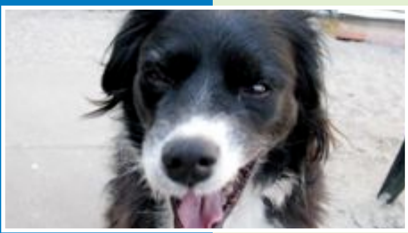
Risk analysis of Possums and Opossums in The Netherlands



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Preface

Some possum and opossum species are known to be kept captive and traded in The Netherlands. The Invasive Alien Species Team of The Netherlands Food and Consumer Product Safety Authority has commissioned Bureau Waardenburg to assess the occurrence of opossums and possums in The Netherlands and the probability of these exotic species establishing free ranging populations in The Netherlands and the subsequent impacts.

This risk analysis was carried out by:

drs. F. van Vliet	report;
drs. ing. R. Lensink	project management and report;

Dr. T.M. van der Have and ir. J.W. Lammers, Invasive Alien Species Team (NVWA), supervised this study. The authors thank all who contributed.

Most of the written information was found as open source on the internet; we have noted all our sources; it is our mistake if some or someone has been forgotten.

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Summary

Framework

This risk analysis has been carried out for possums and opossums. For at least seven species it has been proven that they occur in Western Europe (as a pet). Those species are:

Possums

- Common Brushtail Possum *Trichosurus vulpecula*
- Striped Possum *Dactylopsila trivirgata*

Opossums

- Virginia Opossum *Didelphis virginiana*
- White-eared Opossum *Didelphis albiventris*
- Gray Four-eyed Opossum *Philander opossum*
- Gray Short-tailed Opossum *Monodelphis domestica*
- Small Fat-tailed Opossum *Thylamys pusilla*

In this risk analysis the ecology of species is described as well as the probability that they could be successful in settling en spreading, as derived from their ecology and climate match. Furthermore, we give insight into the expected risk (and damage) from ecological and socio-economic viewpoints. Finally, for all species two methods of formal and transparent risk analysis are filled in.

Information about occurrence in Western Europe was gathered from people and sources dealing with the trade and the keeping of possums and opossums. Information on the ecology of species was mainly found in the formal scientific literature as this is found as open source on the internet.

Probability of settlement and spread

The Common Brushtail Possum is an invasive exotic species in New Zealand and has proven to have negative effects on native flora and fauna. The main reason is that ground predators are lacking on these islands. The costs for control of this species are very high. It is unknown how this possum will behave in an environment were ground predators are present, as in Western Europe. There is a good climate match between its native range and Western Europe. Therefore, a settlement here could easily develop into a successful invasion, as long as management (eradication) is not conducted. The opportunistic lifestyle of this species could be an advantage in its possible success.

The Virginia Opossum is native in North America. Here it has spread further north since colonisation by Europeans started. This species lives in agricultural landscapes as well as in the urban environment. It has an opportunistic lifestyle, which has contributed to its success in North America. There is a fairly good climate match between North America and Western Europe, therefore, the probability of successful settlement and spread into our ecosystem is quite high.

The Striped Possum and Gray Short-tailed Opossum are both tropical species. Based on the climate mismatch it is expected that both species won't settle permanently in Western Europe in case of where animals escape into the wild.

White-eared Opossum, Gray Four-eyed Opossum and Small Fat-tailed Opossum are three species form the tropics and subtropics. Based on their occurrence in the subtropical climate zone, it cannot be excluded that climate in Western Europe will fit with the demanding of these species. All three are small species and settlement here could take place without being noticed by humans; they are secretive animals.

All seven species mentioned have small or very small home ranges, with little capacity for dispersal. The probability of a successful settlement highly depends on the number of animals present (released) in a small area. As long as those species do not occur in the wild this could be a limiting factor in successful settlement and spread. Nevertheless, the release of a single male and female animal represents the beginning of potential establishment.

Vectors

All seven species mentioned are kept as pets in The Netherlands. Estimates on the number vary between some tens up to many tens of individuals. On relevant web sites in both The Netherlands and Germany, there is supply and demand for all seven species. In Belgium, it is not permitted to keep possums and opossums as a pet. On the contrary, it is noteworthy that a Belgian company is advertising on the internet for the control of opossums.

On relevant web sites proof has been found that at least some of the relevant species are known to reproduce in captivity. With this in mind, keeping these species as a pet becomes independent from supply out of the native range of species.

The Gray Short-tailed Opossum is kept in captivity on a large scale as a model species for biomedical research. Those research locations have a high standard of safety rules. Therefore, the chance for escapes is nil. In The Netherlands no research locations with this species are known.

Some cases are known of (o)possums that have reached Western Europe as stowaways on ships. In the harbour of Vlissingen in the south of The Netherlands two cases are known and in Rotterdam one case. Those cases concerned one Common Brushtail Possum and in two cases the species were unknown.

Prevention

In The Netherlands and surrounding countries the trade and possession of possums and opossums reaches only a limited scale. Nonetheless, it could not be excluded that in case a small number of those animals are released or escaped, this could lead to establishment. Preventive measures (limits on trade and possession) could reduce this limited risk even further.

Sporadically possums and opossums are found as stowaways on ships from South Central and North America, as well as from Australia and New Zeeland. Current knowledge indicates that this nearly always concerns single animals and never more on any single ship. The risk of introduction by ships seems to be very limited and, therefore, the control of ships seems to be unnecessary.

Elimination

If a possum or opossum is seen in the wild, it could mean that establishment has taken place or is going to take place; especially in the case it concerns a species with a good climate match. In such cases elimination of the animals is necessary by means of (live) traps.

Management

Possums and opossums have small home ranges. Therefore, trapping of animals is a good management option. Furthermore, larger species could be hunted.

Nederlandse samenvatting

Kader

Deze risicoanalyse is opgesteld voor possums en opossums waarvan op een of andere wijze het voorkomen in West-Europa (in gevangenschap) is aangetoond. Het gaat om:

Possums	
- Common Brushtail Possum *Trichosurus vulpecula*	Voskoesoe
- Striped Possum *Dactylopsila trivirgata*	Gestreepte possum
Opossums	*Buidelratten*
-Virginia Opossum *Didelphis virginiana*	Virginia opossum
- White-eared Opossum *Didelphis albiventris*	Witooropossum
- Gray Four-eyed Opossum *Philander opossum*	Vieroogopossum
- Gray Short-tailed Opossum *Monodelphis domestica*	Korststaartopossum
- Small Fat-tailed Opossum *Thylamys pusilla*	Muisopossum of Dikstaartopossum

In de risicoanalyse wordt ingegaan op de ecologie van deze soorten en de kans dat deze soorten zicht op basis van ecologie en klimaat in West-Europa zouden kunnen vestigen en uitbreiden. Daarnaast wordt inzicht gegeven in hoeverre in dat geval risico's (met eventuele schade) zijn te verwachten in ecologische en sociaal-economisch opzicht. Tot slot zijn voor alle soorten twee methodieken voor een formele en transparante risico-analyse ingevuld.

Informatie omtrent het voorkomen in West-Europa is vergaard door bronnen en mensen die gaan over handel en dierenhouderij te raadplegen. Informatie omtrent de ecologie is voornamelijk uit de wetenschappelijke literatuur gehaald, zoals die als *open source* op het internet is te vinden.

Kans op vestiging en uitbreiding

Common Brushtail Possum heeft bewezen in Nieuw Zeeland uit te groeien tot een invasieve exoot met negatieve effecten op inheemse flora en fauna; vooral omdat grondpredatoren op deze eilanden ontbreken. De kosten die ter bestrijding worden gemaakt zijn hoog. Hoe deze soort zich zal gedragen in een omgeving waar al andere grondpredatoren aanwezig zijn, is onbekend. Klimatologisch gezien heeft deze soort een hoge slagingskans om uit te groeien tot invasieve exoot in West-Europa als een populatie zich weet te vestigen en geen effectieve eliminatiemaatregelen worden uitgevoerd. Daarnaast zal de opportunistische leefwijze een voordeel kunnen zijn.

De Virginia Opossum is een Noord-Amerikaanse soort die zich de afgelopen era in noordelijke richting heeft uitgebreid. De soort leeft in cultuurlandschappen alsook de urbane omgeving. De levenswijze is opportunistisch hetgeen bijdraagt aan het succes in Noord-Amerika. Klimatologisch gezien zou de soort zeer wel uit de voeten kunnen in West-Europa en zich een plek in het ecosysteem kunnen veroveren.

Striped Possum en Gray Short-tailed Opossum zijn beide tropische soorten waarvan op basis van het ontbreken van klimaatovereenkomst mag worden verwacht dat zij geen voet aan de grond zullen krijgen in geval dieren in West-Europa in het vrije veld terecht komen.

White-eared Opossum, Gray Four-eyed Opossum en Small Fat-tailed Opossum zijn drie soorten uit de tropen en subtropen. Vooral het voorkomen in subtropische klimaten sluit niet uit dat het klimaat in West-Europa passend kan zijn voor deze soorten. Het zijn alle drie kleinere soorten buidelratten die vermoedelijk ongezien een plek in een ecosysteem kunnen veroveren.

Alle betrokken soorten kennen kleine tot zeer kleine home-ranges. De kans op een succesvolle vestiging wordt daarmee in hoge mate bepaald door het aantal dieren die op een enkele locatie in vrijheid voorkomt. Zolang er in West-Europa geen dieren in het vrije veld voorkomen kan dit als een beperkende factor voor vestiging gelden. Maar een tweetal (man en vrouw) kan al het begin zijn.

Vectoren

Alle zeven soorten worden in Nederland als huisdier gehouden waarbij de schattingen uiteenlopen van enkele tientallen tot vele tientallen. Op het internet worden ze alle zeven aangeboden en/of gevraagd. Ook in Duitsland worden ze gehouden. In België zijn Possums en Opossums niet opgenomen op de positieflijst met uitheemse soorten die gehouden mogen worden. Opmerkelijk genoeg is op het internet wel een Belgisch bedrijf gevonden dat bestrijding van Opussums tot haar werkzaamheden rekent.

Op het internet zijn aanwijzingen gevonden dat een deel van de genoemde soorten in gevangenschap tot reproductie komt. Daarmee wordt het houden van deze dieren onafhankelijk van aanvoer vanuit de oorspronkelijke verspreidingsgebieden.

De Gray Short-tailed Opossum wordt wereldwijd op grote schaal gehouden voor bio-medisch onderzoek. Deze locaties kennen een zeer streng veiligheid regime ter voorkoming van onder meer ontsnappingen. In Nederland zijn geen onderzoekslocaties waa de soort wordt gehouden.

Er zijn enkele gevallen bekend van een (o)possum die als verstekeling op een schip West-Europa bereikt. De haven van Vlissingen kent twee gevallen, Rotterdam een geval. Het ging om een Common Brushtail Possum en twee onbekende Possums.

Preventie

Alhoewel de handel en het bezit van de beoordeelde soorten Possums en Opossums slechts op bescheiden schaal plaatsvindt, kan niet uitgesloten worden dat bij loslaten of ontsnappen een aantal van deze soorten zich weet te vestigen in Nederland. Preventie (handels- en bezitsbeperkende maatregelen) kan dit kleine risico wegnemen.

Possoms en Opossoms zijn sporadisch waargenomen als verstekelingen op schepen uit Zuid-, Centraal- en Noord-Amerika en vanuit Australia en New Zeeland. Voor zover bekend ging het altijd om 1 exemplaar, nooit om meerdere. Het risico op introducties via scheeptransport is dus zeer gering en havencontroles lijken overbodig.

Eliminatie
Als er meldingen gedaan worden van in het vrije veld voorkomende Possums of Opossums, kan dat betekenen dat zich een populatie heeft gevormd of kan gaan vormen, zeker als het om een soort gaat die hier gezien het klimaat zich zou kunnen vestigen. Effectieve eliminatiemaatregelen zijn:
- vangen (met vallen) met life-traps.

Beheer
Als zich in de toekomst een grote populatie Possums of Opossums in Nederland zou vestigen, dan kunnen de volgende beheermaatregelen worden overwogen: vangen. De soorten hebben zeer kleine home-ranges waardoor dit een goede mogelijkheid is. Daarnaast kunnen de grotere soorten worden geschoten. Omdat het nachtdieren zijn, zijn hulpmiddelen als een lichtbak daarbij vermoedelijk noodzakelijk.

1 Introduction

In The Netherlands some species of possum and opossums are kept as pets. There is a small trade in these pet species in our country. Species that are known to be kept as pets are the Virginia Opossum *Didelphis virginianus*, the Short-tailed Opossum *Monodelphis domestica* and the Common Brushtail Possum *Trichosurus vulpecula*. In 2011 in the eastern parts of The Netherlands a pair of opossums was said to be released (G. Bruens, Natuurmonumenten) into the wild. This incident was the motive to conduct a risk analysis for possums and opossums.

The genus opossum consists of more than 60 species. One of the species, the Virginia Opossum lives in North-America. All other opossums, like the Short-tailed Opossum, occur in Central- en South-America.

In Australia another species of the order of the *Marsupials* occurs: the Common Brushtail Possum *Trichosurus vulpecula*. In its native range in Australia this species is declining. At this moment it is categorized as under threat. Two centuries ago, the Common Brushtail Possum was introduced into New Zealand by human aid (e.g. ships). In New Zealand this species is an invasive alien and is a major threat for the native avifauna. Reason for this is that in New Zealand ground predators are lacking and Common Brushtail Possum fills this niche.

In Europe no settlements are known of possums and opossums. But as these animals are kept as pets, there is a risk of possums and opossums escaping or being released into the wild. The question is what the risk is of possums and opossums establishing free ranging populations in The Netherlands and what the subsequent impacts would be on for instance biodiversity, human and animal life and what the economic impact would be.

1.1 Aim of this project

This project aims to assess the probability of opossums and possum(s) establishing free ranging populations in The Netherlands and the subsequent impacts.

The following questions are addressed.

- To which extent are opossums and Common Brushtail Possum kept and traded in The Netherlands and which species of opossums does it concern?
- Which vectors are important for reaching The Netherlands and which vectors for the establishment of populations in the wild?
- What is the life cycle of relevant species and what are crucial aspects of these life cycles?
- Can relevant species fulfil their life cycle in the Dutch temperate climate and which habitats and geographical areas have most chance of being colonised?
- What can be the impact on native biodiversity?

- What can be the impact on economy, public health and animal health?
- Using the Bomford and ISEIA protocols, what is the likelihood of establishment of relevant species in the wild and what are the probable consequences?

1.2 Methods

Facts and findings

In order to gain insight in these above-mentioned areas of interest, the Internet search engine 'google.com' and ‘scholar.google.com’ was employed to find research documents and other relevant information. Searches using single word search terms and combinations of search terms were applied to identify relevant reports and websites. Search terms comprised: Common Brushtail Possum, *Trichosurus vulpecula* and Opossum (in both Dutch and English language).

(Exotic) animal forums (http://exoticpets.phpbb3.nl/portal.php) and trading websites (www.exotictrade.nl, www.marktplaats.nl) were consulted to learn more about the extent to which possums and opossums are kept as pets and traded in The Netherlands.

For more detailed information and to fill in gaps in the knowledge the following experts or organisations were consulted:

- NFE (Nederlandse Federatie van Edelpelsdierenhouders)
- Alex Ploeg, Dibevo
- Nederlandse Vereniging van Dierentuinen
- Michiel van der Weiden, Gerard Bruuns, Vereniging Natuurmonumenten

Framework for risk assessment

According to the requirements, the following sections (if relevant) will be discussed for each of the relevant species; terms are derived from formal assessments like Bomford (Bomford 2003) and IESA (Appendix 2). For each species a formal assessment have been conducted; see further in the appendices.

1. Risk assessment:
    - 1a Probability of introduction;
    - 1b Probability of establishment;
    - 1c Probability of spreading;
    - 1d Vulnerable areas;
    - 1e Impact;
    - 1f Risk assessment score (according to the ISEIA and the Bomford method).
2. Risk management:
    - 2a Prevention;
    - 2b Eradication;
    - 2c Management.

Climate match

Exotic species have a greater chance of establishing if they are introduced to an area with a climate that closely matches that of their original range. The Climatch web application (http://www.brs.gov.au/Climatch) provides an interface for comparing climate characteristics between regions. It matches the climate of user-selected regions around the world to the climate of other selected regions. The potential range of a species is predicted by matching climate data from weather stations at or adjacent to known locations where the species occurs in a source region to climate data from weather stations in a nominated target region. We have run the model with all or some available parameters active (figure 1.1).

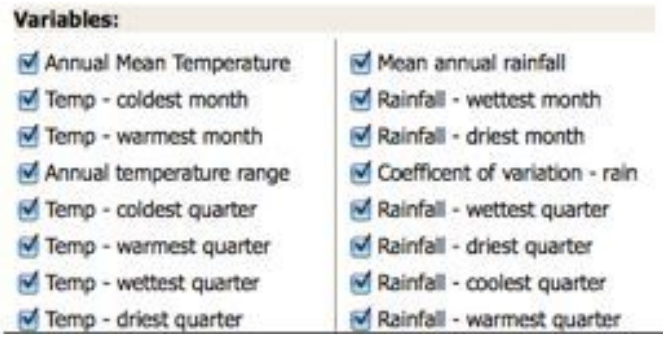

Figure 1.1 Available parameters in the web application Climatch.

1.3 Species of interest

A scan on the internet has revealed that in The Netherlands the following species are kept as pets and/or are traded in:

Possums

- Commom Brushtail Possum *Trichosurus vulpecula*
- Striped Possum *Dactylopsila trivirgata*

Opossums

- Virginia Opossum *Didelphis virginiana*
- Short-tailed Opossum *Monodelphis domestica*
- White-eared Opossum *Didelphis albiventris*
- Gray four-eyed Opossum *Philander opossum*

In surrounding countries the following species are kept or traded:

Germany

- Short tailed Opossum *Monodelphis domestica*
- White-eared Opossum *Didelphis albiventris*
- Small Fat-tailed Opossum *Thylamys pusillus*

Belgium

No traces on the internet are found of species being kept as a pet. In this country possums and opossums are not on the list of mammals for which it is allowed to be kept as pet.

2 Common Brushtail Possum

The Common Brushtail Possum *Trichosurus vulpecula* is a native species in Australia and an invasive alien species in New Zealand. The species is kept as pet in low numbers in Western Europe, inlcuding The Netherlands.

Common Brushtail Possum
(Photo Peter Firminger; (http://flickr.com/photos/wollombi/58499575/)

2.1 Biology and ecology

For this chapter copied text from the following sources is used:

Cowan P.E. 2001. Advances in New Zealand mammalogy 1990-2000: Brushtail possum. Journal of The Royal Society of New Zealand. Volume 31: 15–29.

Morris K., Woinarski J., Friend T., Foulkes J., Kerle A. & Ellis M. 2008. Trichosurus vulpecula. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 20 February 2012.

Global Invasive Species Database, www.issg.org/database

2.1.1 Distribution

Natural geographic range

The Common Brushtail Possum *Trichosurus vulpecula* is native to Australia and Tasmania (Figure 2.1). It ranges over much of northern, eastern and south-western Australia. It occurs as scattered populations in the arid central part of the country (Kerle & How 2008; Morris *et al*. 2008). Common Brushtail Possum has the widest distribution of any Australian marsupial.

Introduced geographic range

Common Brushtail Possums were introduced from Australia to New Zealand in the mid-nineteenth century. Possums have now spread throughout the main islands of New Zealand. Recently, they have been eradicated from several small offshore islands. Besides New Zealand there are no reports of this species being introduced outside Australia. Common Brushtail Possum is listed on the Global Invasive Species Database (GISP 2011) among hundred of the "World's Worst" invaders.

As far as we know there are no free ranging possum populations in Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012), nor in the rest of Europe (DAISIE European Invasive Alien Species Gateway (www.-europe-aliens.org; Global Invasive Species Database (www.issg.org/database) Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

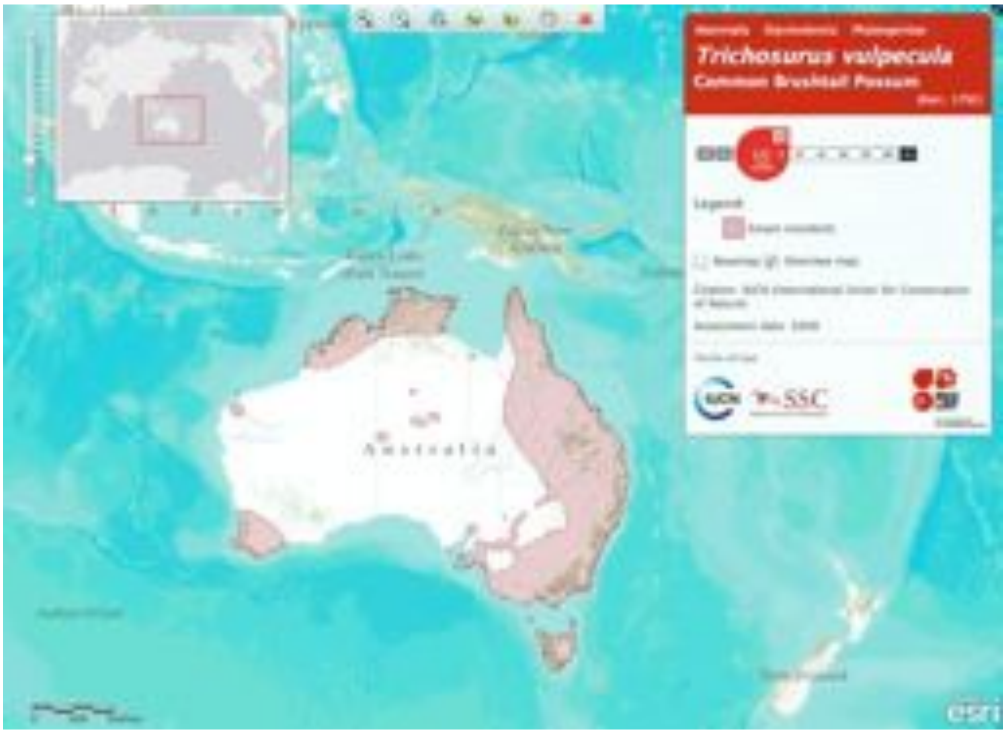

Figure 2.1 Native distribution of Common Brushtail Possum (Morris et al. *2012)*

2.1.2 Habitat

The Common Brushtail Possums is a very adaptable species and lives in a wide variety of habitats: agricultural areas, coastland, natural forests, planted forests, plantations, grasslands, riparian zones, ruderal / disturbed areas, scrublands, (sub)urban areas, wetlands (Global Invasive Species Database, www.issg.org/database). In its native range the preferred habitat of Common Brushtail Possums is eucalypt forest or woodland.

In its natural environment, Common Brushtaill Possum shelters in tree hollows. Ground level sites are used when trees are absent or scarce. In urban areas, possums often seek shelter in buildings (usually between the ceiling and the roof).

2.1.3 Diet

After Cowan (2001):
Nugent *et al*. (2000) review of information on possum diet mostly confirmed earlier data, but showed that the use of podocarps, particularly Hall's totara (*Podocarpiis hallii*) and pahautea (*Libocedrus bidwillii*), has previously been underestimated (Owen & Norton 1995; Allen *et al.* 1997; Nugent *et al.* 1997; Rogers 1997; Nugent *et al.* 2000). Seasonal shifts in diet reflect not only changing availability of non-foliar foods and of foliage of preferred deciduous species, but also seasonal changes in the relative palatability of evergreen foliage. Long-term changes in possum diet also follow changes in vegetation composition induced by their browsing (Allen *et al*. 1997; Nugent *et al.* 2000).

The importance of fruit, flowers, invertebrates and fungi also appears to have been underestimated (e.g., Parkes & Thomson 1995; Rickard 1996; Nugent *et al.* 1997; Sweetapple & Nugent 1998), even in beech forest (Owen & Norton 1995). These non-foliar foods, particularly fruits, generally have greater nutritional value than foliage, and could have a disproportionate effect on possum reproductive success and local possum carrying capacity (Nugent *et al.* 2000; Ramsey *et al.* unpubl.). The availability of these foods may therefore be the key to understanding variable possum densities and impacts in different habitats.

New data confirm that possum diet may be influenced strongly by secondary metabolites and anti-feedant chemicals in leaves (Dearing & Cork 1999; Lawler et al. 1998 1999a,b; Payton & Thomson 1999).

Possums also regularly eat meat, especially native birds and their eggs, and land snails (see Damage). They have been observed feeding on carcasses of deer (Thomas *et al.* 1993), other possums (C. M. H. Clarke, unpubl. data), and rodents (P. Cowan, unpubl. data). They are routinely trapped in leg-hold traps baited with rabbit meat to catch ferrets (Caley 1998).

In its native Australia, the Common Brushtail Possum feeds mainly on Eucalyptus leaves, but high levels of phenolics, terpenoids and other chemical defences in eucalypt foliage limits the intake of any one species. In New Zealand forests a high proportion of plant species is palatable and brushtail possum diets include a wide variety of foliage and fleshy fruits. The New Zealand plants most favoured by possums tend to be those producing foliage or fruits high in carbohydrate. In addition to their staple diet of foliage and fruits, possums also feed on flowers, the pollen cones of introduced pines, insects, and bird eggs and nestlings (Global Invasive Species Database (http://www.issg.org/database)).

2.1.4 Social organisation and behaviour

After Cowan (2001):
Spuu & Jolly (1999) and Day *et al*. (2000) review possum social organization and behaviour, including patterns of interactions. Typically, when two possums interact, one is clearly dominant over the other (Jolly & Spurr 1996; Henderson & Hickling 1997). Older and heavier animals are usually dominant over smaller, younger possums, and females are generally dominant over males in captivity (Jolly & Spurr 1996), although some large old males are dominant over smaller young females (Henderson & Hickling 1997). Disruption of sex steroid levels by ovari-ectomy (Jolly & Spurr 1996), vaccination against gonadotrophin-relcasing hormone (Jolly *et al*. 1996), or castration (McAllum 1996) did not alter established dominance status in groups of captive possums.

Wild possums share dens with variable frequency (Paterson *et al.* 1995). An observed den sharing rate of 7% a day was greatly reduced after possums were controlled (Caley *et al.* 1998). On the other hand, captive possums share dens up to 90% of the time, most commonly as pairs of females or, during the breeding season, male and female "consort" pairs (Day *et al*. 2000; Kerle 1998).

2.1.5 Movements and homeranges

Ranging behaviour (after Cowan 2001)
Where possums live on farmland with scattered patches of remnant forest or scrub, they show two types of ranging behaviour (Cowan & Clout 2000): 1) Some have small ranges centred on preferred habitats, such as stream-side willows or swamps, and never venture far out onto farmland. 2) Others range up to 1.600 m over open pasture and have annual home ranges of up to 60 ha in area (Brockie *et al.* 1997). These two types of ranging behaviour have been recorded for some possums, by both radio-tracking and trapping (Efford *et al.* 2000; P. Cowan, M. Efford, D. Ramsey unpubl. data). Such behaviour may allow possums to take advantage of patches of higher quality or seasonally available foods. Because young female, in particular, tend to establish home ranges close to, or overlapping, those of their mother, home ranges of females are effectively inherited (Efford 1991, 1998). In undisturbed populations this gives rise to spatial groupings of related females, which is reflected in the higher level of inbreeding in female possums compared with males revealed by genetic studies

(Triggs 1987; A. Taylor, D. Cooper, P. Cowan, unpubl. data). The few juvenile males that stay on their natal range gradually shift their home ranges away from those of their mothers over the first 2-3 years after independence to settle, on average, several range lengths away (Efford 1991), suggesting an inbreeding avoidance mechanism.

Areas from which possums have been cleared by control operations have often been likened to "vacuums", supposedly attracting possums in from immediately surrounding areas to take advantage of the newly available excess of food and den sites. There is little evidence to support such an effect (Brockie *et al.* 1991, 1997; Cowan & Rhodes 1993). While some survivors adjacent to controlled areas shifted their home ranges, this effect was detectable only over a distance of 200-300 m from the edge of the controlled zone and seemed to involve animals whose ranges overlapped its edge (Efford *et al*. 2000).

