Deer (Harrington, 1973, 1982; McDevittl et al., 2009; Lowe and Gardiner, 1975; Goodman et al., 1999; Putman, ybrisationpopulation control.

Environmental impact
Introduction of Sika in Europe has led to hybridization and introgression in the wild between Red Deer *(Cervus elaphus*) and Sika deer both in the introduced areas (Wyman et al., 2011; Senn and Pemberton, 2009; Perez-Espona et al., 2009) as in part of Sika's native range along the Russian-Chinese border (Bartos, 2009). The most common direction is between male Sika and female Red Deer. First generation (F1) hybrids show traits of both species. After hybridization the fertile hybrid can backcross with either parent species (introgression). This introgressed hybrid is difficult to identify in the field. Hybridization between Red Deer and Sika Deer in Scotland occurred extensively (6.9%). These hybrids where not detected by hunters shooting them. Some

sites had no hybrids present with both species present, while other sites showed up to 43% introgressed animals.

Hybridization between Sika Deer and Red Deer occurs although they are considered separate species, Thus it seems plausible to designate *Cervus nippon* and *C. elaphus* as a subspecies or deme (strictly a gamodeme; defined as a more or less isolated local intrabreeding community; Carson, 1987). One might question the deleterious impact of hybridization of Sika and Red Deer. Although hybridization is widespread in for instance plant species they are rarely, if ever, observed to disappear due to hybridization (Carson, 1987). Selection could favor Red Deer genes which have been evolved over thousands of years in Europe and reject perturbing influences from Sika genes, as seems to be the case with Red Deer on the Russian-Chinese border (Carson, 1987; Jackson, 2011).

Competition between native ungulates (Roe Deer, Red Deer, Wild boar and Fallow Deer) seems likely, but the outcome cannot be predicted and differs between areas (Bartos, 2009). Sika is reported to outcompete Roe Deer, to outcompete Fallow Deer or to be outcompeted by Fallow Deer and to disturb Red Deer rutting.

At high density Sika can cause significant impact on (semi-)natural habitats (Diaz et al., 2005; Kaji et al., 2009; Takatsuki, 2009). In their native range in Japan Sika influenced the natural vegetation in half of the 83 national parks and form a severe threat to endemic and rare species. On Nakanoshima island at a density of >30/km^2 Sika grazing changed the vegetation of trees, bamboos, forbs and grasses into a short-grass community (Kaji et al., 2009). On Cape Shiretoko (Hokkaido) density after colonization fluctuated due to crashes induced by severe winters from 8/km^2 to 118/km^2. At densities >15/km^2 small trees (dbh<15 cm) disappeared due to browsing and bark stripping. At densities >80/km^2 several palatable species like Elm, *Prunus ssiori* and dwarf bamboos were eliminated and replaced by unpalatable species colonizing the area. In England neither Sika nor Red deer cause significant damage to conservation habitats due to population control, although local areas are affected (Perez-Espona et al., 2009). Deer grazing and browsing can lead to drastic changes in ecosystems (Tanentzap et al., 2012; Côte et al., 2004). Even at low densities deer can have a significant impact on ecosystems because of selective foraging. By foraging selectively, deer affect plant survival and growth, with cascading effects on fauna. At high ungulate densities selective browsing by deer for instance can prevent the regeneration of oak (Kuiters and Slim, 2002; Pellerin et al., 2010). This can cause forest ecosystems to tip to an alternative state, whereby removing the disturbance factor will not automatically result in the return to its previous state (Tanentzap et al., 2012; Côte et al., 2004). Whether or not a shift in an ecosystem occurs depends on whether or not deer primarily consume dominant species. Declines in plant cover and species richness usually occurs once browse resistant or tolerant species become dominant (Côte et al., 2004). Effects of Sika will depend on factors like population dynamics and corresponding density of Sika, habitat use, diet, vegetation available, interactions with other ungulates and site management and is identical to Red Deer impact. The type and magnitude of potential impact of Sika in the Netherlands is difficult to predict, but will be significant on natural habitats.

Economic impact
At high density Sika Deer can cause economic harm to commercial timber production (Akashi and Nakashizuka, 1999; Perez-Espona et al., 2009; Elliger et al., 2011)**.** They have the potential to cause local damage to agricultural crops as in their native range (Perez-Espona et al., 2009). On Hokaido island (Japan) damage by deer to agriculture and forestry was estimated at $30-50 million/year from 1996 onwards with a hunting bag of 40-60000 deer (Matsuda et al., 1999; Takatsuki, 2009). In Europe however damage to arable and horticultural crops currently appears to be of minor significance (Perez-Espona et al., 2009), but here all populations are controlled at low densities by hunting. If Sika Deer would not be controlled it is likely that significant damage will occur to agricultural crops. Because Sika can forage on the same items as Red Deer damage can be expected to graminoids (grasses, maize, grain), potatoes and sugar beets (Groot Bruinderink et al., 2008).

