The raccoon dog (*Nyctereutes procyonoides*) in the Netherlands – its present status and a risk assessment

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Abstract: The raccoon dog (*Nyctereutes procyonoides*) was introduced from East Asia into the former USSR between 1928 and 1957. Since then it has colonised a large part of Europe and is considered an invasive alien species. An earlier paper (Mulder 2012) reviewed the current knowledge about its ecology. This paper deals with its present status in the Netherlands and provides an assessment of its ecological and human health risks. The colonisation of the Netherlands by the raccoon dog started from north-west Germany about 15 years ago. The pattern of colonisation is blurred by the occurrence of individuals escaping from captivity. Up until 2013 'wild' raccoon dogs were probably recorded exclusively in the north-eastern part of the country. This is in accordance with the distribution in Germany. It seems inevitable that the raccoon dog will colonise the whole territory of the Netherlands in the future, maybe with the exception of the islands in the Wadden Sea. Its general impact on biodiversity is expected to be small. Isolated populations of amphibians, however, may be at risk, as may ground breeding birds in marshes. Raccoon dogs may increase the occurrence of diseases and parasites, of which *Trichinella spiralis* and the small fox tapeworm *Echinococcus multilocularis* probably constitute the most important health risks for humans. The options for effectively managing raccoon dogs are limited; only local and intensive measures of control or predation prevention may have the desired effect.

Keywords: raccoon dog, *Nyctereutes procyonoides*, wasbeerhond, risk assessment, distribution, colonisation, the Netherlands, invasive species, management.

Introduction

In October 2007 the Dutch government published its policy on invasive species (Document 20071012-dn-2007-2899.pdf). According to the definition set out in this document an invasive species is an organism which arrives from elsewhere with the aid of humans (by transport or infrastructure) and which is a successful coloniser (by reproduction and population growth). In accordance with the agreements in the Convention on Biological Diversity (Rio de Janeiro 1992) a succession of policies should be applied to control invasive species: prevention of their arrival, eradication when their populations are still small, and isolation and control management when populations have grown too large to eradicate. The intensity of control measures depends on the impact the invasive species is expected to have on biodiversity and human health and safety. In the Netherlands the Invasive Species Team (TIE) of the Ministry of Economic Affairs has the task to advise the Minister on all issues of invasive species. The TIE collects and publishes information, conducts risk analyses for invasive species and recommends measures for the prevention, control and management of such species. The risk assessment for the rac-

coon dog was published as an extensive report (Mulder 2011) and an earlier paper reviewed the raccoon dog's ecology in Europe (Mulder 2012). The present paper deals with the history and present situation (as of January 2013) of the raccoon dog in the Netherlands, and also contains a concise risk assessment. It ends by discussing the management options.

Two earlier publications have dealt with the raccoon dog in the Netherlands and the possible risks it poses (Oerlemans & Koene 2008, van Dijk & de Koning 2009). However, these publications were based on a limited selection of the literature, and did not contain an evaluation and analysis of the raccoon dog observations in the Netherlands.

Distribution

To evaluate the history and present situation of the raccoon dog in the Netherlands, all records of raccoon dog sightings until 1 January 2013 were collected and screened. This exercise drew on the available scientific literature, hunting journals and various databases (Alterra, Dutch Mammal Society, Telmee.nl, Waarneming.nl, Yvette van Veldhuijsen (a private individual with a keen interest in raccoon dogs), the Royal Dutch Hunters Society and the AAP Foundation, a rescue centre and sanctuary for primates and other exotic animals). Efforts were made to collect previously unreported observations, through appeals in hunting journals and on the internet. Many of the original observers were contacted by telephone or email and questioned. Observers were asked for their experience with wildlife in general, and with red foxes (*Vulpes vulpes*) and badgers (*Meles meles*) in particular. Details of the way of walking and other behaviour of the observed animal were asked for, as well as the colours of the pelt and the relative length of legs and tail. Most observations by hunters and naturalists could be accepted. Many observations by less experienced people were, however, too vague or incomplete to accept as certain or probable. If observers mentioned having thought of a raccoon (*Procyon lotor*) when they observed the animal, this was taken as a positive sign. The vast majority of the records could thus be validated in four categories: 'certain', 'probable', 'possible' and 'not likely'. All records which could not be verified with additional information, were placed in the 'possible' category. The resulting database has been submitted to the National Authority for Nature Data.

Of course the validation of others' observa-

Raccoon dogs deposit their faeces in concentrated latrines along their routes. *Photo: J.L.Mulder.*

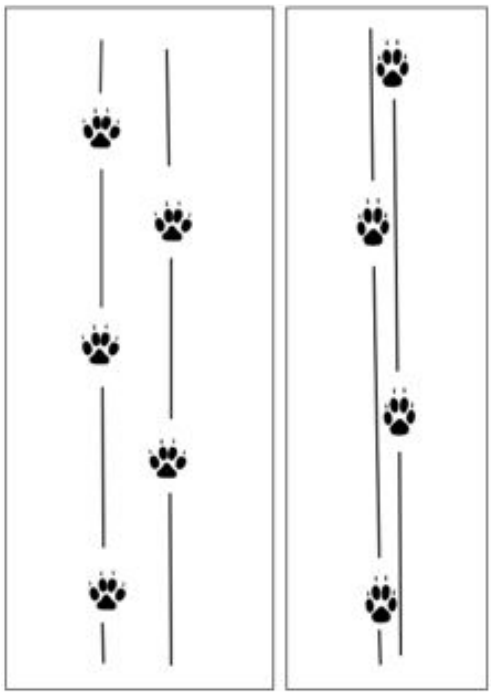

Figure 1. Tracks of raccoon dog (left) and red fox, the former with more rounded prints and with the left and right feet spaced further apart.

