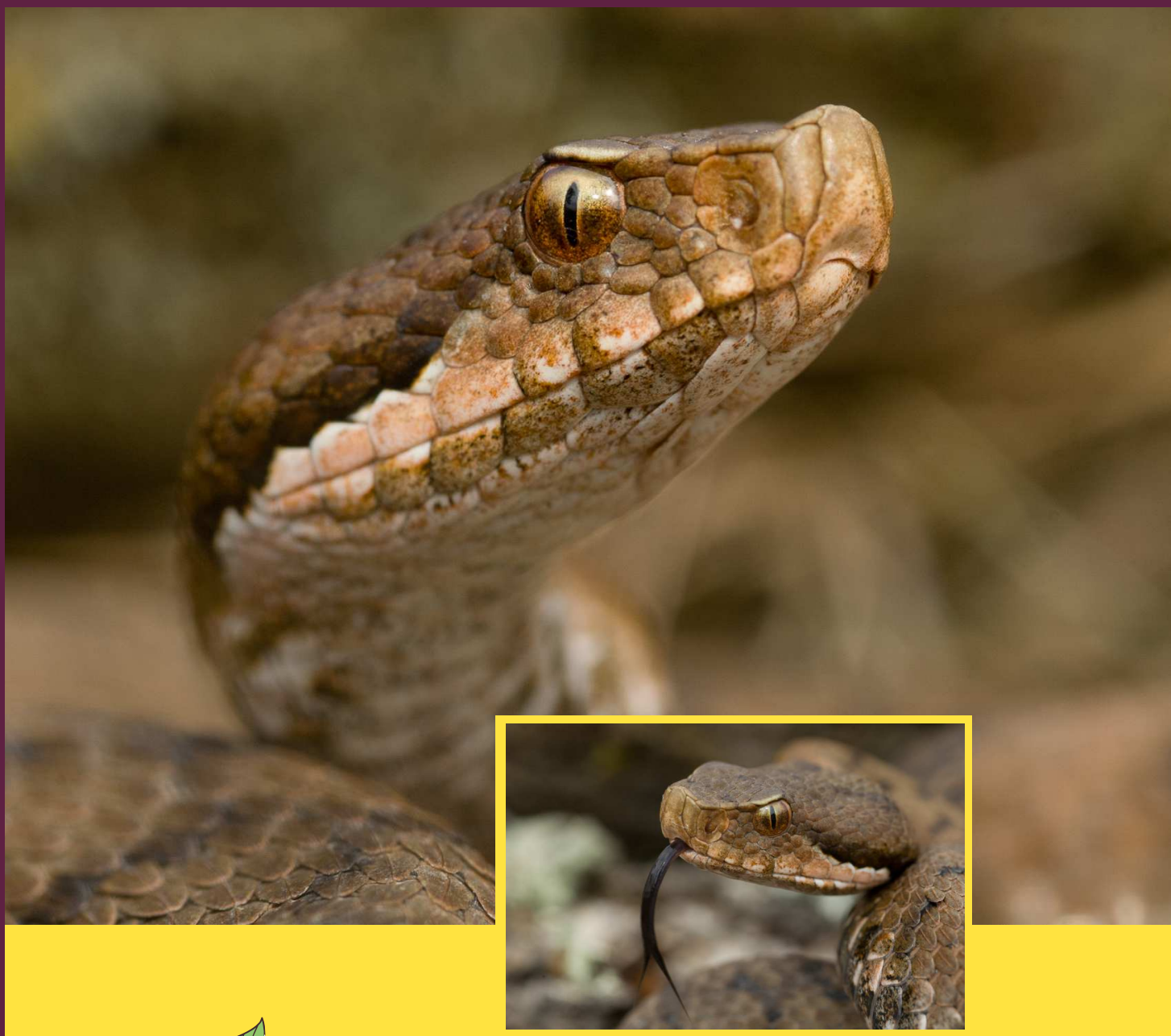
RISK ANALYSIS OF THE ASP VIPER (*VIPERA ASPIS*) IN THE NETHERLANDS



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Radboud University Nijmegen

Commissioned by:
Invasive Alien Species Team
Netherlands Food and Consumer Product Safety Authority
Ministry of Economic Affairs, Agriculture and Innovation

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SUMMARY

This report presents the risk analysis of the asp viper (*Vipera aspis*) in the Netherlands. The study was initiated to provide more insight into the potential effects of the occurrence of non-native populations of asp viper in the Netherlands, their present distribution, introduction pathways, and the probability of establishment and spreading. The risk analysis consists of both risk assessment and risk management, and is based on data analyses, (inter)national literature, and field expertise. The risk analysis is justified by an expert team.

Asp viper is a venomous member of the family Viperidae. The species naturally occurs in southern and central Europe. Dry and sunny areas, mainly in hilly and mountainous areas, with an alternation of rocks and bushes provide the optimal habitat. It highly resembles common European adder (*Vipera berus*), which is native to the Netherlands. Only one record of more than one free-living asp viper outside its natural range has been recorded worldwide. In 2006 eight specimens were found and removed from Bos Valckesteyn near Poortugaal, Rotterdam, the Netherlands. No sightings of the species at the locality have been recorded since.

Risk assessment
The probability of introduction of asp viper into the Netherlands is low. Natural colonisation is not considered a possible pathway. Chances of introduction by deliberate or unintentional release from captivity are estimated to be relatively low.

The probability of establishment of asp vipers in the Netherlands is relatively low. There is only a small chance on introduction of more than one specimen. Within introduction areas (a)biotic factors, mainly climate, are thought to have a limiting effect on establishment chances. In most parts of the country, reproduction will be constrained by unfavourable climatic conditions, affecting several aspects of reproductive success. Nevertheless, microclimatic requirements are potentially met in several parts of the Netherlands.

The probability of asp vipers spreading in the Netherlands is relatively low. Colonisation rate is low, due to site fidelity and specific habitat requirements.

Concerning climatic conditions and preferred habitats, few parts of the Netherlands can be qualified as vulnerable areas. These areas comprise of structures and elements with favourable microclimates, mainly located in ruderal terrains within urban areas and in specific parts of the hilly landscape in the most southern part of the Netherlands in the province of Limburg.

In the vulnerable areas in the Netherlands, economic and social damage might occur to some extent, mainly by social unrest, damage to the regional recreational sector and envenomation. Ecological damage might be caused by predation and competition.

Overall, the risks of the presence and the invasiveness of asp viper in the Netherlands are low.

Risk management

Prevention: because chances of introduction are low it is disputable whether preventive measures should be taken. If prevention is being considered, public education is an important preventive measure against introduction of asp vipers in the Netherlands, although public education programs may also have significant drawbacks.

Eradication: capturing snakes by luring and trapping is considered the most efficient eradication measure. Regarding the situation at Poortugaal, no measures for eradication are recommended. If future sightings are recorded or specific research reveals the presence of asp vipers, eradication is considered important and therefore recommended, especially in the vulnerable areas.

Control: due to the fact that population control management is permanent, accompanied by high costs, control of asp viper populations (minimise dispersal and impact) is not considered an option. Only if eradication is not possible, control of an established population can be used as an absolute last resort to prevent dispersal and impact.

1 INTRODUCTION

Asp viper (*Vipera aspis*) is native to the southwest of Europe, from northern Spain to southern Germany, where its habitat consists of hilly landscapes and mountainous areas (Günther & Lehnert 1996; Fritz & Lehnert 2007). In the Netherlands the species is held in captivity as pet and until now has not been proven to be invasive.