Social impact
Sika Deer are involved in deer-vehicle collisions (DVC's) in Europe and can cause severe damage, injuries and fatalities (Groot Bruinderink and Hazebroek, 1996). The number of potential vehicle collisions with Sika in the Netherlands can only be roughly estimated, because a lot of factors are involved like density of deer, traffic volume, traffic speed, number of lanes, landscape characteristics, vegetation type adjacent to a road and mitigation measures taken (Groot Bruinderink and Hazebroek, 1996; Knapp, 2004; Malo et al., 2004). Approximately 3% of the spring population of 1700 Red Deer in the Dutch Veluwe area are involved on a yearly basis in deer-vehicle collisions (Groot Bruinderink et al., 2010). Based on a modelling exercise with Forspace (Groot Bruinderink et al., 2004) Red Deer densities on the Veluwe area without population control by hunting may reach carrying capacity at approximately 7/km^2, which adds up for the total Veluwe to 3600 deer. This density can be used for poor habitats on sandy soil. In the richer habitat of the Dutch Oostvaardersplassen (on clay soil) Red Deer reach densities of ca. 30/km^2 which is similar to reported Sika densities (Kaji et al., 2009). The total area suitable for Red Deer in the Netherlands is approximately 2000 km^2 (Groot Bruinderink et al., 2003), which can be inhabited by 14000 Sika in poor habitats, to 60000 Sika Deer in rich habitat. Total costs can be calculated by multiplying suitable habitat * deer density * %DVC * Incident cost. In the Netherlands total costs are then estimated at ca. 2.2 (0.8-3.6) million euro/year (Table 3).

Table 3
Calculation of minimum and maximum costs of Sika Deer vehicle collisions (DVC).

Habitat km^2	Sika_min/ km^2	Sika_max/ km^2	NSika_min	NSika_max	Incident cost	%DVC	Min cost €	Max cost €
2000	7	30	14000	60000	2000	3	840000	3600000

Human and animal health impact
Sika can be infected with bacterial and viral diseases of concern to animal and human health, such as *Salmonella*, TB (*Mycobacterium bovis*), Lyme disease and foot-and-mouth disease (Delahay et al., 2002; Böhm et al., 2007; Côte et al., 2004). Sika Deer also introduced and transmitted the Asiatic blood-sucking nematode *Asworthius sidemi* into Europe. This roundworm has affected almost 100% of the Polish population of the European bison *Bison bonasus* and causes chronic diarrhoea, deterioration and death of young animals (Nentwig, 2007; Radwan et al., 2010). Roe Deer, Red Deer, cattle and sheep are also susceptible to this parasite.

High densities of Sika will favor the transmission of diseases. Humans are chiefly exposed to wildlife zoonosis via the spread of infections to domestic livestock or the consumption of contaminated meat. Contact with or ingestion of water contaminated with feces and urine of infected animals is a second pathway for transmission between wildlife and humans. The probability cannot be estimated.

3.6 Risk assessment score

ISEIA score
Invasiveness
High risk, Sika can easily disperse >1km/year and initiate new populations. Score=3

Colonisation of high conservation value habitats (Natura 2000)

Sika can colonize Natura 2000 areas and are a potential threat to red list species due to overgrazing. Score=3

Adverse impact on native species
Sika can locally affect native species by herbivory, competition with native ungulates, transmission of diseases and by genetic effects (hybridization and introgression with Red Deer). Score=3

Alteration of ecosystem functions
Sika can alter succession and colonization rates by grazing and browsing. Effects can possibly be reversed when population decreases. Score=2

Sika have a total of eleven points and therefore are classified as a category A: 'black list species'. Sika are not yet naturalized in the Netherlands, but are invasive in other European countries and are on the SEBI 2010 list of 'Worst invasive alien species threatening biodiversity in Europe' (European Environment Agency, 2007). Sika are therefore classified as an 'Alert list species'.