Figure 2. Front paw of the raccoon dog, showing the connection between the inner toes. *Photo: Annemarie van Diepenbeek.*

tions is ridden with the subjectivity of the validator. It is impossible to use objective criteria, and the dividing line between the categories cannot be clearly defined. Dead animals pose no problem for identification. Sometimes photographs were made of the animal or the tracks it left in mud or snow, making validation easy for an expert. Footprints were only accepted as proof if they were clearly round and not elongated (as in the red fox), and if the prints of left and right feet were spaced apart instead of placed in almost one line (figure 1). Pictures of prints showing the connection between the caudal part of the two central toes were taken as definitive proof (figure 2). This feature is only visible in sharp prints in mud or clay. Less sharp prints are similar to those of small domestic dogs, and can only be taken as produced by a raccoon dog if the presence of a domestic dog can be absolutely excluded. Until 2013 there were, however, no records based exclusively on prints or other signs (only in connection with an observation of an animal), except for one winter-record of a den with a latrine at five metres distance; this observation was judged 'probable'.

Escaping raccoon dogs

The first raccoon dog in the Netherlands was observed in April 1981 in the south-east of the country, in the Province of Limburg (Vergoossen & Backbier 1993). The animal did not seem to be very shy, and may well have escaped from captivity or been deliberately set free. That is all the more likely since the first raccoon dogs in north-eastern Germany (at a distance of 600 km from Limburg) were recorded only 15 years earlier, and it was another ten years before the next raccoon dog was recorded in the Netherlands. This second animal was

Table 1. Known cases of escaping raccoon dogs. Sources: Yvette van Veldhuijsen (third and fourth case) and own research.

Date	Place	Number, sex, etc.	How escaped	What happened next
ca 1997	Speuld, Veluwe, children's farm	Halfgrown male and female	Unknown	Recovered from a fire wood shed in the next village, Putten (5 km away). After some weeks spent with a private individual they were returned to the children's farm.
2001	Gangelt (D), Zoo Hochwild Freigehege, on the Dutch/German border, east of Sittard.	Adult male and female	Unknown	Male was killed on an adjacent road on the night of the escape
August 2002	Private house in Enschede	Yearling male and female, brother and sister	Over a garden fence with horizontal wooden beams	Unknown; no road kills shortly thereafter, but one in autumn 2003
September 2002	Private house in Ingen, Betuwe (Gld)	Two yearling animals	One via a small table through an open window. The other some days later by biting through mesh wire	On 12 October 2002 a young female was found as a roadkill near Wijk bij Duurstede. 9 km away on the other side of the river Rhine. During the autopsy it was suspected of being an escapee.
April 2010	Children's farm Dondertman in Espelo, Holten, Overijssel	Adult male and female, female pregnant	Children left the door of the pen open	Male was killed on the road within 800 m and within a few days, on 26 April 2010.
Autumn 2010	It Schildhus Animal Rescue Asylum, Goengarijp, Friesland (specialising in turtles)	White sterilized adult female and normally coloured neutered adult male. Had been previously kept by private person in Utrecht province.	Were kept in a stable	The white female was shot on 13 November, 5 km away. The male was probably spotted on 11 November, 2-3 km away
ca 10 June 2011	Private person in Egmond-Binnen, Noord-Holland who had already been keeping raccoon dogs for ten years	Two males born in 2010. The third raccoon dog present did not escape.	Over a fence, via the collapsed roof of a dog house	One was killed on the adjacent road 800 m away on 17 June 2011. The other was seen on 20-21 August in Heiloo, around 3 km away, in a chicken coop

found dead by a road east of the town of Groningen (in the north-eastern corner of the Netherlands) in February 1991, and may have been the first 'wild' raccoon dog in the Netherlands (Mulder & Broekhuizen 1992).

Raccoon dogs are sometimes kept as pets, indoors as a domestic dog or outdoors in a kennel or behind fencing. There is no commercial farming of raccoon dogs in the Netherlands. They are rather easy to keep, eat virtually anything, hardly make any noise and deposit their faeces in the same spot. Advertisements offering young or adult raccoon dogs are not uncommon in animal journals or on the internet. It is not known how many people keep raccoon dogs in the Netherlands, but it may be in the order of fifty or more. Although a one metre high fence is enough to contain raccoon dogs (Stier 2006), it appears that escaping animals are not rare, mostly through the negligence of the owners. Seven such cases have been documented (table 1), all regard-

ing two animals each. In four of these seven cases a road killed raccoon dog was found in the vicinity shortly afterwards, and in one case an animal was shot by a hunter. This last animal certainly was the escapee in question, for it was a white sterilised female. Five of the recovered escapees were found within 0.5 to 9 km and within one month of the time of escape; one was killed on the road on the same night it escaped.

These escaped raccoon dogs may blur the pattern of colonisation in the Netherlands. Isolated observations, far away from the majority of the other observations, may indicate such escapees. Proof, however, is rarely available. Sometimes it is obvious from the behaviour of a raccoon dog that it is an escapee: such individuals show no fear of people: it is possible to come within a few metres, or even less, of them. When such behaviour had been reported, or a connection with a known escape was clear, the record was classified as an 'escapee'.

Observations

After validation of all the observations of raccoon dogs until 1 January 2013 the database contained 173 records (excluding the category 'not likely'), of which 77 were certain, 43 were probable and 53 were possible. In the three categories a total of 11, 6 and 1 records respectively were obvious escapees. Figure 3 shows maps of the Netherlands with all these raccoon dog observations, separated into two periods. The majority of observations were made in the north-eastern half of the country, in the Provinces of Groningen, Drenthe, Friesland and Overijssel, and in the Noordoostpolder, a distribution which accords very well with the species' distribution in Germany (figure 4). Most of the records outside this area (indicated with a dashed line in figure 3) could be escaped animals. The Veluwe area (shown as an oval in figure 3), which is far from the German border, is interesting in this respect. Raccoon dogs started to be reported from the Veluwe relatively early (1993) and have continued to be sighted. From their behaviour, at least three of the observed animals were clearly escaped animals. In addition, several people in the region were known to have raccoon dogs as pets. I therefore consider all the raccoon dog records from the Veluwe (until now) as observations of escaped animals.