Nevertheless, in 2006 at least eight specimens of asp viper were discovered in Bos Valckesteyn near Poortugaal, a forested area southwest of the city of Rotterdam, the Netherlands. Most likely these animals were released deliberately. To avoid dispersal of the species, most specimens were caught by employees of reptile zoo SERPO from Delft, the Netherlands. However, at least two snakes were not caught and therefore the species may still occur within the vicinity of Bos Valckesteyn.

In addition, little is known about the dispersal of asp viper in other parts of the Netherlands. Particularly in areas where the native common European adder (*Vipera berus*) occurs, it is quite possible that the presence of asp viper might not be discovered for a long time span. The presence of asp viper can display a negative impact on humans and native biodiversity, e.g., by competition and predation

This study was initiated to provide insight into the potential effects of the occurrence of non-native populations of asp viper in the Netherlands, their present distribution, introduction pathways, and the probability of establishment and spreading. Although some field experience is gained with removing asp vipers, there is relatively little known about what measures should be taken to prevent a sustainable establishment of (populations of) the species. Subsequently, this study deals with both risk assessment and risk management of asp vipers in the Netherlands.

Project definition
The Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (Ministry of Economic Affairs, Agriculture and Innovation) has commissioned Natuurbalans-Limes Divergens BV to perform a concise risk analysis of asp viper in the Netherlands. The risk analysis includes the following objectives:

- To develop a clear picture of the present distribution, probability of entry, establishment, and spreading of asp viper in the Netherlands.

- To provide insight into the potential effects of asp viper on native species and/or communities, economy (e.g., loss of profits or even economic opportunities), and social aspects (e.g., recreational values and public health).

- To provide insight into measures that can be taken from the perspective of risk management with regard to prevention, eradication, and control.

Report structure

Chapter 2 deals with the methods of current risk analysis. Chapter 3 provides a concise general description of the species, which focuses on aspects that are of direct interest to the risk analysis. Chapter 4 presents the risk assessment, divided into probability of introduction, establishment, and spreading, vulnerable areas, and impact. Chapter 5 deals with the options for risk management (prevention, eradication, and control). Finally, the most important conclusions and recommendations are presented in chapter 6.

2 METHODS

2.1 COMPONENTS OF THE RISK ANALYSIS

Research on the following components was conducted in order to cover the complete risk analysis: risk assessment and risk management.

2.1.1 Risk assessment

Probability of introduction
The probability of introduction was determined by the possible introduction pathways of the species into the Netherlands, both present and future.

Probability of establishment
The probability of establishment was determined by the current dispersal range of the species and presence of potential habitat in the Netherlands related to (a)biotic requirements of the species.

Probability of spreading
The probability of spreading was determined with regard to the dispersal capacity of the species by natural means and by human action.

Vulnerable areas
Areas or habitats in the Netherlands that are at risk of invasion were selected and possible effects of the presence of asp vipers within these areas were discussed.

Impact
Based on the results of the three probabilities mentioned above, the impact of the species was determined and the effects and risks were scientifically characterised, using the Invasive Species Environmental Impact Assessement (ISEIA) protocol. Subsequently, the (possible) ecological, economic, and social impacts as a result of the presence of the species were discussed.

2.1.2 Risk management

Based on the results of the risk assessment, measures were identified and proposed to counteract the introduction, establishment, and spreading of and damage caused by the species. The risk management dealt with measures for:

- *Prevention*
- *Eradication*
- *Control*

The (dis)advantages of each measure were investigated in terms of effectiveness, feasibility, and costs. Finally, a concise protocol was developed, which can be used to act adequately if the species occurs somewhere in the Netherlands in the future.

2.2 DATA-ANALYSES

The risk analysis was based on existing data. Several databases and other sources of information were used. These are discussed in further detail below.

2.2.1 Literature

National (e.g., reports and species distribution atlases) and international literature (e.g., scientific articles via ISI web of knowledge, Google Scholar, Wiley Interscience, and Zoological Records) was investigated in order to get a clear view of existing knowledge regarding the subject. Additionally, several websites, e.g., Global Invasive Species Database and IUCN Red List, were used.

2.2.2 Distribution data

Data on the present distribution of asp viper in the Netherlands was obtained using several databases. The extensive database of Natuurbalans-Limes Divergens BV on Dutch fauna was consulted, together with several general websites, e.g., www.waarneming.nl and www.telmee.nl. Also several organisations, e.g., reptile zoo SERPO and local herpetological societies and nature groups, were consulted.

2.3 EXPERT TEAM

The risk analysis was conducted in collaboration with an expert team in order to guarantee a sound scientific basis and justification. The expert team was formed by dr. H.J.R. (Rob) Lenders, assistant professor at the Department of Environmental Science of the Radboud University Nijmegen, W. (Walter) Getreuer, director of reptile zoo SERPO, and ir. B.H.J.M. (Ben) Crombaghs, managing director of Natuurbalans-Limes Divergens BV.

Dr. H.J.R. Lenders en ir. B.H.J.M. Crombaghs are authorities regarding research on reptiles and amphibians in the Netherlands. Mr. W. Getreuer delivered a major contribution to the risk analysis regarding knowledge about the present dispersal range of the species and determining possible vulnerable areas in the Netherlands. Furthermore, he has an extensive field experience in removing non-native reptile populations, including the asp vipers near Poortugaal. Therefore, he provided an important input regarding possible measures in prevention, eradication, and control of the asp viper.

3 GENERAL SPECIES DESCRIPTION AND DISTRIBUTION

This chapter presents a short species description of the asp viper. Aspects that are of importance for the risk analysis are considered, mainly distribution, habitat, reproduction, and diet of the species. Table 1 presents an overview of several general characteristics of the species description.

Table 1. Characteristics of the asp viper (*Vipera aspis*).

Characteristic		**Source**
Length	50 - 60 cm (max.: 85 cm)	Günther & Lehnert 1996 Fritz & Lehnert 2007
Weight	60 - 235 g	Fritz & Lehnert 2007
Livespan	20 years	Fritz & Lehnert 2007
Range	France, Germany, Italy, Slovenia, Spain, Switzerland	Fritz & Lehnert 2007 IUCN 2009a
Habitat	Sun exposed and dry rocky areas, open scrubland, open to half-open forests	Günther & Lehnert 1996 Fritz & Lehnert 2007
Food	Small mammals, lizards	Luiselli & Agrimi 1991 Fritz & Lehnert 2007
Reproductive age	5 - 6 years (northern range)	Fritz & Lehnert 2007
Reproductive cycle	Female: 2 - 4 years (energy dependent) Male: annual	Flatt *et al.* 1997 Naulleau *et al.* 1999 Aubret *et al.* 2002
Gestation	2 - 4 months (weather dependent)	Günther & Lehnert 1996 Fritz & Lehnert 2007
Mean litter size	5 - 9 juveniles, ovoviviparous	Günther & Lehnert 1996 Fritz & Lehnert 2007
IUCN Red List	Least Concern (ver 3.1)	IUCN 2009a
First sighting in NL	August 2006	www.waarneming.nl
Last sighting in NL	October 2006	www.waarneming.nl reptile zoo SERPO

Species description

The asp viper is a member of the family Viperidae. The species is also known as asp, European asp, and aspic viper. The overall length of the species is about 50-60 cm (Günther & Lehnert 1996; Fritz & Lehnert 2007). In exceptional cases, the snakes can grow up to maximally 85 cm (Fritz & Lehnert 2007). The weight of adults ranges from 60 g to 235 g, and up to 250 g for gravid females (Fritz & Lehnert 2007). Basic colour of asp vipers is pale gray-brown, dark brown, or dark reddish brown. Females have a distinct bright dark pattern on their back. This pattern is less distinct in males.