Bomford score

- A1: Sika are unlikely to make an unprovoked attack, but can cause serious injury (requiring hospitalization) with antlers and hoofs or can cause fatality if cornered or handled. Score=1
- A2: The risk of irresponsible use of products obtained from Sika is highly unlikely. Score=0
- B1: No climate match index have been calculated but Sika are an established/naturalized species in Europe. Score=6
- B2: Sika are established in many European countries. Score=4
- B3: Sika are mammals. Score=1
- B4: Sika can migrate long distances in their native range. Score=1
- B5: Sika are a generalist herbivore. Score=1
- B6: Sika can live in human-disturbed habitats (grazing and agricultural lands, intensively managed forest). Score=1
- C1: Sika can cause habitat degradation and are prone to cause agricultural damage. Score=4
- C2: Sikas global range is 2,5 million km^2 (http://eol.org/pages/328650/details), therefore the geographic range is less than ten million square kilometres. Score=0
- C3: Sika are intermediate species (browsers and grazers). Score=3
- C4: Sika can't climb trees. Score=0
- C5: Sika can cause severe declines in abundance of plant species. Score=3
- C6: Sika score above 1 for C3 and C5 and have a 100% climate match in the Netherlands. Score=5
- C7: Sika cause local damage to agricultural crops and commercial timber production. Score=2
- C8: Sika can cause local damage to timber production and agriculture. Agriculture, forestry and fishery in total form 1.5% of the Gross domestic product of the Netherlands (www.lei.wur.nl/nl/statistieken). The Commodity value index is an index of the value of the annual production value of a commodity for the Netherlands. Grassland is the main commodity in the Netherlands (>50% of the total surface area; 0.9 million ha), followed by maize (0.23 million ha), grain (0.22 million ha), potatoes (0.16 million ha), sugar beets (0.07 million ha), (www.compendiumvoordeleefomgeving.nl).
  Forestry yield in the Netherlands is 0.8 million m^3 trees/year, yielding 68 euro/ha (Probos, 2011). After deduction of costs and adding subsidies yield is 34 euro/ha. Added value of forestry therefore is considered null. The added yearly value by agriculture and derived index is given in Table 4 (Data in euro/ha, from Goedemans and Kind, 2004).

Table 4
Commodity value index calculation.

	€/ha	ha		Index
grass	1400	900000	€ 1,260,000,000.00	13
maize	1485	230000	€ 341,550,000.00	3
potatoes	5300	160000	€ 848,000,000.00	8
sugar beet	3400	70000	€ 238,000,000.00	2
grain	1100	220000	€ 242,000,000.00	2

The potential Commodity Impact Score is 3 for timber and agricultural products (damage can occur at high levels; see 3.5).

Most likely damage will occur inside and adjacent to nature reserves. Less than 10% of all commodities (except timber production) are produced in areas where the species can settle (www.compendiumvoordeleefomgeving.nl/indicatoren/nl2119-Agrarisch-grondgebruik.html?i=11-61): Climate Match to Commodity Score is 1.

In Table 5 we represent the calculation of the Commodity Damage Score.

Table 5
Calculation of the total commodity damage score.

Industry	Commodity Value Index	Potential Commodity Impact Score (0-3)	Climate Match to Commodity Score (0-5)	Commodity Damage Score (columns 2 x 3 x 4)
Grassland	12	3	1	36
Maize	3	3	1	9
Timber	0	3	1	0
Grain	2	3	1	6
Potatoes	8	3	1	24
Sugar beets	2	3	1	6
total	27	18	6	81

The total commodity damage score in Table 4 falls into category TCDS = 50 - 99: score=3.
C9: For all birds and mammals score=2
C10: The property damage risk for vehicles is estimated at 2.2 million euro/year. Score=1
C11: Sika can be infected with bacterial and viral diseases. Score=1

Table 6
Calculation of the threat category.

Factor		Score
A1.	Risk to people from individual escapees (0 - 2)	1
A2.	Risk to public safety from individual captive animals (0 - 2)	0
Stage A.	**Risk to public safety from captive or released individuals: A = A1 + A2 (0 - 4)**	**1**
B1.	Degree of climate match between species overseas range and the Netherlands (1 - 6)	6
B2.	Exotic population established overseas (0 - 4)	4
B3.	Taxonomic Class (0 - 1)	1
B4.	Non-migratory behaviour (0 - 1)	1
B5.	Diet (0 - 1)	1
B6.	Lives in disturbed habitat (0 -1)	1
B.	**Establishment risk score: B = B1 + B2 + B3 + B4 + B5 + B6 (1 - 14)**	**14**
C1.	Taxonomic group (0 - 4)	4
C2.	Overseas range size (0 - 2)	0
C3.	Diet and feeding (0 - 3)	3
C4.	Competition with native fauna for tree hollows (0 - 2)	0
C5.	Overseas environmental pest status (0 - 3)	3
C6.	Climate match to areas with susceptible native species or communities (0 - 5)	5
C7.	Overseas primary production pest status (0 - 3)	2
C8.	Climate match to susceptible primary production (0 - 5)	3
C9.	Spread disease (1 - 2)	2
C10.	Harm to property (0 - 3)	1
C11.	Harm to people (0 - 5)	1
C.	**Pest risk score: C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 (1 - 37)**	**24**