Possums are unlikely to move further than 200 - 400 m over 1-2 weeks to reach bait stations and poison lines (Hickling *et al*. 1990; Thomas & Fitzgerald 1994). This roughly matches estimates of average home-range lengths in similar habitats (Cowan & Clout 2000).

Paterson *et al.* (1995) observed peak numbers of possums between 23.00 and 02.30 hours, and that strong winds depressed activity. Herbert & Lewis (1999) concluded, from a study of the activity patterns of possums in captivity and the neural mechanisms controlling circadian behaviours, that possum activity is controlled by an internal circadian clock, modulated by responses to environmental factors such as rain and wind. In Australia, predators such as foxes influence possum activity, and possums significantly increase the time they spend feeding and moving on the ground after fox control (Pickett 1997).

Density (after Cowan 2001)

Efford (2000) reviews information on possum density, population structure and dynamics, and extends available data on habitat/density relationships. Among sites in mixed podocarp- and broadleaved forest, density was unrelated to latitude. The highest accurately measured possum densities (>15.0/ha) have all been at forest margins within 250 m of pasture (Coleman *et al*. 1980; Brockie *et al*. 1997; M. G. Efford, B. Warburton, A. Byrom, unpubl. data). Possums favour such areas because the diversity and biomass of under storey species is greater there, particularly where livestock are excluded. The location of forest-pasture edges is likely to correlate with discontinuities in soil fertility and forest composition, for historical and economic reasons. Edge forests are also more likely to have been disturbed and to include several species thought to be highly nutritious and favoured by possums (e.g., Owen & Norton 1995; Nugent *et al.* 2000).

Grid-based live trapping data from the Orongorongo Valley showed that the distribution of individuals was spatially random or dispersed rather than aggregated. The number of captures per live trap also showed no autocorrelation at any spatial lag

(Efford 2000). Captures may be clustered along trap lines used for kill-sampling (Hickling 1995), but such clusters probably reflect unevenness in the habitat or the transient effects of control rather than any tendency of possums to form social aggregations.

Dispersal (after Cowan 2001)
About 20-30% of juvenile possums disperse, mostly at the age of 8-12 months (Efford 1991; Cowan 2000b), or, where maturation is delayed in forest populations, at the ages of 18-24 months (Efford 1998). Dispersal movements are most frequent about the time of peak breeding in late summer and early autumn, and also in the spring if the population breeds then. Dispersing possums can cover long distances in a short time, up to 3 km in a night, and 10 km in a week, for a total average of about 5 km (Cowan & Rhodes 1992, 1993; Cowan et al.1996, 1997). They also may make several consecutive moves before finally settling in a new area, for example, one juvenile female in the central King Country moved five times in 72 days (Cowan & Rhodes 1993). Dispersing female possums tend to move further than males (the two longest recorded moves, 32 and 41 km, were both by females) and make more moves before settling (Efford 1991).

Dispersal of possums from their natal areas appears to be independent of density. After a control operation that killed more than 90% of possums, the absolute number of juvenile possums that dispersed decreased, but the proportion that dispersed remained unchanged (Cowan *et al*. 1997). Control therefore reduces but does not eliminate juvenile dispersal. The distances moved by juveniles dispersing from the controlled population also did not change significantly, so that, even after control, some juvenile possums are still likely to disperse through areas of reduced possum density (buffer zones) established for bovine tuberculosis management.

Possums are also capable of homing over distances significantly greater than their normal nightly movements. In a translocation experiment, four possums moved 4 km from the same location on Manawatu farmland all returned to their original home areas within 3 to 19 days (Cowan in press). The translocations were repeated for two of them, and they again returned successfully.

2.1.6 Reproduction and survival

After http://www.issg.org/database:
Common Brushtail Possums have 1 - 2 young per year. Females can breed at one year of age and males at age 2. Reproduction is highly seasonal with the main breeding season in autumn. A secondary season in spring sometimes occurs when nutrition is good. Gestation is 17-18 days. Single newborn young (c. 0,2 g) crawl into the pouch and attach to a teat. Most development occurs within the pouch, where they remain for 120 - 140 days. Young remain with the mother (initially riding on her back) for a further 100 days or more, becoming independent from 240 -270 days old.

Females may mature at one year old; males at 15 months or more (After: Global Invasive Species Database, http://www.issg.org/database).

After Cowan (2001):
The hope of achieving biological control of possums via manipulation of fertility has stimulated an enormous increase in knowledge and understanding about possum reproductive physiology, lactation and development of young. This information is not reviewed here, but readers are directed to Eckery *et al.* (1996), Moore *et al.* (1997a, b), Crawford *et al.* (1998b), Frankenberg and Selwood (1998), and relevant papers in Lynch (1998), Sutherland (1999), and references therein. Experimental analysis of possum biology has been greatly enhanced by research into improved husbandry protocols, procedures and detailed analyses of responses to stress and adaptation to captivity (Buddie *et al.* 1992; Jolly *et al*. 1995; McLeod *et al.* 1997; Baker *et al.* 1998; Mate *et al*. 1998) (after Cowan, 2001).

Fletcher and Selwood (2000) recently reviewed possum reproduction and development. As in many mammals of temperate regions, the onset of the breeding season in possums is controlled by day length (Gemmell & Sernia 1995).

The mating systems of wild possums are not well understood, although current research suggests that they are not monogamous (Sarre & Clout 1998; Taylor *et al*. 1999), and may be polygynous (Sarre *et al*. 2000; Taylor *et al.* 2000). Captive males will mate with several females per season (Jolly *et al*. 1995), and both consort and casual matings were fertile (Day *et al*. 1998). Male possums of the highest rank, both wild and captive, have the greatest reproductive opportunity, as they are able to exclude subordinate males from access to females (Jolly et al. 1998); and female possums may also "choose" dominant sires (McAllum 1996). Heavier females (>3 kg), usually dominant over lighter females, produced more offspring than lighter ones (Jolly *et al*. 1995).

Breeding in one-year-old females is variable, but thereafter age has little effect on breeding rate, and >80% of females produce one pouch young each year (Ramsey *et al.* unpubl.). The probability of breeding declines rapidly as body condition falls below average. Breeding rate and body condition were both related to an index of food used by possums (hinau fruit-fall), population density in the current year, and population density in the previous year. High density in the previous year coupled with low hinau fruitfall in the current year predicted below average body condition and reduced breeding rate (Ramsey *et al*. unpubl.).

Mortality rate and lifespan (after Animal Diversity Web)
The mortality rate for Common Brushtail Possums is 75% in individuals around 1 year of age. This rate drops considerably as the young mature and in adult Common Brushtail Possums the mortality rate is only around 20%. They have an average life span of 7 years in the wild. One Common Brushtail Possum survived in captivity for

over 14 years (http://animaldiversity.ummz.umich.edu/site/accounts/information/Trichosurus_vulpecula.html).

Population regulation (after Cowan 2001)
Possum populations in New Zealand have been monitored annually over many years in two areas: the Pararaki Catchment in southern Wairarapa, and the Orongorongo Valley near Wellington. Analysis of population trends at Pararaki support an "irruptive fluctuation" type of model explaining the coupled dynamics of possums and their food supply (Thomas *et al*. 1993). Segments of the post-1965 Pararaki data can be interpreted as varying around an equilibrium (Thomas *et al.* 1993), although this level may have declined over time (Coleman *et al.* 1998).

The Orongorongo pattern is rather different. Possums have been in the area since 1893 (Brockie 1992), and the present population shows only weak evidence for an initial irruption and subsequent decline. There has been only a slight long term trend in density of possums there over the last 30 years, not significantly different from zero (slope ± 95% confidence interval: + 0.04 ± 0.06/ha/yr) (Efford 2000). But over the short term there is 4-year cycle in possum numbers. Between 1967 and 1998 the population fluctuated between 5.5 and 13.3 per hectare (9.2 ± 1.47, mean ± SD). Major departures from the mean in 1971-72, 1977, and 1995-96, apparently caused by extreme weather patterns, were in each case followed by an abrupt correction.

In statistical terms, a population is "regulated" if it displays a long-term stationary distribution of population structure and size. The Orongorongo Valley possum population meets this criterion, at least on a long term (>10 year) timescale. Recent analysis (Efford & Cowan unpubl.) provides strong support for the hypothesis that the mechanism regulating possum numbers in the Orongorongo Valley is delayed density dependence acting through the food supply. The natural behaviour of possum populations in areas that have had possums for decades is therefore probably a modest annual fluctuation around the mean.

The annual rate of survival of Orongorongo possums varies strongly with age, and is higher in females. Annual survival peaks at about 90% for females aged 2-5 years old, compared with 80% for similar-aged males (Efford 1998, 2000) .

2.1.8 Diseases and natural causes of death

After Cowan (2001):
In some areas of Australia, successful fox control has been followed by a fivefold increase in possum numbers, implying a previously unsuspected degree of predation pressure by foxes on populations of possums and other marsupials (Anonymus 1997).

New identifications have increased the number of known bacterial, fungal and viral diseases infecting possums (Mackintosh *et al*. 1995; Cowan *et al*. 2000), but the effects of parasite infection on the well-being of free-living possums appear to be slight. A newly identified possum adenovirus, and the nematode *Parastrongyloides trichosuri*, are being investigated as potential vectors for biological control (Cowan 2000a).

The possum-specific bacterium *Leptospira interrogans serovar balcanica* is transmitted between possums only during affiliative or sexual interactions, but not during agonistic interactions that involve equally close contact (Day *et al*. 1998). Ramsey (in press) demonstrated that experimentally increasing the frequency of mating contacts between possums resulted in an increase in the transmission rate of leptospirosis.

Possums are a maintenance host for bovine tuberculosis (*Mycobacterium bovis*). Possum populations infected with bovine tuberculosis now occupy 28 discrete areas covering about 25% of New Zealand (Coleman & Livingstone 2000). Typically, 1-10% of possums in a Tb-infected population show macroscopic lesions, though prevalence of up to 60% have been observed. Once they develop clinical symptoms, infected possums generally survive for only about six months, although a few are known to have survived much longer. Tuberculosis infection is aggregated into "hot-spots" that may persist in both time and space. Possum-to-possum transmission is possible between mother and young, and between adults during mating, den sharing or fighting (Caley *et al.* 1999; Coleman & Livingstone 2000).

2.2 Risk Analysis

To become invasive, a species must pass through a number of transitions. The invasion process can be divided into three stages: (1) introduction (transport and release / escape), (2) establishment and (3) spread. When a species arrives in a region beyond its native range and escapes or is released into the wild it is referred to as introduced. Next, if an introduced species survives and successfully reproduces without direct human intervention it is referred to as established. Finally, the third step of the invasion process is "spread", this is if a species establishes new populations within the non native range (http://www.enveurope.com/content/23/1/23#B55).

This risk analyses involves estimating the likelihood of the introduction, establishment and spread of Common Brushtail Possum in The Netherlands and subsequent economic, public health or environmental consequences.

2.2.1 Probability of introduction

Based on Hulme *et al*. (2008) alien mammal species may arrive and enter a country through three broad mechanisms: 1) importation as a commodity, 2) arrival by a transport vector (hitchhiking), and/or 3) natural spread from a neighbouring region where the species is itself alien. Importation as a commodity can result in (deliberate) release or (accidental) escape to the wild.

The probability of entry of a pest depends on the pathways from the exporting country to the destination, and the frequency and quantity of pests associated with them. The higher the number of pathways is, the greater the probability of the pest entering.

Documented pathways for the pest to enter new areas should be noted. Pest interception data may provide evidence of the ability of a pest to be associated with a pathway and to survive in transport or storage.

Importation as commodity and escape / release to the wild
Most terrestrial vertebrate animals established in Europe (or elsewhere throughout the world) were intentionally introduced as commodities, e.g. by the pet trade, the live food trade, or as stock for the trade in fur pelts. Although some of these pathways have been modified and restricted to reduce the risk of invasion, many remain very active. For example, the pet trade remains a dominant pathway for the introduction of invasive species to Europe (Hulme *et al*. 2008, Genovesi *et al*. 2009, Kark *et al*. 2009, *in* Keller *et al.* 2011). For Common Brushtail Possum goes the same. The principle mechanism for the introduction of these species in our country is the importation as pet. There are no legal restrictions for importing Common Brushtail Possums as pets in The Netherlands. This goes for the rest of Europe, except for Belgium. Belgium has a 'positive list' of mammals, which are allowed to be kept as a pet, excluding possums.

It is unknown how many possums arrive as pets in The Netherlands on a yearly basis. Imports are not registered or regulated. Based on an Internet search, forums and interviews, Common Brushtail Possums in The Netherlands are mainly imported from Germany.

The probability of introduction in The Netherlands for other purposes than the pet trade is very low. Introduction of possums in The Netherlands for the fur industry can be ruled out. Possums are not kept in fur farms in The Netherlands, because national law does not allow possums to be kept for the production of fur. Other possible purposes include zoo's and (biomedical) research. However, possums are not kept in zoo's at this moment (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). Dierenpark Amersfoort hosted a couple of Common Brushtail Possums in the past (pers. com. R. van der Meer, Dierenpark Amersfoort). In the past ten years, there are no reports of possums being used in medical research (Source: Voedsel en Waren Autoriteit http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

Escape will happen by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands

Unintentional arrival of Common Brushtail Possum by a transport vector has occurred at least once. In April 2006 a Common Brushtail Possum hitchhiked on a cargo ship from New Zealand to The Netherlands and was noticed on the way. Upon arrival in The Netherlands the animal could not be found. The ship moved on to the United Kingdom where the Possum was captured after all (AAP Foundation, 2006). This is the only report of Common Brushtail Possum arriving as a stowaway. Therefore, the probability of Possums entering The Netherlands by hitchhiking is thought to be low.

Possums can survive the transit from their current distribution range to The Netherlands. The chance of being detected is high. The probability of release into a suitable receiving environment is low. Ports are not the most suitable habitat (food shortage?)

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.

Keeping and trading

The number of captive possums in The Netherlands is unknown (not registered). Based on a search on Internet, fora and interviews this number is estimated to be low (< 10 animals). Possums are primarily kept captive as pets. In general, pet owners are trying to prevent escapes and releases of their pets. The animals are kept for the purpose of enjoying. Also, the animals are expensive (up to € 500,-). Breeding of these animals in The Netherlands is limited and small scale (one breeding centre found on the Internet). Possums are not sold in pet shops nowadays (Pers. comm. Alex Ploeg, Dibevo).

Reports of keeping and trading in The Netherlands

- 2011: offered one female (€500,-) and sold in 2012 (owners keep other female) (http://exoticpets.phpbb3.nl/portal.php).
- 2011: birth of one Brushtail Possum (http://exoticpets.phpbb3.nl/portal.php).
- 2006: offered one Common Brushtail Possum in pet shop (http://exoticpets.phpbb3.nl/portal.php).
- Nineties: one Common Brushtail Possum sold pet shop in Noord-Brabant (AAP Foundation 2002)

Reports of keeping and trading in Belgium

- 2004: one Common Brushtail Possum was captured in the wild and taken to the Natuurhulpcentrum (http://www.natuurhulpcentrum.be/index.php/news/50/58/Voskoesoe-in-het-Natuurhulpcentrum).

Reports of keeping and trading in Germany

- 2011: 7 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)
- 2010: 2 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)

- 2009: 6 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)
- 2008: 3 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)

Price: 350,- to 650,- / animal

2.2.2 Probability of establishment

There is considerable scientific literature on the ecological theory of invasions, proposing a suite of factors that may influence whether or not species will establish in new environments. Overall, results showed that propagule pressure (this is the number of individuals released and number of release events) is the factor most strongly associated with the establishment of exotic vertebrates (Simberloff 2009; Hayes & Barry, 2008, Lockwood *et al*., 2009; Davis 2010, Henderson & Bomford, 2011).

Besides propagule pressure Forsyth *et al.* (2004) and Bomford *et al.* (unpublished data) both found that, relative to failed species, successfully established mammal species (Bomford *et al*. 2009):

- had higher average climate or habitat matches to the countries where they were introduced,
- were more likely to have established exotic populations elsewhere,
- had larger average world geographic range sizes.

Bomford (2003) discusses a range of additional factors that have been proposed to affect establishment success for exotic mammals. Further quantitative assessment is required to determine the role of these factors (Bomford 2008).

Propagule pressure

The release of large numbers of animals at different times and places enhances the chance of successful establishment. The basis for this relationship is the greater risk of extinction that small populations suffer because of intrinsic and extrinsic factors including random changes in birth and death rates, small - scale catastrophes like extreme weather events, inbreeding depression, reduced efficiency in mate location and competition with native species. Repeated releases over an extended period increase the chance of successful invasion simply because the release experiment is repeated many times, under different biotic and abiotic conditions, for example, in different climates and seasons and with variations in the fitness of released animals (cited from Henderson & Bomford, 2011).

The threshold minimum population size of possums for successful invasion is not known, as is for most species. Although there is a general principle of small numbers of animals being less successful, there are many examples of less than ten individuals, and sometimes even single pairs, establishing an non-native populations outside their original range (Bomford, 2003).

Propagule pressure for Possums is low. The number of animals that escape or are released is likely to increase if more species are kept, in higher numbers, and in more locations. Numbers of captive possums in The Netherlands is low. Possums are not kept in large numbers. As said before, possums are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals. The number of animals that hitchhike is very low / incidents.

Climate match

Exotic species have a greater chance of establishing if they are introduced to an area with a climate that closely matches that of their original range. The Climatch web application (http://www.brs.gov.au/Climatch) provides an interface for comparing climate characteristics between regions. It matches the climate of user-selected regions around the world to the climate of other selected regions. The potential range of a species is predicted by matching climate data from weather stations at or adjacent to known locations where the species occurs in a source region to climate data from weather stations in a nominated target region.

Climate modelling using climate data from its natural (Australia and Tasmania) and established (New Zealand) global distribution as a reference, suggests that the Dutch climate is suitable for establishment of Common Brushtail Possum (see figure 2.2).

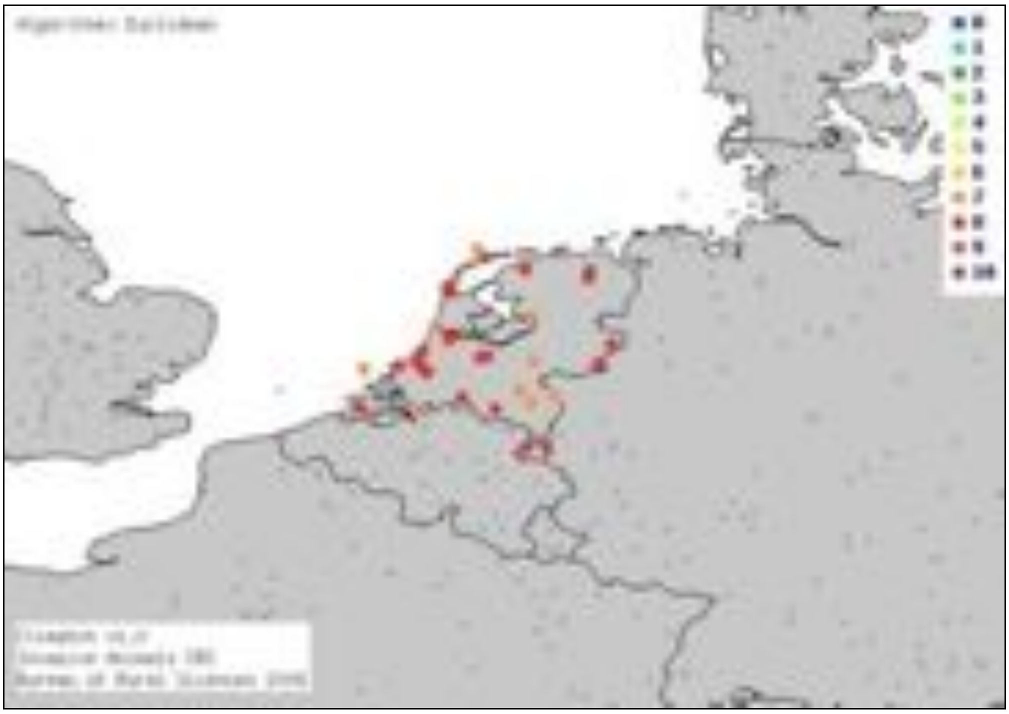

Figure 2.2 Climatch output for Common Brushtail Possum showing the match between climate data from weather stations in the native and introduced range of Common Brushtail Possum and weather stations in The Netherlands. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 7 and 8.

Habitat match

Across its native range possums survive in a very diverse range of habitats including agricultural areas, coastland, natural forests, planted forests, plantations, grasslands, riparian zones, rural / disturbed areas, scrublands, wetlands and (sub)urban areas. Some habitats exist in The Netherlands. Habitats most at risk are most likely dry forests in the eastern half of the country and urban areas.

Extensive natural range

An extensive range tends to reflect a species' ecological "flexibility" (i.e. the ability to opportunistically adapt to dynamic environmental conditions). In its native Australia, the Common Brushtail Possum is one of the most widely distributed native marsupials. It occurs naturally in a variety of habitat types in most parts of mainland Australia. It also occurs in Tasmania and on some offshore islands. This wide natural distribution suggests a broad environmental tolerance. Montague (2000) states that in retrospect this was an indication that the brushtail possum had the potential to become invasive in New Zealand.

Pest history

Common Brushtail Possum has successfully invaded New Zealand. Common Brushtail Possum is therefore listed on the Global Invasive Species Database (GISP 2011) among hundred of the "World's Worst" invaders.

2.2.3 Probability of spread

Based on the previous two paragraphs the probability of initial settlement is low. Once a small number has settled the probability of further increase and spread is high

2.2.4 Impact

General (After: http://www.issg.org/database)

Common Brushtail Possums have multiple impacts, as a browser of forest vegetation, frugivore, competitor for tree hollows, predator of invertebrates and bird nests, and disease vector. Long term changes in forest structure and composition (including canopy collapse in extreme cases) can result from sustained possum browsing pressure. Some highly palatable and chemically "unprotected" plant species are so preferred by Common Brushtail Possums that their selective browsing can result in local plant extinctions. Effects on native wildlife include depletion of fruit crops, competition for tree hollows, and predation by possums on invertebrates and the eggs and nestlings of birds (including threatened species). Possums are vectors of bovine tuberculosis, and consequently pose a significant threat to cattle and dairy industries

Impact on biodiversity (After Cowan (2001), Sweetapple *et al.* (2004), http://www.issg.org/database):

In New Zealand Possums eat eggs, nestlings, or adults of native bird species such as kokako (*Cullaeas cinerea*), kiwi (*Apteiyx spp.*), kahu (*Circus approximans*), fantail

(*Rhipiclura fuliginoxa*), kereru/kukupa (*Hemiphaga novaeseelandiae*) and mutton bird (*Puffimis griseus*) (Brown *et al.* 1993; Innes 1995; G. Nugent, unpubl. data). All those species, and others, are mainly ground nesting species. Those effects are sufficient to drive some species into decline (James & Clout 1996). Populations of native snails, particularly in infertile or heavily browsed forest where alternative possum foods are scarce, are severely damaged by possums; a single possum is capable of eating more than 60 Powelliphanla snails in a night (K. Walker, unpubl. data) (Cowan 2001).

With the exception of some alpine areas and parts of South Westland and Fiordland (all New Zealand), Common Brushtail Possums occur throughout the main islands of New Zealand, and are generally considered to be a serious conservation pest because of their widespread impact on indigenous ecosystems (Payton 2000; Sadleir 2000). The impact of possums on the indigenous vegetation has been the subject of numerous studies, and now there is some appreciation of their impacts on common forest species [see Payton (2000) for a review]. A few studies provide evidence that possums adversely affect indigenous forest birds and other wildlife through predation (Cowan & Moeed 1987; Pierce & Graham 1995; Brown *et al*. 1993, 1996; Innes *et al.* 1996; McLennan *et al*. 1996), while others have suggested that forest bird populations may have declined as a consequence of possum-induced forest modification and competition for food (Leathwick *et al*. 1983; Fitzgerald 1984; Cowan 1990b). However, few studies have attempted to quantify these predatory or competitive impacts, particularly for common forest birds. While a few studies have provided some details of varying possum impacts with increasing length of site occupation (e.g. Pekelharing & Reynolds 1983; Leutert 1988; Campbell 1990; Rose *et al*. 1993), knowledge of the sequence, time frame, and magnitude of possum impacts with respect to possum colonisation and length of site occupation is limited (Sweetapple *et al*. 2004).

Common Brushtail Possums in New Zealand prefer newly grown leaves over old leaves. In certain regions of New Zealand, possums are known to have consumed entire canopies of certain species. A survey conducted in 1990 in South Westland's mixed beech-broadleaved forests between the Mahitahi and Arawata Rivers concluded that, 16% of trees affected by conspicuous canopy dieback were caused by possum browsing. This figure is estimated to climb as high as 44% if the population of possums are not kept under control (http://www.issg.org/database).

Expected impact on biodiversity in The Netherlands
It is hard to say what the impact of this species would be in The Netherlands. As this species lives on the ground and in trees all kinds of animals (especially birds) might become victim of predation on eggs and young. Secondly, since this species also depends on vegetarian sources, it might damage foliage in forest or orchards. This migth lead to habitat alteration, modification or destruction.

Impact on human health (after Eymann, 2006**)**
Common Brushtail Possum may act as a disease vector. Studies showed that the species is susceptible to *Leptospira spp*. and *Toxoplasma gondii*. Public health

concerns may arise if, for example, water tanks are used by urban households. When possums move across the roof, urine and faecal contamination of water collected from the roof is possible. Disease transmission involving urban Common Brushtail Possums is a mostly unexplored field.

Impact on animal health (after Cowan 2001)
Possums are a maintenance host for bovine tuberculosis (*Mycobacterium bovis*), and their transmission of the disease to livestock is of major economic significance. Possums infect livestock by environmental contamination and directly, mainly when inquisitive animals encounter terminally ill or recently dead infected possums. Intensive possum control results in rapid and sustained reductions in Tb infection in livestock (Caley *et al.* 1999; Coleman & Livingstone 2000).

During the 1980s, there was a steady increase in the level of Tb infection in cattle and deer herds, largely because of a reduction in funding for possum control after 1979 that was not sufficiently redressed till the 1990s. Infection levels in cattle and deer herds peaked in 1994, but have since declined to 1980 levels (i.e., a 50% reduction over the last 5 years) in response to a fifteen-fold increase in possum control expenditure between 1984 and 1999 (Coleman & Livingstone 2000). Despite this achievement, average levels of Tb in New Zealand's cattle and deer herds remain significantly higher than those typical of New Zealand's major trading competitors (Animal Health Board 2000; Coleman & Livingstone 2000). Consumer concerns relating to food quality may be exploited directly or used to justify the imposition of non-tariff trade barriers by importing countries in order to discriminate against New Zealand's meat and dairy products. Such barriers could potentially cost New Zealand up to $1.3 billion in lost export earnings (Animal Health Board 2000).

Economic impact (after Cowan 2001)
Estimates of the total cost of possum damage and control in New Zealand range from $40 to 100 million a year (Cowan 1993; Parliamentary Commissioner for the Environment 1994, 2000; Hackwell & Bertram 1999).

2.3 Bomford and ISEIA method for Risk assessment

For the Common Brushtail Possum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species has not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are relatively high. This implies that the overall establishment risk score in the Bomford method will inevitably give a high risk score.

2.3.1 Method of Bomford

The Common Brushtail Possum is no threat to public health or safety. The risk for establishment is extreme, mainly due to the high climate match. Furthermore the invasion history in New Zealand shows the species can become a risk for native ecosystems.

Table 2.1 Summary of the Bomford risk analysis Common Brushtail Possum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	14	B. Establishment Risk Score	Extreme risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	12	C. Pest Risk Score	Moderate risk to become a pest
VPC threat categorie			**Serious**

2.3.2. ISEIA

According to the ISEIA method the total score is 10 on a scale from 4 to 12.