Focussing on the north-eastern corner of the country only (with 55 certain, 24 probable and 24 possible observations) and excluding the clear escapees, the pattern of raccoon dog observations over time becomes clear (figure 5). After three isolated observations in the early 1990s, there have been continuous observations of raccoon dogs every year since 2001. In north-east Germany the first raccoon dogs were seen in 1964. That means that the raccoon dog has crossed the distance to the Netherlands in 37 years, at an average speed of 13 km/year. Since 2001 roughly 3 to 8 raccoon dog observations have been recorded in the Netherlands each year, with a maximum of 11-15 in 2006. Most probably however, many raccoon dogs go undetected. The Netherlands apparently has reached the stage of irregular, sporadic but steady observations of raccoon dogs. In other countries this period lasted 20-30 years before the population started to grow exponentially (Mulder 2012). This is in keeping with the apparent lack of reproduction in the Netherlands so far. With their preference for badger setts the pups of raccoon dogs or their signs (latrine) are likely to be easily detected by badger watchers and hunters; up till now no such observations have been reported. Based on the temporal pattern of raccoon dog colonisation in other countries, the exponential growth period may be expected roughly to begin around the year 2025. By 2035 the raccoon dog may be a common inhabitant of the Netherlands.

At present it is unclear how the (probably rather lonely) raccoon dogs behave. Some animals apparently settle for a while in a limited area and are spotted several times. In 2003 a raccoon dog seems to have spent an entire

A

B

Figure 3. All records of raccoon dogs in the Netherlands. Left: until 1 January 2006. Right: between 1 January 2006 and 1 January 2013. The observations from within the oval (Veluwe) are all considered escapees from captivity. The records north-east of the dashed line are mostly considered to be natural colonisers and are used as the basis of figure 5. The records south-west of the dashed line probably all relate to escaped animals, at least before 2006. Black dot: certain; black triangle: probable; open triangle: possible; cross: certainly or most probably an escaped animal.

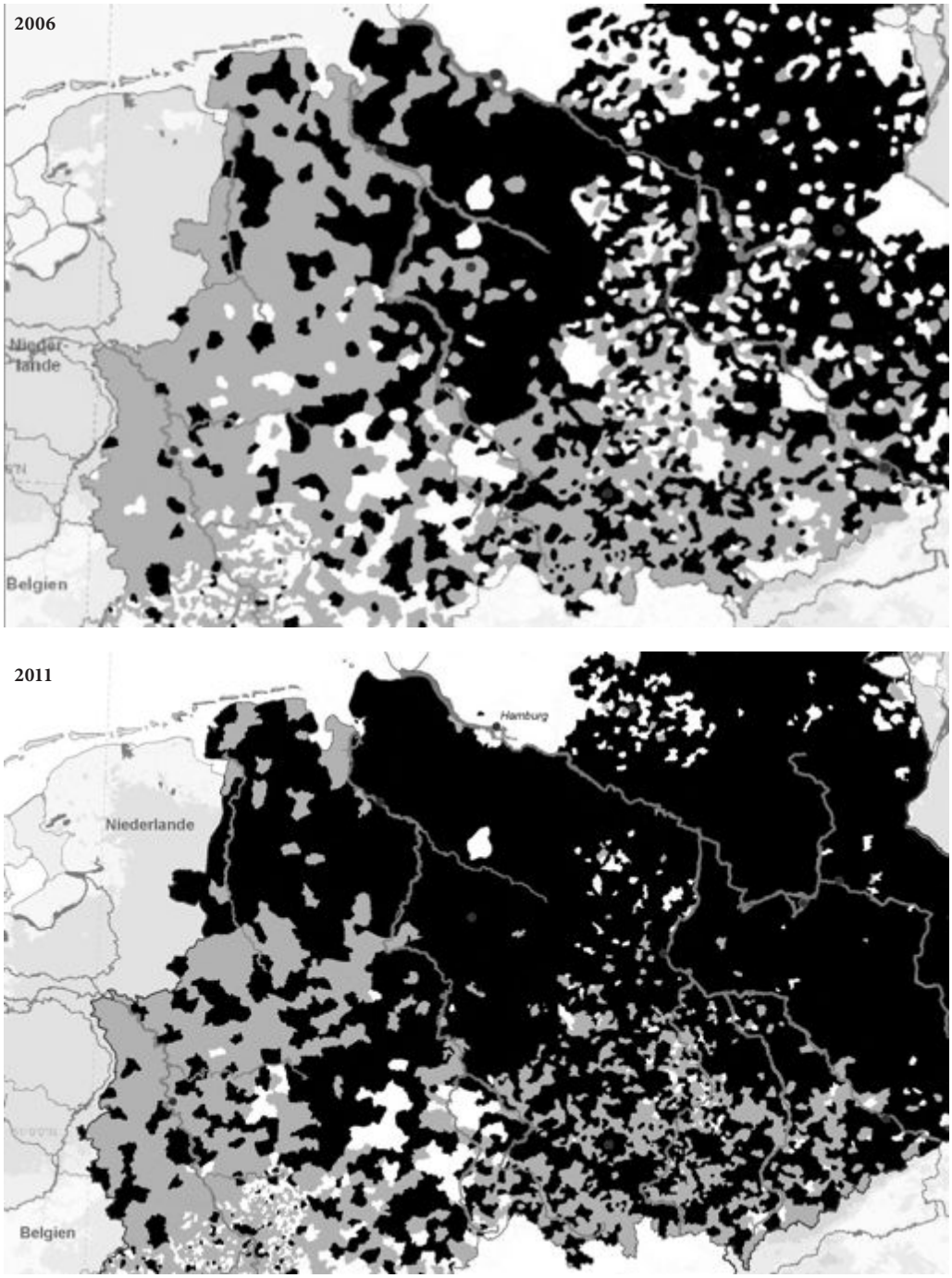

Figure 4. Distribution of the raccoon dog in Germany, by municipality, according to a repeated inquiry among hunters, by the German project WILD. Black: at least one observation. Grey: no observations. White: no data. Upper map: 2006. Lower map: 2011 (adapted from: http://medienjagd.test.newsroom.de/wild_2011_low_rz_neu.pdf).