Only slight differences in appearance exist between common European adder and asp viper. The latter has a clear tapering point of the nose, slightly wider back of the head, and two rows of small shields between eye and supra labials (Ameling 1978; Günther & Lehnert 1996).

Natural distribution range and habitat

The asp viper's natural distribution range is located in large parts of France, Italy, and Switzerland, northern Spain, southern Germany, and western Slovenia (figure 1) (Ameling 1978; Fritz & Lehnert 2007). The species prefers hilly landscapes and mountainous areas, mainly at elevations ranging from 800 to 1600 meters. It can even be found up to 3000 meters. Asp viper occurs mainly in dry rocky areas, screes, quarries, open scrubland, and in or near open to half-open forests. The species is cold-blooded and therefore prefers sun exposed slopes. Especially gravid females and juveniles seem to be highly dependant on these structures. Dry and sunny areas with an alternation of rocks and bushes form the optimal habitat (photograph 1) (Günther & Lehnert 1996; Flatt *et al.* 1997; Fritz & Lehnert 2007).

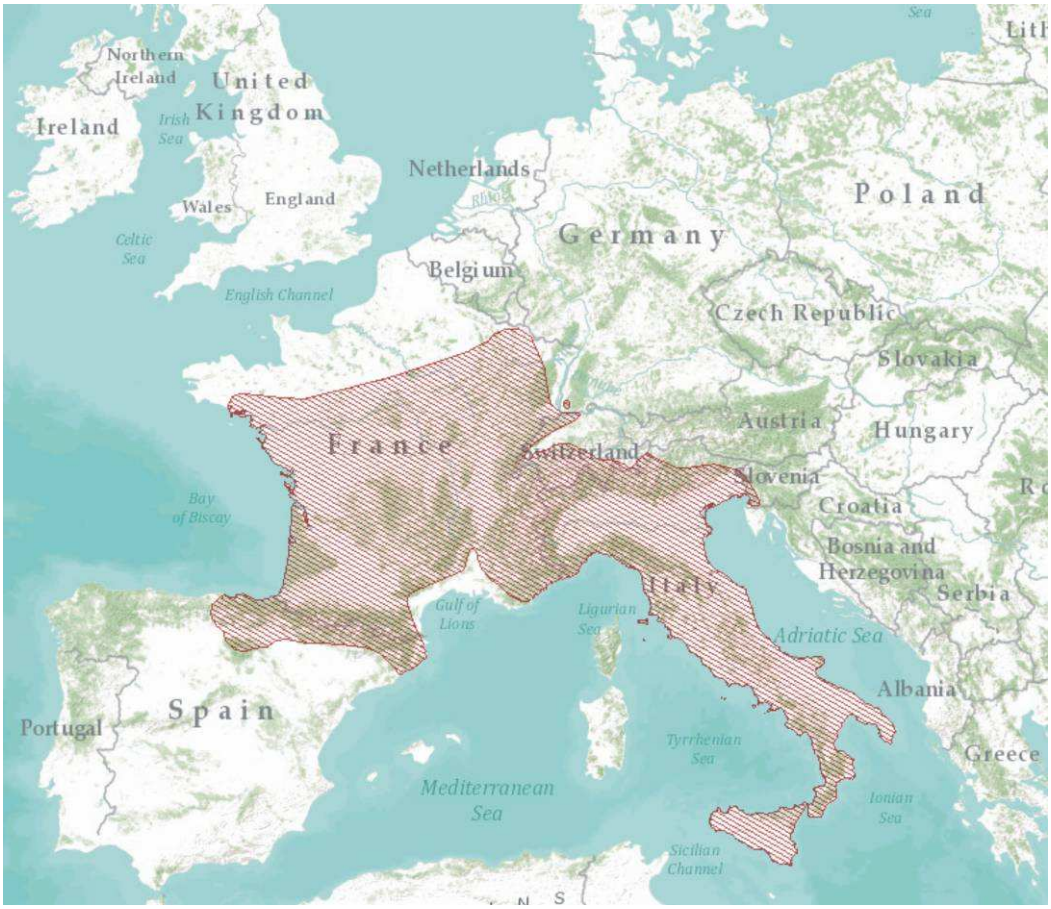

Figure 1. Natural distribution range of asp viper (source: IUCN Red List 2009a).

Photograph 1. Asp viper in its natural habitat in France. Photograph by: Paul van Hoof Natuurfotografie, Arnhem, The Netherlands.

Introductions outside the natural distribution range

Only one record of more than one free-living asp viper outside its natural distribution area has been recorded worldwide. Eight specimens were found in the wooded area Bos Valckesteyn near Poortugaal, southwest of Rotterdam (the Netherlands). Most likely the animals were introduced deliberately from captivity (SERPO 2006). However, the exact source of this introduction remains unknown. After removing six of the eight animals in October 2006, no sightings of the species at the locality have been recorded since (table 2). Additionally, one melanistic asp viper was sighted in the Zomerlandse Tunnelbos in the Hoekschewaard near the village of Heinenoord, the Netherlands, in July 2006. No additional information of this sighting has been recorded. The species has not been sighted in the surroundings more recently.

Table 2. Sightings of asp viper in the Netherlands.

Date	Number	Life stage	Location	Source
17 October 2006	1	Adult	Poortugaal	www.waarneming.nl
15 October 2006	3	Adult	Poortugaal	www.waarneming.nl
20 August 2006	1	Unknown	Poortugaal	www.waarneming.nl
12 August 2006	1	Unknown	Poortugaal	www.waarneming.nl
July 2006	1	Unknown	Heinenoord	www.hwl.nl

Reproduction

Reproduction of asp vipers is highly influenced by climatic factors, see also §4.3. Within the northern part of their range, asp vipers reach sexual maturity at the age of five or six years (Fritz & Lehnert 2007). Overall, males are able to mate annually. The reproductive cycle of females is on average every two to four years. It is highly energy and climate dependent and decreases up to once in a lifetime in populations at the northern limits of their distribution range (Flatt *et al*. 1997; Naulleau *et al.*

1999; Aubret *et al.* 2002). Also the length of gestation depends on climatic conditions and ranges from two to four months within the natural distribution range. In cooler climates, e.g., the Netherlands, gestation is probably longer than four months. Asp vipers are ovoviviparous and on average produce an offspring of five to nine individuals (Günther & Lehnert 1996; Fritz & Lehnert 2007).

Diet

Vipers are generally considered opportunistic feeders (Luiselli 2006). The main diet of asp vipers consists of small mammals, like mice, shrews, and voles, and lizards. Infrequently also little birds and frogs are predated by asp vipers (Fritz & Lehnert 2007). Research in central Italy showed that about 80% of adult asp viper's diet consists of small mammals. Juveniles (up to 35 cm) mainly consume reptiles (81% of the diet) and to a lesser extent (19%) nestling mice (Luiselli & Agrimi 1991).

Predators

The main predators of asp vipers are birds, for example members of the families Falconidae and Corvidae. Moreover, hedgehogs, badgers, foxes, martens, weasels, and polecats are considered as incidental predators of the species. Also snake species (e.g., smooth snake, *Coronella austriaca*) are potential predators of asp vipers, mainly of juveniles (Fritz & Lehnert 2007).