Table 2.2 Summary of the ISIA risk analysis.

	category	estimate	score
5.1	Dispersal potential	High	3
5.2	Colonisation of natural habitat	High	3
5.3	Impact on native species		2
	Predation	Medium	
	Competition	Medium	
	Spread of disease	Low	
	Hyridisation	Low	
5.4	Impact on ecosystems		2
	Nutrient circle	Low	
	physical alterations	Low	
	Natural succesions	High	
	Food webs	High	
	Total score		10
	List		B1
	Category, stadium invasion		A

2.3.3 Conclusions

Based on both models (Bomford and ISEIA) there is a serious risk for the Common Brushtail Possum becoming a pest once the species has settled. However, both models do not include the risk of settlement. This risk is currently low in The Netherlands since the species is kept in low numbers, an never (so far) in high numbes on one location.

3 Striped Possum

Besides Common Brushtail Possum, Striped Possum (*Dactylopsila trivirgata*) have been reported as pet in The Netherlands in very low numbers (< 10 animals).

Striped Possum
(photo Jacqui Rock; http://en.wikipedia.org/wiki/File:Striped_Possum_on_bananas_edited.jpg)

3.1 Biology and ecology

For this chapter copied text from the following sources are used:

Salas L., Dickman C., Helgen K., Burnett S. & Martin R. 2008. Dactylopsila trivirgata. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 06 February 2012. http://www.iucnredlist.org/apps/redlist/details/6226/0

Langstaff L. 2004. "Dactylopsila trivirgata" (On-line), Animal Diversity Web. Accessed February 13, 2012 at.

3.1.1 Distribution

Natural geographic range

The Striped Possum is native in Australia, Indonesia and Papua New Guinea. This species ranges from the islands of Waigeo, Yapen, and the Aru Islands (all

Indonesia); through much of the lower elevation forests of the island of New Guinea (Indonesia and Papua New Guinea); into Queensland, Australia, where it ranges from Mt. Spec, near Townsville to the Iron Range (Handasyde 2008).

Introduced geographic range

There are no established populations of Striped Possum outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

Figure 3.1 Native distribution of the Striped Possum (Handasyde 2008).

3.1.2 Habitat

After Langstaff (2004):

Striped Possum is highly arboreal and lives almost exclusively in lowland tropical rainforest and adjacent woodlands. Within this habitat, it most commonly inhabits vine forests, riparian woodlands, and monsoonlands. Individuals are sometimes observed feeding in more open eucalypt (Eucalyptus spp.) and melaleuca woodlands.

The human alteration and destruction of rainforest may have several ecological impacts on this species. In fragmented landscapes, Striped Possum requires habitat corridors that are connected to large tracts of continuous forest. These forests must also contain large trees over 30 cm DBH, because common striped possums need large trees with hollows for den sites. (Handasyde & Martin 1996; Laurance & Laurance 1999; Menkhorst 2001; Van Dyck 1979)

3.1.3 Diet

After Langstaff (2004):
Striped Possum is a generalist insectivore that eats primarily social insects, such as ants and termites, and wood-boring larvae of beetles and moths. It is more reliant on invertebrates than other members of the Petauridae, which is suggested not only by observations of foraging and stomach contents, but also by the simplicity and shortness of the digestive tract. In particular, the length of the caecum, an organ used in fermentation, is significantly shorter in Striped Possum than in Sugar Glider and *Gymnobelideus leadbeateri*.

Striped Possums eat insects from at least 8 orders, including *Coleoptera, Hymenoptera, Lepidoptera, Isoptera, Blattodea, Orthoptera, Hemiptera*, and *Diptera*. The insects that contribute most to the diet of Striped Possums are moth and beetle larvae, ants, termites, and crickets. The high frequency of wood-boring larvae and social insects in stomach samples suggests that Striped Possum targets these high-energy foods. The fat content in these items is between 20 and 44%.

Many unusual adaptations allow Striped Possum to be successful as an arboreal insectivore. It uses its forepaws to tap rapidly on wood to locate larvae. Once the insects are located, the powerful jaws and tooth orientation of Striped Possums make them great at excavating bark and wood from living and dead trees. Ant and termite eggs present in stomach contents suggests that Striped Possum uses its jaws to break into insect mounds too. The Striped Possum has a dexterous elongated fourth finger that is used for collecting wood-boring larvae while it is excavating trees. The fourth digit is highly sensitive and some observations suggest that it is used to discriminate different vibration frequencies of various insects and larvae. The fourth finger is so sensitive that it represents 10% of the entire primary somatosensory area (SI) of the brain. This compares to a 4-5% representation of the SI for the fourth digit of Northern Quolls, *Dasyurus hallucatus*.

Pollen, nectar, flowers, sap, and fruit also contribute to the diet of Striped Possums. These items, however, comprise very little of the total diet. Interestingly, Striped Possums have been observed eating small mammals in captivity. (Fleay 1942; Handasyde & Martin 1996; Huffman *et al*. 1999; Rawlins & Handasyde 2002; Smith 1982; Van Dyck 1979; Van Dyck 1995)

3.1.4 Social organisation and behaviour

After Langstaff (2004):
Striped Possum is a nocturnal, arboreal insectivore. It is most active from 2100 hours to 0550 hours, and may spend up to 9 hours foraging each night. It forages in trees of

different diameters, ranging from 10 cm diameter breast height (dbh) to 110 cm dbh. Striped Possum looks for food on living trees, dead snags, downed trees, and rotting logs. The species most often feeds in the cover of the forest, but has been observed feeding in adjacent open lands as far as 400 meters from the edge of the woods. It forages from the trunk to the canopy at least as high as 33 meters. While feeding and looking for food, Striped Possums move rapidly through the canopy jumping from tree to tree, accomplishing long-distance jumps with precision. Striped Possum has a lithe gait that gives limb movement a distinct 'rowing' motion. The feeding activity of Striped Possum is very noisy as it rustles through the leaves, scratching and snorting. When it stops to feed, much debris falls to the forest floor and the loud sound of chewing and slurping has been noted by several researchers.

The adult male Striped Possum is generally solitary, except during breeding season. Males den alone. Juveniles and females often have been found denning together. Striped Possum dens during the day in dry leaf nests in tree hollows or on mats of epiphytes. Both males and females use a number of den sites, which are spread throughout their home range. Dens are always in forest trees that have a DBH over 30 cm. *Cordia dichotoma* is a common den tree species (Handasyde & Martin 1996; Nowak, 1999; Rawlins & Handasyde 2002; Smith 1982; Van Dyck 1979; Van Dyck 1995).

3.1.5 Movements and home range

After Langstaff (2004):
Home ranges of Striped Possums have been determined from radio-collared males. Younger males occupy a smaller home range than adult males. Subadult males may have a range as small as 5.2 ha and adult males may have a home range of about 21.3 ha. (Handasyde & Martin 1996)

3.1.6 Reproduction and survival

After Langstaff (2004):
Not much is known about the mating systems of Striped Possum. Observations suggest that there is intense male rivalry for breeding females. Males chase each other and make threatening, raucous vocalizations when in close contact. While coupled, both male and female repeatedly make loud, guttural vocalizations ("gar-gair, gar-gair") and intertwine and thrash their tails about. According to a single observation, copulation lasts approximately ten minutes (Handasyde & Martin 1996; Van Dyck 1979; Van Dyck 1995).

Limited research has been conducted on the breeding biology of Striped Possum. Observations of mating in Australia have been made from February to August, and from January to October in New Guinea. This suggests a breeding seasonality. The breeding peak in Australia is June to July. Females have well-developed pouches with two mammae. They have one to two young, but almost always have two. The breeding interval for this species is not known. No detailed information has been documented on the development of young and the age to sexual maturity. (Handasyde & Martin 1996; Smith 1982; Van Dyck 1979; Van Dyck 1995)

The degree to which female common Striped Possums provide care for their young is not known. Males have not been documented to take part in providing for the offspring. Females will carry their offspring on their back after weaning, but it is not known for how long. The provisioning of post-weaning food to the young is not known either (Handasyde & Martin 1996).

The average lifespan of Striped Possums is five years. In captivity maximum age was nine years and seven months.

3.1.7 Natural causes of death

Predators (After Langstaff (2004)):
Amesthistine pythons (*Morelia amethistina*) prey on Striped Possums. These pythons are common in the Australian habitat of Striped Possum and may have a significant impact on young.

In open areas, Striped Possum is quite cryptic, due to its contrasting black and white coloration. The white markings make it difficult to make out when there are openings in the canopy that allow beams of light to penetrate. Striped Possum possesses a foul, pungent odor. Its scent is said to be worse than other marsupial scents, which can be quite powerful. The purpose of the odor is not known, but it has been suggested that it is an enemy deterent. (Fleay, 1942; Handasyde and Martin, 1996)

Diseases (After Langstaff (2004)):
Striped Possum is a host to many species of parasites. The first records of certain parasite species have been made from Striped Possums. *Ixodes holocyclus* Neumann and *Ixodes cordifer* Neumann are both parasites of Striped Possums, along with at least two species of intranasal mites from the family *Trombiculidae*. Striped Possums also may limit insect populations (Jackson 1998; Kaneko *et al*. 1999).

3.2 Risk Analysis

See for detail introduction and explanation on a risk analysis § 2.2 of the Common Brushtail Possum.

3.2.1 Probability of introduction

Importation as commodity and escape / release to the wild
It is unknown how many Striped possums arrive as pets in The Netherlands on a yearly basis. Imports are not registered or regulated.

The probability of introduction in The Netherlands for other purposes than the pet trade is low. Striped possum is not allowed to be kept for the furtrade. Possums are not kept in zoo's at this moment (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, there are no reports of possums being used in medical research (Source: Voedsel en Waren Autoriteit http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

Escape will happen by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands

This species is not recorded as a hitchhicker on ships to The Netherlands.

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.

Keeping and trading

Based on information on the Internet the number of Striped Possums kept as pets in The Netherlands is estimated to be very low (< 5 animals). There is one report of Striped Possums on the forum of http://exoticpets.phpbb3.nl/portal.php of animals bred in the UK to be imported into The Netherlands. There are few requests for Striped Possums on the Internet (< 5 animals).

Reports of keeping and trading in The Netherlands

- 2008: 1 report of import from the UK: "Mocht er nog iemand interesse hebben in gestreepte opossums. Een vriend van me krijgt er een aantal en verkoopt een deel. Als iemand interesse heeft laat het even weten voor zondag en stuur me ff een PM. Het zijn nakweek dieren van 2007 uit Engeland." on (http://exoticpets.phpbb3.nl/portal.php)
- 2008: 1 report of couple of Striped Possums in Borgstein, Nederland (http://exoticpets.phpbb3.nl/portal.php)
- 2012: 1 request for Striped Possum http://www.exobreedingcenter.nl/Ned/vraag-enaanbod.html

Reports of keeping and trading in Germany:

No requests or offers in Germany were found. There is one report in 2007 that Striped possums "Streifenbeutler" were on the market during a short period of time (http://www.tiergarten.com/forum.php?go=view&BeitragsID=900).

3.2.2 Probability of establishment

The probability of establishment is zero due to the mismatch of climate (see below) and habitat (almost exclusively in lowland tropical rainforest; see § 3.1.2).

Propagule pressure

Propagule pressure for Striped Possums is very low. Numbers of captive possums in The Netherlands is very low. Possums are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals. This species is not recorded as a hitchhicker on ships to The Netherlands.

Climate match

Climate modelling using climate data from its natural (New Guinea, Australia) global distribution as a reference, suggests that the Dutch climate is totally unsuitable for establishment of Striped Possum (see figure 3.2).

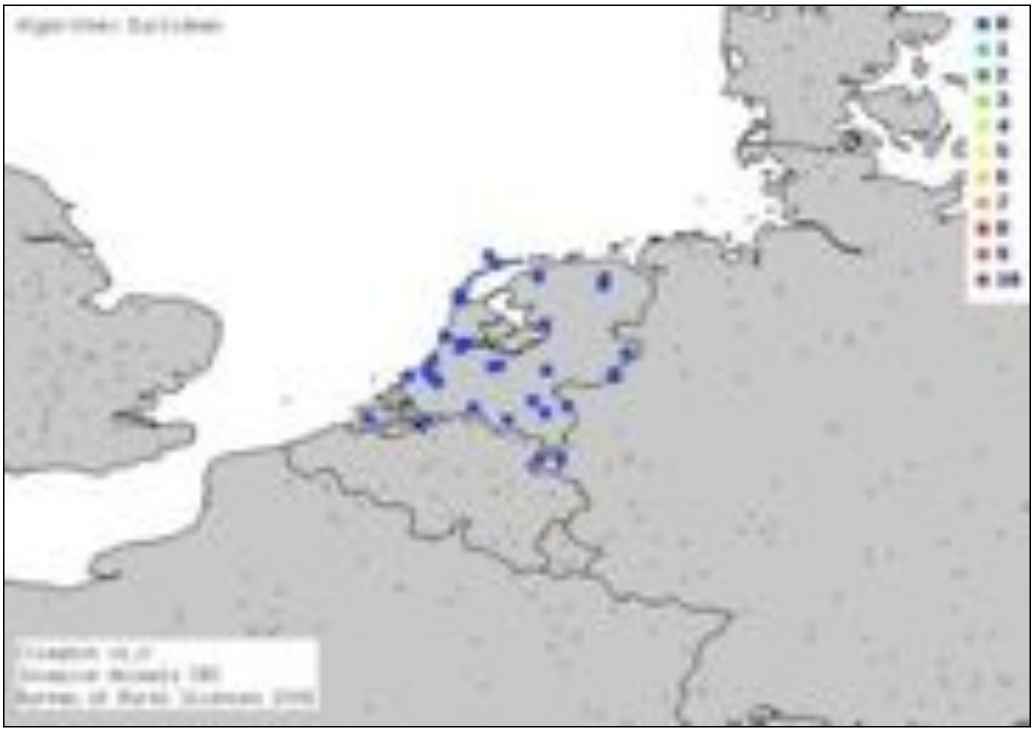

Figure 3.2 Climatch output for Striped Possum showing the match between climate data from weather stations in the native and introduced range of Striped Possum and weather stations in The Netherlands; all 16 variables. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 0.

Habitat match

The Dutch habitat is unsuitable for Striped Possum. This species lives almost exclusively in lowland tropical rainforest and adjacent woodlands.

Extensive natural range
This species is has no wide distribution (see § 3.1.1)

Pest history
This species has no pest history (DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org; Global Invasive Species Database (www.issg.org/database) Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

3.2.3 Probability of spread

The probability of spread is zero.

3.2.4 Impact

In their native range Striped Possums sometimes cause slight damage to sugar cane crops in agricultural areas that border lowland rainforest. They break into sugar cane stalks, but it is not known if they consume the sap or are simply looking for insects (Smith 1982; in Langstaff 2004).

Since the probability of establishment of Striped Possum in The Netherlands is zero, there is no risk of damage to native biodiversity, economy, public health and animal health.

3.3 Bomford and ISEIA method for Risk assessment

For the Striped Possum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are always relatively low. This implies that the overall establishment risk score in the Bomford method will inevitably give a low risk score.

3.3.1 Method of Bomford

The Striped Possum is no threat to public health or safety. The risk for establishment is low, mainly due to the climate mismatch (Table 3.1, appendix 1 for details).

Table 3.1 Summary of the Bomford risk analysis Striped Possum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	4	B. Establishment Risk Score	Low risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
VPC threat categorie			**Low**

3.3.2 ISEIA

According to the ISEIA method the total score is 6 on a scale from 4 to 12 (Table 3.2).

Table 3.2 Summary of the ISEIA risk analysis Striped Possum.

	category	estimate	score
5.1	Dispersal potential	Medium	2
5.2	Colonisation of natural habitat	Medium	2
5.3	Impact on native species		1
	Predation	Low	
	Competition	Medium	
	Spread of disease	Low	
	Hyridisation	Low	
5.4	Impact on ecosystems		1
	Nutrient circle	Low	
	physical alterations	Low	
	Natural succesions	Low	
	Food webs	Low	
	Total score		6
	List		A
	Category, stadium invasion		A

3.3.3 Conclusions

There is no serious risk for the Striped Possum becoming a pest once the species has settled. The risk of settlement is very low because of the climate mismatch.

4 Virginia Opossum

The Virginia Opossum *Didelphis virginiana* is a North-American species. It is kept as a pet in very low numbers in The Netherlands. Climate in parts of its native range is comparable with Europe.

Virginia Opossum
(Photo: http://en.wikipedia.org/wiki/File:Opossum_2.jpg#filehistory).

4.1 Biology and ecology

For this chapter copied text from the following sources is used:

Wilemon B.L., 2008. Virginia Opossum (Didelphis virginiana). In Mammals of Mississippi 1: 1-8. Department of Wildlife and Fisheries, Mississippi State University, Mississippi.

Cuarón A.D., Emmons L., Helgen K., Reid F., Lew D., Patterson B., Delgado C. & Solari S. 2008. Didelphis virginiana. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 03 January 2012.

Krause W.J. & W.A. Krause 2006. The opossum: its amazing story. Department of Pathology and Anatomical Sciences, School of Medicine, University of Missouri, Columbia, Missouri.

4.1.1 Distribution

Natural geographic range (after Wilemon 2008; Cuarón *et al*. 2008)
The Virginia Opossum is the only marsupial native to the United States. The current distribution of the opossum is over most of the United States except for some of the northern and western states as shown in figure 4.1. This Virginia Opossum is found in Central America, from Costa Rica to Mexico and in the United States east of the Rocky Mountains, and north into southwestern Ontario, Canada. Some populations are also found along the west coast of the United States. The distribution ranges from temperate tot subtropical. In the past it occured further southward into the tropics (After Cuarón *et al*. 2008).

The Virginia Opossum has been noted as one of the most successful mammal species in history. This is due to the recent expansion of the species northern and western range (Weber and O'Conner 2000). The northern boundary of the opossums region is limited by the low winter temperatures (Kanda *et al.* 2005). It is very common for species to experience frostbite or mortality due to starvation at the northern edge of their boundaries (Kanda 2005) (After Wilemon 2008).

Figure 4.2 Native distribution of the Virginia Opossum (Gardner 2005, Reid 1997).

Introduced geographic range
There are no established populations of Virginia Opossums outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database,

Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

There are no reports of free ranging Virginia Opossums in The Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012).

4.1.2 Habitat

After Krause & Krause (2006):
The opossum's preferred habitat is deciduous woodlands in areas close to water. However, Virginia Opossums are extremely adaptable creatures and are often found in prairies, marshes, and farmlands. They generally keep to the woody vegetation along rivers and streams, a behavior that has permitted them to move into treeless grasslands and some desert environments. They often will live in very close proximity to human habitation. This adaptable mammal is very successful at surviving or even thriving not only in agricultural areas but also in residential and suburban areas. Here it adapts buildings, woodpiles, or accumulations of other materials as potential sites to den and is able to feed on human refuse or food provided for pets or domestic animals.

4.1.3 Diet

After Krause & Krause (2006):
The opossum is omnivorous, consuming both animal and plant material. Its diet includes a variety of insects, earthworms, slugs, snails, crayfish, snakes and lizards, frogs, small rodents (primarily mice and rats), young rabbits, small birds, eggs, grasses, vegetables, fruits, berries, grains, human garbage, and carrion (dead animal material). Opossums seem to have a preference for sweet items such as various fruits and berries when available. The opossum is an opportunistic feeder and will eat whatever is available in its environment at a given time and its diet will change with the seasons. Olfaction (the sense of smell) of the opossum is keen and clearly important in prey and/or the location of food.

Although the types of food the opossum eats are highly varied, they must be abundant and closely spaced to support a significant population. If food resources become depleted in one area, the opossum simply will expand its territory or move to a new area.

4.1.4 Social organisation and behaviour

After Krause & Krause (2006):
The opossum is generally considered to be a somewhat nomadic, shy, solitary animal that may occupy a specific area or territory for a length of time (six months to a year) before moving on. The time and the size of the area occupied by an opossum are dependent primarily on the abundance of food and water. Individuals will defend the space occupied against other opossums at a given time. The social behavior between

individuals is reported to be poorly developed or antisocial except between sexes during the mating season. However, after mating, females are no longer receptive and will fight persistent males. At other times encounters between adults of either sex are said to be antagonistic.

More recent studies of captive opossums suggest that these animals form stable, hierarchical social relationships with females usually being dominant. Most observed interactions among unrelated opossums kept in large outdoor enclosures were neutral with females often found nesting together. The extreme agonistic behavior observed was almost always between two males. Meetings of the opposite sex during the breeding season results in initial aggressive displays followed by courtship with the two opossums spending several days together. Such studies together with a growing body of evidence from field studies of unrestrained, wild animals indicate that the social behavior of opossums may be much more complex than was once thought. Overlapping home ranges and a well-developed system of chemical (olfactory) communication suggests much higher encounter rates than previously thought. Environmental factors and availability of food clearly influence space use and the population density of this species. These factors also must influence opossum social structure, as it appears flexible enough to allow high population densities when food is abundant. Such social flexibility, though poorly understood, together with generalized den and food requirements, accounts at least in part, for the opossum's success in continuing to expand its overall range into a variety of environments.

The opossum is primarily a nocturnal mammal (active at night) and forages for food shortly after dark, a behavior that continues until dawn. However, opossums may become active during daylight hours during cold weather (winter usually) when food is more difficult to obtain and its metabolic need is greater. The opossum, as is the case for most other mammals active during cold weather, needs a greater caloric intake in order to survive.

Like most nocturnal animals, the opossum must build a rough nest or find a den in which to rest during the daylight hours. Depending on the location, the opossum den can take a variety of forms: an abandoned burrow or underground tunnel, cavities in hollow trees, abandoned squirrel nests, crevices in rocks, or crawl spaces under houses, in attics or in some other dark, hidden spaces of buildings. Opossums do not dig their own burrows, but occupy abandoned burrows of other animals. They will seek some quite dark space that is dry. The dens are most often temporary but if a food source is nearby may be occupied for several weeks. A single opossum may have several dens that it will use periodically. Females with young tend to be the exception to this behavior and use the same den site for several weeks at a time. The dens usually are lined by grass or thin twigs mixed with dry leaves. In warmer months its construction is similar to that of a bird's nest. In the cooler months of fall and winter its construction resembles a hollow sphere and is similar in appearance to a mouse or squirrel nest.

4.1.5 Movements and home range

After Krause & Krause (2006):
The Virginia Opossum is not territorial in the strict sense of the term, but represents a solitary species that excludes other individuals from its area when they are encountered. An opossum's territory is highly variable and depends on the availability of food and on an individual opossum tendency to wander. They generally have elongated rather than circular territories as most follow the edges of streams or rivers. If food is plentiful the range be may very small. If food is scarce the opossum may travel up to two miles in search of food. The average home range of an adult male opossum is about 300 acres that it appears to wander through during its lifetime. That of the female opossum is thought to be considerably smaller, about 150 acres, and the boundaries more permanent. Individual ranges tend to overlap considerably. The life of the adult male is totally solitary and is in contrast to the female, which has young with her during much of the year. A late, second litter of young may stay with the female during the winter until the following spring.

The Virginia Opossum is primarily a terrestrial species and spends the majority of its time on the ground

4.1.6 Reproduction and survival

Breeding season (after Krause & Krause 2006).)
The Virginia Opossum is a seasonal breeder, with the reproductive cycle beginning shortly after the winter solstice and lasting until June through most of its range. The female opossum is polyestrous with each cycle lasting about twenty-eight days. Variations of the cycle do occur and are thought to be due to a seasonal shift in the cycle length and may be due to dietary deficiency as well. Females are receptive for one-two days. The opossum usually produces two litters of young per year in the United States with an occasional third litter occurring in southern California and in southern Texas. In general, the Virginia Opossum breeds less often and has larger litters in the north whereas in the south more litters of smaller size are a common occurrence. However, the net production of young for both regions is about the same. First matings usually occur in January or February in most of the United States but may be as late as March in regions of southern Canada or as early as mid December in Florida or Louisiana. The interval between litters is about 120 days. An average of about twenty-three young are born in the breeding season, with as many as fifty or more being reported. Only those that are able to locate a teat and attach to it survive, the rest quickly perish. It is thought that female opossums have only two years of reproductive activity.

Life Span (After Krause & Krause 2006)
Although the opossum has a high mortality rate at all stages of its life cycle, mortality is particularly high during the first year. The death rate of young while still being carried in the pouch is high and ranges between ten and twenty percent. Of those that survive until after weaning, to go out on their own, fewer that ten percent live beyond

the first year. A few tagged wild opossums have been shown to have a life span of about two or three years. Thus, the turnover rate of the opossum population is rapid and the indigenous population of a given region is heavily weighted toward the young of the year. The most important cause of death leading to their relatively short life span is human-caused deaths due to automobiles (road-kill victims). It is estimated that between four million and eight million opossums are killed each year in the United States by automobiles.

Opossums, for their size, are one of the shortest-lived animals in the world. Those individuals that do live into their second year show many of the classic signs of advanced aging such as weight loss, lessened motor coordination, and formation of cataracts. Why this occurs so early in this species is unknown. Captive opossums have been recorded as living about twice as long as wild opossums with an occasional individual living up to ten years of age.

4.1.7 Natural causes of death

Predators (After Wilemon (2008)):
The Great horned owl is the major predator for Virginia Opossums. Other predators known to the opossum are carnivores such as dogs and coyotes (Fitch & Shirer 1970). Many avian predators can be detrimental to young opossums (McManus 1974).

Diseases (After Wilemon (2008)):
The opossum is host to a multitude of external and internal parasites. Opossums can become infected with protozoa's such as a trypanosome. The Virginia Opossum was first found to be infected with this disease in Texas. Virginia Opossums can also be infected with *Leptospirosis*, which is caused by *L. pomona*. The first opossums to ever be noted as carriers of *L. pomona* were found in Virginia and Louisiana (Barr 1963). Opossums are also susceptible to yellow fever and they do not produce a good antibody response to the disease. Opossums have been known to be carriers of rabies. Rabid opossums have a very widespread distribution and have been noted to be present in many different areas of the United States. Opossums have been known to contract rabies mainly through contact with other infected species. In one particular study, 34 opossums were examined and only 4 of them showed symptoms of the virus. The symptoms recorded were signs of an affected central nervous system. The 4 opossums that were infected were capable of transmission (Barr 1963). The main ectoparasite that affects opossums is ticks. A study examined 56 individuals and only 5 of the individuals were completely free of ticks. The infected individuals were somewhat less fit, but there was no major impact on the infected individuals. Fleas have also been observed in many opossums (Lay 1942).

4.2 Risk Analysis

See for detail introduction and explanation on a risk analysis § 2.2 of the Common Brushtail Possum.

4.2.1 Probability of introduction

Importation as commodity and escape / release to the wild

It is unknown how many Virginia opossums arrive as pets in The Netherlands on a yearly basis. Imports are not registered or regulated.

The probability of introduction in The Netherlands for other purposes than the pet trade is low. Virginia oppossum is not allowed to be kept for the furtrade. Virginia oppossums are not kept in zoo's at this moment (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, the use of opossums in research has been reported only twice (in 2003 en 2004). Species used was not reported (Voedsel en Waren Autoriteit 2003, 2004). http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

Escape will happen by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands

Unintentional arrival of opossums of unknown species by a transport vector has occurred at least twice. The animals were both specimens of the genus *Didelphis*, which contains the largest American opossums.

In August 2009 a specimen arrived in Vlissingen Port with a cargo ship with wood from Brazil. The animal is captured and handed over to the animal sanctuary 'de Mikke' in Middelburg. There the animal escaped or was stolen/released. In a reaction of 'de Mikke': the opossum was of unknown species. Coming from Brazil and based on its appearance (it had a more brownish coat), it was not a Virginia opossum.

In 2010 another specimen of unkown opossum species arrived in the Port of Vlissingen. The animal also hitchhiked on a cargo ship transporting wood from Brazil. The opossum has been captured and housed by the AAP Foundation (AAP Foundation, 2010). This was the first opossum to be housed by the AAP Foundation. The AAP Foundation could not tell which species it was.

Based on photo's it might have been Common Opossums (*Didelphis marsupialis*), also called the Southern or Black-eared Opossum, but this is only speculation.

It can be concluded that *Didelphis* opossums can survive the transit from their current distribution range to The Netherlands. The chance of being detected is high. The probability of release into a suitable receiving environment is low.