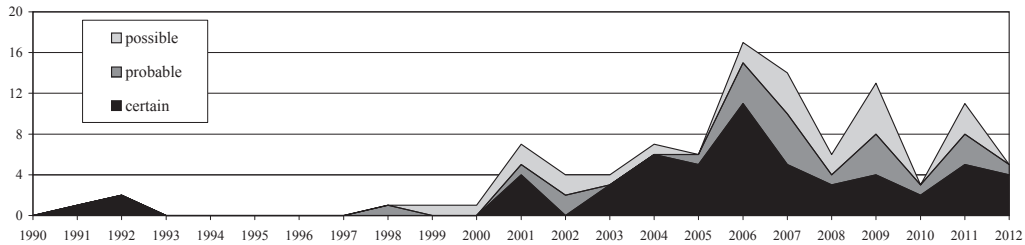

Figure 5. All observations of the raccoon dog in the north-eastern part of the Netherlands (see figure 3) since 1990, grouped in three classes of certainty. Apparent escapees have been excluded.

summer at a tree nursery near Steggerda, Province of Friesland; it was last spotted in November. Another example is a raccoon dog which was seen on 29 May 2011 in Saeftinghe, in tidal salt marshes in the south-west of the Netherlands, far from any other raccoon dog observation. Its tracks in the mud were found at least eight times throughout the summer, for the last time on 25 August (see photo on page ...). Despite many visits to the area, no tracks were found thereafter (personal communication, M. Buise). Other raccoon dogs probably roam the country. On a permanent feeding station (under video surveillance) for wild boar (*Sus scrofa*), badgers and foxes in the Veluwe area, a raccoon dog showed up only once, in December, which suggests that it had not settled there.

Considering the same raccoon dog observations as in figure 5 (for the north-eastern part of the country, excluding escapees) but taking into account only the 'certain' and 'probable' categories (*n*=79), the methods of observation were as follows: observed in the field (*n*=38), killed on the road (*n*=24), killed by a harvesting machine (*n*=7), shot (*n*=4), caught alive and killed (*n*=2) and drowned (*n*=1). In three cases the details of observation were not exactly recorded. Crops in which raccoon dogs were killed, were beets (*n*=4) and maize (*n*=3). Observations of live animals in the field were often made in the headlights of a car (*n*=11), during lamping (fox shooting with a spotlight, *n*=6) or during daylight hunting (*n*=4). Once (and twice outside the north-eastern part of the country) a raccoon dog was captured on photo by an automatic wildlife camera. Two dead raccoon dogs (one traffic victim, one drowned) appeared to be juvenile; they were collected on 12 and 30 August, in Stiens (Province of Friesland) and Delden (Province of Overijssel) respectively. They most probably are examples of early dispersers, from Germany (see Mulder 2012). Alternatively, they may have been born in the Netherlands; however, if reproduction was already occurring here and there, more juvenile traffic victims, and observations of pups should be expected (see above). Of the few animals which were sexed, ten were males and two were females. Two raccoon dogs were observed together on four occasions (in the years 2001, 2007, 2011 and 2012); the first pair

Footprints of the raccoon dog observed in the salt marshes of Saeftinghe, summer of 2011. The pencil is 10 cm long. The connection between the two front toes is clearly visible. *Photo: Stefaan Thiers.*

Many of the reliable records of raccoon dogs are traffic victims. *Photo: J.L.Mulder.*

were found as traffic victims on consecutive nights, only 50 m apart, the other three were field observations of two animals close to each other.

In conclusion, the raccoon dog is presently regularly but sporadically observed in the north-eastern half of the Netherlands, in accordance with its distribution in Germany. Every year between about three and eight certain or probable observations are reported. Elsewhere it is still very rare, and most of the raccoon dogs recorded in the south-western half of the country probably escaped (or were deliberately set free) from captivity.

Risk assessment of the raccoon dog in the Netherlands

Probability of arrival and establishment

The analysis of the raccoon dog observations in the Netherlands shows that the first observation of a raccoon dog, which probably dispersed from Germany, occurred in 1991. Considering the present colonisation speed of the raccoon dog in Germany, the lack of potential barriers (i.e. mountain ranges) and the presence of suitable habitats in the Netherlands, it is likely that the raccoon dog will continue with its westward colonisation by dispersal and eventually become established in the whole of the Netherlands. Raccoon dogs have a high dispersal and reproduction potential which, in the Netherlands, will not be adversely affected by predators or diseases (see below). The climate matches that of regions where it has already successfully invaded large areas (for instance the north-east of Germany, with an average annual temperature of 9.7 °C, ranging from a mean of 0.8° C in January to a mean of 18.2 °C in July), so the raccoon dog has the potential to be a truly invasive alien species.

Almost all of the Dutch territory is suitable, or even very suitable, for raccoon dogs. Only the built-up areas will probably not be occupied by the species. Research from elsewhere in Europe indicates that resident raccoon dogs

avoid settlements and have not been observed to cross villages, even when these were located in the middle of their home range (Drygala et al. 2008). The numerous wetlands in the low-lying north and west of the Netherlands, as well as wet areas in the rest of the country, will probably harbour a dense population of raccoon dogs in the future. Areas of higher ground, that have badger populations and adjoin marshy areas with lots of dense cover (reeds, willow and alder thickets) will probably constitute the optimal habitat, with a maximum of two adults.km^{-2} locally in the most varied landscapes (Kauhala et al. 2006). Less favoured habitats will be large predominantly pine and fir forests and plantations (such as the Veluwe) and large scale agricultural areas (such as most of the Flevopolders). The presence of enough cover, in the form of dense vegetation, is very important for the raccoon dog. Average pre-breeding population density over large suitable areas will probably be between 0.5 and 1.0 adults.km^{-2}.