Sika are classified according to Table 6 as:

Risk to public safety posed by captive or released individuals (A)
A = 1 moderately dangerous

Risk of establishing a wild population (B)
B > 10 for birds and mammals: extreme establishment risk

Risk of becoming a pest following establishment (C)
C > 19: extreme pest risk

The VPC Threat Category according to Bomford (2003): extreme.

4 Risk management

Prevention

The chances of permanent settlement of Sika in the Netherlands largely depend on the effectiveness of population control in Germany, prevention of spread into uninhabited areas in Germany and the Netherlands, prevention of release out of enclosures within the Netherlands, and the release and colonization rate in Belgium.

The EU biodiversity strategy to 2020 (COM (2011), 244) aims at reversing biodiversity loss and speeding up the EU's transition towards a resource efficient and green economy. Combatting invasive alien species is an important target of the 2020 biodiversity strategy. It proposes filling the legislative gap with a dedicated EU legislative instrument by 2012 which could tackle challenges relating to pathways, early detection and response, and containment and management of invasive alien species. At this moment it remains uncertain whether Sika Deer will be incorporated in EU legislation.

The co-occurrence of several other deer species throughout the Netherlands and neighbouring countries increases the chance of an undetected spread of Sika and Sika hybrids, because people that are not fully familiar with deer species differences can easily misidentify Sika for Fallow or Red Deer. Therefore the presence of Sika hybrids may go undetected for a long time, and the presence of Sika hybrids is often disbelieved even by hunters until demonstrated by DNA analysis (Bartos, 2009).

As populations in Germany are controlled by hunting, colonisation by dispersal of young adult Sika is possible, but not foreseeable in the immediate future. In the Netherlands two populations of Red Deer, the Oostvaardersplassen and the Veluwe, exist. Chances for Sika to colonize these areas without being noticed appear to be slim. Sika - Red Deer hybrids however might reach the Netherlands undetected. Gathering DNA samples (tissue or fresh dung) from now onwards of Red Deer dispersing into Twente, de Achterhoek and the province of Limburg might yield important information on colonization by hybrids, either from Germany or Belgium. Genetic analysis can be used as input in the decision process on starting an eradication campaign.

Sika deer crossing the border from neighbouring countries cannot be prevented, although it is unlikely to occur in the near future. To prevent settlement caused by release or escape out of enclosures highly secure premises are needed. Another effective measure would be to keep the numbers of individuals per enclosure low or to not keep the species at all, especially in or near the Veluwe and Oostvaardersplassen where Red Deer occur. Once escapes or releases do occur, as is the case near ‘s Graveland, culling or recapturing of Sika should commence immediately in order to prevent permanent establishment and population build-up.

Eradication

Eradication, the permanent removal of all wild populations by a time-limited campaign, is achievable by heavy culling in areas shortly after the detection of Sika Deer when (sub)populations are localised and small. For an effective eradication campaign it is essential that the removal rate exceeds the rate of increase, that reinvasion is prevented and all reproductive individuals should be at risk. Eradication, even on a local scale, is very costly and in most cases unsuccessful (Caughley, 1978; Elliger et al., 2011). Main problem will be locating individuals at low density which results in higher costs and effort with decreasing density (Van Deelen and Etter, 2003).

Once the spread of Sika is too advanced this approach to eradicate the population will not be effective, as was the case in Scotland and Germany (Perez-Espona et al., 2009; Elliger et al., 2011). No eradication campaign against a wide spread established vertebrate species has ever been successful on any continent (Bomford, 2003). Once established populations in the Netherlands do exist, the only option will be to maintain low population density in colonized areas and to prevent the spread of Sika into new areas.

Control

Methods available to control populations and minimize their impact are culling, contraception and exclusion of the deer from vulnerable areas. Relatively high winter temperature and corresponding food availability prevent successful trapping of high numbers using corrals/enclosures.