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.v

Keeping and trading

There is minor trade in Europe in Virginia Opossum as a pet.

Reports of keeping and trading in The Netherlands

- 2011: one request for Virginia Opossum (www.exotictrade.nl)
- 2010: one request for Virginia Opossum (www.exotictrade.nl)
- 2008: two people on the exoticpets-forum are known to have Virginia Opossum (http://exoticpets.phpbb3.nl/portal.php)
- 2007: Virginia Opossum sold on the rodent market 'Exoknaag' in Houten (http://exoticpets.phpbb3.nl/portal.php)
- 2007: report of two Virginia Opossum as pet (http://exoticpets.phpbb3.nl/portal.php)

Reports of keeping and trading in Germany:

- 2011: 4 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)
- 2009: 2 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)
- 2008: 15 pair on stock on Exotic-Animal.De (http://cms.exoticanimal.de))

4.2.2 Probability of establishment

The probability of establishment is high because of:
- suitable climate
- suitable habitat

and the probability of expansion is low to moderate, due to:
- low propagule pressure.

Propagule pressure

Propagule pressure is low. Numbers of captive Virginia Opossums in The Netherlands is low. Possums are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals. This species is not recorded as a hitchhicker on ships to The Netherlands.

Climate match

Climate modelling using climate data from its natural (North-America) global distribution as a reference, suggests that the Dutch climate is moderate suitable for establishment of the Virginia Opossum (see figure 4.3), based on all climatologic parameters. The species have shown to be sensitive for winter temperatures. If only the mean annual temperature and mean annual rainfall are taken the climate match is very high (figure 4.4). In the northern part of its distribution range winter temperatures are lower and summer temperatures higher, compared to The Netherlands. Concluding, the climate in The Netherlands cannot be a bottleneck for successful settlement.

Figure 4.3 *Climatch output for Virginia Opossum showing the match between climate data from weather stations in the native and introduced range of Virginia Opossum and weather stations in The Netherlands; all 16 variables (table 1.1) are used. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 4, 5 and 6.*

Habitat match

Virginia Opossums live in wide variety of habitats and the species is very adaptable. Virginia Opossums will find suitable habitat in The Netherlands.

Extensive natural range

This species has a wide distribution (see § 4.1.1).

Pest history

This species has no pest history (DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org; Global Invasive Species Database (www.issg.org/database) Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

Figure 4.4 *Climatch output for Virginia Opossum showing the match between climate data from weather stations in the native and introduced range of Virginia Opossum and weather stations in The Netherlands; mean temperature and mean rainfall (table 1.1) are used as variables. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (*http://www.brs.gov.au/Climatch*). Calculated values for The Netherlands are all 9.*

4.2.3 Probability of spread

After Wilemon (2008):
In the US this species is found in a variety of habitats, ranging from relatively arid to mesic environments. They prefer wet areas, especially woodlands and thickets near streams and swamps. Also in shrubland (sub)urban areas. The opportunistic denning and feeding habits of the Virginia Opossum has led to the success of the species, especially in areas of habitat fragmentation. High reproductive potential further contributes to increasing population size (McManus 1974). Abandoned burrows, buildings, hollow logs, and tree cavities are generally used for den sites (Cuarón *et al*. 2008).

The Virginia Opossum is a widespread and common species throughout its range, and is adaptable to human dominated landscapes. Although hunted or trapped locally for food, sport and as predators of poultry, the species has not been adversely affected by human settlement, in fact its range appears to be expanding. Commercial hunting for the fur trade does not appear to have much impact (Cuarón *et al*., 2008)

Due to these arguments the probability of spread (after settlement) in The Netherlands is high.

4.2.4 Impact

Impact on biodiversity

Virginia Opossum is an opportunistic feeder and will eat whatever is available in its environment at a given time and its diet will change with the seasons. Therefore it might become a threat for native species and food webs.

Impact on human health

After Krause & Krause (2006):

Although Virginia Opossums often live in close proximity to human habitation, they are seldom if ever the cause of serious problems for farmers, ranchers, or suburban homeowners. Opossums are often blamed for raiding trash containers, but more often than not, they are secondary in such raids and are foraging in what remains following the previous activity of domestic animals (dogs and cats) or raccoons. When pets are routinely fed outside and any excess food remains, if discovered by an opossum, it will adapt that location as a feeding area. This activity can be discouraged by simply removing the food source and when this is done the opossum will move on to a new area in which to feed as is its habit.

Impact on animal health

After Krause & Krause (2006):

The only potential threat opossums may pose to pets or domestic livestock is with regard to horses. Opossums should be considered a threat to the health of horses and other equines particularly if opossums den or feed where horses are being housed and/or have access to the horses' food/water source that can be contaminated. A protozoan known as *Sarcocystis neurona* is thought to be a major contributing factor of a neurologic disease in horses known as equine protozoal *myeloencephalitis* or EPM. Opossums are the definitive hosts, and horses and other mammals are the aberrant hosts for this protozoan. If sporocysts (the larval form or infectious agent in the next host) from the intestinal tract (via feces) of infected opossums are ingested by horses in contaminated food or water, they are at high risk for contracting this disease. Studies that examined the blood serum for antibodies against *Sarcocystis neurona* of horses from the Rocky Mountain states demonstrated that these horses have a lower sero-prevalence for this protozoan organism than horses from the eastern regions of the United States. This data corresponds to areas with higher opossum population density.

4.3 Bomford and ISEIA method for Risk assessment

For the Virginia Opossum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are always relatively high. This implies that the overall establishment risk score in the Bomford method will inevitably give a high risk score.

4.3.1 Method of Bomford

The Virginia Opossum is no threat to public health or safety. The risk for establishment is high mainly due to the climate match (Table 4.1, appendix 1 for details).

Table 4.1 Summary of the Bomford risk analysis Virginia Opossum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	12	B. Establishment Risk Score	Serious risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	15	C. Pest Risk Score	Serious risk to become a pest
VPC threat categorie			**Serious**

4.3.2 ISEIA

According to the ISEIA method the total score is 10 on a scale from 4 to 12 (Table 4.2).

4.3.3 Conclusions

There is serious risk for the Virginia Opossum becoming a pest once the species has settled. The risk of settlement is high because of the climate match

Table 4.2 Summary of the ISEIA risk analysis Virginia Opossum.

	category	estimate	score
5.1	Dispersal potential	High	3
5.2	Colonisation of natural habitat	High	3
5.3	Impact on native species		2
	Predation	High	
	Competition	Medium	
	Spread of disease	Low	
	Hybridisation	Low	
5.4	Impact on ecosystems		2
	Nutrient circle	Low	
	Physical alterations	Low	
	Natural succession	High	
	Food webs	High	
	Total score		10
	List		B1
	Category, stadium invasion		A

5 White-eared Opossum

The White-eared Opossum *Didelphis albiventris* is kept as a pet in very low numbers (<10 animals).

PM photo

5.1 Biology and ecology

For this chapter copied text from the following sources is used:

Smith P. 2007. White-eared Opossum *Didelphis albiventris.* Handbook of the Mammals of Paraguay Number 1.

Costa L., Astua de Moraes D., Brito D., Soriano P., Lew D. & Delgado C 2008. Didelphis albiventris. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 07 February 2012.

5.1.1 Natural geographic range

The species occurs from northeast Brazil to central Argentina (Costa *et al*., 2008). It is widely distributed east of the Andes from Colombia and western Venezuela south to Provincia Rio Negro (41ºS) in Argentina, north to the Atlantic coast of Brazil, though absent from the Amazon Basin where it is replaced by other species. In Argentina the species occurs west as far as Barreal (31°36’ S, 69°27’ W) in Province San Juan at an altitude of 1.900 m (Teta & de Tomasso 2009). In Paraguay the species is widely distributed throughout eastern Paraguay where it even occurs in the suburbs of Asunción, and also through the Humid Chaco and Pantanal region, being absent only from the Dry Chaco ecotone (Parera 2002, SEAM *et al.* 2001, Smith 2007).

Figure 5.1 *Native distribution of White-eared Opossum (Costa* et al. *2008).*

Introduced geographic range
There are no established populations of White-eared Opossum outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

There are no reports of free ranging White-eared Opossum in The Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012). http://www.iucnredlist.org/apps/redlist/details/40489/0

5.1.2 Habitat

After Costa *et al*. (2008)
White-eared Opossum is encountered in a wide variety of habitats, on plains, marshes, grasslands, marginal and rain forests at high altitudes and at subtropical latitudes. It tolerates areas next to cultivation, cultivated lands, deforested zones and urban areas. In the Caatinga, they are found in zones of high and low chaparral and thorny vegetation, and in dísturbed areas (Mares *et al.* 1981, Streilen 1992*).*

After Smith (2007):
White-eared Opossum is an adaptable habitat generalist able to tolerate a large degree of habitat disturbance and actively seeking human habitation and exploiting

them for food resources in rural areas. White-eared Opossums occur in humid forest and edge (P. Smith pers.obs.) being most common where degraded or affected by human activity, but they are equally at home in cerrado and relatively open grassland areas provided that sufficient food, some tree cover and sleeping places are available.

This common marsupial comfortably tolerates the close proximity of humans and in some areas may even actively seek human dwellings for access to food resources. It is likely that human activity has enabled them to extend considerably their range, with deforestation creating optimal habitat (Parera 2002).

5.1.3 Diet

After Smith (2007):
Omnivorous and opportunistic, able to exploit a wide range of food sources from plant matter including fruit, leaves and seeds, to animal matter such as invertebrates, small mammals and birds. When a particular foodstuff is abundant it is typically exploited repeatedly until it is exhausted (Smith 2007).

Talamoni & Dias (1999) described the diet of this species as "generalist" in São Paulo after analysing the contents of 31 scats and five stomachs. They found the following percentage occurrence: invertebrates stomach 33.4% scat 51.7%; vegetable material stomach 27.8% scat 5.2%; birds stomach 16.7% scat 12.1%; fruits/seeds stomach 11.1% scat 24.2%; unidentified vertebrates stomach 5.5% scat 3.4%; grasses stomach 5.5% scat 0%; rodents stomach 0% scat 3.4% (Smith 2007).

Cáceres (2002) found the species to be strongly omnivorous and that diet did not vary with age. Invertebrates occurred in 100% of scats, fruits in 76%, vertebrates in 58% and refuse 8%. Fruit consumption and the consumption of some animal prey (e.g. reptiles and *coleoptera*) increased during the wet season, whilst other fruits and different animal prey (e.g. birds and diplopods) were more prominent during the drier part of the year. Animal prey consisted largely of species occurring in leaf litter, suggesting predominately terrestrial foraging. The following items were recorded in scats, with percentages representing the percentage of scats which contained the given item: Vertebrates (58%) - Birds 28%, Reptiles 19% (wet season only and mainly *Liotyphlops beui*), Mammals 15% and Fish 1%. Invertebrates (100%) (Smith 2007).

Fruits taken were mainly coloniser species emphasising the role of the species as important dispersers. In areas close to human habitation they take advantage of agriculture, orchards and even refuse (Massoia *et al.* 2000, Smith 2007). Gazarini *et al*. (2008) reported that an individual in Maringá, southern Brazil predated bats caught in bat nets, including at least one example of *Artibeus lituratus* and likely also *Sturnira lilium*. At Estancia Nueva Gambach, San Rafael National Park, they have been seen feeding on mandarin fruits (Citrus sp.), fruits of the Pindó Palm (*Syagrus romanzoffiana*) and frequently raid the area around the house in search of chicken and quail eggs from the coup, occasionally killing adult birds without consuming them

(Hans Hostettler pers. comm., Smith 2007) - the Spanish name Comadreja overa refers to their fondness for birds eggs. In Misiones (Argentina) stomachs contained worms, ants, small birds, eggshell and plant matter (Redford & Eisenberg 1992).

5.1.4 Social organisation and behaviour

After Smith (2007):
Though captive individuals have exhibited remarkable social behaviours, wild White-eared Opossums are solitary animals and generally nocturnal in behaviour. All levels of the forest strata are utilised and they are also capable of swimming short distances and frequently do so to cross streams (Massoia *et al.* 2000).

5.1.5 Movements and home range

After Smith (2007):
Though they are not strictly territorial and even slightly nomadic in behaviour, adults will defend the area occupied at any given time (Novak 1991) and there is apparently a greater tendency towards territoriality in areas of sympatry with Black-eared Opossums (Parera 2002). A study in Tucumán, Argentina found the average home range to be 5,700 m^2 for six animals (Redford & Eisenberg 1992). Home ranges in Argentina averaged 0.57ha (Eisenberg 1989). Densities of 0.4-4.4 per hectare have been recorded in the Caatinga of Brazil and 2.5 per hectare in Tucuman Argentina.

Home range in the Brazilian Caatinga was estimated at 7,705.3 m^2 (± 5,306.3 m^2) for males and 5885.4 m^2 (+/-4575.3 m^2) for females, with a combined sex total of 7022.9 m^2 (± 5047.8 m^2) (Streilein 1982c). Almeida *et al.* (2008) estimated daily home ranges in a highly disturbed urban forest fragment in Minais Gerais, Brazil and found that adults of both sexes had greater home ranges than subadults. They recorded the following results: adult male 1100.38 m^2 (± 519.01) subadult male 355.61 m^2 (± 72.51) adult female 1166.65 m^2 (± 279.09) subadult male 541.81 m^2 (± 133.45). Talamoni & Dias (1999) estimated a mean residence time for males in semideciduous forests of Sao Paulo of 1.3 months (± 0.9) and for females of 2.8 months (± 3), the difference between the sexes being significant.

Adults spend the day in a hollow trunk or other suitable nest hole lined with grass, fur and feathers and emerge at sunset to begin the daily routine. Roost sites are defended ferociously. They sniff the air on emergence and if disturbed can remains motionless for several minutes with the ears directed towards the source of the disturbance (Massoia *et al.* 2006). Nest holes are changed with regularity. Carusi *et al*. (2009) describe refuges in hollow trunks covered with branches and human rubbish. An individual in San Rafael National Park roosted in a large fallen log of approximately 80cm diameter adjacent to a Pindo palm tree which it used for foraging (P. Smith pers. obs.). A juvenile individual found in some distress at Hotel Tirol 25 October 2010 curled into a ball in leaf litter in shady vegetation and fell asleep, but otherwise was exposed to the elements (P.Smith pers. obs.). Dias *et al.* (2008) mention a nest in a palm *Attalea speciosa* in Ceará, Brazil.

5.1.6 Reproduction and survival

After Smith (2007):
The stimulus for breeding in White-eared Opossum is the amount of daylight and acts primarily on the sexual cycle of the female (Rademaker & Cerquiera 2006). Astúa de Morães & Geise (2006) captured a pregnant female that was young enough to have been born and reproduce in the same reproductive season.

Breeding activity takes place from August to February in Misiones, Argentina (Massoia *et al.* 2006). Two reproductive cycles have been reported during the course of the year in the Argentinian Chaco and in temperate Buenos Aires (Regidor & Gorostiague 1996) but in the Brazilian Caatinga only one period of oestrus is recorded annually, timed to coincide with the rains. Rigueira *et al*. (1987) found females with pouched young from August to March in Minas Gerais, though they were much less common in February and March, and all females had pouched young in August and September.

Carusi *et al.* (2009) stated that breeding in Provincia Buenos Aires, Argentina takes place from mid-August to the end of February with two distinct reproductive "events" during that time. Peaks of reproduction in Provincia Buenos Aires are at the beginning of September and in late November or December with the first breeding period accounting for about 70% of the total young produced and only females that conceived early in the first breeding period being able to reproduce a second time (Regidor & Gorostiague 1996).

No information found on the lifespan of White-eared Opossum However, within the genus. Lifespan seems to fairly short. Females of the related species D. virginiana only reproduce for two seasons, and very few of that species reach more than three years of age. Although White-eared Opossum may live somewhat longer, it is not likely that they have a really long life. (Nowak, 1999)

Regidor & Gorostiague (1996) stated that few individuals in Buenos Aires survive more than 20 months in the wild and only survive long enough to participate in one reproductive season.

Fluctuations in population have been noted throughout the year. Cáceres (2000) found that the species was up to three times as abundant in spring and summer, than it was in autumn and winter in an urban area. Oliveira *et al.* (2010) however captured more specimens in the winter (dry season) in São Paulo. They attributed these fluctuations to high recruitment of juveniles and a correspondingly high mortality rate for this short-lived species (Smith 2007).

In a roadkill study in Santa Catarina, Brazil this species was found to be the second most common victim of traffic constituting 17.1% of the 256 individuals of 20 species sampled (Cherem *et al.* 2007). In other similar studies in Brazil, on the B2-277 bordering PN Iguacu in Paraná State, Brazil *D. aurita* and White-eared Opossum represented 16.2% of the mammals hit by cars (Lima & Obara 2004), whilst this species represented 48.9% of all the roadkill on the RS-040 (Rosa & Mauhs 2004) and 28.8% of roadkill on six rodavias in São Paulo State (Prada 2004).

Carusi *et al.* (2009) suggested that anthropological causes were the major sources of mortality for a population in Provincia Buenos Aires, Argentina and that the population showed no signs of senescence usually associated with individuals around 28 months of age. Individuals killed by electrocution from power lines have been documented in Argentina (Massoia *et al.* 2006).

5.1.7 Natural causes of death

Predators

This species is frequently preyed upon by felines, foxes, raptors (including *Rupornis magnirostris* and *Tyto alba*) and large snakes such as *Eunectes notaeus* and *Boa constrictor* (Parera 2002).

Diseases

The causative agent of Chaga´s disease is *Trypanosoma cruzi*, a digenetic kinetoplastid and enzootic parasite of almost 100 mammal species, including humans. Though typically transmitted to humans via the Reduviid bug *Triatoma infestans*, oral infection with the disease does occur and is often associated with acute forms of the disease. White-eared Opossum is an important natural host for *Trypanosoma cruzi* (Fernandes *et al.* 1991).

Sherlock *et al.* (1984) documented an individual from Bahía State, Brazil as infected with Leishmania donovani (=chagasi), the first record of infection of a non-canid animal in the wild. In the same area the known vector of neotropical visceral leishmaniasis *Lutzomyia longipalpis* was also found feeding on trapped opossums. The fact that the species is often found close to human habitation means it plays a potential role in the transmission of this disease. Sherlock *et al.* (1988) also describe experimental infection of this species with the parasite.

The pathogenic protozoan *Sarcocystis speeri*, one of the causal agents of the typically mild digestive infection *sarcosproidiosis*, has been found occurring naturally in specimens of this species in La Plata, Argentina (Dubey *et al*. 2000).

Rickettsia is a genus of non-motile spore-forming bacteria carried by ticks, fleas and lice and responsible for a variety of sometimes serious diseases in humans. *R. rickettsii,* causative agent of Rocky Mountain Spotted Fever has been isolated from this species in São Paulo, Brazil (Travassos 1937).

This species is also an important reservoir for Leptospirosis, spreading the pathogen *Leptospira interrogans* by excretion but with infected animals showing no obvious pathology (Brihuega *et al.* 2007, Carusi *et al*. 2009). Carusi *et al.* (2009) found 13% of specimens (n=105) in Provincia Buenos Aires to possess antibodies to Leptospira and the presence of *Salmonella enterica* was found in 4% of individuals. It was suggested that these infections were probably contracted via a close association with poultry and that the species probably contributes to infection between poultry farms. Snake venom inhibition is exhibited by the serum of this species which has made it an important laboratory animal (Hingst *et al.* 1998).

5.2 Risk Analysis

5.2.1 Probability of introduction

Importation as commodity and escape / release to the wild
White-eared Opossum has been introduced as pet into The Netherlands. No records have been found of White-eared Opossum escaping or being released into the wild in The Netherlands.

Other purposes for importation include zoo's and (biomedical) research. At this moment, White-eared Opossum are not kept in zoo's (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, the use of opossums (species unknown) in research has been reported only twice in 2003 en 2004 (Voedsel en Waren Autoriteit 2003, 2004). http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

If imported into The Netherlands, escapes or releases are not very likely, but cannot be ruled out. In general, pet owners are trying to prevent escapes and releases of their pets; especially if they are rare and/or expensive. Escape will happen only by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands
This species is not recorded as a hitchhicker on ships to The Netherlands. The probability of White-eared Opossum entering our country by hitchhiking is thought to be low. *Didelphis* opossums can survive the transit from their current distribution range to The Netherlands. The chance of being detected is high. The probability of release into a suitable receiving environment is low.

Natural spread from a neighbouring region
Since there are no free ranging populations in Europe (see paragraph 6.1.1) there is no risk of natural spread from neighbouring regions.

Keeping and trading

Reports of keeping and trading in The Netherlands

White-eared Opossum is kept as a pet in our country in very low numbers. One offer of a White-eared Opossum (€ 650,-) by Zoo-Logisch in Utrecht was found on http://www.terraristik.com. One request was found for two White-eared Opossumin 2011 (http://www.exotictrade.com/)

Reports of keeping and trading in Germany

There is a small scale trade in White-eared Opossum in Germany (http://cms.exoticanimal.de).

5.2.2 Probability of establishment

The probability of establishment is moderate because of:

- suitable climate
- suitable habitat.

Propagule pressure

Propagule pressure for White-eared Opossum is low. This species is kept as pet in our country in small numbers. The entrance as hitchhiker is possible, involving most likely one animal at a time.

Climate match

Climate modelling using climate data from its natural distribution (Brasil, Argentina) as a reference, suggests that the Dutch climate is suitable for establishment of White-eared Opossum (figure 5.2); in the southern parts of is native range climate is quit comparable with that in Western Europe.

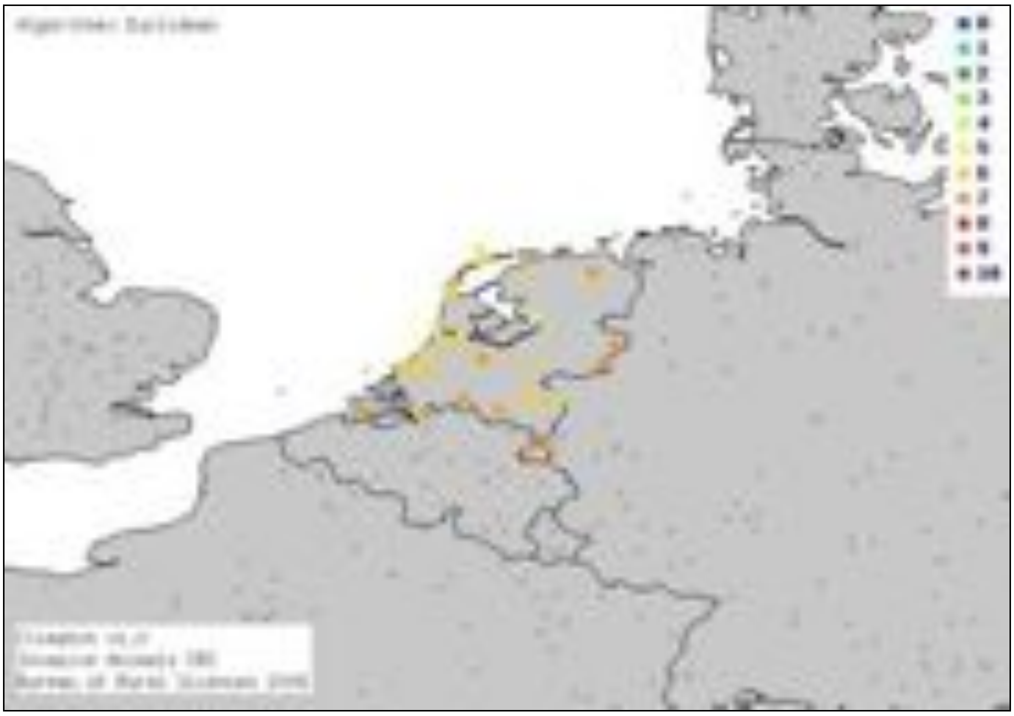

Figure 5.2 *Climatch output for White-eared Opossum showing the match between climate data from weather stations in the native range of White-eared Opossum and weather stations in The Netherlands; all 16 variables. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 5 (3), 6 (19) and 7 (9).*

Habitat match

White-eared Opossum is encountered in a wide variety of habitats, on plains, marshes, grasslands, marginal and rain forests at high altitudes and at subtropical latitudes. It tolerates areas next to cultivation, cultivated lands, deforested zones and urban areas. White-eared Opossum is an adaptable habitat generalist able to tolerate a large degree of habitat disturbance and actively seeking human habitation and exploiting them for food resources in rural areas. It is likely White-eared Opossum finds suitable habitat in our country.

Extensive natural range

This species has a wide distribution in South America (see § 6.1.1)

Pest history

White-eared Opossum has no history of establishment elsewhere outside its native range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

5.2.3 Probability of spread

Once established the probability of spread is high. The species is very adaptable and survives in a wide range of habitats.

5.2.5 Impact

Impact on biodiversity
White-eared Opossum is an opportunistic feeder and will eat whatever is available in its environment at a given time and its diet will change with the seasons. Therefore it might become a threat for native species and food webs.

Impact on human health
See paragraph 6.1.7 'diseases'.

Impact on animal health
See paragraph 6.1.7 'diseases'.

Economic impact
They are attracted to fruiting trees in orchards and gardens where they likely have a low impact on yield (Smith 2007).

White-eared Opossum is considered a pest species in some areas as it regularly breaks into to chicken coups to steals eggs and birds (Hans Hostettler pers. comm.) and in Argentina they are actively persecuted for that reason (Massoia *et al.* 2006). In Paraguay three separate individuals were killed raiding the same chicken coup in Alto Verá, Departamento Itapúa during the course of December 2006 (Hans Hostettler pers. comm.).

5.3 Bomford and ISEIA method for Risk assessment

For the White-eared Opossum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are moderate. This implies that the overall establishment risk score in the Bomford method will inevitably give a moderate score.

5.3.1 Method of Bomford

The White-eared Opossum is no threat to public health or safety. The risk for establishment is low mainly due to the climate mismatch (Table 5.1, appendix 1 for details).

Table 5.1 Summary of the Bomford risk analysis White-eared Opossum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
VPC threat categorie			**low/moderate**

5.3.2 ISEIA

According to the ISEIA method the total score is 7 on a scale from 4 to 12 (Table 5.2).

Table 5.2 Summary of the ISEIA risk analysis White-eared Opossum.

	category	estimate	score
5.1	Dispersal potential	Medium	2
5.2	Colonisation of natural habitat	High	2
5.3	Impact on native species		1
	Predation	Low	
	Competition	Medium	
	Spread of disease	Low	
	Hybridisation	Low	
5.4	Impact on ecosystems		1
	Nutrient circle	Low	
	physical alterations	Low	
	Natural successions	Low	
	Food webs	Low	
	Total score		7
	List		A
	Category, stadium invasion		A

5.3.3 Conclusions

There is a low risk for the White-eared Opossum becoming a pest once the species has settled. The risk of settlement is only moderate because of the climate match.

6 Gray Four-eyed Opossum

The Gray Four-eyed Opossum *Philander opossum* is kept in very small numbers (<10 animals).

Gray Four-eyed Opossum
(Photo: André de Souza Pereira http://en.wikipedia.org/wiki/File:Cuica_verdadeira.jpg)

6.1 Biology and ecology

For this chapter copied text from the following sources is used:

Castro-Arellano I., H. Zarza & R. Medellín 2000. Philander opossum. Mammalian species, 638:1-8.

Reid F. 1997. A field guide to the mammals of Central America and southeast Mexico. Oxford University Press, New York, USA.

6.1.1 Distribution

Natural geographic range (After: Castro-Arellano *et al*. 2000)
Gray Four-eyed Opossum is Neotropical and ranges from east-central Mexico to northeastern Argentina (Figure 6.1). In Mexico it occurs in south-central part of Tamaulipas and throughout coastal plain of the Gulf of Mexico, including eastern San Luis Potosı, northern and eastern Hidalgo, Puebla, Veracruz, northeastern Oaxaca, Chiapas, and all the Yucatan Peninsula. In Central America it is present in all countries (Hall 1981; Jones et al. 1974). In northern South America its range occupies

lowlands of northern and southern Venezuela, Guyana, Suriname, French Guiana, and from northern Colombia to northern Peru west of the Andes. East of this mountain range it is present in almost all the Amazon basin except for the high basin area in eastern Colombia. Gray Four-eyed Opossum is also absent from extreme eastern Brazil. It has been reported in the Parana´ River basin and eastern Paraguay, reaching its southernmost distribution in the Chaco region and in Formosa and Misiones provinces, Argentina (Eisenberg 1989; Emmons & Feer 1990; Handley 1976; Pe´rez-Herna´ndez I., 1994). The Gray four-eyed Opossum is generally found from sea level to 1,650 m (Hall & Dalquest 1963, Reid 1997).