Impact on native predators

The raccoon dog is an omnivorous, medium-sized predator whose ecology has shared aspects with several native and non-native predators: badger, red fox, polecat (*Mustela putorius*) and American mink (*Mustela vison*). Since the American mink is a non-native species itself, and nothing is known about its relations with the raccoon dog, the species of interest here are badger, red fox and polecat. Impacts can occur as a result of interference competition or resource competition (Pianka 1978). Raccoon dogs rarely seem to directly interfere with badgers (Mulder 2012). Raccoon dogs may kill badger cubs (Sidorovich 2011) but the reverse, badgers killing raccoon dog pups, may be more common (Kowalczyk et al. 2008). Once an adult raccoon dog was observed which had died of wounds on its back most probably inflicted by a badger (Drygala 2009). Indirect interference of raccoon dogs with badgers is suspected to be contributing to the decline of the badger population in central Belarus. Several dead badgers were found in their setts during winter, which apparently had died of suffocation: raccoon dogs often hibernate in badger setts and block almost all the entrances (Sidorovich 2011). In the mild winters in the Netherlands this will be less of a problem. Interference with foxes probably is much more common and both species occasionally kill cubs of the other species. In north-east Germany fox numbers (measured as the number of foxes shot annually) decreased in the first period after the arrival of the raccoon dog, but this effect disappeared later (Zoller 2006). An increase in the infection rate of sarcoptic mange (see below), which is more common in raccoon dogs, might have been responsible for this temporary decline in the fox population. Drygala (2009) concludes that in Europe competition between raccoon dog, red fox and badger might take place, but that it is unlikely that the competition is very severe or leads to a significant decrease of either species.

In northern Belarus, an area with severe winters, the strong increase of the raccoon dog population coincided with a strong decrease in polecat numbers in two study areas, and with a decrease in pine marten (*Martes martes*), red fox and brown bear (*Ursus arctos*) in one of the two study areas. The mechanism behind the impact of raccoon dogs on other generalist predators is thought to be the effective exploitation of available carrion by raccoon dogs in early winter, resulting in a lack of food for the other predators in late winter; a classic example of resource competition (Sidorovich et al. 2000). In the Netherlands such a competition over carrion seems unlikely, except perhaps with the raven (*Corvus corax*). However, some resource competition between raccoon dog and polecat might be feasible, especially with regard to amphibians. Both polecat and raccoon dog, although generalist predators, have a clear preference for amphibians.

Impact on prey species

Raccoon dogs forage while slowly walking, mostly in dense vegetation. They do not 'hunt' like foxes, chasing their prey species. Upon encountering bird nests, they will eat the eggs and chicks, but only rarely the adult breeding bird (Mulder 2012). However, remains of eggs in raccoon dog stomachs are rare in diet studies. According to most authors, the added impact (on top of the impact of native predators such as the red fox) of the raccoon dog on the breeding success of ground nesting birds will probably be negligible. However, solid research into the impact of the raccoon dog on its prey species is still lacking. The predictions in this section are thus mainly based on expert judgment.

Bird colonies in wetlands (e.g., greylag goose (*Anser anser*), black-headed gull (*Croicocephalus ridibundus*)) might be especially vulnerable to raccoon dog predation; as a raccoon dog can possibly destroy many nests in a short time. For the Netherlands, with its many low-lying wetland areas, including many Natura 2000 areas, the most vulnerable species will probably be the purple heron (*Ardea purpurea*), the black tern (*Chlidonias niger*) and the solitary bittern (*Botaurus stellaris*). Although the red fox has already (in recent decades) arrived in most of these wetlands, the raccoon dog may pose an added threat because of its greater readiness to swim. The species mentioned above are possibly at risk and measures to prevent predation by raccoon dogs may be necessary in the future.

The raccoon dog's preference for amphibians may lead to local declines of more or less isolated populations of toads, frogs and possibly newts, for instance in and around cattle drinking ponds in the dryer east and south of the Netherlands. Raccoon dogs also forage on grass snakes (*Natrix natrix*) (Drygala 2009), and might be a threat to isolated populations of this species as well. The common practice of protecting amphibians from being killed on the road in spring, by erecting fences and catching the animals in buckets during the night, may in the future attract the unwelcome attention of raccoon dogs, seeking to gather an easy meal from the buckets (Puffpaff 2008).

Viruses and parasites

The raccoon dog can play a role in the transmission of several infectious diseases, including parasitic diseases, to other species and/or to humans. As far as is known there are no new viruses or parasites imported by raccoon dogs to Europe, however, they may act as a reservoir for several pathogens already present in Europe. Rabies, caused by the classic rabies virus, is an important disease in canids. Until the introduction of the raccoon dog, the red fox was by far the main reservoir and vector of rabies in Europe. That situation has now changed. In Estonia about 50% of wildlife rabies cases were raccoon dogs (WHO 2004 as cited in Kauhala et al. 2007). During the rabies epizootic in Finland in the late 1980s, and later in Poland and the Baltic states, the raccoon dog was the main vector and victim of rabies, accounting for 73% of all reported rabies cases (Westerling 1991, Mól 2005, Kowalczyk 2007, Zienius et al. 2007). Many countries in Western Europe are free of rabies as a result of oral vaccination campaigns. Currently the front of rabies and rabies vaccination campaigns runs from eastern Poland to Croatia (figure 6). In the new situation in Europe, with two main rabies vectors, the vaccination campaigns may not be as effective as before; rabies might persist in the animal community (due to incubation times of up to several months), even if the disease is not spreading in an individual vector species as a result of its low density (Holmala & Kauhala 2006, Kauhala & Kowalczyk 2011). However, Poland has in fact been largely freed from rabies as a result of vaccination campaigns between 2000 and 2010, when raccoon dogs were already as common as foxes. Apparently the oral vaccination campaigns there were as

effective for raccoon dogs and foxes together, as they were for foxes alone.

As in other canids, canine distemper caused by canine distemper virus (a paramyxo-virus), an important disease in domestic dogs, has been observed in the raccoon dog. Recently it has become rather widespread in eastern Germany (N. Stier, personal communication). An outbreak of canine distemper in 1991 near Tokyo killed about 70% of the local raccoon dog population (Machida et al. 1993). Canine distemper virus is not known to be zoonotic and thus is harmless for humans, but domestic dogs are susceptible; in fact, wild carnivores around the world may be more likely to be infected by non-vaccinated domestic dogs, than vice versa (http://en.wikipedia.org/wiki/Canine_distemper).