Culling is the most cost-effective way for controlling population numbers of Sika (Côte et al., 2004). Controlling deer populations by contraception is being used when legal, safety issues or public acceptance prohibits traditional lethal programs (Kirkpatrick et al., 2011). For free ranging species the method is less effective. Current technology suffers from a variety of technical, physiological and regulatory challenges such as the efficacy of contraceptives on free-ranging deer or necessary repeated treatments which involves high labour-costs (Powers et al., 2011; Kirkpatrick et al., 2011).

Sika Deer can be excluded from vulnerable areas by erecting wire mesh fences (Takatsuki, 2009). Individual tree protectors can effectively protect young trees against browsing.

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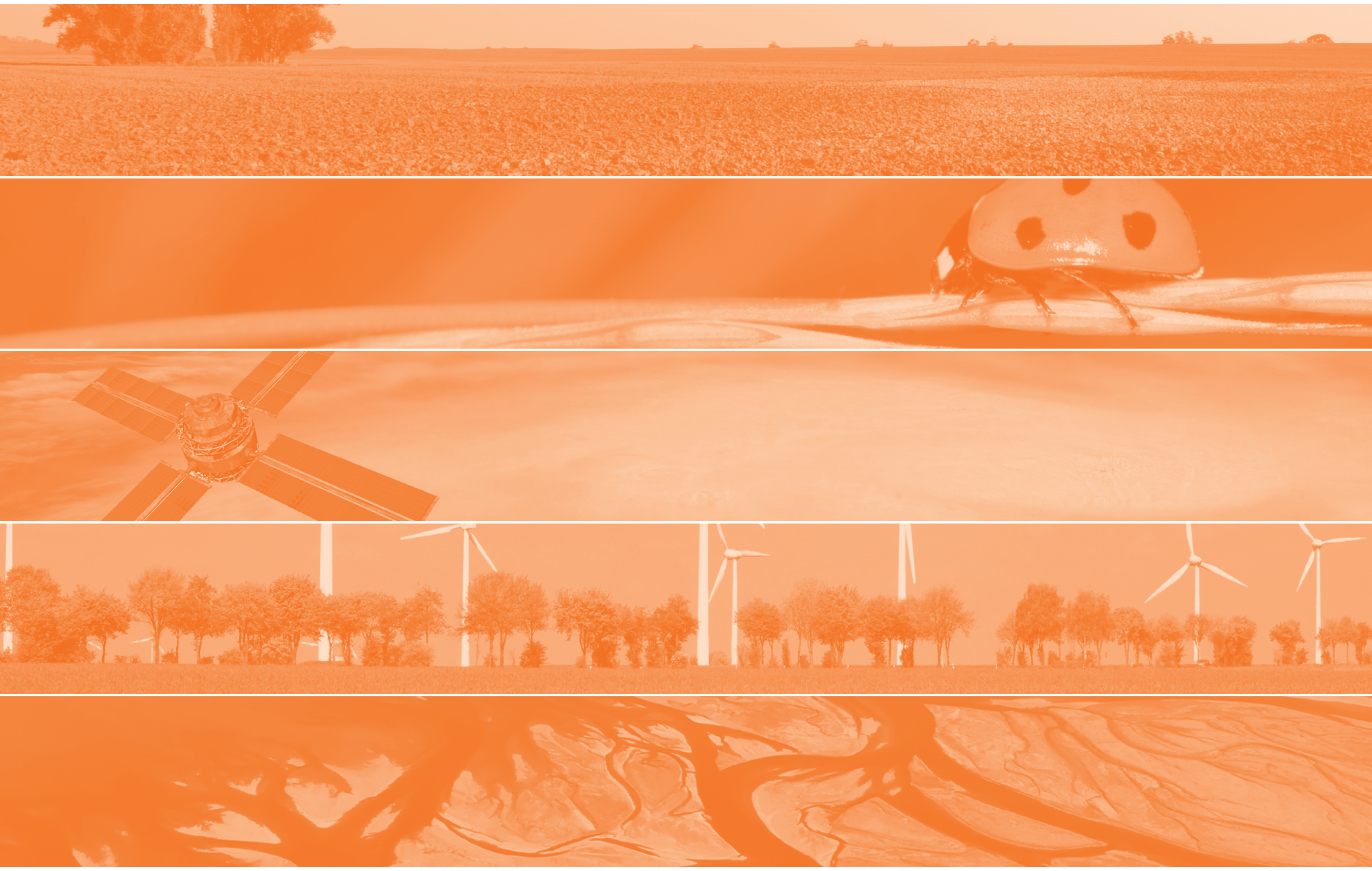

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