Figure 6.1 Native distribution of Gray four-eyed Opossum (Brito et al. *2011).*

Introduced geographic range

There are no established populations of Gray four-eyed Opossum outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

There are no reports of free ranging Gray four-eyed Opossum in The Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012).

6.1.2 Habitat

After (Brito 2008):
This species is found in humid forest, secondary growth, and along watercourses. It is found most commonly in moist areas, but it occurs through nearly all vegetation types. The species can be found in deciduous and evergreen forest, second growth, and sometimes disturbed habitat; often found near streams (Reid 1997).

After: Castro-Arellano *et al*. (2000):
Gray Four-eyed Opossum normally inhabits tropical evergreen forests and secondary growth forests but also invades croplands (Charles-Dominique 1983; Eisenberg 1989; Handley 1976). Of 46 specimens collected in Venezuela, 98% were on the ground and 2% were on logs. All were captured in streams or moist areas with 91% in evergreen forests and 9% in openings such as orchards, cropfields, and yards (Handley 1976). Gray Four-eyed Opossum is mainly associated with streams and other moist areas such as swamps (Alvarez 1963; Atramentowicz 1986; Hershkovitz 1997; Jones *et al*., 1974; Villa-R. 1949). In Veracruz, Mexico, Gray Four-eyed Opossum was mainly found near rivers and streams, but was also recorded in a sugar cane field and on a hillside far from water (Hall & Dalquest 1963).

6.1.3 Diet

After: Castro-Arellano *et al*. (2000):
Gray Four-eyed Opossum has been reported as primarily carnivorous (Emmons & Feer 1990; Hunsaker 1977; Streilein 1982), omnivorous (Hall & Dalquest 1963; Hershkovitz 1997), and frugivorous–insectivorous (Atramentowicz 1986). Reported food items include sweet-lemons, jobo plums (Spondias), fruit of the chicozapote (*Manilkara sapota*—Hall & Dalquest 1963), corn (Kuns & Tashian 1954), nectar, frogs (Eisenberg 1989), pulp of *Corozo oleifera* nuts, spiny rats (*Proechimys semispinosus*—Fleming, 1972), other small mammals, birds and their eggs, reptiles, amphibians, insects, crustaceans, snails, earthworms (Pe´rez-Hernandez *et al*. 1994), and carrion (roadkills; Davis 1944).

In Chiapas, Mexico, during a year-long study at Montes Azules Biosphere Reserve, 24 food items were identified in 99 scats. The three most important food items were beetles from the family Scarabaeidae (74% mean occurrence), crustaceans (67%), and seeds of Cecropia obtusifolia (60%). Other important food items were seeds of Piper and cockroaches (Blattidae). The only vertebrates in the diet were birds, which occurred in 3% of scats. Diet was seasonal with plant matter more frequent during the wet season and insects dominant during the dry season (Clemente 1994).

In captivity, Enders (1935, p. 410) reported that Gray four-eyed Opossum ‘‘are more carnivorous than any of the other opossums. They ate meat of all kinds including ant-eater, carcasses of rodents, grasshoppers, and eggs in preference to any kind of fruit, although they did eat banana, papaya, pineapple and figs.’’ Field collectors have used flesh as bait to capture Gray four-eyed Opossum.

Sex ratio of Gray Four-eyed Opossum populations varies geographically. In Lacandona, Mexico, overall sex ratio was 1.75:1. Sex ratio was 1.19:1 in pouch young. Thirty-eight percent of females produced more males than females and 44% of the litters were male-biased (Medellı´n 1992). In Nicaragua and Panama all litters had a 1:1 sex ratio or a very close figure (Fleming 1972, 1973; Phillips & Jones 1969). In French Guiana females were slightly more abundant, with a sex ratio of males to females of 1.28:1 (Atramentowicz 1986) and in Brazil a litter with four females and one male was found (Fonseca & Kierulff 1989).

6.1.4 Social organisation and behaviour

After: Castro-Arellano *et al*. (2000):
Some consider Gray Four-eyed Opossum to be the fiercest fighter of the opossums (Enders 1935; Goldman 1920). The Gray four-eyed Opossum is generally nocturnal but is active during the day in Surinam (Nowak 1991). Mainly terrestrial, P. opossum can also climb and swim well. Gray Four-eyed Opossum is somewhat scansorial and uses the ground and middle vegetation levels while foraging (Charles-Dominique *et al.* 1981; Handley 1976). This opossum is agile and quick, and appears more alert than most other didelphids (Eisenberg & Wilson 1981, Emmons & Feer 1990, Nowak 1991). Generally solitary, adults have minimal contact apart from mating. This opossum is not territorial and overlap among ranges of neighboring adults is broad (Charles-Dominique 1983; Emmons & Feer 1990; Redford & Eisenberg 1992).

6.1.5 Movements and home range

After: Castro-Arellano *et al*. (2000):
Home range depends on availability of resources and the Gray Four-eyed Opossum seems to be nomadic with large variation in home range (Hunsaker 1977). From the data of Fleming (1972), Hunsaker (1977) calculated home range size as 0.34 ha in the Panama Canal Zone. Nests of dry leaves are built in hollow trees, tree forks, fallenlogs, and in ground burrows. In Peru, nests were found in cultivated banana and swamp palm trees (*Mauritia flexuosa*—Fleck & Harder, 1995). In Veracruz, Mexico, two Gray Four-eyed Opossum nests were found in roofs of palms of abandoned houses (Hall & Dalquest 1963). Nests are globular with a diameter of ca. 30 cm (Emmons & Feer 1990; Enders 1935).

Although the Gray Four-eyed Opossum is widely distributed and fairly common, information on its population density and dynamics is relatively scarce. In Montes Azules Biosphere Reserve in Chiapas, Mexico, average density was estimated as 0.48 individuals/ha. Highest density was recorded in October and density was lowest in April. Both sexes moved an average of 47.1 m between captures (SD 36.7, n 590) and greatest movement was 117 m by an adult male (Medellı´n 1992).

In the Panama Canal Zone population levels were similar in two different biomes: second-growth tropical forest and mature moist tropical forest. Highest densities occurred in the dry season in both sites and were 0.65 ex/ha and 0.55 ex/ha, respectively. Population density of Gray four-eyed Opossum was lower than that of sympatric *D. marsupialis*.

6.1.6 Reproduction and survival

After: Castro-Arellano *et al*. (2000):
Reproductive activity of Gray four-eyed Opossum varies temporally across its range. Gray Four-eyed Opossum breeds throughout the year in some areas, but breeds seasonally in others (Hunsaker & Shupe 1977). In general, reproductive activity increases during the rainy season (Fleck & Harder 1995, Fleming 1972) and has been reported at the end of the rainy season from December through January (Fleming 1973). Reproduction seems to be interrupted only when a female cannot meet increased nutritional requirements due to rearing of young (Julien-Laferrie`re & Atramentowicz 1990). In mature forest Gray four-eyed Opossum breeds all year, but fewer births occur in secondary forest during the period of low fruit availability from July through August (Fleck & Harder 1995).

Number of young per litter in Gray Four-eyed Opossum varies from one to seven, but litter size averages four or five young (Collins 1973; Fleck & Harder 1995) and varies with latitude (Fleming 1973). Female age or mass at parturition has great influence on survival of pouch young. Birth to weaning lasts ca. 68–75 days in Gray four-eyed Opossum (Charles-Dominique 1983).

Maximum life span is 3 years 6 months in captivity (Hunsaker 1977), but, based on dental wear, Atramentowicz (1986) estimated that longevity in the field does not exceed 2.5 years.

Females are sexually mature at 6–7 months of age (Hershkovitz 1997). In captivity, it seems to occur at 15 months of age. Females can produce two or more litters per season, but young from a third litter are mostly aborted while in the pouch (Fleming 1973; Gentile *et al.* 1995; Hershkovitz 1997).

6.1.7 Natural causes of death

Predators
Predators of Gray Four-eyed Opossum are the boa *Corallus enhydris* (Eisenberg 1989), the crotalid *Lachesis muta* (Atramentowicz 1986), and possibly *D. marsupialis* (Wilson 1970). Ocelots (*Leopardus pardalis*) and other felids such as the eyra cat (*Herpailurus yaguarondi*) are potential predators, as well as the tayra (*Eira barbara*), the grison (*Galictis vittata*), foxes (e.g., *Urocyon cinereoargenteus*), and large owls (e.g., *Tyto alba* - Atramentowicz 1986, Hershkovitz 1997).

Diseases
Many arboviruses occur naturally in the Gray Four-eyed Opossum (see for details Hunsaker 1977, Hershkovitz 1997, Collins 1973). Gray Four-eyed Opossum, as well as other forest-dwelling marsupials, serves as a reservoir for Trypanosoma cruzi: 5%

of 85 individuals from 19 different localities in French Guiana harbored trypanosomes. An even higher infection level occurred at Cacao, French Guiana: 2 of 5 individuals (40%) in nearby forest sites and 4 of 31 (13%) individuals in settlement surroundings tested positive for T. cruzi (Julien-Laferrie`re *et al.,* 1989). Although Gray Four-eyed Opossum is not eaten by the Mayan Lacandon in Chiapas (March, 1987), it is hunted for food in other parts of Mexico (Medellı´n, pers. obs.) and was eaten by Creoles and Indians of Guyana (Hershkovitz, 1997).

6.2 Risk Analysis

6.2.1 Probability of introduction

Importation as commodity and escape / release to the wild

Gray four-eyed Opossum has been introduced as pet into The Netherlands. No records have been found of Gray Four-eyed Opossum escaping or being released into the wild in The Netherlands.

The species is offered in Germany (see below). Other purposes for importation include zoo's and (biomedical) research. At this moment, Gray Four-eyed Opossum are not kept in zoo's (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, the use of opossums (species unknown) in research has been reported only twice in 2003 en 2004 (Voedsel en Waren Autoriteit 2003, 2004). http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

If imported into The Netherlands, escapes or releases are not very likely, but cannot be ruled out. In general, pet owners are trying to prevent escapes and releases of their pets; especially if they are rare and/or expensive. Escape will happen only by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands

This species is not recorded as a hitchhicker on ships to The Netherlands. The probability of Gray Four-eyed Opossum entering our country by hitchhiking is thought to be low. These opossums can survive the transit from their current distribution range to The Netherlands. The chance of being detected is high. The probability of release into a suitable receiving environment is low.

Keeping and trading

There is minor trade in Europe in Gray Four-eyed Opossum as a pet.

Reports of keeping and trading in The Netherlands

- 1 report of three animals in 2011 (http://www.dierenforum.nl/forum/website.php?page_id=2&web_id=790)
- 1 request for Philander opossum (http://www.dierenforum.nl/forum/website.php?page_id=2&web_id=790)

Reports of keeping and trading in Germany:

- 2011: 1 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)
- 2010: 4 animals offered on Exotic-Animal.De (http://cms.exoticanimal.de)

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe (see paragraph 6.1.1) there is no risk of natural spread from neighbouring regions.

6.2.2 Probability of establishment

The probability of establishment is moderate because of:
- moderately suitable climate,
- suitable habitat.

Propagule pressure

Propagule pressure for Gray Four-eyed Opossum is low. Species are kept as pets in The Netherlands on a very small scale. The entrance as hitchhiker is possible but if it does occur involves most likely one (few) animals (animals live solitary).

Climate match

Climate modelling using all climate data from its natural distribution as a reference, suggests that the Dutch climate is moderately suitable for establishment of Gray Four-eyed Opossum (figure 6.2).

If we look only to the temperature in the coldest Dutch winter months the climate match is relative good (Figure 6.3).

Habitat match

Grey Four-eyed Opossum can be found in deciduous and evergreen forest, second growth, croplands and sometimes disturbed habitat. Therefore suitable habitat seems to be available in Western Europe.

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.

Extensive natural range

This species has a wide distribution in South America(see § 7.1.1).

Pest history

Grey Four-eyed Opossum has no history of establishment elsewhere outside its native range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

Figure 6.2 Climatch output for Grey Four-eyed Opossum showing the match between climate data from weather stations in the native and introduced range of Short tailed opossum and weather stations in The Netherlands; all 16 variables are used. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 4 and 5.

6.2.3 Probability of spread

The probability of initial settlement is low. Once a small number has settled the probability of further increase and spread is moderate.

6.2.4 Impact

Gray Four-eyed opossum is an opportunistic feeder and will eat whatever is available in its environment at a given time and its diet will change with the seasons. Therefore it might become a threat for native species and food webs.

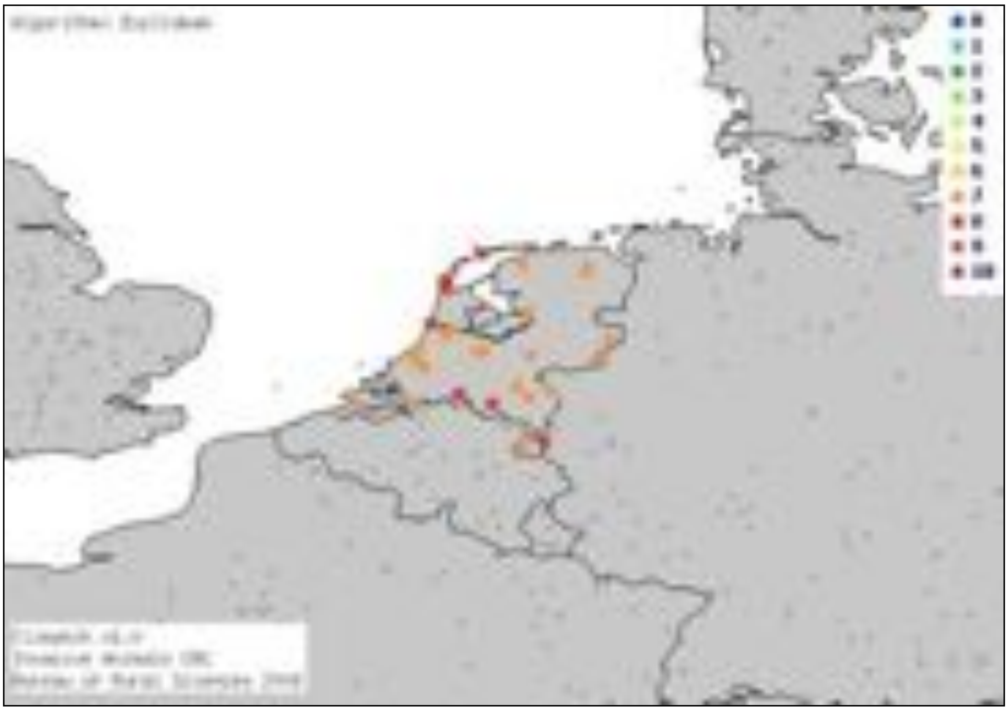

Figure 6.3 Climatch output for Grey Four-eyed Opossum showing the match between climate data from weather stations in the native and introduced range of Short tailed opossum and weather stations in The Netherlands; lowest temperature, mean annual rainfal. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 7 and 8.

6.3 Bomford and ISEIA method for Risk assessment

For the Grey Four-eyed Opossum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are always relatively high. This implies that the overall establishment risk score in the Bomford method will inevitably give a moderate risk score.

6.3.1 Method of Bomford

The Grey Four-eyed Opossum is no threat to public health or safety. The risk for establishment is moderate mainly due to the partial climate match (Table 6.1, appendix 1 for details).

Table 6.1 Summary of the Bomford risk analysis Grey Four-eyed Opossum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 =	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15 19 = serious, >19 = extreme	9	C. Pest Risk Score	Moderate risk to become a pest
VPC threat categorie			**moderate**

6.3.2 ISEIA

According to the ISEIA method the total score is 8 on a scale from 4 to 12 (Table 6.2).

Table 6.2 Summary of the ISEIA risk analysis Grey Four-eyed Opossum.

	category	estimate	score
5.1	Dispersal potential	Medium	2
5.2	Colonisation of natural habitat	High	3
5.3	Impact on native species		1
	Predation	Low	
	Competition	Medium	
	Spread of disease	Low	
	Hybridisation	Low	
5.4	Impact on ecosystems		2
	Nutrient circle	Low	
	physical alterations	Low	
	Natural successions	Medium	
	Food webs	Low	
	Total score		8
	List		A
	Category, stadium invasion		A

6.3.3 Conclusions

There is low risk for the Grey Four-eyed Opossum becoming a pest once the species has settled. The risk of settlement is moderate because of the climate match

7 Gray Short-tailed Opossum

The Gray Short-tailed Opossum *Monodelphis domestica* is a small member of the *Didelphidae* family of opossums. It was the first marsupial to have its genome sequenced. It is a model species in bio-medical research and kept as a pet in low numbers (<20 animals).

Gray Short-tailed Opossum
(Photo: Paul Samollow, Southwest Foundation for Biomedical Research, San Antonio; http://www.genome.gov/pressDisplay.cfm?photoID=93)

For this chapter copied text from the following sources is used:

Macrini T.E. 2004. *Monodelphis domestica*. Mammalian Species 760: 1-8.
Vilela J., Solari S., Flores D., de la Sancha N. & Astua de Moraes D. 2011. *Monodelphis domestica*. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 03 January 2012.Wilson D. & S. Ruff 1999. The Smithsonian Book of North American Mammals. Washington and London: Smithsonian Institution Press.

7.1 Biology and ecology

Natural geographic range
The Gray Short-tailed Opossum is distributed in eastern and central Brazil, eastern Bolivia, north Paraguay, and north Argentina (Gardner 2007). In Paraguay is

extremely abundant in the Chaco region in western Paraguay, but the records from Argentina are scarce (figure 5.1) (Vilela *et al*. 2011).

Gray Short-tailed Opossum is most common in Brazil. In Paraguay it is abundant in the Chaco region in western Paraguay. Records from Argentina are scarce (Vilela *et al*. 2011 and references therein).

Figure 7.1 Native distribution of Gray Short-tailed Opossum (Vilela et al*. 2011).*

Introduced geographic range
There are no established populations of Short-tailed opossum outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

There are no reports of free ranging Short-tailed opossum in The Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012).

7.1.2 Habitat

Gray Short-tailed Opossum is primarily found in xeric rocky habitats. In the Caatinga region of Brazil, short tailed Opossum uses rainforest, thorn scrub, cultivated and abandoned fields and granitic outcrops. It is tolerant of man-made clearings. Gray

Short-tailed Opossum lives in and near human dwellings in Brazil (Macrini, 2004 and references therein; Vilela *et al*. 2011).

In the Caatinga region of Brazil Gray Short-tailed Opossum often takes refuge in crevices in rock outcrops. Substantial nests are constructed in crevices by using leaves, grasses, bark, snake skins, paper, plastic, and cloth (Macrini 2004).

7.1.3 Diet

Gray Short-tailed Opossums primarily feed on invertebrates and small vertebrates including rodents, lizards, frogs and snakes. They can take prey similar in size to their own body mass. They may take fruit, seeds and carrion when available (Macrini 2004; Smith 2008).

7.1.4 Social organisation and behaviour

From limited observations it seems that Gray Short-tailed Opossum is solitary in the wild, only coming together to mate. The species is highly intolerant of conspecifics (Macrini 2004).

7.1.5 Movements and home range

Home range in the Brazilian Caatinga region was estimated at 1,209.4m^2 (± 1,050.4 m^2) for males and 1,788.8m^2 (± 487.8 m^2) for females. Population densities in the same area varied from 0 to 4 adults/ha (Smith 2008; Macrini 2004; and references therein).

Macrini (2004) states that the greatest period of activity is for the first 1 to 3 hours after dusk and that activity continues periodically through the night.

7.1.6 Reproduction and survival

After Vilela *et al*. (2011):
Captive breeding studies of Gray Short-tailed Opossums collected in the Brazilian Caatinga make this one of the most well-known small opossums. Females breed year-round in the wild in the Caatinga region of Brazil. Elsewhere in Brazil, breeding occurs mainly during the wet season. Under optimal conditions, females in the Caatinga region produce five or six litters a year, with six to eleven young per litter and a mean of 8,4 young. In captivity breeding occurs year-round and females can produce up to four litters per year, some studies suggest up to six litters (Macrini 2004; and references therein). Vilela *et al*. (2011) give a litter range of three to fourteen, with an average of seven. Reported age of first reproduction ranges from five to seven months to fifteen months (Vilela *et al*. 2011).

Captive individuals have a natural lifespan of 36 to 42 months, with one individual living 49 months (Macrini 2004; Smith 2008).

7.1.7 Natural causes of death

Predators
Published data on natural predators of Gray Short-tailed Opossum have not been found.

Diseases
Endoparasites of Gray Short-tailed Opossum include the coccidian Eimeria, the tapeworm Linstowia schmidti, the trematode Rhopalias dobbini, the nematode Viannaia monodelphisi, and flagellate protozoans. Ectoparasites, include the tick Amblyomma dissimile (Macrini, 2004 and references therein).

7.2 Risk Analysis

See for detail introduction and explanation on a risk analysis § 2.2 of the Common Brushtail Possum.

7.2.1 Probability of introduction

Detected as stowaways entering The Netherlands
It is unknown how many Gray Short-tailed Opossums arrive as pets in The Netherlands on a yearly basis. Imports are not registered or regulated.

The probability of introduction in The Netherlands for other purposes than the pet trade is low. Gray Short-tailed Opossums are not allowed to be kept for the furtrade. The species is not kept in zoo's at this moment (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, the use of opossums in research has been reported only twice (in 2003 en 2004). Species used was not reported (Voedsel en Waren Autoriteit 2003, 2004). http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

Escape will happen by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands
This species is not recorded as a hitchhiker on ships to The Netherlands. The probability of Gray Short-tailed Opossums entering our country by hitchhiking is very low.

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.

Keeping and trading

Reports of keeping and trading in The Netherlands

Grey short tailed Opossums are reported quite frequently on the forums (http://exoticpets.phpbb3.nl/portal.php). For instance an offer in 2012 of two males and two females of grey short tailed Opossums six months of age (€150,- per couple) ((http://exoticpets.phpbb3.nl/portal.php) There is some breeding with this species (http://www.exobreedingcenter.nl/Ned/home.html). There is one report of breeding in the past (until 2011) on http://www.dierenforum.nl/forum/website.php?page_id=2&web_id=790.

Reports of keeping and trading in Germany

Grey short tailed Opossums are offered in Germany quite frequently (http://cms.exoticanimal.de/index.php?searchadv=Kurzschwanzopossum+&catid=9&type=8&Itemid=99999999&option=com_classifieds). There is some breeding with this species (http://www.kurzschwanzopossums.de).

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is no risk of natural spread from neighbouring regions.

7.2.2 Probability of establishment

Propagule pressure

The probability of establishment is low because of:

- unsuitable climate,
- unsuitable habitat,

Propagule pressure

Propagule pressure for Gray Short-tailed Opossum is low. Species are kept as pets in The Netherlands on a very small scale. The entrance as hitchhiker is very low and but if it does occur involves most likely one (few) animals (animals live solitary).

The Gray Short-tailed Opossum is used as a research model in science, http://en.wikipedia.org/wiki/Gray_Short-tailed_Opossum - cite_note-sfbr-2 and is also found in the exotic pet trade. Laboratory breeding colonies of Gray Short-tailed Opossum were founded in the United States. Colonies are maintained in Australia, Brazil, Britain and Germany (VandeBerg and Robinson 1997). These sites are known for a high standard of risk prevention (e.g. risk for escape).

Climate match

Climate modelling using climate data from its natural distribution (Brasil) as a reference, suggests that the Dutch climate is not suitable for establishment of Gray Short-tailed Opossum (figure 5.2).

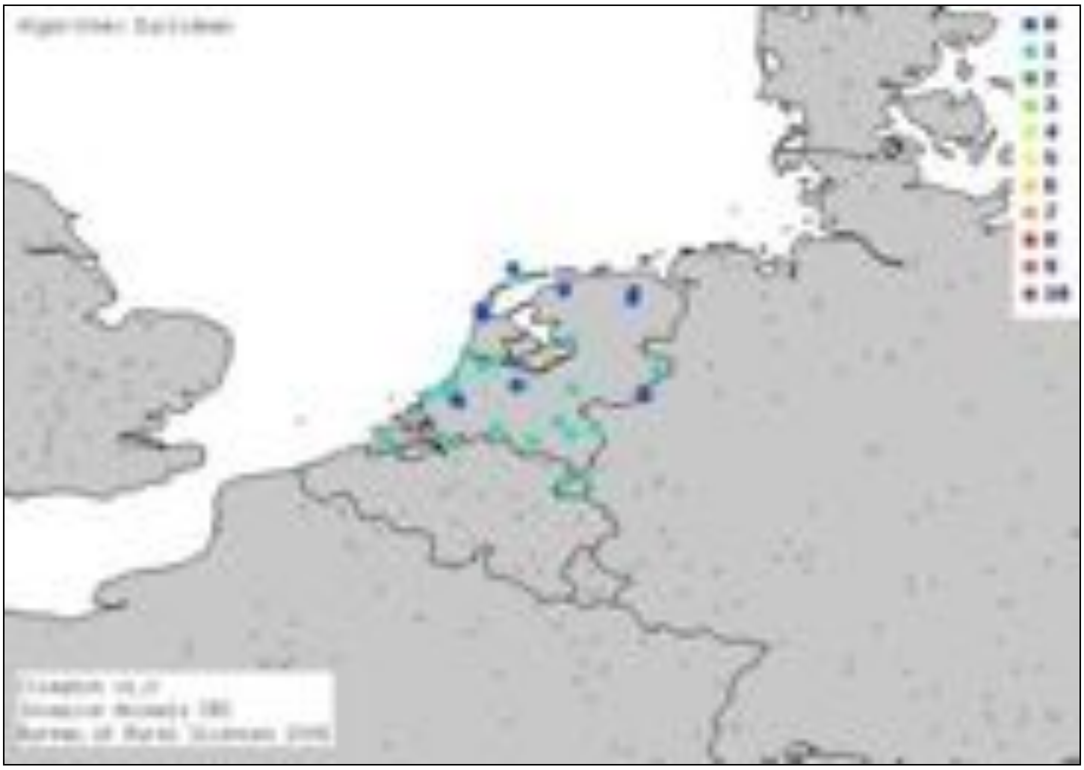

Figure 7.2 Climatch output for Gray Short-tailed Opossum showing the match between climate data from weather stations in the native and introduced range of Gray Short-tailed opossum and weather stations in The Netherlands; all 16 variables. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/Climatch). Calculated values for The Netherlands are 0 and 1.

Habitat match

The Dutch habitat does not match with its native habitat. Gray Short-tailed Opossum is primarily found in xeric rocky habitats and also in rainforest, thorn scrub, cultivated and abandoned fields and granitic outcrops. This species is no likely to find suitable habitat in our country.

Extensive natural range

Gray Short-tailed Opossum has a wide distribution in South America.

Pest history

Gray Short-tailed Opossum has no history of establishment elsewhere outside its native range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

7.2.3 Probability of spread

Due to the climate mismatch the probability of spread is very low.

7.2.5 Impact

Not relevant due to climate mismatch.

7.3 Bomford and ISEIA method for Risk assessment

For the Gray Short-tailed Opossum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are always relatively low. This implies that the overall establishment risk score in the Bomford method will inevitably give a low risk score.

7.3.1 Method of Bomford

The Gray Short-tailed Opossum is no threat to public health or safety. The risk for establishment is low mainly due to the climate mismatch (Table 7.1, appendix 1 for details).

Table 7.1 Summary of the Bomford risk analysis Gray Short-tailed Opossum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	5	B. Establishment Risk Score	Low risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
VPC threat categorie			**Low**

7.3.2 ISEIA

According to the ISEIA method the total score is 6 on a scale from 4 to 12 (Table 5.2).