Three parasites are of importance in raccoon dogs: the roundworm *Trichinelle spiralis*, the tapeworm *Echinococcus multilocularis* and *Sarcoptic scabie* var. *vulpesi*, a mite causing Sarcoptic mange. In Finland 53 to 72% of the examined raccoon dogs were infected with *Trichinella* sp. (Mikkonen et al. 1995) and in eastern Germany 5.8% (Thiess 2004). In Finland an association between the density of raccoon dogs and the incidence of infection with *Trichinella* larvae in the European lynx (*Lynx lynx*) has been demonstrated (Oksanen et al. 1998). The role of the raccoon dog as a reservoir of *Trichinella* sp. seems remarkable: where raccoon dogs are common (Finland, Estonia) the prevalence of *Trichinella* in foxes is much higher than elsewhere (Oksanen et al. 1998, Oivanen et al. 2002). The percentage of infected wild boar in north-east Germany also increased in line with the number of raccoon dogs shot each year (Pannwitz et al. 2010). Trichinellosis is also a human disease. However, as a result of the control measures in the meat industry, it is rare in Western Europe (J. van der Giessen, personal communication). Trichinellosis is caused by nematodes of the genus *Trichinella* and the disease results from eating raw or undercooked meat from infected domestic pigs (mostly if they have access to outdoor pens) or game animals. Several carnivorous or omnivorous wildlife species (red fox, raccoon dogs, wild boar, rats, other rodents) can be carriers of *Trichinella*, and if pigs eat their bodies, they become infected. In pigs, clinical symptoms are very rare, but in humans clinical symptoms can occur and are dependent on the dose of *Trichinella* larvae ingested. In worst-case scenarios, the central nervous system and the myocard may be affected, with potentially fatal consequences.

Figure 6. All cases of sylvatic rabies (excluding bats and domestic animals) in Europe in 2012. Map generated with http://www.who-rabies-bulletin.org/Queries/Maps.aspx.

The most important parasite in raccoon dogs (and foxes) is the small fox tapeworm *Echinococcus multilocularis*. This can cause a severe infection in humans, and if not diagnosed and treated properly the infection may lead to death. The parasite is very small (1.2 to 3.7 mm; Faust & Russell 1964) and has no effect on the carnivore carrier, even if it has a high burden of tapeworms. Eggs are excreted with the faeces, thus contaminating the vegetation. Rodents, especially voles, eat the grass and act as secondary hosts. When foxes or other predators consume an infected vole, the life cycle of the parasite is closed. If humans ingest eggs of this parasite, the larval stage develops in internal organs, primarily in the liver. The incubation time is long, 5-15 years, and the route of transmission is as yet

unknown. *Echinococcus* eggs are very small and may be ingested via water, contaminated food or direct contact with infected animals, such as a domestic dog.

In Poland and eastern Germany several studies on *E. multilocularis* in raccoon dogs have been conducted (Machnika-Rowinska et al. 2002, Tackmann et al. 2003, Thiess 2004, Schwarz et al. 2011). The percentage of infected animals ranged from 0 to 10.7%, but the studies have been limited in scope and number, so far.

Intestinal parasites such as nematodes, cestodes and trematodes are common in raccoon dogs, as in foxes, and are relatively harmless. Barbu (1972) found an emaciated raccoon dog at the end of spring, with the exceptional number of 1700 trematodes in its intestines.

Sarcoptic mange (*Sarcoptes scabie var. vulpesi*, a mite) is rather common in raccoon dogs (Stier 2006). The mite lives in the skin, causing bare patches, severe itching and, if the infection is severe, may cause death from exposure. Sarcoptic mange sometimes comes in 'waves', decimating the populations of red foxes (Lindström & Mörner 1985) and probably also of raccoon dogs. At other times it is permanently present in low intensities in fox, raccoon dog and other wildlife populations, claiming few victims. Raccoon dogs seem to be more frequently infected with mange than foxes (N. Stier, personal communication). At present mange is rare among red foxes in the Netherlands, and the arrival of the raccoon dog may boost its occurrence (cf. Stier 2006), especially in the fox population, but other species may be affected as well. Humans may be infected by the *Sarcoptes scabei* mite of dogs, and also of foxes, although the mite is not able to finish its life cycle in humans.

Human safety and health risks

Up till now there are no records of raccoon dogs being aggressive towards people. They avoid contact and when cornered keep quiet and can be grabbed easily. However, raccoon dogs can be carriers of diseases and parasites that are harmful to people, i.e. the rabies virus and the fox tapeworm *Echinococcus multilocularis*. Kauhala & Kowalczyk (2011) consider this to be the most severe risk of the raccoon dog's colonisation of Europe. However, rabies has been eradicated in Western Europe and it is highly unlikely that it will return with the arrival of the raccoon dog (see above). The risk of rabies in Western Europe now mainly comes from imported pets (dogs and cats) and from a few bat species (Lina & Hutson 2006). This said, the rabies control measures in Europe should be scrutinised and, where necessary, reviewed in order to remain successful (Kauhala & Kowalczyk 2011).

The most important health risk constitutes the small fox tapeworm *Echinococcus multilocularis*, of which the raccoon dog is a carrier. Before the arrival of the raccoon dog, the red fox was the only vector of *Echinococcus*. It is unknown whether the raccoon dog will show the same prevalence of *E. multilocularis* in the future as the red fox does now. In the Netherlands the distribution of the small fox tapeworm is restricted to two areas, the north-east and the south-east corners of the country (Giessen et al. 2004a, Giessen et al. 2004b, Opsteegh et al. 2013). It is expected that the distribution of *E. multilocularis* will slowly expand, as a result of the mobility and especially the dispersal of the red fox. Since the indications are that average dispersal distances of raccoon dogs are larger than those of foxes, it is to be expected that the distribution area of *E. multilocularis* will expand slightly faster than with the fox as the sole vector.

Since raccoon dogs will live alongside the existing fox population, the density of potential *E. multilocularis*-carriers will increase and might double in the future. This implies that the infection risk in endemic areas may increase as well. Red foxes spread their faeces diffusely over their whole territory, while raccoon dogs defecate in just a few latrines. Raccoon dogs thus contaminate only a few

confined areas of the environment with *E. multilocularis* and pose a, potentially lower risk for human infection than foxes which contaminate a wider environment. The only known method to combat *E. multilocularis,* and diminish the risk for humans, is the (costly) permanent application of anthelminthic baiting, targeting foxes and raccoon dogs. This involves distributing baits containing the worm-killer Praziquantel in the field (Hegglin & Deplazes 2008).