4 RISK ASSESSMENT

The risk assessment examines the situation in which no measures for prevention, eradication, or control are taken. It focuses on the potential risks of the presence and invasiveness of asp viper in the Netherlands. Therefore the probability of introduction, establishment, and spreading are discussed, resulting in an overview of vulnerable areas and an evaluation of the potential impact of the species.

4.1 PROBABILITY OF INTRODUCTION

Natural colonisation

Distribution of asp viper by natural means from its natural range into the Netherlands is very unlikely. The northern limit of its natural distribution range is situated at least 160 km from the Dutch border. Climatic conditions are expected to prevent the species from extending its range northwards (Lourdais *et al.* 2004). Even with ongoing climatic change, the distance from its natural distribution range is substantial and several unsuitable areas would have to be crossed. Natural colonisation is therefore not considered to be a possible pathway.

Release from captivity

Introduction pathways caused by humans, both accidentally and deliberately, can result in introduction of asp vipers into the Netherlands. Asp vipers that are kept as pet by snake keepers can escape from captivity. If snakes manage to escape, they will generally be found (an recaptured) within a short distance from the source of introduction, often near urban areas, where most snakes are kept. Hence, the risk of accidental introduction from captivity into natural areas is estimated to be very low. In contrast to accidental introductions, deliberate releases of asp vipers can more easily result in introduction into natural areas. Deliberate releases occur most likely on some distance from urban areas, as releasing non-native species is illegal in the Netherlands. However, asp viper is not commonly held as pet. Exact numbers are not available, but it is roughly estimated that more than hundred asp vipers are held in captivity in the Netherlands. Thus, the probability of introduction by release from captivity (both accidentally and deliberately) is estimated to be relatively low.

Introduction through transport

Another possible introduction pathway is caused by transport. Animal and plant species are introduced accidentally through transport worldwide (Floerl & Inglis 2000; Mack *et al.* 2000; Wilson *et al.* 2009). Species travel from one place to the other for instance in luggage of people, cars, or cargo transport. As a result of this pathway, an asp viper ended up in an animal shelter in Belgium in 2007. It was prevented from introduction because of the alertness of the travellers who found the snake in their luggage. After a short stay in the animal shelter, the snake was returned to France (Natuurhulpcentrum 2007). This example is the only described occurrence of an asp viper's unintentional introduction through transport. Moreover, it is an elusive species (Günther 1996; Fritz & Lehnert 2007) and therefore it is unlikely that this kind of introduction occurs frequently. Complementary, asp vipers are relatively large animals and therefore will be noticed relatively easy. Chances of introductions by this pathway are therefore considered to be very low.

In summary, probability of introduction of asp viper into the Netherlands is low. Natural colonisation into the Netherlands from its natural distribution range is not considered to be a possible pathway. The probability of introduction caused by deliberate or unintentional release of asp vipers is estimated to be relatively low.

4.2 Probability of establishment

Not all introductions result in the establishment of populations. The most important underlying factors are propagule pressure, habitat structure, climatic factors, and reproduction success.

Propagule pressure
No literature is available on the propagule pressure, i.e., the quality, quantity, and frequency of introduced organisms, of asp viper. Nevertheless, it is obvious that more than one specimen or at least a gravid female is needed to establish a population of the species. In the unintentional cases, e.g., escapes from captivity or introduction by transport, it is most likely that only one snake will be introduced, thereby reducing the chances of establishment of a population. In the cases that more specimens or a gravid female are introduced, a population might be able to establish if other (a)biotic factors are suitable.

Habitat structure and climatic factors
Habitat structure and climatic factors are thought to be important determinants of the chances of establishment of (a population of) asp vipers. Asp vipers have distinct habitat preferences and, as the species is ovoviviparous and thermophilic, are bound to areas which are sun exposed and warm up quite rapidly (Lourdais *et al.* 2002; Lourdais *et al.* 2004). The preferable summer temperature is approximately 29 °C, within a range of 23-37 °C (Fritz & Lehnert 2007). Therefore they live at southern exposed slopes in hilly or mountainous areas with a rocky surface and little shade. Areas that meet these distinct requirements are relatively scarce in the Netherlands, and can only be found in specific southern parts of the Netherlands in the province of Limburg and in (ruderal) parts of urban areas.

The relatively cool summers in the Netherlands may result in serious limitations regarding establishment probability. The summer temperature in the Netherlands in the period of 1981-2010 was on average 17.0 °C (www.knmi.nl). Successful reproduction can be highly constrained by these low average summer temperatures. However, average temperatures in urban areas are significantly higher, thereby increasing establishment probability. Moreover, on microclimatic level, distinct climatic requirements of asp vipers are potentially met in several parts of the Netherlands, mainly in (ruderal parts of) urban areas, e.g., former industrial areas.

Besides constraints on establishment probability as a result of low summer temperatures, severe winters cause a decrease in population growth rates of the species, mainly caused by effects of low winter temperatures on the survival of juvenile asp vipers (Altwegg *et al.* 2005). It is doubtful to which extent asp vipers in the Netherlands are indeed affected by winter temperature. Decrease of survival up to 50% is reached at approximately 35 days with below 0 °C temperatures, and a decrease of even 80% at roughly 50 days with below 0 °C temperatures (Altwegg *et al.* 2005). Average winter temperature in the Netherlands is 3.0 °C (average during

the period of 1971-2000) and days with below 0 °C temperatures range from seven to fourteen (www.knmi.nl). Hence, Dutch winters are not likely to cause a significant decrease of asp viper survival.

Reproduction success

Body condition and accumulation of large amounts of energy reserves are of great importance to reproduction (Bonnet *et al.* 2000; Aubret *et al.* 2002). For male asp vipers there is a gradual positive relation between courtship intensity and body condition (Aubret *et al.* 2002). Females only become sexually receptive if their body reserves increase above a critical threshold. If the minimal level of body reserves is not reached, reproduction is unlikely to occur (Naulleau *et al.* 1999; Aubret *et al.* 2002). This indicates the importance of large food supplies and favourable climatic conditions on reproductive success. As a consequence, most females in regions at asp viper's northern range limits breed only once in their lifetime, due to the high costs for survival and reproduction (Bonnet *et al.* 2002). In more suitable climatic regions, e.g., Tuscany (central Italy), most females have an annual reproductive cycle, probably due to a longer period of feeding activity (Zuffi *et al.* 1999).

Climate also has a major impact on reproduction success directly (Bonnet *et al.* 2002; Lourdais *et al.* 2002; Lourdais *et al.* 2004). When climatic conditions are optimal, mean body weight increases and gravid females are able to maintain a constantly high temperature for developing offspring. As a consequence, mean offspring mass and litter size increases (Zuffi *et al.* 1999; Bonnet *et al.* 2000; Lourdais *et al.* 2002), resulting in higher survival rates of the juveniles.