Table 7.2 Summary of the ISEIA risk analysis Gray Short-tailed Opossum.

	category	estimate	score
5.1	Dispersal potential	Medium	2
5.2	Colonisation of natural habitat	Medium	2
5.3	Impact on native species		1
	Predation	Low	
	Competition	Medium	
	Spread of disease	Low	
	Hybridisation	Low	
5.4	Impact on ecosystems		1
	Nutrient circle	Low	
	physical alterations	Low	
	Natural successions	Low	
	Food webs	Low	
	Total score		6
	List		A
	Category, stadium invasion		A

7.3.3 Conclusions

There is low risk for the Gray Short-tailed Opossum becoming a pest once the species has settled. The risk of settlement is low because of the climate mismatch between The Netherlands and the native area of this species.

8 Small Fat-tailed Opossum

The Small Fat-tailed Opossum *Thylamys pusilla* has not set foot on Dutch ground (yet). There is some interest for the Small Fat-tailed Opossum as pet in The Netherlands. The species is reported for Germany as pet (one report).

English common names are: Chaco Fat-tailed Opossum, Chacoan Thylamys (Gardner 2007), Common Fat-tailed Mouse Opossum (IUCN 2009), Small Fat-tailed Mouse Opossum (IUCN 2009), Common Mouse Opossum (Canevari & Vaccaro 2007), Small Fat-tailed Opossum (Wilson & Cole 2000, Canevari & Vaccaro 2007) (After: Smith 2009).

Small Fat-tailed Opossum
(Photo: Louise Emmons; http://www.knowyoursto.com/didelphidae/thylamys.html)

8.1 Biology and ecology

For this chapter copied text from the following sources is used:

Smith P. 2009. Fauna Paraguay Handbook of the Mammals of Paraguay Number 32 Thylamys pusillus. http://www.faunaparaguay.com/mamm32Thylamyspusillus.pdf

Giarla T. 2012. "Thylamys pusillus" (On-line), Animal Diversity Web. Accessed February 13, 2012 at http://animaldiversity.ummz.umich.-edu/site/accounts/information/Thylamys_pusillus.html.

Flores D., de la Sancha N. & Albanese M.S. 2011. Thylamys pusillus. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 06 April 2012.

8.1.1 Distribution

Natural geographic range (After: Flores *et al*. 2011; Smith 2009)
The geographical range of this species is poorly known and further confused by various taxonomic changes and errors in the published literature (Smith 2009).

The Small Fat-tailed Opossum occurs in northern Argentina, southern central Bolivia, and Central and Western Paraguay. The Small Fat-tailed Opossum is not abundant in its natural range (Gardner 2007, Teta *et al.* 2009; after Flores *et al*. 2009).

Figure 8.1 Native distribution of Small Fat-tailed Opossum (Flores et al. *2011).*

Introduced geographic range
There are no established populations of Small Fat-tailed Opossum outside its natural range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

There are no reports of free ranging Small Fat-tailed Opossum in The Netherlands (www.waarneming.nl, database Zoogdiervereniging VZZ; accessed 24 January 2012).

8.1.2 Habitat

After Smit (2009):
This species is confined to xeric, wooded, scrubby and frequently thorny habitats. Voss *et al.* (2009) describe typical habitat as xerophytic woodlands that are dominated by low (usually <15 m), thorny, deciduous trees including quebracho, palo

santo, palo borracho, and labón (Tabebuia nodosa). The understory typically includes algarrobo (Prosopis spp.), Maytenus spp., Mimosa spp., Ephedra spp., and several species of cacti. Dense patches of spiny bromeliads (caraguatá: Bromelia hieronymi, B. serra) provide groundcover that is nearly impenetrable to mammalian or avian predators.

8.1.3 Diet

After Smit (2009):
Small Fat-tailed Opossum is considered primarily an insectivore with omnivorous tendencies (Cannevari & Vaccaro 2007), though no detailled information has ever been published on the diet of the species. Fruit likely plays a significant part in the diet at least seasonally. The species is able to accumulate fat in the tail during times of plentiful resources, which help it to survive leaner times in its harshly seasonal environment.

8.1.4 Social organisation and behaviour

After Giarla (2012):
Little is known about the behavior of Small Fat-tailed Opossum . This species is likely solitary, as most small, insectivorous mammals are. As is the case for other members of this genus, Small Fat-tailed Opossum is likely nocturnal and probably enters torpor during the day. (Palma, 1997)

8.1.5 Movements and home range

Small Fat-tailed Opossum is considered nocturnal and arboreal in behaviour. It spends the day in burrows holes or abandoned nests (Cannevari & Vaccaro 2007). Specimens have been taken on the ground in pitfall traps as well as in trees and shrubs (Gardner 2007) (after Smith 2009).

No studies have examined the home range of Small Fat-tailed Opossum (Giarla *et al*. 2010).

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8.1.6 Reproduction and survival

Little is known about the general reproductive behavior of Small Fat-tailed Opossum. Canevari & Vaccaro (2007; in Smit 2009) state that females apparently reproduce twice a year giving birth to 14 or 15 young per brood.

Little is known about parental investment in Small Fat-tailed Opossum. Like all marsupials, females nurse their highly altricial young. However, because members of the genus *Thylamys* lack a pouch (marsupium), the young must cling to their mother's venter (Giarla *et al*. 2010).

No records of this species' lifespan are available (Giarla *et al*. 2010).

8.1.7 Natural causes of death

Predators

Like other small mammals, Small Fat-tailed Opossum is likely well adapted to avoiding predators by being nocturnal and inconspicuous. No records of known predators are available (Giarla *et al*. 2010).

Diseases

No information on diseases has been found.

8.2 Risk Analysis

8.2.1 Probability of introduction

Importation as commodity and escape / release to the wild

No records of Small Fat-tailed Opossums being imported into The Netherlands have been found (not registered). Also, no records have been found of Small Fat-tailed Opossum escaping or being released into the wild in The Netherlands.

Importation of Small Fat-tailed Opossum as a pet is not unlikely. The species is offered in Germany (see below). Other purposes for importation include zoo's and (biomedical) research. At this moment, opossums are not kept in zoo's (Nederlandse Vereniging van Dierentuinen, http://www.nvddierentuinen.nl/). In the past ten years, the use of opossums (species unknown) in research has been reported only twice in 2003 en 2004 (Voedsel en Waren Autoriteit 2003, 2004). http://www.vwa.nl/onderwerpen/wetenregelgeving/dossier/wetopdedierproeven/dossieroverzicht/onderwerp/inspectieresultaten).

If imported into The Netherlands, escapes or releases are not very likely, but cannot be ruled out. In general, pet owners are trying to prevent escapes and releases of their pets; especially if they are rare and/or expensive. Escape will happen only by carelessness and if the animals are poorly maintained in outdoor cages. Generally, the animals are kept alone or in pairs. If an escape occurs it concerns only a limited number of individuals.

Detected as stowaways entering The Netherlands

This species is not recorded as a hitchhicker on ships to The Netherlands. The probability of Small Fat-tailed Opossums entering our country by hitchhiking is thought to be low. There is no little chance of hitchhicking by boat as the species ranges in central South America, not along the coast. If the species does manage to hitchhike the chance of being detected is small (because of it's small size: head body length ±10 cm).

Natural spread from a neighbouring region

Since there are no free ranging populations in Europe there is currently no risk of natural spread from neighbouring regions.

Keeping and trading

Reports of keeping and trading in The Netherlands

No records have been found of Small Fat-tailed Opossum being kept as pets in The Netherlands. Only one request for a Small Fat-tailed Opossum was found on the Dutch forums (http://www.dierenforum.nl/forum/website.php?page_id=2&web_id=790)

Reports of keeping and trading in Germany

There is only one report of a Small Fat-tailed Opossum as pet on a forum (http://www.exotickeepersforum.co.uk/phpBB3/viewtopic.php?f=17&t=626).

8.2.2 Probability of establishment

The probability of establishment is moderate because of:
- moderately suitable climate,
- suitable habitat.

Figure 8.2 Climatch output for Small Fat-tailed Opossum showing the match between climate data from weather stations in the native and introduced range of Short tailed opossum and weather stations in The Netherlands; all 16 variables are used. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (http://www.brs.gov.au/-Climatch). Calculated values for The Netherlands are 3, 4 and 5.

Propagule pressure
Propagule pressure for Small Fat-tailed Opossum is very low. Species are not (yet) kept as pets in The Netherlands. There is no trade in this species in The Netherlands or in surrounding countries. The entrance as hitchhiker is not likely and if it does occur involves most likely one (few) animals (animals live solitary).

Climate match
Climate modelling using all climate data from its natural distribution as a reference, suggests that the Dutch climate is moderately suitable for establishment of Small Fat-tailed Opossum (figure 8.2).

If we look only to the temperature in the coldest Dutch winter months the climate match is relative good (Figure 8.3). Therefor climate seems not to be a limiting factor for settlement in The Netherlands.

Figure 8.3 *Climatch output for Small Fat-tailed Opossum showing the match between climate data from weather stations in the native and introduced range of Short tailed opossum and weather stations in The Netherlands; lowest temperature and mean annual rainfall. 10 is a 'perfect' climate match and 0 is a very dissimilar climate match (*http://www.brs.gov.au/Climatch*). Calculated values for The Netherlands are 7 and 8.*

Habitat match
Small Fat-tailed Opossum is confined to xeric, wooded, scrubby and frequently thorny habitats. This species is likely to find suitable habitat in our country.

Extensive natural range
This species is has no wide distribution (see § 8.1.1)

Pest history
Small Fat-tailed Opossum has no history of establishment elsewhere outside its native range (Global Invasive Species Database (www.issg.org/database); DAISIE European Invasive Alien Species Gateway (www.europe-aliens.org); Harmonia database, Belgian Forum on Invasive Species, http://ias.biodiversity; accessed 24 January 2012).

8.2.3 Probability of spread

Not relevant. The probability of establishment is zero.

8.2.4 Impact

Since the probability of establishment of Small Fat-tailed Opossum in The Netherlands is low, there is no risk of damage to native biodiversity, economy, public health and animal health.

8.3 Bomford and ISEIA method for Risk assessment

For the Small Fat-tailed Opossum risk analysis two methods have been used: Bomford (Bomford 2003, 2006, 2008) and the Invasive Species Environmental Impact Assessment (ISEIA). The first method is strong in detail and in assessing risk of entries. The second method is strong in assessing risks of ecological effects, but refers only to species with established populations. The Bomford (2003) method includes an assessment of social and economic impact, which the ISEIA-method lacks. The Bomford-method seems to be the most appropriate at this moment, since the species have not settled in The Netherlands yet.

In a continental situation as in The Netherlands the risks of establishment are always relatively moderate. This implies that the overall establishment risk score in the Bomford method will inevitably give a moderate risk score.

8.3.1 Method of Bomford

The Small Fat-tailed Opossum is no threat to public health or safety. The risk for establishment is moderate mainly due to the climate match (Table 8.1, appendix 1 for details).

Table 8.1 Summary of the Bomford risk analysis Small Fat-tailed Opossum.

Factor	Score		Conclusion
A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 =	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
C. <9 = low, 9-14 moderate, 15 19 = serious, >19 = extreme	9	C. Pest Risk Score	Moderate risk to become a pest
VPC threat categorie			**moderate**

8.3.2 ISEIA

According to the ISEIA method the total score is 8 on a scale from 4 to 12 (Table 5.2).

Table 8.2 Summary of the ISEIA risk analysis Small Fat-tailed Opossum.

	category	estimate	score
5.1	Dispersal potential	Medium	2
5.2	Colonisation of natural habitat	High	3
5.3	Impact on native species		1
	Predation	Low	
	Competition	Medium	
	Spread of disease	Low	
	Hybridisation	Low	
5.4	Impact on ecosystems		2
	Nutrient circle	Low	
	physical alterations	Low	
	Natural successions	Medium	
	Food webs	Low	
	Total score		8
	List		A
	Category, stadium invasion		A

8.3.3 Conclusions

There is moderate risk for the Small Fat-tailed Opossum becoming a pest once the species has settled. The risk of settlement is moderate because of the climate match

9 Risk management

This report deals with the probability of occurrence and spread of seven non-native mammals in The Netherlands and elsewhere in Western Europe. The main vector is trade and keeping as pet and to a lesser degree as stowaways on ships. Among the seven species two of them do have a good climate match, three of them do have a moderate climate match and two of them have a lack in climate match (table 9.1).

To start with the latter; if Striped Possum or White-eared Opossum should occur in the Netherlands or elsewhere in Western Europe, the possibility of settlement will be zero. Therefore, management options such as shooting or trapping do not make any sense. Sooner or later those animals will die, due to food shortage or winter cold.

For five species there is the probability for successful settlement once they occur in the field with at least a male and a female. Among those five species there are two species that are relative large in size and three that are relative small in size. Furthermore, all five are mainly active by night.

The only possible management option for three small species is trapping. Since they have small home-ranges this is a good option. One should use life-traps, in order exclude species not wanted such as mice. A second method could be species specific infertilisers. But, so far, the have not been developed by the industry. Thirdly, the larger species could be hunted or trapped. Since they are mostly active by night, attractants such as artificial light might be necessary for successful hunting.

Tabel 9.1 *Summary of risk* cf. *Bomford, body size (cm) and body mass (g).*

species	risk	body size	body mass
Possums			
Common Brushtail Possum	serious	32-58	1.200-4.500
Striped Possum	low	26	450
Opossums			
Virginia Opossum	serious	35-94	800-6.400
White-eared Opossum	low	25-28	540-800
Gray Four-eyed Opossum	moderate	25-35	750
Gray Short-tailed Opossum	moderate	12-18	100
Small Fat-tailed Opossum	moderate	7-12	38

10 Conclusions and recommendations

Probability of settlement and spread
The Common Brushtail Possum is an invasive exotic species in New Zealand and has proven to have negative effects on native flora and fauna. The main reason is that ground predators are lacking on these islands. The costs for control of this species are very high. It is unknown how this possum will behave in an environment were ground predators are present, as in Western Europe. There is a good climate match between its native range and Western Europe. Therefore, a settlement here could easily develop into a successful invasion, as long as management (eradication) is not conducted. The opportunistic lifestyle of this species could be an advantage in its possible success.

The Virginia Opossum is native in North America. Here it has spread further north since colonisation by Europeans started. This species lives in agricultural landscapes as well as in the urban environment. It has an opportunistic lifestyle, which has contributed to its success in North America. There is a fairly good climate match between North America and Western Europe, therefore, the probability of successful settlement and spread into our ecosystem is quite high.

The Striped Possum and Gray Short-tailed Opossum are both tropical species. Based on the climate mismatch it is expected that both species won’t settle permanently in Western Europe in cases where animals escape into the wild.

White-eared Opossum, Gray Four-eyed Opossum and Small Fat-tailed Opossum are three species from the tropics and subtropics. Based on their occurrence in the subtropical climate zone, it cannot be excluded that climate in Western Europe will fit with the demanding of these species. All three are small species and settlement here could take place without being noticed by humans; they are secretive animals.

All seven species mentioned have small or very small home ranges, with little capacity for dispersal. The probability of a successful settlement highly depends on the number of animals present (released) in a small area. As long as those species do not occur in the wild this could be a limiting factor in successful settlement and spread. Nevertheless, the release of a single male and female animal represents the beginning of potential establishment.

Vectors
All seven species mentioned are kept as pets in The Netherlands. Estimates on the number vary between some tens up to many tens on individuals. On relevant web sites in both The Netherlands and Germany, there is supply and demand for all seven species. In Belgium, it is not permitted to keep possums and opossums as a pet. On the contrary, it is noteworthy that a Belgian company is advertising on the internet for the control of opossums.

On relevant web sites proof has been found that at least some of the relevant species are known to reproduce in captivity. With this in mind, keeping these species as a pet becomes independent from supply out of the native range of species.

The Gray Short-tailed Opossum is kept in captivity on a large scale as a model species for biomedical research. Those research locations have a high standard of safety rules. Therefore, the chance for escapes is nil. In The Netherlands no research locations with this species are known.

Some cases are known of (o)possums that have reached Western Europe as stowaways on ships. In the harbour of Vlissingen in the south of The Netherlands two cases are known and in Rotterdam one case. Those cases concerned one Common Brushtail Possum and in two cases the species were unknown.

Prevention
In The Netherlands and surrounding countries the trade and possession of Possums and Opossums reaches only a limited scale. Nonetheless, it could not be excluded that in case a small number of those animals are released or escaped, this could lead to establishment. Preventive measures (limits on trade and possession) could reduce this limited risk even further.

Sporadically possums and opossums are found as stowaways on ships from South Central and North America, as well as from Australia and New Zeeland. Current knowledge indicates that this nearly always concerns single animals and never more on any single ship. The risk of introduction by ships seems to be very limited and, therefore, the control of ships seems to be unnecessary.

Elimination
If a possum or opossum is seen in the wild, it could mean that establishment has taken place or is going to take place; especially in the case it concerns a species with a good climate match. In such cases elimination of the animals is necessary by means of (live) traps.

Management
Possums and opossums have small home ranges. Therefore, the trapping of animals is a good management option. Larger species could be hunted.

11 Literature

AAP Foundation 2002. Apenote. Nummer 39. AAP Foundation, Almere.

AAP Foundation 2006. Apenote. Nummer 55. AAP Foundation, Almere.

AAP Foundation 2010. Apenote. Nummer 72. AAP Foundation, Almere.

Allen R.B., A.E. Fitzgerald, M.G. & Efford, 1997: Long-term changes in the diet of common brushtail possums (*Trichosurus vulpecula*), Orongorongo Valley, New Zealand. New Zealand Journal of Ecology 21: 181–186.

Almeida A.J. de, Torquetti C.G., Talamoni S.A. 2008. Use of Space by Neotropical Marsupial *Didelphis albiventris* (Didelphimorphia: Didelphidae) in an Urban Forest Fragment - Revista Brasileira de Zoologia 25: 214-219.

Animal Health Board 2000. Bovine tuberculosis pest management strategy 2001-2011. A discussion paper on the future options towards a Tb free New Zealand. Wellington, Animal Health Board.

Andromeda Oxford Ltd. 2001. American Opossums. Pp. 808-814 in D. Macdonald, S Norris, *eds*. The New Encyclopedia of Mammals, Vol. 1/1, 1 Edition. Oxford, UK: Oxford University Press.

Anonymus 1997. Brushtail possum. Western Shield progress report, November 1997. Perth, Department of Conservation and Land Management (Western Australia).

Astúa de Morães D. & Geise L. 2006. Early Reproductive Onset in the White-eared Opossum *Didelphis albiventris*, Lund 1840 (*Didelphimorphia: Didelphidae*) - Mammalian Biology 71: 299-303.

Atkinson I.A.E. 1995. Possums and possum control; effects on lowland forest ecosystems (1995). Science for Conservation no.1

Barr T.R.B. 1963. Infectious diseases in the opossum: a review. Journal of Wildlife Management 27: 53-71.

Bomford M. 2008. Risk assessment models for establishment of exotic vertebrates in Australia and New Zealand. Invasive Animals Cooperative Research Centre, Canberra.

Bomford M. 2003. Risk Assessment for the Import and Keeping of Exotic Vertebrates in Australia. Bureau of Rural Sciences, Canberra

Bomford M., Kraus F., Barry S.C. & Lawrence E. 2009. Predicting establishment success for alien reptiles and amphibians: a role for climate matching. Biological Invasions 11: 713–724.

Brito D., Cuarón A.D., Reid F. & Emmons L. 2008. Philander opossum. *In:* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 07 February 2012.

Brockie R.E., Ward G.D. & Cowan P.E. 1997: Possums (*Trichosurus vulpecula*) on Hawke's Bay farmland: spatial distribution and population structure before and after a control operation. Journal of the Royal Society of New Zealand 27: 181-191.

Brockie R.E., Ward G.D., Herritty P.J. & Smith R.N. 1991. Recolonisation and dispersal of possums on Hawke's Bay farmland 1988-1991: a progress report. DSIR Land Resources Technical Record 51.

Broome L. & D. Lindenmayer 2001. Ringtails, Pygmy Possums, and Gliders. Pp. 834-839 in D MacDonald, S Norris, *eds*. The Encyclopedia of Mammals. New York: Barnes & Noble Books.

Brown K., Innes J. & Shorten R. 1993. Evidence that possums prey on and scavenge bird eggs, birds, and mammals. Notornis 40: 169-177.

Buddle B.M., Aldwell F.E., Jowett G., Thomson A., Jackson R. & Paterson B.M. 1992: Influence of stress of capture on haematological values and cellular immune responses in the Australian brushtail possum (*Trichosurus vulpecula*). New Zealand Veterinary Journal 40: 155-159.

Cáceres N.C. 2002. Food Habits and Seed Dispersal by the White-eared Opossum *Didelphis albiventris* in Southern Brazil – Studies on Neotropical Fauna and Environment 37: 97-104.

Cáceres N.C. 2000. Population Ecology and reproduction of the White-eared Opossum *Didelphis albiventris* (Mammalia, Marsupialia) in an Urban Environment of Brazil - Ciência e Cultura 52: 171-174.

Caley P., Hickling G.J., Cowan P.E. & Pfeiffer D. 1999. Effects of sustained control of brushtail possums on levels of *Mycobacterium bovis* infection in cattle and brushtail possum populations from Hohotaka, New Zealand. New Zealand Veterinary Journal 47: 133-142.

Caley P., Spencer N.J., Cole R.A. & Efford M.G. 1998. The effect of manipulating population density on the probability of den-sharing among common brushtail possums and the implications for transmission of bovine tuberculosis. Wildlife Research 25: 383-392.

Campbell D.J. 1990. Changes in the structure and composition of a New Zealand lowland forest inhabited by brushtail possums. Pacific Science 44: 277-296.

Cannevari M. & Vaccaro O. 2007. Guía de Mamíferos del Sur de América del Sur. LOLA, Buenos Aires.

Carusi L.C.P., Farace M.I., Ribicich M.M. & Villafañe I.E.G. 2009. Reproduction and Parasitology of *Didelphis albiventris* (Didelphimorphia) in an Agroecosystem Landscape in Central Argentina - Mammalia 73: 89-97.

Castro-Arellano I., H. Zarza & R. Medellín 2000. Philander opossum. Mammalian species 638: 1-8.

Cherem J.J., Kammers M., Ghizoni I.R. & Martins A. 2007. Mamíferos de Médio e Grande Porte Atropelados em Rodavias do Estado de Santa Catarina, Sul do Brasil - Revista Biotemas 20: 81-96.

Coleman J. & Caley P. 2000. Possums as a reservoir of bovine Tb. *In*: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 92-104.

Coleman J. D., Gillman A. & Green W.Q. 1980. Forest patterns and possum densities within podocarp/mixed hardwood forests on Mt Bryan O'Lynn, Westland. New Zealand Journal of Ecology 3: 69 84.

Coleman J. & Livingstone P. 2000. Fewer possums less bovine Tb. *In*: Montague, T. *ed*. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 220-231.

Coleman J. D., Thomas M.D., Pracy L.T. & Hansen Q. 1998. Fluctuations in possum numbers and life history parameters revealed through thirty years of trapping in the Pararaki Valley, Haurangi State Forest Park. Unpublished Landcare Research Contract Report LC9899/29.

Costa L., Astua de Moraes D., Brito D., Soriano P., Lew D. & Delgado C. 2008. Didelphis albiventris. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 07 February 2012.

Cowan P.E. 2001. Advances in New Zealand mammalogy 1990-2000: Brushtail possum. Journal of The Royal Society of New Zealand. Volume 31: 15–29.

Cowan P.E. 1993: Environmental pests: how can we identify the values at risk? New Zealand Journal of Zoology 20: 279-283.

Cowan P.E. 2000a. Biological control of possums: prospects for the future. In: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 262-270.

Cowan P.E. 2000b. Factors affecting possum re-infestation — implications for management. Science for Conservation 144. Wellington, Department of Conservation.

Cowan P.E. 2001. Responses of common brushtail possums (*Trichosurus vulpecula*) to translocation on farmland, southern North Island, New Zealand. Wildlife Research 28 , 277–282.

Cowan P.E., Brockie R.E., Smith R.N. & Hearfield M.E. 1997. Dispersal of juvenile brushtail possums, *Trichosurus vulpeeula*, after a control operation. Wildlife Research 24: 279-288.

Cowan P.E., Brockie R.E., Ward G.D. & Efford M.G. 1996. Long-distance movements of juvenile brushtail possums (*Trichosums vulpecula*) on farmland, Hawke's Bay, New Zealand. Wildlife Research 23: 237-244.

Cowan P., Clark J., Heath D., Stankiewiez M. & Meers J., 2000. Predators, parasites and diseases of possums. *In*: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 82-91.

Cowan P. & M. Clout 2000. Possums on the move: activity patterns, home ranges, and dispersal. *In:* Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 24-34.

Cowan P.E. & Rhodes, D.S. 1992. Restricting the movements of brushtail possums (*Trichosurus vulpecula*) on farmland with electric fencing. Wildlife Research 19: 47-58.

Cowan P.E. & Rhodes D.S. 1993. Electric fences and poison buffers as barriers to movements and dispersal of brushtail possums (*Trichosums vulpecula*) on farmland. Wildlife Research 20: 671- 686.

Cowan P.E. 1990b. Fruits, seeds, and flowers in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/broadleaf forest, Orongorongo Valley, New Zealand. New Zealand Journal of Zoology 17: 549-566.

Cowan P.E. & Moeed A. 1987. Invertebrates in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/mixed hardwood forest, Orongorongo Valley, New Zealand. New Zealand.

Crawford J.L., Shackell G.H., Thompson E.G., McLeod B.J. & Hurst,P.R. 1998b. Preovulatory follicle development and ovulation in the brushtail possum (*Trichosums vulpecula*) monitored by repeated laparoscopy. Journal of Reproduction and Fertility 110: 361-370.

Cuarón A.D., Emmons L., Helgen K., Reid F., Lew D., Patterson B., Delgado C. & Solari S. 2008. Didelphis virginiana. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 03 January 2012.

Cunha A.A. & Vieira M.V. 2002.Support Diameter, Incline and Vertical Movements of Four Didelphid Marsupials in the Atlantic Forest of Brazil. Journal of Zoological Society of London 258: 419-426.

Day T., O'Connor C. & Matthews L. 2000. Possum social behaviour. *In:* Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 35-46.

Day T.D., O'Connor C.E., Waas J.R., Pearson A.J. & Matthews L.R. 1998. Transmission of Leptospira interrogans serovar balcanica infection among socially housed brushtail possums in New Zealand. Journal of Wildlife Diseases 34: 576-581.

Dearing M.D. & Cork, S. 1999. Role of detoxification of plant secondary compounds on diet breadth in a mammalian herbivore, Trichosurus vulpecula. Journal of Chemical Ecology 25: 1205-1219.

Dexter R.W. 1951. Earthworms in the winter diet of the opossum and raccoon. Journal of Mammalogy 32: 464.

Dias F.B.S., Bezerra C.M., Machado E.M. de M, Casanova C. & Diotaiuti L. 2008. Ecological Aspects of *Rhodnius nasutus* Stahl 1859 (Hemiptera: Reduviidae: Triatominae) in Palms of the Chapada do Araripe in Ceará, Brazil. Memorias Instituto Oswaldo Cruz 103: p824-830.

Doutt J.K. 1954. The swimming of the opossum. Journal of Mammalogy 35: 581-583.

Eckery D.C., Tisdall,D.J., Heath D.A., McNatty K.P. 1996. Morphology and function of the ovary during fetal and early neonatal life: A comparison between the sheep and brushtail possum (*Trichosums vulpecula*). Animal Reproduction Science 42: 551-561.

Efford M.G. 1991. A review of possum dispersal. DSIR Land Resources Scientific Report 23.

Efford M. 1998. Demographic consequences of sex-biased dispersal in a population of brushtail possums. Journal of Animal Ecology 67: 503-517.

Efford M. 2000. Possum density, population structure and dynamics. *In:* Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 47-61. Journal of The Royal Society of New Zealand, Volume 31, 2001.

Efford M., Warburton, B., Spencer, N. 2000. Home-range changes by brushtail possums in response to control. Wildlife Research 27: 117-127.