Other risks

The raccoon dog is quite an isolated species in the canid family (Mulder 2012), and hybridisation with other dog species is unknown, even in captivity. There is, therefore, no risk of genetic effects on native species. It is unlikely that raccoon dogs will have a substantial impact, directly or indirectly, on ecosystems as a whole, e.g. by disrupting the existing food webs, maybe with the exception of some small island situations (Mulder 2012). To date, there is no record of raccoon dogs having an economic or social impact in Europe. They are shy and clumsy and avoid the vicinity of people and their infrastructures. Direct damage to property is not known, nor is there competition with economically important animals. They do not climb and do not normally predate on pets or poultry. Raccoon dogs might have some economical impact (although there are no data about this as yet) by eating from commercial crops of low hanging fruit (strawberries, blueberries, blackberries etc.) and maize.

Overall assessment

Several methods have been developed to make a numerical risk assessment for invasive species. Branquart (2007) and colleagues devised a simplified hazard assessment for ecological impacts: the Invasive Species Environmental Impact Assessment protocol (ISEIA). The ISEIA protocol is originally designed for species already established somewhere in Europe, and is therefore the most appropriate in the case of the raccoon dog. In this assessment a number of aspects receive a score of 1, 2 or 3 (for low, medium and high risk respectively) and the sum of scores leads to a classification in one of three categories: A. the 'black list', i.e. high environmental risk; B. the watch list', i.e. a moderate environmental risk and; C. species that are not considered a threat for native biodiversity and ecosystems. Table 2 shows how the raccoon dog scores according to this protocol. According to this protocol, the raccoon dog receives a score of 9 (more details in Mulder 2011), and falls in category B, representing a 'moderate environmental risk'. The main factors responsible for this score are its high dispersion and colonisation potential. It should be noted that the ISEIA protocol does not take the human health aspect into account.

Management

In many countries the year round killing of raccoon dogs is permitted (e.g., Sweden, Norway, Estonia, Latvia, Lithuania, Hungary and Poland). However, in Finland, females with pups are protected in May, June and July, and in Belarus hunting is allowed from 1 October to the end of February (Kowalzcyk 2007, Kauhala & Saeki 2008). In Denmark hunting is not allowed unless there is a negative impact on game animals (Kowalczyk 2007). In Germany the different federal regions (*Bundesländer*) have different rules; in most of them raccoon dogs can be hunted year round. The exceptions are: Niedersachsen and Nordrhein-Westfalen, where adult raccoon dogs are protected from March to August, and Schleswig-Holstein where adult raccoon dogs are protected from March to June; Hamburg, where adult and juvenile raccoon dogs are protected from May to August

Table 2. Scoring the ecological risks of the raccoon dog, according to the ISEIA-protocol.

Aspect	Sub-aspect	Risk	Score	Maximum score
Dispersion potential		High	3	3
Colonisation of high value conservation habitat		High	3	3
Adverse impacts on native species	Predation	Medium	2	2
	Competition	Low	1	
	Disease	Low	1	
	Genetic interaction	Low	1	
Alteration of ecosystem function	Nutrient cycling	Low	1	1
	Physical alteration	Low	1	
	Natural succession	Low	1	
	Food web	Low	1	
Total score				9

and Bremen and Saarland, where raccoon dogs are protected year round (http://www.schonzeiten.de; viewed April 2013).

Kowalczyk (2007) discussed the hunting intensity in Europe: "In Finland, the annual hunting bag varied between 75,000-130,000 in 1998-2003 (Kauhala & Saeki 2004, Kauhala, personal communication), ca. 20,000 in Germany (S. Schwarz, personal communication), 6,000-10,000 in Poland (data of Research Station of Polish Hunting Society in Czempiń), 4,000-5,000 in Estonia, 3,500-4,000 in Lithuania (L. Baltrūnaitė, personal communication), and 2,000 in Latvia. In other countries raccoon dogs are hunted occasionally. (…) Locally, intensive trapping with box and wire traps and hunting with dogs may be methods of raccoon dog eradication. Eradication is, however, difficult, because raccoon dogs, like other canids, tend to increase their litter size when hunting pressure on them is high."

Figure 2 in Mulder (2012) shows the bag record of the raccoon dog between 1994 and 2011 for the whole of Germany. It peeked in the hunting season 2007/08 with more than 35,000 raccoon dogs shot. Since then the increase in numbers seems to have stopped, most probably due to epizootics of canine distemper and sarcoptic mange in the north-east of the country. In the mean time the expansion to western parts of Germany is still continuing. In Germany most raccoon dogs are being shot more or less opportunistically, by hunters waiting near a feeding ground for wild boar or roe deer (*Capreolus capreolus*). Raccoon dogs are also attracted to the bait in feeding pits for foxes, and are shot there as well. Some hunters do target raccoon dogs and use dogs to corner them or to find them in burrows, from which they are dug out. Many raccoon dogs are shot in autumn, when they flee from maize fields during the harvest. When fishponds are being drained for the harvest, they work as magnets for raccoon dogs (and their hunters). As with the fox, box and wire cage traps work for juvenile animals but are ineffective for adults (Stier & Joisten 2006).

Stier (2006) argues that the high hunting bag in eastern Germany may look impressive, but that a two- to three-fold intensification of the hunting pressure would be needed to start reducing the breeding population of the raccoon dog. Rabies, one major natural cause of death has recently disappeared, increasing the raccoon dog's expansion potential; however, another cause is slowly returning: the wolf. In his calculations Stier assumes (rather conservatively) a 300% annual potential increase (2 adults getting 6 pups), and a mortality by hunting of 50% and by other causes (traffic, diseases, old age, etc) of 50%. However, a two- to three-fold intensification of hunting is not

feasible and not realistic, and in view of the favourable circumstances in habitat and food availability might still have a limited effect. Stier (2006) advises to address specific possible problems, such as predation of bird colonies, on a local scale. Very intensive control between November (end of dispersal) and April (start of reproduction) is needed, each year, to reduce the spring population in a target area (which should not be too large) in order to achieve the desired results.