However, if climatic conditions are less favourable, reproduction success decreases. Studies in west-central France, at the most northern limit of asp viper's natural distribution range, showed that ecological aspects, mainly reproduction, are highly constrained by unfavourable, cooler climatic conditions. These conditions may comprise periods of relatively low temperatures during gestation and quickly fluctuating weather conditions, as is common in temperate-oceanic climates. Low temperatures in early embryonic development (June) cause a phenotypic modification in neonates (lower number of ventral scales), which may influence offspring quality and thereby reduce juvenile survival (Lourdais *et al.* 2004). Moreover, relatively low temperatures during gestation cause a prolongation in gestation period, e.g., an increase of 25 days (±30%) if mean temperature is 23.0 °C instead of 25.5 °C (Lourdais *et al.* 2002). Also, embryos are predominantly vulnerable to low temperatures late in development. Decreased temperatures in August lead to a higher probability of late mortality in embryos and a larger percentage of stillborn offspring (Lourdais *et al.* 2004). From these studies it becomes clear that even at the northern limits of its natural distribution area, asp vipers face unfavourable climatic conditions. Therefore serious limitations regarding dispersal probability are present. This could explain why the species is replaced by the common European adder further north, a species with lower metabolic rates and less pronounced climatic requirements (Lourdais *et al.* 2004). Additionally, Lourdais *et al.* (2004) conclude that "embryonic thermal requirements may prevent *Vipera aspis* from extending into cooler conditions further north".

In summary, the probability of establishment of asp vipers in general is relatively low. First, it depends on the number of snakes introduced. Chances of introduction of more than one specimen are low. Within introduction areas (a)biotic factors, mainly the summer climate, are thought to have a limiting effect on establishment chances. In most parts of the country, reproduction will be constrained by unfavourable climatic conditions, affecting several aspects of reproductive success. Females are less likely to reach the body conditions needed for reproduction and if they do, they are likely to reproduce only once in their life. If reproduction takes place, mean offspring mass and litter sizes are low and proportion of stillborn offspring is relatively high, resulting in decreased juvenile survival. However, microclimatic requirements are potentially met in several parts of the Netherlands, e.g., in specific southern habitats in the province of Limburg and in urban (ruderal) areas. The latter may be located within the natural distribution range of common European adder, e.g., on the Veluwe and in Drenthe.

4.3 Probability of spreading

If an alien species becomes established, the probability of spreading, determined by colonisation rate, is the third key aspect regarding the risk of the presence and the invasiveness of the species.

Colonisation rate

Asp viper is considered as a sedentary species. It does not spread far from once selected retreats. Site fidelity is especially pronounced in areas where hiding places, sun exposed slopes, and a good food supply are close to each other. If no suitable places for hibernation are close to summer habitats, asp vipers migrate relatively short distances, i.e., several hundred metres (Fritz & Lehnert 2007).

Colonisation rate of asp vipers in new habitat is also expected to be inhibited by the specific habitat requirements of the species. As unsuitable areas surround possible introduction sites of asp vipers in every part of the Netherlands, spreading will be constrained and the snakes are bound to a limited area, e.g., in ruderal areas.

In summary, the probability of asp vipers spreading in the Netherlands is relatively low. Colonisation rate of the species in the Netherlands is expected to be low, due to site fidelity and specific habitat requirements.

4.4 Vulnerable areas

In relation to asp viper's requirements concerning climatic conditions and preferred habitats, few parts of Netherlands can be qualified as potentially suitable for the species, and thus as vulnerable areas. As temperature is limiting, these areas with an alternation of rocks and bushes and sun exposed slopes can mainly be found in the most southern part of the Netherlands in the province of Limburg, where specific required microclimates occur in the hilly landscape. Examples of such habitats in South-Limburg are found in former quarries and calcareous grassland (photographs 2-5). Also in specific parts of urban areas, mainly ruderal terrains, microclimatic requirements are potentially met. These may be located within the natural

distribution range of common European adder, e.g., on the Veluwe and in Drenthe. Moreover, introductions will probably occur in the direct vicinity of built-up areas.




Photographs 2-5. Examples of suitable habitat for asp viper in South-Limburg. Photos were taken in former quarries and calcareous grasslands. Photographs by: Sander van de Koppel (2-4) and Douwe Schut (5).

4.5 Impact

As concluded in the previous paragraphs, the risks of the introduction, establishment and spread of asp viper in the Netherlands are low. Nevertheless, if asp viper would establish in vulnerable areas, ecological, economic, and social damage may occur to some extent. These aspects are discussed below. The ecological risks were also assessed using the Invasive Species Environmental Impact Assessement (ISEIA) protocol (appendix, Branquart 2009).

4.5.1 Ecological damage

Hybridization

Indications for hybridization between several subspecies of asp vipers exist (Zuffi & Bonnet 1999; Ursenbacher *et al.* 2006; Barbanera *et al.* 2009), but the rank and validity of specific subspecies is disputable (IUCN 2009a). Moreover, hybridization

between asp vipers and two other, closely-related viper species is known. In contact zones of asp viper and a sibling viperid, Lataste's viper (*Vipera latastei*), in northern Spain, hybridization has occurred (Martínez-Freiría *et al.* 2010). Secondly, analyses of the origin of neurotoxins in venom of asp vipers in southeast France revealed that interbreeding between the closely related species asp vipers and nose-horned viper (*Vipera ammodytes*) has occurred (Jan *et al.* 2002; Guillemin *et al.* 2003).

Besides hybridization with these species, no occurrences of hybridization between asp vipers and other snake species are known. Also no occurrence of hybridization with the common European adder (the only naturally occurring viperid in the Netherlands) is known, while their distribution ranges overlap and these species live closely together in some areas (Saint-Girons 1975 and Monney 1996, according to Luiselli 2006; Guillemin *et al.* 2003; Scali *et al.* 2011). Moreover, the species are discerned as phylogenetically distant (Martínez-Freiría *et al.* 2010). The only occurrence of hybridization between common European adder and another viper in nature, as described in literature, is with Nikolsky's adder (*Vipera nikolskii*), at that time considered as a closely related species (Zinenko 2004). However, according to the IUCN Red List, Nikolsky's adder is not a separate species, but a synonym for common European adder (IUCN 2009b). Hence, no occurrences of hybridization between common European adder and other viper species are known to date.

In summary, hybridization between asp viper and common European adder is not very likely, even if asp vipers live in areas with common European adder without being discovered due to strong similarities in appearance (Ameling 1978; Günther & Lehnert 1996). Thus, the risk on negative influences due to hybridization, such as gene flow (Howard *et al.* 2003, according to Martínez-Freiría *et al.* 2010), can be considered to be low, but cannot be totally ruled out.

Competition

Most snake species are opportunists and therefore may compete for food and space with other species (Luiselli 2006). With regard to competition for space, sympatric vipers generally partition the available habitat (Luiselli 2006; Luiselli *et al.* 2007), as is the case for co-occurring populations of asp viper and common European adder. In areas where these species are sympatric, the common European adder is bound to cooler, humid, forested zones, while asp vipers are found in more sunny, warm, and dry zones (Saint-Girons 1975 and Monney 1996, according to Luiselli 2006; Scali *et al.* 2011). As the species occupy different realized ecological niches, the authors conclude that the potential for competition is low (Luiselli *et al.* 2007; Scali *et al.* 2011). The species partition the available habitat mainly on thermal, altitudinal, and habitat features (Scali *et al.* 2011). It is not known if partitioning also occurs in a non-native area where asp viper is introduced.

Competition for food is likely to occur with several native species, especially in areas where prey abundance is limited. Asp viper mainly feeds on small mammals, like mice, shrews, and voles, and lizards (Luiselli & Agrimi 1991; Fritz & Lehnert 2007). Competition for food could occur with a variety of other species, like birds of prey, native snakes, and foxes. Impacts of competition have not been recorded but are estimated to be limited in the Netherlands.