Fitch H.S., & H.W. Shirer. 1970. A radiotelemetric study of spatial relationships in the opossum. American Midland Naturalist 84:170-186.

Fitzgerald A.E. 1984. Diet overlap between kokako and the common brushtail possum in central North Island, New Zealand. *In*: Smith, A.P., Hume, I.D. (Editors), Possums and gliders, pp. 569-573. Surrey Beatty in assoc. with the Australian Mammal Society, Chipping Norton, N.S.W., Australia.

Fleay D. 1942. The Remarkable Striped Possum. Victorian Naturalist, 58: 151-155.

Fletcher T. & Selwood L. 2000. Possum reproduction and development. *In*: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 62-81.

Frankenberg S. & Selwood L. 1998. An ultrastructural study of the role of an extracellular matrix during normal cleavage in a marsupial, the brushtail possum. Molecular Reproduction & Development 50: 420-433.

Gardner A.L. 2005. Order *Didelphimorphia. In* D.E. Wilson and D.M. Reeder (eds.). Mammal Species of the World, pp. 3-18. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Gazarini J, Brito J.E.C. & Bernardi I.P. 2008. Predações Oportunísticas de Morcegos por Didelphis albiventris no Sul do Brasil. Chiroptera Neotropical 14: 408-411.

Gardner A.L. 2007. Order Didelphimorphia. *In*: A. L. Gardner (ed.), Mammals of South America, pp. 669. University of Chicago Press, Chicago, USA.

Gemmell R.T. & Sernia C. 1995. Effect of changing from a shortday to longday photoperiod on the breeding season of the brushtail possum (*Trichosurus vulpecula*). Journal of Experimental Zoology 273: 242-246.

Genovesi P., S. Bacher, M. Kobelt, M. Pascal & R. Scalera, 2009. Alien mammals of Europe. In Handbook of Alien Species in Europe. Edited by: DAISIE. Dordrecht: Springer: 119-128.

Giarla T., R. Voss & S. Jansa. 2010. Species Limits and Phylogenetic Relationships in the Didelphid Marsupial Genus *Thylamys* Based on Mitochondrial DNA Sequences and Morphology. Bulletin of the American Museum of Natural History 346: 1-67.

Gillete L.N. 1980. Movement patterns of radio-tagged opossums in Wisconsin. American Midland Naturalist 104 (1) 1.

Global Invasive Species Database, 2007. *Trichosurus vulpecula*. Available from: http://www.issg.org/database/ [Accessed 1st March 2012].

Hackwell K. & Bertram K. 1999. Pests and weeds. The cost of restoring an indigenous dawn chorus. Wellington, New Zealand Conservation Authority.

Hamilton W.J. Jr. 1953. The food of the opossum in New York State. Journal of Wildlife Management 15: 258-264.

Handasyde K. & R. Martin. 1996. Field Observations on the Common Striped Possum (*Dactylopsila trivirgata*) in North Queensland. Wildlife Research, 23 (6): 755-766.

Handasyde K.A. 2008. Striped Possum, *Dactylopsila trivirgata*. *In*: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition, pp. 224-225. Reed New Holland, Sydney, New South Wales, Australia.

Hansen B., J. French, K. Handasyde, T. Kendal & A. Taylor. 2003. A set of microsatellite primers for the Striped Possum, *Dactylopsila trivirgata* (Petauridae: Marsupialia). Molecular Ecology Notes, 3 (2): 212-214.

Hayes K.R. & Barry S.C. 2008. Are there any consistent predictors of invasion success? Biological Invasions 10: 483-50.

Henderson W. & M. Bomford 2011. Detecting and preventing new incursions of exotic animals in Australia. Invasive Animals Cooperative Research Centre, Canberra.

Henderson R.J. & Hickling G.J. 1997. Possum behaviour as a factor in sub-lethal poisoning during control operations using cereal baits. Unpublished Landcare Research Contract Report LC9798/03.

Herbert P.A. & Lewis R.D. 1999. The chronobiology of the brushtail possum, *Trichosurus vulpecula* (Marsupialia: Phalangeridac): test of internal and external control of timing. Australian Journal of Zoology 47: 579-591.

Hickling G.J. 1995. Clustering of tuberculosis infection in brushtail possum populations: implications for epidemiological simulation models.

????? & Griffin, F., de Lisle, G. ed. Tuberculosis in wildlife and domestic animals. Otago Conference Series No. 3. Dunedin, Otago University Press. Pp. 174-177.

Hickling G.J., Thomas M.D., Grueber L.S. & Walker R. 1990. Possum movements and behaviour in response to self-feeding bait stations. Unpublished Forest Research Institute Contract Report FEW 90/9.

Huffman K., J. Nelson, J. Clarey & L. Krubitzer 1999. Organization of Somatosensory Cortex in Three Species of Marsupials, *Dasyurus hallucatus, Dactylopsila trivirgata*, and *Monodelphis domestica*: Neural Correlates of Morphological Specializations. The Journal of Comparative Neurology, 403 (1): 5-32.

Hulme P.E., Bacher S., Kenis M., Klotz S., Kühn I., Minchin D., Nentwig W., Olenin S., Panov V., Pergl J., Pyšek P., Roques A., Sol D., Solarz W. & Vilà M. 2008. Grasping at the routes of biological invasions: a framework for integrating pathways into policy. J Appl. Ecol. 45: 403-414.

Innes J. 1995. The impacts of possums on native fauna. *In*: O'Donnell, C. F. J. (Comp.), Possums as conservation pests. Wellington, Department of Conservation. Pp. 1 1-15.

Innes, J., Brown K., Jansen R. & Williams, D. 1996. Kokako population studies at Rotoehu Forest and on Little Barrier Island. Science for Conservation 30. Department of Conservation Wellington, N.Z.

Jackson J. 1998. A new host record for Ixodes holocyclus Neumann and Ixodes cordifer Neumann (Acarina: Ixodidae) in Australia. Australian Journal of Entomology, 37 (2): 113-114.

James R.E. & Clout M.N.I 1996. Nesting success of New Zealand pigeons (Hemiphaga novaeseelandiae) in response to a rat (Rattus rattus) poisoning programme at Wenderholm Regional Park. New Zealand Journal of Ecology 20: 45-51.

Jolly S.E., Scobie S. & Coleman M.C. 1995. Breeding capacity of female brushtail possums Trichosurus vulpecula in captivity. New Zealand Journal of Zoology 22: 325-330.

Jolly S.E., Scobie S., Spurr E.B., McAllum C. & Cowan P.E. 1998. Behavioural effects of reproductive inhibition in brushtail possums. *In:* Lynch, R. ed. Biological control of possums. Royal Society of New Zealand Miscellaneous Series 45. Pp. 125-127.

Jolly S.E. & Spurr E.B. 1996. Effect of ovariectomy on the social status of brushtail possums *Trichosurus vulpecula* in captivity. New Zealand Journal of Zoology 23: 27-32.

Kalafut M. 2005. "Know Your STO" (On-line). Short-Tailed Opossums, Keeping and Caring for These Pets. Accessed February 15, 2006 at http://www.knowyoursto.com/.

Kanda L.L. 2005. Winter energetics of Virginia opossums *Didelphis virginiana* and implications for the species' northern distributional limit. Ecography 28: 731-744.

Kanda L.L., T.K. Fuller & K.D. Friedland. 2005. Temperature sensor evaluation of opossum winter activity. Wildlife Society Bulletin 33(4): 1425-1431.

Kaneko K., T. Kadosaka, E. Kimura. 1999. Two new species of intranasal mites (Acarina, Trombicidae) from a common Striped Possum (Marsupialia, Petauridae). Journal of the Acarological Society of Japan, 1 (2): 89-94.

Kark S, Solarz W., Chiron F., Clergeau P. & Shirley S. 2009. Alien birds, amphibians and reptiles of Europe. In Handbook of Alien Species in Europe. Edited by: DAISIE. Dordrecht: Springer, 2009: 105-118.

Keller R.P., Geist J., Jeschke J.M. & Kühn I. 2011. Invasive species in Europe: ecology, status and policy. Environmental Sciences Europe, 23 (23), 1-17.

Kerle J.A. 1998. The population dynamics of a tropical possum, *Trichosurus vulpecula* arnhemensis Collett. Wildlife Research 25: 171-181.

Kerle J.A. & How R.A. 2008. Common Brushtail Possum, Trichosurus vulpecula. In: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition, pp. 274-276. Reed New Holland, Sydney, New South Wales, Australia.

Krause W.J. & W.A. Krause 2006. The opossum: its amazing story. Department of Pathology and Anatomical Sciences, School of Medicine, University of Missouri, Columbia, Missouri.

Langstaff L. 2004. "Dactylopsila trivirgata" (On-line), Animal Diversity Web. Accessed February 13, 2012 at.

Laurance S. & W. Laurance. 1999. Tropical Wildlife Corridors: Use of Linear Rainforest Remnants by Arboreal Mammals. Biological Conservation, 91: 231-239.

Lawler I.R., Eschler B.M. & Schliebs D.M. & Foley W.J. 1999a. Relationship between chemical functional groups on Eucalyptus secondary metabolites and their effectiveness as marsupial antifeedants. Journal of Chemical Ecology 25: 2561-2573.

Lawler I.R., Foley W.J., Eschler B.M., Pass D.M & Handasyde K. 1998. Intraspecific variation in Eucalyptus secondary metabolites determines food intake by folivorous marsupials. Oecologia 116: 160-169.

Lawler I.R., Stapley J., Foley W.J. & Eschler, B.M. 1999b. Ecological example of conditioned flavour aversion in plant-herbivore interactions: Effects of terpenes of Eucalyptus leaves on feedingby common ringtail and brushtail possums. Journal of Chemical Ecology 25: 401-415.

Lay D.W. 1942. Ecology of the opossum in eastern Texas. Journal of Mammalogy 23: 147-159.

Leathwick J.R., Hay J.R. & Fitzgerald A.E. 1983. The influence of browsing by introduced mammals on the decline of North Island kokako. New Zealand Journal of Ecology 6: 55-70.

Leutert A. 1988. Mortality, foliage loss, and possum browsing in southern rata (*Metrosideros umbellata*) in Westland, New Zealand. New Zealand Journal of Botany 26: 7-20.

Lima S.F. & Obara A.T. 2004. Levantamento de Animais Silvestres Atropelados na BR-277 às Margens do Parque Nacional do Iguaçu. Subsídios ao Programa Multidisciplinar de Proteção à Fauna – Accessed Online January 2009.

Little E.C.S. & Cowan P.E. 1992. Natural immigration of brushtail possums, Trichosurus vulpecula, onto Aroha Island, Kerikeri Inlet, Bay of Islands, New Zealand. New Zealand Journal of Zoology 19: 53-59.

Llewellyn L.M. & F.H. Dale. 1964. Notes on the ecology of the opossum in Maryland. Journal of Mammalogy 45:113-122.

Lockwood J.L., Cassey P. & Blackburn T.M. 2009. The more you introduce the more you get: the role of colonization pressure and propagule pressure in invasion ecology. Diversity and Distributions 15: 904–910.

Long C.A. & F.A. Copes 1968. Notes on the rate of dispersion of the opossum in Wisconsin. American Midland Naturalist 80:283-284.

Lynch R. ed. 1998. Biological control of possums. Royal Society of New Zealand Miscellaneous Series 45.

Mackintosh C.G., Crawford J.L., Thomson E.G., McLeod B.J., Gill J.M. & O'Keefe J.S. 1995. A newly discovered disease of the brushtail possum: wobbly possum syndrome. New Zealand Veterinary Journal 43: 126.

Macrini T.E. 2004. *Monodelphis domestica*. Mammalian Species 760: 1-8.

Mares M.A, Ojeda R.A. & Kosco M.P. 1981. Observations on the Distribution and Ecology of the Mammals of Salta Province, Argentina. Annals of the Carnegie Museum 50: 151-206.

Massoia E., Forasiepi A. & Teta P. 2000. Los Marsupiales de la Argentina. LOLA, Buenos Aires.

Massoia E., Chebez J.C., Bosso A. 2006. Los Mamíferos Silvestres de la Provincia de Misiones, Argentina. DVD-ROM.

Mate K.E., Molinia F.C. & Rodger J.C. 1998. Manipulation of the fertility of marsupials for conservation of endangered species and control of over-abundant populations. Animal Reproduction Science 53: 65-76.

McAllum P. 1996. Social rank, hormones and reproductive behaviour of male brushtail possums (*Trichosurus vulpecula*): Implications for biocontrol. Unpublished MSc thesis, Lincoln University, Lincoln, New Zealand.

McLennan J.A., Potter M.A., Robertson H.A., Wake G.C., Colbourne R., Dew L., Joyce L., McCann A.J., Miles J., Miller P.J. & Reid J. 1996. Role of predation in the decline of kiwi, *Apteryx* spp., in New Zealand. New Zealand Journal of Ecology 20: 27-35.

McLeod B. J., Thompson E.G., Crawford J.L. & Shackell G.H. 1997. Successful group housing of wildcaught brushtail possums (*Trichosurus vulpecula*). Animal Welfare 6: 67-76.

Mcmanus J.J. 1974. *Didelphis virginiana*. Mammalian Species 40: 1-6.

McManus J.J. 1967. Observations on sexual behavior in the opossum, Didelphis marsupialis. Journal of Mammalogy 48:486-487.

McManus J.J. 1969. Temperature regulation in the opossum, *Didelphis marsupialis virginiana*. Journal of Mammalogy 50:550-558.

Lay D.W. 1942. Ecology of the opossum in eastern Texas. Journal of Mammalogy 23:147-159.

Llewellyn L.M. & F.H. Dale. 1964. Notes on the ecology of the opossum in Maryland. Journal of Mammalogy 45:113-122.

Menkhorst P. 2001. A Field Guide to the Mammals of Australia. South Melbourne, Australia: Oxford University Press.

Meyer G. 2000. "*Trichosurus vulpecula*" (On-line), Animal Diversity Web. Accessed February 13, 2012 at http://animaldiversity.ummz.umich.edu/site/accounts/-information/Trichosurus_vulpecula.html.

Montague T.L. 2000. The Brushtail Possum: biology, impact and management of an introduced marsupial New Zealand. Manaaki Whenua Press.

Moore L.G., Ng Chie W., Lun S., Lawrence S.B., Young W. & McNatty K.P. 1997a. Follicle stimulating hormone in the brushtail possum (*Trichosurus vulpecula*): purification, characterization and radioimmunoassay. General & Comparative Endocrinology 106: 30-38.

Moore L.G., Ng Chie W., Lun S., Lawrence S.B., Heath D.A. & McNatty K.P. 1997b. Isolation, characterization and radioimmunoassay of luteinizing hormone in the brushtail possum. Reproduction, Fertility and Development 9: 419-425.

Moore D. 2006. "Monodelphis domestica" (On-line), Animal Diversity Web. Accessed February 13, 2012 at http://animaldiversity.ummz.umich.edu/site/accounts/-information/Monodelphis_domestica.html.

Moore J.C., 1955. Opossum taking refuge under water. Journal of Mammalogy 36:559-561.

Morris K., Woinarski J., Friend T., Foulkes J., Kerle A. & Ellis M. 2008. Trichosurus vulpecula. *In:* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 20 February 2012.

Murray J., S. Donnellan, G. McKay, R. Rofe, P. Baverstock, D. Hayman & M. Gelder. 1990. The Chromosomes of Four Genera of Possums from the Family Petauridae (Marsupialia: Diprotodonta). Australian Journal of Zoology, 38 (1): 33-39.

Newell T. & R. Berg 2003. "*Didelphis virginiana*" (On-line), Animal Diversity Web. Accessed March 06, 2012 at http://animaldiversity.ummz.umich.edu/-site/accounts/information/Didelphis_virginiana.html

Nowak R.M., 1999. Walker's Mammals of the World. 6th ed. Vols. I and II. Johns Hopkins University Press, Baltimore, Maryland.

Nowak R.M. 1991. Walker´s Mammals of the World. 5th Ed Volume I. Johns Hopkins, Baltimore.

Nugent G., Fraser K.W. & Sweetapple P.J. 1997. Comparison of red deer and possum diets and impacts in podocarp-hardwood forest, Waihaha Catchment, Pureora Conservation Park. Science for Conservation 50. Wellington, Department of Conservation.

Nugent G., Sweetapple P., Coleman J. & Suisted P. 2000. Possum feeding patterns: dietary tactics of a reluctant folivore. *In*: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 10-23.

Oliveira M.L., Ferreira R.M., Gomes M.P., Iha D.S., Lorenzon C.S. & Duarte J.M.B. 2010. Estudo Populacional de Gambás, Didelphis albiventris (Mammalia, Didelphidae), em um Pequeno Fragmento Florestal. Mastozoologia Neotropical 17: p161-165.

Owen H.J. & Norton D.A. 1995: The diet of introduced brushtail possums *Trichosurus vulpecula* in a low-diversity New Zealand Nothofagus forest and possible implications for conservation management. Biological Conservation 71: 339-345.

Palma R. 1997. *Thylamys elegans*. Mammalian Species, 572: 1-4.

Parkes J.P. & Thomson C. 1995. Management of thar Part II: Diet of thar, chamois, and possums. Science for Conservation 7. Wellington, Department of Conservation. Pp. 22-42.

Parliamentary Commissioner for the Environment 1994: Possum management in New Zealand. Wellington, Parliamentary Commissioner for the Environment: Te Kaitiaki Taiao a Te Whare Paremata.

Parliamentary Commissioner for the Environment 2000: Caught in the headlights: New Zealanders' reflections on possums, control options and genetic engineering. Wellington, Parliamentary Commissioner for the Environment: Te Kaitiaki Taiao a Te Whare Paremata.

Parera A. 2002. Los Mamíferos de la Argentina y la Región Austral de Sudamérica. Editorial El Ateneo, Buenos Aires.

Paterson B.M., Morris R.S., Weston J. & Cowan P.E. 1995. Foraging and denning patterns of brushtail possums, and their possible relationship to contact with cattle and the transmission of bovine tuberculosis. New Zealand Veterinary Journal 43: 281-288.

Payton I.J. 2000. Damage to native forests. *In:* Montague, T.L. (Editor), The brushtail possum: biology, impact and management of an introduced marsupial, pp. 111-125. Manaaki Whenua Press, Lincoln, N.Z.

Payton I. & Thomson C. 1999. Can antifeedants predict browsing by possums in New Zealand forests? He Korero Paihama — Possum Research News 12: 4-5.

Pekelharing C.J. & Reynolds R.N. 1983. Distribution and abundance of browsing mammals in Westland National Park in 1978, and some observations on their impact on the vegetation. New Zealand Journal of Forestry Science 13: 247-265.

Pickett K. 1997. The sublethal effects of predation on the common brushtail possum (*Trichosurus vulpecula*) at Lake Burrendong, New South Wales. Poster presentation, 10th Annual Conference, Australasian Wildlife Management Society, University of New England, 25-27 November 1997.

Pierce R.J. & Graham P.J. 1995. Ecology and breeding biology of kukupa (*Hemiphaga novaeseelandiae*) in Northland. Science and Research Series 91. Department of Conservation, Wellington, N.Z.

Pracy L.T. 1974. Introduction and liberation of the opossum (*Trichosurus vulpecula*) into New Zealand. New Zealand Forest Service, Wellington, New Zealand.

Prada C.S. 2004. Atropelamento de Vertebrados Silvestres em uma Região Fragmentada do Nordeste do Estado de São Paulo: Quantificação do Impacto e Análise dos Fatores Envueltos. Tese de Doutorado, Universidade Federal de São Carlos, Brasil, 129pp.

Rademaker V. & Cerqueira R. 2006. Variation in the Latitudinal Reproductive Patterns of the Genus Didelphis (Didelphimorphia: Didelphidae). Austral Ecology 31: p337-342.

Ramsey D.S.L. 2000. The effect of fertility control on the population dynamics and behaviour of brushtail possums (*Trichosurus vulpecula*) in New Zealand. Proceedings of the 19th Vertebrate Pest Control Conference, San Diego, California.

Rawlins D. & K. Handasyde. 2002. The feeding ecology of the Striped Possum *Dactylopsila trivirgata* (Marsupialia: Petauridae) in far north Queensland, Australia. Journal of Zoology, uk, 257 (2): 195-206.

Redford K.H., Eisenberg J.F. 1992. Mammals of the Neotropics: Volume 2 The Southern Cone -University of Chicago Press, Chicago.

Regidor H.A., Gorostiague M. 1990. Age Determination in the White-eared Opossum *Didelphis albiventris*. Vida Silvestre Neotropical 2: p75-76.

Reid F. 1997. A field guide to the mammals of Central America and southeast Mexico. Oxford University Press, New York, USA.

Regidor H.A. & Gorostiague M. 1996. Reproduction in the White-eared Opossum *Didelphis albiventris* Under Temperate Conditions in Argentina. Studies in Neotropical Fauna and Environment 31: p133-136.

Rickard C.G. 1996. Introduced small mammals and invertebrate conservation in a lowland podocarp forest, South Westland, New Zealand. MForSc thesis, University of Canterbury, Christchurch, New Zealand.

Rigueira S.E., Carvalho Valle C.M. de, Varejão J.B.M., Albuquerque P.V. de & Noquiera J.C. 1987. Algumas Observações Sobre o Siglo Reprodutivo de Fêmeas do Gambá Didelphis albiventris (Lund 1841) (Marsupialia, Didelphidae) em Populações Naturais no Estado de Minas Gerais, Brasil. Revista Brasileira de Zoologia 4: p129-137.

Rogers G. 1997. Trends in health of pahautea and Hall's totara in relation to possum control in central North Island. Science for Conservation 52. Wellington, Department of Conservation.

Rosa A.O. & Mauhs J 2004. Atropelamento de Animais Silvestres na Rodovia RS. 040. Caderno de Pesquisa, Série Biologia 16: p35-42.

Rose A.B., Pekelharing C.J., Platt K.H. & Woolmore C.B. 1993. Impact of invading brushtail possum populations on mixed beech-broadleaved forests, South Westland, New Zealand. New Zealand Journal of Ecology 17: 19-28.

Sadleir R. 2000. Evidence of possums as predators of native animals. *In*: Montague, T. ed. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln, New Zealand, Manaaki Whenua Press. Pp. 126-131.

Salas L., Dickman C., Helgen K., Burnett S. & Martin R. 2008. *Dactylopsila trivirgata*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 06 February 2012.

Sarre S.D., Aitken N., Clout M.N., Robins J. & Lambert D.M. 2000. Molecular ecology and biological control: the mating system of a marsupial pest. Molecular Ecology 9: 723-733.

Sarre S. & Clout M. 1998. Mating patterns of possums. *In*: Lynch, R. ed. Biological control of possums. Royal Society of New Zealand Miscellaneous Series 45. Pp. 128-129.

SEAM Guyra Paraguay, PRODECHACO 2001. Especies Silvestres del Paraguay: Guía de Identificación de Especies con Importancia Económica. PRODECHACO, Asunción.

Simberloff D. 2009. The role of propagule pressure in biological invasions. Ann. Rev. Ecol. Syst. 40: 81–102.

Smith P. 2008. Gray Short-tailed Opossum *Monodelphis domestica.* Handbook of the Mammals of Paraguay Number 10.

Smith P. 2007. White-eared Opossum *Didelphis albiventris.* Handbook of the Mammals of Paraguay Number 1.

Smith A. & I. Hume. 1984. Possums and Gliders. Chipping Norton, NSW: Surrey Beatty & Sons Pty Limited in association with the Australian Mammal Society.

Smith A. 1982. Is the Striped Possum (*Dactylopsila trivirgata*, Marsupialia, Petauridae) an Arboreal Anteater? Australian Mammalogy, 5 (3): 229-234.

Spurr E.B. & Jolly S.E. 1999. Dominant and subordinate behaviour of captive brushtail possums (*Trichosurus vulpecula*). New Zealand Journal of Zoology 26: 263-270.

Strahan R. 1995. The Mammals of Australia. Chatswood, NSW: Reed Books for the Australian Museum Trust.

Sutherland G. *ed*. 1999. Advances in the biological control of possums. Royal Society of New Zealand Miscellaneous Series 56.

Sweetapple P.J. & Nugent G. 1998. Comparison of two techniques for assessing possum (*Trichosurus vulpecula*) diet from stomach contents. New Zealand Journal of Ecology 22: 181-188.

Sweetapple P.J., K.W. Fraser & P.I. Knightbridge, 2004. Diet and impacts of brushtail possum populations across an invasion front in South Westland, New Zealand. New Zealand Journal of Ecology 28: 19-33.

Talamoni S.A. & Dias M.M. 1999. Population and Community Ecology of Small Mammals in Southeastern Brazil. Mammalia 63: 167-181.

Tasmanian Parks Wildlife Service, October 1996. "Management Program for the Brushtailed Possum *Trichosurus vulpecula* in Tasmania. Review of Background Information" (On-line). Accessed November 5, 1999 at http://www.biodiversity.environment.gov.au/plants/wildlife/possm01.htm.

Taube C.M. 1947. Food habits of Michigan opossums. Journal of Wildlife Management 11: 97-103.

Taylor A.C., Cowan P.E., Fricke B.L. & Cooper D.W. 2000. Genetic analysis of the mating system of the common brushtail possum (*Trichosurus vulpecula*) in New Zealand farmland. Molecular Ecology 9: 869-879.

Taylor A.C., Cowan P.E., Lam M.K., Harrison G.A. & Cooper D.W. 1999. Genetic marker studies in New Zealand brushtail possum populations (*Trichosurus vulpecula*). *In:* Sutherland G. ed. Advances in the biological control of possums. Royal Society of New Zealand Miscellaneous Series 56. Pp. 77-79.

Teta P. & de Tommaso D.C. 2009. Un Registro Marginal para la Comadreja Overa *Didelphis albiventris* (Didelphimorphia, Didelphidae) en la Provincia de San Juan, Argentina. Notulas Faunisticas 2a Serie 27.

Thomas M.D. & Fitzgerald, H. 1994: Bait-station spacing for possum control in forest. Unpublished Landcare Research Contract Report LC9394/118.

Thomas M.D., Hickling G.J., Colcman J.D.& Pracy L.T. 1993. Long-term trends in possum numbers at Pararaki: Evidence of an irruptive fluctuation. New Zealand Journal of Ecology 17: 29- 34.

Triggs S.J. 1987. Population and ecological genetics of the brush-tailed possum (*Trichosurus vulpecula*) in New Zealand. Unpublished PhD thesis, Victoria University of Wellington, Wellington, New Zealand.

Vandenberg J.L. & Robinson E.S. 1997. The laboratory opossum (*Monodelphis domestica*) in laboratory research. Inst Lab Anim Resources J. 38: 4-12.

Van Dyck S. 1995. Striped Possum (*Dactylopsila trivirgata*). Pp. 222-223 in R Strahan, ed. The Mammals of Australia. Chatswood, NSW: Reed Books.

Van Dyck S. 1979. Mating and other aspects of behaviour in wild Striped Possums. Victorian Naturalist, 96 (3): 84-85).

Voedsel en Waren Autoriteit 2000 – 2010. Zodoende. Jaaroverzichten van de Voedsel en Waren Autoriteit over dierproeven en proefdieren. http://www.vwa.nl/onderwerpen/wet-en-regelgeving/dossier/wet-op-de-dierproeven/dossieroverzicht/onderwerp/inspectieresultaten

Voss R., P. Myers, F. Catzeflis, A. Carmignotto & J. Barreiro 2009. The Six Opossums of Felix de Azara: Identification, Taxonomic History, Neotype Designations, and Nomenclatural Recommendations. Bulletin of the American Museum of Natural History, 331: 406-433.

Vilela J., Solari S., Flores D., de la Sancha N. & Astua de Moraes D. 2011. *Monodelphis domestica*. *In*: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 03

January 2012.Wilson D. & S. Ruff 1999. The Smithsonian Book of North American Mammals. Washington and London: Smithsonian Institution Press.

Walker 1991. Walker's Mammals of the World. Baltimore, MD: John Hopkins University Press.