One interesting example may illustrate the effect of shooting raccoon dogs. In southern Finland raccoon dogs and other medium-sized predators (red fox, pine marten, American mink) were killed by shooting and capturing in a 'removal area' of 55 km², in order to study the effects of these predators on the breeding success of ducks. In a similar control area (48 km²) the numbers of medium-sized predators were not controlled. The experiment lasted five years. Raccoon dogs were killed between 1 August to 31 April each year by volunteer hunters. An index of raccoon dog density was obtained using 50 scent stations each spring. A total of 280 raccoon dogs were killed, i.e. 0.73 to 1.36 individuals/km² each year. Notwithstanding this effort, no significant decrease in the raccoon dog index was observed. One reason behind this may be that most raccoon dogs were killed in the autumn and were juveniles that would have died anyway (Kauhala 2004). It is clearly not easy to substantially reduce a population of raccoon dogs.

Options for future management

In all or most of the European countries where raccoon dogs are living today, they have been hunted from the moment of their arrival. Despite the high numbers of raccoon dogs killed by hunters, their expansion has not been halted anywhere and there are no indications that the population density has decreased as a result of hunting. To limit population increase it is necessary to annually remove at least the numbers produced each year in excess of the annual mortality. Despite the large hunting bag this seems to be far from the case in areas where the raccoon dog has become common now (Stier 2006). The 'usual' shooting of raccoon dogs will, at the most, decrease their expansion rate a little. Preventing the raccoon dog from establishing itself in the Netherlands, if possible at all, would at least require an effort and professional organisation similar to that established for controlling muskrat (*Ondatra zibethicus*) and coypu (*Myocastor coypus*) (Broekhuizen 2007).

At the moment (February 2013) in the Netherlands the raccoon dog is placed in a category of species that may be controlled according to Clause 67.1 of the Bill on Flora and Fauna (Appendix 1 of the Regulation of Management and Damage Control). This list contains mostly non-native and feral species, but also some species which may be harmful to crops or to flora and fauna. However, firearms can only be used to control these species with the permission of the province. Such permission has only been granted in the Province of Friesland.

All this means that two realistic management options remain:

A. Intensive hunting on a local scale (a few km²) in places where problems (might) arise, during the months with no dispersal and no reproduction (December – March).
B. Prevention of predation by blocking access for raccoon dogs, for instance by (electric) fencing of colonies of breeding birds or ponds with rare species of amphibians. This method has proved to be effective in the case of the fox (J.L. Mulder, unpublished data).

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Samenvatting

De wasbeerhond (*Nyctereutes procyonoides*) in Nederland – zijn huidige status en een risico-analyse

De wasbeerhond heeft zijn natuurlijke verspreidingsgebied in het verre oosten van Azië. Tussen 1928 en 1957 werden duizenden wasbeerhonden uitgezet in de voormalige Sovjet Unie, voornamelijk ten westen van de Oeral. Van daaruit heeft de soort zich over een groot deel van Europa verspreid. De soort wordt beschouwd als een invasieve exoot, omdat hij door mensen is geïntroduceerd, zich succesvol voortplant en zich verder verspreidt. Het beleid in Nederland met betrekking tot invasieve exoten bestaat uit het schatten van de risico's voor de biodiversiteit met aandacht voor de impact op dier- en volksgezondheid en economie. Een vorig artikel (Mulder 2012) bevatte een samenvatting van de huidige kennis van de ecologie van de wasbeerhond in Europa; het onderhavige artikel geeft een overzicht van zijn huidige voorkomen in Nederland en een analyse van de ecologische, veterinaire en sanitaire risico's.

Bijna vijftien jaar geleden werden in Nederland de eerste uit Duitsland afkomstige wasbeerhonden waargenomen. Het patroon van die kolonisatie wordt verstoord door het regelmatig voorkomen van uit gevangenschap ontsnapte dieren. Tot 2013 werden 'wilde' wasbeerhonden waarschijnlijk uitsluitend aangetroffen in het noordoosten van Nederland: de provincies Groningen, Friesland, Drenthe en Overijssel, plus de Noordoostpolder. Dit patroon sluit aan bij het huidige voorkomen in Duitsland. Er is in Nederland nog geen voortplanting geconstateerd. De huidige fase, met jaarlijks een beperkt aantal waarnemingen, heeft in andere landen 20 tot 30 jaar geduurd. Pas daarna begon de populatie snel toe te nemen.

Het is te verwachten dat de wasbeerhond heel Nederland gaat koloniseren, waarschijnlijk met uitzondering van de Waddeneilanden. Zijn invloed op de biodiversiteit wordt in het algemeen ingeschat als beperkt. Alleen kleine geïsoleerde populaties van amfibieën en grondbroedende vogels in moerasgebieden kunnen gevoelig zijn voor predatie. De wasbeerhond heeft geen nieuwe ziektes meegebracht naar Europa, maar zou wel het voorkomen van

reeds aanwezige ziektes en parasieten kunnen bevorderen: hondenziekte, *Trichinella*, schurft en de vossenlintworm *Echinococcus multilocularis*. De wasbeerhond is ook een potentiële verspreider van hondsdolheid, maar deze ziekte komt tegenwoordig na het uitvoeren van grootschalige orale immunisatie-campagnes niet meer voor. De belangrijkste problemen voor de volksgezondheid worden waarschijnlijk gevormd door *Trichinella* en de vossenlintworm.

De mogelijkheden om wasbeerhonden effectief te bestrijden zijn beperkt. De bestrijding die vanaf het begin van de kolonisatie in Duitsland is toegepast, heeft de verdere verspreiding van de wasbeerhond niet merkbaar verminderd en heeft geen invloed gehad op de voorjaarsstand. Er zijn twee beheeropties voor het tegengaan van mogelijke problemen:

A. Intensieve bestrijding op een lokale schaal (maximaal enkele km^2) waar problemen, zoals predatie, zijn, of te verwachten zijn. Alleen effectief in de maanden zonder dispersie van jonge dieren en zonder reproductie: december tot en met maart.
B. Preventie van predatie door de toegang voor wasbeerhonden te verhinderen, bijvoorbeeld door middel van (schrik-)hekwerk rond kwetsbare plaatsen als poelen met zeldzame amfibieën of broedvogelkolonies.

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