Predation
It is expected that predation does not have a negative impact on populations of prey species, as vipers are opportunists and do not concentrate on specific, rare species (Luiselli 2006). However, in the Netherlands the most suitable habitats are found in former quarries and calcareous grasslands. These areas are home to a few (very) rare potential prey species, e.g., yellow-bellied toad (*Bombina variegata*), midwife toad (*Alytes obstetricans*), viviparous lizard (*Zootoca vivipara*), and slow worm (*Anguis fragilis*). If asp vipers are able to establish in these areas, impact on populations of these native species could be significant. This is especially the case for both toad species which are most vulnerable to predation, as they are (severely) threatened and limited to these specific habitats in southern Limburg. Impacts of predation on native species have not been recorded.

4.5.2 Social damage

Public health
Asp vipers, as venomous snakes, are of public health importance and viper bites can pose a common medical emergency (Audebert *et al.* 1992; Jan *et al.* 2002). The activity of the venom is comparable, but an order of magnitude higher due to its effects on coagulation, to that of common European adder, acting on blood pressure, inflammation, and haemostasis by several proteins (Stahel *et al.* 1985; Komori & Sugihara 1988; Komori & Sugihara 1990; Caldéron *et al.* 1993; Komori *et al.* 1999). Envenomation generally causes local symptoms and, in severe cases, systemic effects (Audebert *et al.* 1992) or even neurological symptoms (Beer & Purtoti 1998; Jan *et al.* 2002). Common local symptoms are oedemas, pain, and phlyctenosis. Systemic effects mainly comprise hypotension, gastrointestinal syndromes (like diarrhoea and vomiting), coagulation, and shock. In rare, extreme cases these may lead to death (Stahel *et al*. 1985; Audebert *et al.* 1992). Though rare, neurological symptoms that might be caused by bites of asp vipers are paralysis, diplopia, and dysphonia (Beer & Purtoti 1998; Jan *et al.* 2002). These symptoms are the result of two neurotoxins in the venom of asp vipers, namely vaspin (acting at postsynaptic neuromuscular junctions) and a monomeric PLA_2 identical to ammodytoxin B (acting presynaptically) (Jan *et al.* 2002). Cases of neurological symptoms after envenomation by asp vipers are only known from southeast France (Jan *et al.* 2002; Guillemin *et al.* 2003) and Italy (Beer & Purtoti 1998). Overall, asp vipers can be classified as moderately dangerous (Audebert *et al.* 1992).

In literature, besides envenomation, no examples of diseases or parasites that could be transmitted by asp vipers are known (Fritz & Lehnert 2007).

Fear factor
Sightings of asp vipers in the Netherlands may attract certain people to specific areas and thereby have a positive effect on recreational values. However, it is more likely that sightings of the species will cause a reaction of fear in the majority of the Dutch population. As a consequence, people, especially with small children, horses, or dogs, tend to avoid the location, which in turn poses a negative effect on the life of neighbouring people, and ultimately also on recreational values of the area. This will particularly be the case in areas that are frequently visited by people and/or areas near built-up areas.

4.5.3 Economic damage

Economic damage of asp vipers might occur to some extent. However, as a low overall risk of the species forming an invasion is estimated, total economic damage will be relatively low. In a worst case scenario economic damage might be caused by:

- (Possibility of) envenomation: costs for public health, for acquiring antivenom, for hospital treatments, etc.

- Fear: damage to the recreational sector of the area in which asp vipers are sighted can be significant, especially in nature areas that are frequently visited by people, or in areas near recreational facilities (e.g., sports centres, holiday parks, and swimming pools).

4.6 CASE STUDY: ASP VIPERS AT POORTUGAAL

In this section, the three probabilities and possible impact are assessed relating to the asp vipers at Poortugaal, after a short general background of this introduction is given.

Background
Only one record of more than one free-living asp viper outside its natural distribution range has been recorded worldwide. In 2006 at least eight asp vipers were discovered in Bos Valckesteyn near Poortugaal, a forested area southwest of Rotterdam, the Netherlands. Six animals were captured by reptile zoo SERPO from Delft in October 2006 (photographs 6 and 7). At least two snakes were not caught. No sightings of the species at the locality have been recorded since October 2006.

Probability of introduction
Most likely the asp vipers in Bos Valckesteyn were introduced deliberately from captivity. If snakes manage to escape, they will generally be found within a short distance from the source of introduction, often within 150 metres from built-up areas. As the asp vipers near Poortugaal were sighted at a larger distance from built-up areas, this introduction was probably caused by intentional release of the snakes (SERPO 2006). However, the exact source of this introduction remains unknown. Moreover, asp vipers are not often kept as pets, so the probability of new introductions by this pathway is relatively low.


Photographs 6-7. Mr. W. Getreuer of reptile zoo SERPO capturing an asp viper in Bos Valckesteyn, Poortugaal, the Netherlands. Photographs by: Walter Getreuer, SERPO.

Probability of establishment and spreading
To avoid establishment and dispersal of the species, most specimens were captured by reptile zoo SERPO from Delft, the Netherlands, in October 2006 (SERPO 2006). Two snakes were not captured. As management has taken place, no firm conclusions can be drawn about the probability of establishment and spreading of the species, based on the case in Poortugaal. As the most recent sighting of asp vipers near Poortugaal dates back from 17 October 2006, it is doubtful whether the species is still present in this area. Due to a high amount of disturbance after the first snakes were caught (e.g., frequent entry of interested people and the mowing management), remaining specimens might have escaped to less accessible parts of the park, where they can reside without being discovered by humans. It is also possible that the snakes have been captured in the meantime or did not survive. However, the absence of sightings of asp vipers in the last five years suggests that the species did not establish and certainly did not spread into the surrounding area. This might be due to the fact that the majority of the snakes was removed or due to a low probability of establishment and spreading, or a combination of both.

Impact
As most snakes were removed in an early stage, the potential impact of the species can not be inferred to the full extent from the case in Poortugaal. In this specific case (with only a few specimens present in the area) only some *social damage* (i.e., fear factor) was noticeable. The sightings were broadcasted in the national news and it was advised to avoid certain parts of the forested area. No effects on public health (e.g., envenomation) were recorded. Measures were taken as response to the sightings. The snakes were captured by employees of SERPO and the public was informed about the species. Because snakes were captured some costs were made for these measures.

Conclusion
The risks of the presence and the invasiveness of asp vipers in Bos Valckesteyn near Poortugaal are relatively low, possibly because of the fact that the majority of the snakes was captured in an early stage. Although it is uncertain whether the two snakes that were not captured are still alive, it can be concluded that the species has not been able to establish a population and disperse, probably due to the population management that has taken place (i.e., capturing and removing six out of eight snakes).

5 RISK MANAGEMENT

In this chapter measures are identified and proposed to counteract introduction, establishment, and spreading of and damage caused by asp vipers in the Netherlands. The presented measures are based on the results of the risk assessment. Also a concise protocol is presented, which can be used to act adequately if the species is introduced anywhere in the Netherlands in the future.

5.1 PREVENTION

Possible measures to prevent introduction of asp vipers in the Netherlands are discussed below. Policy, trade-related possibilities (e.g., import bans and legislation) are not described, as commissioned.

Releases from captivity are considered as most important introduction pathway, though still with an overall low probability. Education is the only possible measure for prevention of both deliberate and accidental releases of asp vipers. Public education campaigns, in which traders and retailers can play an important role, are essential to reach potential releasers. Information should be clearly directed at snake keepers, focussing on consequences and impacts of introductions, and appropriate measures to prevent snakes escaping from their captive environment. Moreover, it should be stated explicitly that releasing non-native animals is illegal.