Waters M. 2000. "Philander opossum" (On-line), Animal Diversity Web. Accessed February 13, 2012 at http://animaldiversity.ummz.umich.edu/site/accounts/-information/Philander_opossum.html

Weber J.M. & T. O'Connor. 2000. Energy metabolism of the Virginia opossum during fasting and exercise. The Journal of Experimental Biology 203:1365-1371.

Wilemon B.L. 2008. Virginia Opossum (Didelphis virginiana). *In* Mammals of Mississippi 1: 1-8. Department of Wildlife and Fisheries, Mississippi State University, Mississippi.

Wilson D. & S. Ruff 1999. The Smithsonian Book of North American Mammals. Washington & London: Smithsonian Institution Press.

Websites

- www.exoticpets.nl
- http://cms.exoticanimal.de
- http://www.nvddierentuinen.nl/
- http://www.brs.gov.au/Climatch

Appendix 1 Details of the Bomford method

	Common Brushtail Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes (0-2)	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living			
B1	Climate match score (1-6)	5	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (very good).	The situation in Europe suggests that climate is not really a restriction. In Australia and New Zeeland it both occurs in moderate en subropical climates.. Therefor the climate match score is set to extreme (6).
B2	Established exotic populations Score (0-4)	4	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a	Nowadays established in New Zeeland
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause negative effects.
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	non-migratory
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	Wide range of food
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	1	In million km2: 0 = 0-1, 1 = 2-69, 2 = ≥70	Natural distribution is about 40 million km2
	B. Establishment Risk Score	**14**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Extreme risk**
	Stage C: Probability an established exotic mammal or bird will become a pest.			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores. None is applicable to the Brushtailed possum
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is about 40 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal	
C4	Competition with native fauna for nesting space (0-2)	2	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less abundant breeding space)	Brush-tailed possum
C5	Pest status (0-3)	3	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	Observations in New Zeeland suugest a high pest status; but there is a lack of ground predatorsin NZ; in Europe competition with other predators might be expected.
C6	Match to areas with susceptible native species or communities (0-5)	2	Identify any native animal or plant species or communities that could be susceptible to harm Compare the geographic distribution of this susceptible species with the possible distribution (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable species or	Overlap with the natural distribution of several scarce hole breeding bird species and hole using mammals (bats, stoats). Due to these uncertainties set to 3.
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops. Related species are reported to eat pest
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production commodity.	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other domestic animals.
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 =	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many fatalities)	
	C. Pest Risk Score = Som C1-C11 (1-37)	**12**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 =	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	14	B. Establishment Risk Score	Extreme risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	12	C. Pest Risk Score	Moderate risk to become a pest
	VPC threat categorie			**Serious**

	Striped Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	0	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (very	Tropical species Therefor the climate match score is set to extreme (0).
B2	Established exotic populations Score (0-4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or	Nowhere else esthablished
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause negative
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	non-migratory
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	Wide range of food
B6	Habitat score (0-1)	0	0 = undisturbed habitat, 1 = including human disturbed habitats	Found mainly in undisturbed habitats.
B7	Range size score (0-2)	1	In million km2: 0 = 0-1, 1 = 2-69, 2 =	Natural distribution is about 40 million
	B. Establishment Risk Score	**4**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**low risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores. None is applicable to the
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is about 40 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal	
C4	Competition with native fauna for nesting space (0-2)	0	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less abundant	
C5	Pest status (0-3)	1	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	
C6	Match to areas with susceptible native species or communities (0-5)	1	Identify any native animal or plant species or communities that could be susceptible to harm Compare the geographic distribution of this susceptible species with the possible distribution (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable	Overlap with the natural distribution of several scarce hole breeding bird species and hole using mammals (bats, stoats). Due to these uncertainties set to 3.
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops. Related species are reported to eat pest species like locusts.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production commodity.	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 = > $50 million	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many fatalities)	
	C. Pest Risk Score = Som C1-C11 (1-37)	**7**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Low**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	4	B. Establishment Risk Score	Low risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
	VPC threat categorie			**Low**

	Virginia Opossum			
	Factor	Score	Information	Conclusion
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	6	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (exteme).	The situation in Europe suggests that climate is not really a restriction. In the USA it lives in colder (winter) areas and warmer (summer) areas than the climate in Western Europe. Therefor the climate match score is
B2	Established exotic populations Score (0 4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a continent	
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	resident
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	omnivorous
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	2	In million km2: 0 = 0-1, 1 = 2-69, 2 =	Natural distribution is >70 million
	B. Establishment Risk Score	**12**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Serious risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores.
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is >70 million km2
C3	Diet and feeding (0-3)	2	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal mammal	
C4	Competition with native fauna for nesting space (0-2)	1	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less abundant breeding space)	
C5	Pest status (0-3)	3	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	Observations in France suggests incidental predation of eggs and young of several species (including terns). Predation in some colonies in South Africa is high. The xtent of predation is not known. Due to the
C6	Match to areas with susceptible native species or communities (0-5)	4	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the species (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable	Overlap with the natural distribution of several scarce birds, including spoonbill and species of tern (possible imoacts are predation and nest competition). Dutch population partly prfits from food supply, some evidence for higher mortality in cold winters. Due to these uncertainties
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other domestic animals.
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 = > $50 million	
C11	Harm to people	1	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many	
	C. Pest Risk Score = Som C1-C11 (1-37)	**15**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	12	B. Establishment Risk Score	Serious risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	15	C. Pest Risk Score	Serious risk to become a pest
	VPC threat categorie			**Serious**

	Gray Short-tailed Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	0	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (exteme).	The situation in Europe suggests that climate is big restriction fot this trpopical species. Therefor the climate match score is set to extreme (0).
B2	Established exotic populations Score (0-4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a continent	
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	resident
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	omnivorous
B6	Habitat score (0-1)	0	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	2	In million km2: 0 = 0-1, 1 = 2-69, 2 =	Natural distribution is >70 million km2
	B. Establishment Risk Score	**5**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Serious risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores.
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is >70 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal mammal	
C4	Competition with native fauna for nesting space (0-2)	1	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less	
C5	Pest status (0-3)	0	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	
C6	Match to areas with susceptible native species or communities (0-5)	1	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the species (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable species or	
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 = > $50 million	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many	
	C. Pest Risk Score = Som C1-C11 (1-37)	**7**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	5	B. Establishment Risk Score	Low risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
	VPC threat categorie			**Low**

	Whie-eared Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	4	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (exteme).	The situation in Europe suggests that climate is quit suitable fot this species. Therefor the climate match score is set to extreme (4).
B2	Established exotic populations Score (0-4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a continent	
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	resident
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	omnivorous
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	2	In million km2: 0 = 0-1, 1 = 2-69, 2 =	Natural distribution is >70 million km2
	B. Establishment Risk Score	**10**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Serious risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores.
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is >70 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal mammal	
C4	Competition with native fauna for nesting space (0-2)	1	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less	
C5	Pest status (0-3)	0	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	
C6	Match to areas with susceptible native species or communities (0-5)	1	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the species (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable species or	
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 = > $50 million	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many	
	C. Pest Risk Score = Som C1-C11 (1-37)	**7**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	7	C. Pest Risk Score	Low risk to become a pest
	VPC threat categorie			**low/moderate**

	Gray Four-eyed Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes (0-2)	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	4	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (exteme).	The situation in Europe suggests that climate is quit suitable fot this species. Therefor the climate match score is set to extreme (3).
B2	Established exotic populations Score (0-4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a continent	
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	resident
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	omnivorous
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	2	In million km2: 0 = 0-1, 1 = 2-69, 2 =	Natural distribution is >70 million km2
	B. Establishment Risk Score	**10**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Serious risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural damage	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the scores.
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is >70 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal mammal	
C4	Competition with native fauna for nesting space (0-2)	1	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less abundant breeding space)	
C5	Pest status (0-3)	1	1 = minor pest, 2 = moderate pest, 3 = major pest (uncluding species with unknown pest status)	
C6	Match to areas with susceptible native species or communities (0-5)	2	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the species (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable species or	
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other domestic animals.
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3 = > $50 million	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many	
	C. Pest Risk Score = Som C1-C11 (1-37)	**9**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	9	C. Pest Risk Score	Moderate risk to become a pest
	VPC threat categorie			**moderate**

	Smaal Fat-tailed Possum			
	Factor	**Score**	**Information**	**Conclusion**
	Stage A: Risks posed by captive or released individuals			
A1.	Risk to people from individual escapes (0-	0	only relates to aggressive behaviour	Not Dangerous
A2.	Risk to public safety from individual captive animals (0-2)	0	about the irrisponsible use of products obtained from captive individuals of the species (e.g. Toxins)	n.a.
	A. Public safety Risk Score	**0**		**Not Dangerous**
	Stage B: Porbability escaped or realeased individuals will establish a free-living population			
B1	Climate match score (1-6)	4	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (exteme).	The situation in Europe suggests that climate is quit suitable fot this species. Therefor the climate match score is set to extreme (3).
B2	Established exotic populations Score (0-4)	0	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or on a	
B3	Taxanomic class score (0-1)	1	0 = bird, 1 = mammal, reptile or amphibian	Mammals, reptiles and amphibians have a larger potention to cause negative effects.
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	resident
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	omnivorous
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Found in undisturbed and human disturbed habitats.
B7	Range size score (0-2)	2	In million km2: 0 = 0-1, 1 = 2-69, 2 = ≥70	Natural distribution is >70 million km2
	B. Establishment Risk Score	**10**	**Low = ≤6; moderate = 7-11; serious = 12-13; Extreme ≥14**	**Serious risk**
	Stage C: Probability an established exotic mammal or bird will become a			
C1	Taxanomic group (0-4)	0	0 = none, 1 = known to hybridise, 2 = within the group that cause agricultural	Bomford (2003, 2006, 2009) mentioned the taxanomic groups belonging to the
C2	Range (0-2)	2	in million km2: 0 = <10, 1 = 10-30, 2 = >30 (including range unknown)	Natural distribution is >70 million km2
C3	Diet and feeding (0-3)	1	0 = not a herbivorous mammal or a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = herbivorous or carnivore an arboreal	
C4	Competition with native fauna for nesting space (0-2)	1	0 = no competition, 1 = minor competition, 2 = strong competition (breeding in tree hollows, less abundant	
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C6	Match to areas with susceptible native species or communities (0-5)	3	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the species (0-5). From 0 (no overlap) to 5 (complete overlap with vulnerable species	
C7	Primary production pest status (0-3)	0	0 = no damage to crops, 1 = minor, 2 = moderate, 3 = major	Is not reported to damage e.g. crops.
C8	Match with susceptible primary production (0-5)	0	Assess potential commodity impact score for each primary production commodity.	No reports of any damage to primary production.
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites and thus can be a risk for livestock or other domestic
C10	Harm to property (0-3)	0	damage to e.d. Buildings, vehicles, fences, road, ornamental gardens. 0 = $0, 1 = $1.000-$10 million, 2 = $11-$50 million, 3	
C11	Harm to people	0	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many fatalities)	
	C. Pest Risk Score = Som C1-C11 (1-37)	**9**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Moderate**
	Factor	**Score**		**Conclusion**
	A. 0 = not dangerous, 1 = moderately dangerous, ≥2 = highly dangerous	0	A. Public safety Risk Score	Not Dangerous
	B. ≤6 = low, 7-11 = moderate, 12-13 = serious, ≥14 = extreme	10	B. Establishment Risk Score	Moderate risk to establishing a wild population
	C. <9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme	9	C. Pest Risk Score	Moderate risk to become a pest
	VPC threat categorie			**moderate**

Appendix 2 Outline of the ISEIA method

Biodiversity.be

Guidelines for environmental impact assessment and list classification of non-native organisms in Belgium.

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Version 2.6 (07/12/2009)

1. Introduction

Harmonia is an information system on non-native invasive species in Belgium, which is developed at the initiative of scientists gathered within the Belgian Forum on Invasive Species (http://ias.biodiversity.be). This system aims at collecting standardised information on exotic species which are assumed to be detrimental to native biodiversity in Belgium. It aims to include a high diversity of taxonomic groups from terrestrial, freshwater and marine environments.

Species included in the system are allocated to different list categories based on a simplified environmental impact assessment protocol (ISEIA), and geographic distribution in Belgium (species invasion stage). Such categorisation offers a scientific background to prioritise actions to prevent introduction and mitigate the impact of invasive species, including the improvement of the legislative framework at the federal and the regional levels. This standard provides detailed instructions about the methodology used for this categorisation.

2. Data source

Information is provided to the system by scientists involved in the Belgian Forum on Invasive Species. As much as possible, data entered in the database refers to the available published literature, which include peer-reviewed journals, books, grey sources (reports, etc.) and on-line databases dedicated to invasive species in Europe. Data from field surveys are also used as they provide important information about the naturalisation of new exotic species in Belgium and their habitat preferences.

Scientific nomenclature refers either to national (e.g. Flora of Belgium and neighbour areas) or international standards (e.g. Fishbase).

3. Species classification in the BFIS list system

A list system designed as a two dimensional ordination (environmental impact x invasion stage) is used to categorise non-native alien species found in Belgium and in neighbour areas, based on the guidelines proposed by the CBD decision VI/7 and the European strategy on Invasive Alien Species (figure 1).

Environmental impact and invasion stage are assessed for each species by different scientists, based on the methodology described hereafter. Results are discussed afterwards within the group to find a consensus before being published on the internet.

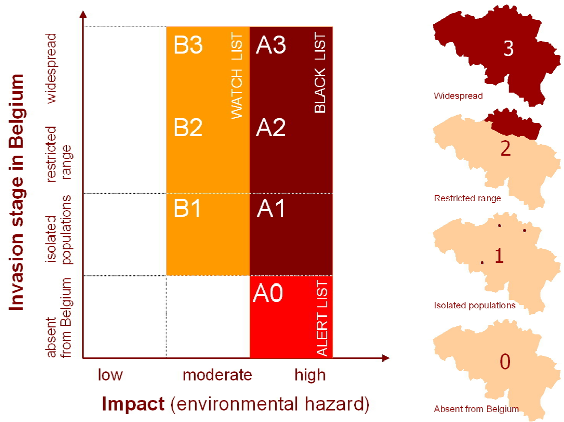

Figure 1 - List system proposed by the Belgian Forum on Invasive Species to identify organisms of most concern for preventive and mitigation actions.

4. Species screening

Not all non-native species are considered to be integrated in the *Harmonia* information system. Only organisms that are already established in Belgium or in neighbour areas characterised by similar eco-climatic conditions (hereafter Western Europe) are taken in consideration. Atlantic and Continental biogeographical regions in Europe (EEA 2005) and hardiness zones 7 and 8 *sensu* USDA definitions, based on the ability of a species to withstand the minimum temperatures of the zone (Cathey 1990) are taken as a reference area. It includes Denmark, Western Germany, Ireland, Luxembourg, Netherlands, Northern France, Southern Sweden, Western Switzerland and UK (see figure 2)[1].

A species is considered as established or naturalised as soon as it is able to reproduce consistently in the wild and sustain populations over several life-cycles through sexual or asexual modes without direct intervention by man (= self-perpetuating populations).

Among the non-native species established in Western Europe, a special attention is given to:

(i) Non-native species that are known to cause adverse impacts on biodiversity and/or ecosystem functioning, including those that already colonised most of their potential habitats;

[1] Non-native species for which there is no evidence of establishment in Western Europe should be evaluated using additional criteria to assess likelihood of introduction and establishment in this area (see e.g. Baker et al. 2005 and EPPO 2006).

(ii) Species that recently expanded their geographic range, for which an adverse impact on biodiversity and/or ecosystem functioning is likely.

A

B

Figure 2 – The reference area used in the ISEIA protocol covers the Atlantic and Continental biogeographical regions (map A after EEA 2005) and the USDA hardiness zones 7 and 8 in Europe (map B after Cathey 1990).

5. Methodology for environmental hazard assessment

A simplified hazard assessment methodology referred to as the Invasive Species Environmental Impact Assessment (ISEIA) was developed to classify non-native species into the BFIS list system and to identify those of most concern for preventive and mitigation actions.

This protocol is intended to allocate non-native species within the different hazard categories of the *Harmonia* information system, as an attempt to minimise the use of subjective opinions and to warrant the transparency and the repeatability of the assessment process (Daehler et al. 2004). The ISEIA protocol consists of four sections matching the last steps of the invasion process, i.e. potential for spread, colonisation of natural habitats and adverse ecological impacts on native species and ecosystems. It has to be noted that this protocol aims to assess environmental risks only and that direct impacts of non-native species on human interests (public health, plant protection, etc.) are not explicitly taken in consideration in the *Harmonia* system, even if adverse ecological impacts frequently induce economic damages in the long term.

Contrary to predictive pest risk assessment protocols mainly based on species' intrinsic attributes for evaluating invasion likelihood (e.g. EPA, EPPO and IPCC standards), the ISEIA approach favours the use of documented invasion histories in previously invaded areas of Western Europe to assess properly their potential to cause adverse ecological effects on the Belgian territory (non native species are likely to cause significant impacts on native species and ecosystems in Belgium if they already proved to do so in neighbour areas).

The ISEIA protocol allows to allocate species in one of the three following risk categories:

- Category A (black list): includes species with a high environmental risk;
- Category B (watch list): includes species with a moderate environmental risk on the basis of current knowledge;
- Category C: includes other non-native species, that are not considered as a threat for native biodiversity and ecosystems (low environmental risk).

Scoring system

A three point scale is selected for the assessment as it is felt to provide an adequate balance between resolution and simplicity. Providing that information exists and is well documented in the literature (low level of uncertainty), the following scores are used as much as possible for the different parameters,:

- L = low, score = 1
- M = medium, score = 2
- H = high, score = 3

When the parameter is only poorly documented, leading assessment to be based only on expert judgement and field observations, the scoring system is adapted as follows:

- Unlikely, score = 1
- Likely, score = 2

At last, when nothing can be said about the parameter (no information):

- DD = deficient data, no score.

5.1 Dispersion potential or invasiveness

This section addresses the potential of an organism (individuals, seeds, propagules, etc.) to spread in the environment by natural means and/or by human assistance, as a function of dispersal mode, reproduction potential and human commensalism.

The three following situations are recognised:

Low risk. The species doesn't spread in the environment because of poor dispersal capacities and a low reproduction potential. Examples: *Aesculus hippocastanum*, *Zea mays*.

Medium risk. Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential. Examples: *Ameiurus nebulosus, Arion lusitanicus, Robinia pseudacacia, Tamias sibiricus*.

High risk. The species is highly fecund, can easily disperse through active or passive means over distances > 1 km/year and initiate new populations. Are to be considered here plant species that take advantage of anemochory (*Senecio inaequidens*), hydrochory (*Ludwigia grandiflora*) and zoochory (*Prunus serotina*), insects like *Harmonia axyridis* or *Cameraria ohridella* and all the bird species.

5.2 Colonisation of high conservation value habitats

This addresses the potential for an exotic species to colonise habitats with a high conservation value (irrespective of its dispersal capacities), based on habitat preference information from native and invaded areas. This potential is mainly limited by the ability of the new species to establish in habitats with specific abiotic conditions and to outcompete native species that are already present ('biotic resistance').

Habitats with a high conservation value are those where disturbance by man is minimal, thus allowing specific natural communities and threatened native species to occur. Natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers and ponds provided with natural banks and estuaries (see e.g. the list of natural habitats in the Annex 1 of the 92/43/EEC Directive) are considered as habitats with a high conservation value. Parks, orchards, planted forests, fallow lands, road embankments are habitats with an intermediate value. At last, man-made habitats like channels, farmlands or urban areas are classified as sites with a low conservation value.

Scoring system (adapted from the invasive categories of Cronk & Fuller 1995):

Low risk. Populations of the non-native species are restricted to man-made habitats (low conservation value). Examples: *Linepithema humile*, *Setaria verticillata*;

Medium risk. Populations of the non-native species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation value habitats. Examples: *Lepomis gibbosus, Sander lucioperca, Solidago gigantea*;

High risk. The non-native species often colonises high conservation value habitats (i.e. most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species. Examples: *Ludwigia grandiflora*, *Lysichiton americanus*, *Procyon lotor*, *Spartina townsendii*, *Umbra pygmaea*.

5.3 Adverse impacts on native species

This section addresses the potential of exotic species to cause species replacement through different mechanisms. Impacts may include (i) predation/herbivory, (ii) interference and exploitation competition (including competition for plant pollinators), (iii) transmission of diseases to native species (parasites, pest organisms or pathogens) and (iv) genetic effects such as hybridisation or introgression with native species. Such interactions may lead to change in native population abundance or in local extinction. They should be documented from invasion histories within Belgium or other regions characterised by similar eco-climatic conditions.

Exotic species that act as generalist predators or those which have native congeners showing similar eco-morphological traits are especially on target. The different types of interactions are considered separately for each non-native species. Their severity is scored as follows:

Low risk. Data from invasion histories suggest that the negative impact on native populations is negligible;

Medium risk. The non-native species is known to cause local changes (< 80%) in population abundance, growth or distribution of one or several native species, especially among common and ruderal species. This effect is usually considered as reversible. Examples: transmission of sublethal diseases to native species (*Crassostrea gigas, Mustela vison, Sander lucioperca*), predation/herbivory pressure leading to abundance decrease of native species (*Branta canadensis, Nysius huttoni*), moderate competition with native species (*Pimephales promelas, Senecio inaequidens*);

High risk. The development of the non-native species often cause local severe (> 80%) population declines and the reduction of local species richness[2]. At a regional scale, it and can be considered as a factor precipitating (rare) species decline. Those non-native species form long-standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals (*Fallopia japonica, Prunus serotina, Solidago spp*., etc.), intraguild predation leading to local extinction of native species (*Dikerogammarus spp., Harmonia axyridis, Neogobius melanostomus, Rana catesbeiana*), transmission of new lethal diseases to native species (*Pacifastacus leniusculus, Pseudorasbora parva, Rana catesbeiana, Sciurus carolinensis*).

Species impact score = maximal score recorded for predation/herbivory, competition, disease and genetic interaction sections.

5.4 Alteration of ecosystem functions

This section addresses the potential of an exotic species to alter native ecosystem processes and structures in ways that significantly decrease native species ability to survive and reproduce. Ecosystem impacts may include (i) modifications of nutrient cycling or resources pools (e.g. eutrophication), (ii) physical modifications of the habitat (changes or hydrologic regimes, increase of water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications of natural successions and (iv) disruption of food webs, i.e. a modification of lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

Scoring system:

Low risk. The impact on ecosystem processes and structures is considered as negligible.

Medium risk. The impact on ecosystem processes and structures is moderate and considered as easily reversible. Examples: temporary modification of soil or water properties (*Lemna spp*.), decrease or increase of the rate of colonisation of open habitats by shrubs and trees (*Pinus nigra*);

High risk. The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alteration of physico-chemical properties of water by invasive aquatic plants (*Hydrocotyle randunculoides, Ludwigia spp., Myriophyllum aquaticum*), facilitation of river bank erosion (*Impatiens glandulifera*), prevention of natural regeneration of trees (*Lonicera japonica, Prunus serotina, Rhododendron ponticum*), destruction of river banks, reed beds and/or fish nursery areas (*Eriocheir sinensis, Myocastor coypus, Ondatra zibethicus*), food web disruption (*Crassostrea gigas*, *Lates niloticus*).

Ecosystem impact score = maximal score recorded for nutrient cycling, physical alteration, natural successions and food web sections.

Note: When impact is strongly dependent on the type of ecosystem, one should consider the worst case scenario, with a special focus on vulnerable ecosystems.

[2] Exotic plants that are known to often form large and dense monospecific stands are considered as a high risk for native plant communities when the potential for species replacement is poorly documented.

5.5 Global environmental risk

Consistent with other risk assessment standards, equal weight is assigned to each of the four sections, i.e. dispersion potential, colonisation of natural habitats, species and ecosystem impacts. The global ISEIA score is the sum of risk rating scores from the four previous sections (global score is between 4 and 12). It is used to allocate species to the different risk categories (see table).

ISEIA score	List category
11-12	A (black list)
9-10	B (watch list)
4-8	C

6. Invasion stage in Belgium

In addition to species classification in risk categories, invasion stage is also taken in consideration in the list system as it provides important information to prioritise actions in the field, especially for invasive species which are highly detrimental.

As illustrated in figure 1, a distinction is made between:

(i) Alert list species: species that are not yet naturalised in Belgium but are invasive in neighbour areas. Note that only species with a high environmental impact among non established species are taken in consideration, e.g. organisms from the list of worst invasive alien species threatening biodiversity in Europe (SEBI 2010) or from the priority list of invasive alien plants to be managed in EPPO member countries. Importation and trade regulation are the adequate tools to avoid intentional introduction of alert list species in our country;

(ii) Species under naturalisation (isolated populations): species that are at the prime stage of the invasion process in Belgium, that only form recent and small isolated populations located in the immediate vicinity of their introduction points, resulting in a non contagious or random distribution of the observations. These species only colonised few of their potential habitats in the country and can still be eradicated at a national scale at a very low cost corresponding to the damage they can cause in the future if no action is undertaken;

(iii) Naturalised species with a restricted range: species whose populations are in strong expansion in the wild and form new populations far away from their introduction points after an active dispersion phase, but whose distribution is still limited to some biogeographic areas in Belgium. Those species are likely to be contained in some regions of the country providing that active control measures are undertaken;

(iv) Widespread naturalised species: species that are widely distributed in the country and that already colonised most of suitable sites for their establishment.

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8. References

Andersen M.C., Adams H., Hope B. & Powell M., 2004 – Risk assessment for invasive species. Risk analysis 4: 787-793.

Baker R., Hulme P., Copp G.H., Thomas M., Black R. & Haysom K., 2005 – Standard methodology to assess the risks from non-native species considered possible problems to environment. DEFRA.

Branquart E, Baus E, Pieret N, Vanderhoeven S & Desmet P (eds), 2006 - SOS invasions, Conference 09-10 March 2006, Brussels. Abstract book. 76 pp.

Cathey H.M., 1990 - USDA plant hardiness zone map. USDA, Washington D.C.

Copp, G.H., Garthwaite, R. and Gozlan, R.E., 2005. Risk identification and assessment of non-native freshwater fishes: concepts and perspectives on protocols for the UK. Sci. Ser. Tech Rep., Cefas Lowestoft, 129: 32pp.

Cronk Q.C.B. & Fuller J.L., 1995. Plant invaders : the threat to natural ecosystems, Chapman & Hall, London, 241 pp.

Daehler C.C., Denslow J.S., Ansari S. & Kuo H.C., 2004 – A risk assessment system for screening out invasive pest plants from Hawaii and other Pacific islands. Conservation Biology 18: 360-368.

EEA, 2005 – Indicative map of the European biogeographical regions.

EPPO, 2006 – EPPO standards: guidelines on Pest Risk Analysis, PM 5/3 (2).

Genovesi P. & Shine M.C. 2003 – European strategy on invasive alien species. Europe Council, Convention on the conservation of European wildlife and natural habitats.

Lockwood J.L., Hoopes M.F. & Marchetti M.P., 2007 – Invasion ecology. Blackwell Publishing, 304 pp.

Park K., 2004 – Assessment and management of invasive alien predators. Ecology and Society 9(2): 12.

Parker IM., Simberloff D. & Lonsdale W.M., 1999 – Impact: toward a framework for understanding the ecological effects of invaders. Biological invasions 1: 3-19.

Ricciardi A. & Cohen J., 2007 – The invasiveness of an introduced species does not predict its impact. Biolgical Invasions 9: 309-315.

Ricciardi A., Steiner W.M., Mack R.N. & Simberloff D., 2000 – Toward a global information system for invasive species. Bioscience 50(3): 239-244.

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD & West CJ, 2000 Naturalization and invasion of alien plants: concepts and definitions. *Biodiversity and Distributions* 6:93-107.

Simberloff D., 2005 – The politics of assessing risk for biological invasions: the USA as a case study. TREE 20(5): 216-221.

Weber E., Köhler B., Gelpke G., Perrenoud A. & Gigon A., 2005 - Schlüssel zur Einteilung von Neophyten in der Schweiz in die Schwarze Liste oder die Watch-Liste Botanica Helvetica 115: 169-194.

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