Besides releases from captivity, chances of introduction of asp vipers through transport are very low. The most likely preventive measure is increasing awareness amongst people who travel to areas within the species' natural range. Public education could help preventing asp vipers ending up in luggage or cars of travellers. Moreover, it will support people in making the right decision (i.e., alert an animal shelter or animal ambulance) if asp vipers are discovered in luggage when arrived home. The species hitch-hiking in cargo transport could be prevented by thorough controls of the cargo before shipment.

A disadvantage of public education is the need of ongoing active maintenance and accompanying costs. This makes it hard to sustain an adequate campaign for a long time span, with effects rapidly fading. Moreover, whether education campaigns indeed prevent future introductions is uncertain. They can even have an opposite effect, encouraging people to release the species.

In summary, public education is an important preventive measure against introduction of asp vipers in the Netherlands. However, as chances of introduction are low and public education programs have significant drawbacks (including high costs), it is disputable whether preventive measures should be taken.

5.2 ERADICATION

Although the probability of establishment and spreading of asp vipers in the Netherlands are estimated to be relatively low, measures for eradication of the

species can be undertaken. These measures are designed to completely remove (a population of) the species.

Capturing asp vipers is a possible eradication measure. As previously discussed, if the species is introduced, chances are high that only a few specimens are involved. In such cases it is likely that all specimens can be removed if well-time adequate action is taken, or that the remaining number of snakes is so low that successful establishment can be prevented. Costs are involved, but the economic damage is relatively low.

Early detection is essential in eradication of the species. If introduced species are detected in an early stage and measures are taken accordingly, establishment is not likely (Genovesi 2001). However, if the species remains undetected for a longer period of time, the probability of establishment increases (Mack *et al.* 2000). Early detection is more likely in areas outside the distribution range of native snake species, as the sudden presence of snakes is often noticed in an early stage. However, if asp viper gets introduced within the distribution range of common European adder, early detection of the species becomes more improbable, as a result of the morphological resemblance between the species.

Capturing snakes is best performed by luring and trapping them by providing optimal habitat and climatic circumstances. Therefore refuges are presented in the area, which attract snakes if used in large quantities in the right places. These may comprise carpet tiles, heat lamps, or other trapping systems. By monitoring these elements regularly it is likely all animals will be captured. Captured snakes can be housed in shelters and zoos, serving educational functions. Monitoring and capturing involve costs. However, it is considered the most efficient eradication measure and once totally eradicated, no extra measures and accompanying costs are involved. Additionally, eradication will decrease social damage, as people know that actively measures are taken.

Regarding the situation at Poortugaal, no measures for the eradication of asp vipers are recommended, as it is expected that the species is not present anymore. If future sightings are recorded or specific research reveals the presence of the species, capturing snakes by luring is recommended to eradicate the species.

5.3 Control

The third possible way of risk management is formed by measures to control an established population of the species. This means that further dispersal and impact of the species is minimised.

Due to the fact that population control management is permanent, accompanied by high costs, this possibility of risk management is not considered an option. If asp viper does occur in Bos Valckesteyn, in contrast to the expectations, they are restricted in dispersal due to the unsuitability of the surrounding areas, i.e., barriers in the form of densely populated areas and infrastructure. Regarding Poortugaal, additional control management would not be necessary.

In some cases, control of an established population can be used as an absolute last resort in order to prevent dispersal and impact of asp vipers. For example, a land owner might refuse providing access permission to his property, thereby preventing adequate eradication measures. In such cases, control management of the population is the only possibility left. Specimens can be lured and trapped within the direct surroundings. However, as chances of asp vipers establishing and spreading in the Netherlands are relatively low, it is expected that controlling a population will not be necessary.

5.4 Protocol

This paragraph provides a concise overview of all necessary and/or possible steps for reacting adequately if the species occurs somewhere in the Netherlands in the future. Development of an extensive education program in this stage is considered premature and will not be discussed.

If the species occurs somewhere in the Netherlands, adequate action is necessary to prevent establishment and dispersal of the species. The following actions are considered essential (more detailed information on http://serpo.nl/verstekeling-slang.html).

The person who sights the snake should consider the following:

- Always assume that it is a dangerous snake, until the contrary is proven indisputably.
- Do not try to capture or frighten the snake.
- Keep a distance of at least 1 m to the snake. If you are closer, do not move and give the snake the possibility to crawl away.
- Try to follow the snake within a safe distance.
- Try to develop a clear description of the snake for a correct determination.

After these precautionary instructions have been taken into account, a sighting should be reported directly to the appropriate authorities among which the municipality in which the snake is sighted. Every sighting should be reported to reptile zoo SERPO (015-2122184) and to waarneming.nl / telmee.nl. By doing so, other (national) authorities are informed as well. In the case of a medical emergency, e.g., snake bites, human health is of main priority and emergency services should be alarmed instantly.

Reptile zoo SERPO or another licensed authority will react on the sighting. They will verify the sighting and decide which actions should be taken in order to react adequately. If possible, the species will be captured and removed. If instant eradication is not possible, it should be decided, in consultation with the municipality, which subsequent steps are to be taken. Often these comprise informing the public, e.g., signs warning for snakes and briefings to local residents, informing other entities, e.g., general practitioners to be aware of victims of snake bites, and developing an action plan to eradicate the species.

6 CONCLUSIONS AND RECOMMENDATIONS

Free-living asp vipers have been recorded outside their natural distribution range only once worldwide. Eight specimens were discovered and six were recaptured in 2006 in Bos Valckesteyn near Poortugaal, a forested area southwest of Rotterdam, the Netherlands (SERPO 2006). As recent sightings of the species are lacking, it is uncertain whether it is still present. The current study was initiated to provide insight into the potential effects of the occurrence of non-native populations of asp viper in the Netherlands, their present distribution, introduction pathways, and the probability of establishment and spreading. Besides risk assessment, the risk analysis deals with possible measures regarding risk management of the species.

6.1 RISK ASSESSMENT

The risk assessment defines probabilities of introduction, establishment, and spreading, and vulnerable areas, and describes potential impacts by ecological, social, and economic damage.

The probability of introduction of asp viper into the Netherlands is low. Natural colonisation into the Netherlands from its natural distribution range is considered impossible. Climatic conditions are expected to prevent the species from extending its range northwards (Lourdais *et al.* 2004). Introduction pathways caused by humans, both accidentally and deliberately, can result in the presence of asp viper in the Netherlands. However, as the species is not commonly held as pet and introduction through global transport is unlikely, chances of introduction caused by humans are relatively low.

The probability of establishment of asp viper in the Netherlands is relatively low. The (a)biotic factors in the Netherlands are estimated to limit establishment chances. Asp vipers have distinct habitat preferences and are bound to sun exposed areas which warm up quite rapidly (Lourdais *et al.* 2002; Lourdais *et al.* 2004). Reproduction success will be highly constrained by unfavourable climatic conditions in the Netherlands. Females are less likely to reach the body conditions needed for reproduction (Naulleau *et al.* 1999; Aubret *et al.* 2002) and if they do, they probably reproduce only once in their life (Bonnet *et al.* 2002). If reproduction takes place, mean offspring mass and litter sizes are low and proportion of stillborn offspring is relatively high, resulting in decreased juvenile survival (Lourdais *et al.* 2002; Lourdais *et al.* 2004). Even at the northern limits of its natural distribution area, asp vipers face unfavourable climatic conditions. Therefore serious limitations regarding establishment probability may be present. Southern exposed slopes and hilly areas with a rocky surface and little shade are scarce in the Netherlands, and can only be found in specific southern parts of the Netherlands in the province of Limburg. Nevertheless, also specific (ruderal) parts of urban areas may provide a suitable microclimate. Besides climate limiting establishment chances to some extent, introduction of more than one specimen is not likely, thereby reducing the probability of establishment of a population.

The third key aspect regarding the risk of the presence and the invasiveness of the species, i.e., probability of spreading, is also estimated to be relatively low. Dispersal

is constrained by the low colonisation rate of the species, due to site fidelity and specific habitat requirements (Günther & Lehnert 1996; Fritz & Lehnert 2007).

Based on the probability of introduction, establishment, and spreading, the risks of the presence and the invasiveness of asp viper in the Netherlands are low. Nevertheless, ecological, social, and economic damage may occur to some extent. Ecological damage could be caused by competition and predation. However, vipers do not concentrate on specific, rare species (Luiselli 2006) and sympatric vipers generally partition the available habitat (Luiselli 2006; Luiselli *et al.* 2007), although it is uncertain whether this is also the case in non-native populations. Also, no impacts of competition or predation have been recorded. Hybridization with common European adder is unlikely, but not impossible, as the species are discerned as phylogenetically distant (Martínez-Freiría *et al.* 2010) and no occurrences have been recorded. According to the ISEIA protocol (Branquart 2009), asp vipers in the Netherlands are categorised as low environmental risk, i.e., no threat to native biodiversity and ecosystems. Social damage is possible with respect to public health. As venomous species, asp viper can pose a common medical emergency (Audebert *et al.* 1992; Jan *et al.* 2002). Overall, the species is classified as moderately dangerous to humans (Audebert *et al.* 1992). Sightings of the species can also cause a reaction of fear among residents, thereby posing a negative influence on the lives of people and possibly on recreational values. Economic damage is expected to be relatively low. It might be caused by costs for public health and damage to the recreational sector of an area due to fear.

6.2 Risk management

Risk management deals with measures to counteract introduction, establishment, and spreading of and damage caused by asp vipers in the Netherlands. Recommendations for these measures are based on the risk assessment. Risk management is subdivided into measures for prevention, eradication, and control of the species. Public education is an important preventive measure against introduction of asp vipers in the Netherlands. Since chances of introduction are low and public education programs have significant drawbacks (e.g., ongoing active maintenance and high costs), it is disputable whether preventive measures in the case of asp viper introductions into the Netherlands should be taken.

Eradication programs are designed to completely remove (a population of) the species. Capturing asp vipers by luring and trapping is considered to be the most efficient eradication measure. As it is expected that the species is not present anymore at Poortugaal, no eradication measures are recommended. If future sightings or specific research reveals the presence of the species, luring and trapping is recommended to instantly eradicate the species, for which early detection is essential. If asp viper gets introduced within the distribution range of common European adder, early detection of the species becomes less probable, as a result of the morphological resemblance between the species (Ameling 1978; Günther & Lehnert 1996).

Finally, control management of populations can be used to minimise dispersal and impact of asp vipers. Due to the fact that population control management is permanent, accompanied by high costs, this kind of management is not considered

an option. Only if eradication is not possible, control of an established population can be used as an absolute last resort in order to prevent dispersal and impact of asp vipers.

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APPENDIX. ISEIA PROTOCOL

The Invasive Species Environmental Impact Assessement (ISEIA, Branquart 2009) protocol is used to scientifically assess the environmental risks (not impacts on human interests, e.g., public health or economic damage) of asp vipers and to identify whether preventive and mitigation actions are of concern. In this appendix the results of the ISEIA for asp vipers in the Netherlands are presented.

Risk categories

Using the ISEIA protocol, species are placed in one of the following risk categories.

- Category A (black list, score 11-12): species with a high environmental risk.
- Category B (watch list, score 9-10): species with a moderate environmental risk on the basis of current knowledge.
- Category C (low environmental risk, score 4-8): species that are not considered as a threat for native biodiversity and ecosystems.

Scoring system

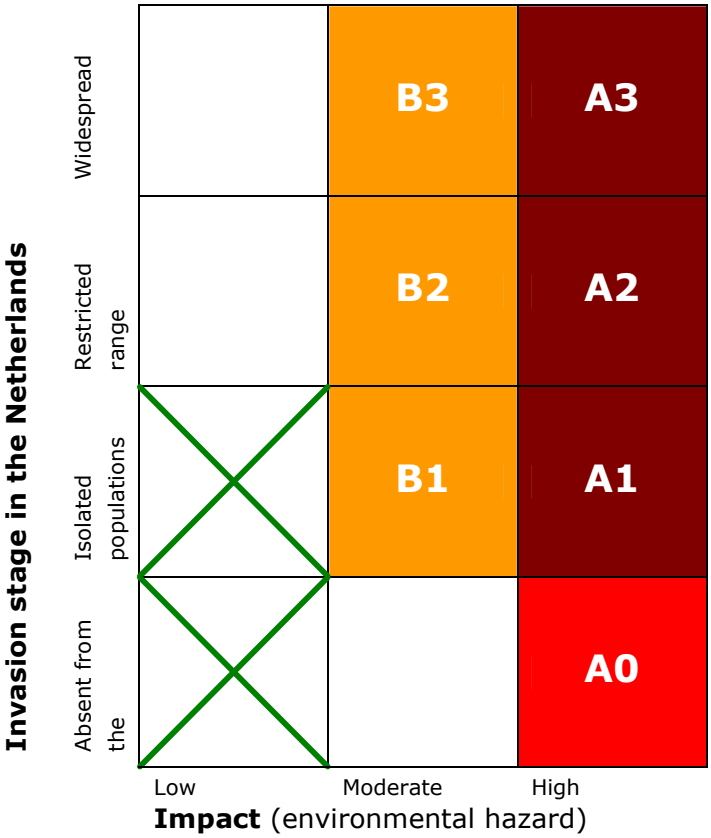
The scoring system used in the ISEIA depends on the availability of information.

- Low level of uncertainty (information documented in literature):
  - Score 1 = low
  - Score 2 = medium
  - Score 3 = high
- High level of uncertainty (information poorly documented):
  - Score 1 = unlikely
  - Score 2 = likely
- No information available:
  - No score = deficient data

Assessment asp viper in the Netherlands

Section	Category	Score	Reasoning
Dispersion potential or invasiveness	Medium risk	1	Relatively poor dispersal capacity and low reproduction potential.
Colonisation of high conservation value habitats	Medium risk	2	Low colonisation potential, introduced to area with intermediate value, potential in high conservation value habitats.
Adverse impacts on native species	Unlikely	1	No data from invasion histories available. Expert judgement: hybridization impossible; competition and predation only to a limited extent.
Alteration of ecosystem functions	Unlikely	1	No data from invasion histories available. Expert judgement: no alterations are expected.
Global ISEIA score	**C**	**5**	

Conclusion: The global ISEIA score of asp vipers in the Netherlands sums up to 5. This means that the environmental risk level is low, i.e., category C. Asp viper is not considered as a threat to native biodiversity and ecosystems. Considering the invasion stage in the Netherlands, asp viper can be categorized as either "absent from the Netherlands" or "isolated populations", depending on the current occurrence of the species. The outcome of the total list system of the ISEIA protocol is presented in the figure underneath, indicated by the green crosses.



Black list: A1 – A3
Alert list: A0
Watch list: B1 – B3