

# The raccoon dog in the Netherlands – a risk assessment



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Colophon:

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## Summary

The raccoon dog *Nyctereutes procyonoides* has its natural distribution in the far east of Asia. Between 1928 and 1957 thousands of raccoon dogs have been introduced in the former Soviet Union, mainly west of the Ural, from where it has colonized parts of Europe. The raccoon dog is considered an invasive alien species, because it has been introduced by man, has established reproducing populations and is spreading. The policy with invasive alien species is to assess the risks they may have for biodiversity, human and animal health and economy. This report contains the current knowledge on the biology and ecology of the raccoon dog, an overview of its present occurrence in the Netherlands and the assessment of the ecological and health risks.

The raccoon dog has about the size of a red fox, but with shorter legs and a shorter tail. In autumn it accumulates fat, and in areas with cold winters it hibernates and stays underground for weeks or months. While foraging it moves slowly, mostly keeping to cover. It does not climb or dig, it mainly uses badger and fox dens for reproduction. In summer and autumn it sleeps in cover above ground. Raccoon dogs are monogamous and the pair forages mostly close together. Each pair occupies a fixed home range, of which the core is exclusive but the periphery is overlapping with neighbouring pairs. Pre-breeding population density in mixed habitats usually is between 0.5 and 1.0 adults/km<sup>2</sup>.

Habitat use is characterized by a preference for shores, wet habitats and deciduous forests, and an avoidance of coniferous forests and open fields and meadows. However, except for built up areas, all available habitats are used to some extent. Raccoon dogs are omnivorous and 'gatherers' rather than 'hunters'. Their diet is very variable, but a large proportion of it consists of amphibians, small mammals, carrion and maize and fruits. There are indications that raccoon dogs predate on nests of ground breeding birds, but well designed studies into the effects on the population level is lacking. To date, there are no indications of severe impacts on prey populations. Only on islands where predators were lacking before, raccoon dogs have been responsible for extinctions of amphibians, and have affected colonies of ground breeding birds.

Raccoon dogs produce a relatively large litter of usually 6 to 9 cubs, around the end of April, often in a badger or fox den. The cubs are guarded almost continuously by at least one of the parents. After six weeks the den is left and the whole family wanders around within the home range. From July onwards the cubs, still half grown, start to disperse and may travel more than 100 km before settling. Most cubs, however, stay within 5 to 30 km of their place of birth.

The introduction of the raccoon dog has brought no new diseases to Europe, but raccoon dogs may enhance the occurrence of endemic diseases and parasites, such as rabies, canine distemper, *Trichinella*, sarcoptic mange and the small fox tapeworm *Echinococcus multilocularis*. Rabies has been successfully eradicated in western Europe with immunisation campaigns. The most important threats, for humans, now probably are *Trichinella* and *Echinococcus*.

The colonization of the Netherlands by the raccoon dog has started from Germany about ten years ago. The pattern of colonization is, however, somewhat blurred by the regular occurrence of individuals escaped from captivity. Up till 2011 raccoon dogs were observed or found dead probably exclusively in the north-eastern part of the country, in the provinces Groningen, Friesland, Drenthe and Overijssel, and in the Noordoostpolder. This is in accordance with the distribution in Germany. Reproduction has not yet been observed in the Netherlands. This phase, with occasional observations, has in other European countries lasted for 20 to 30 years, before the population really started to reproduce and grow.

It seems inevitable that the raccoon dog will colonize the whole territory of the Netherlands in the future, except for 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 enhance the occurrence of diseases and parasites, of which the small fox tapeworm probably constitutes the most important health risk for humans. There are, however, only limited possibilities to combat this tapeworm in the field.

Effective management options for raccoon dogs are few; the efforts in Germany to control them have not halted their expansion and have no effect on spring densities. This means that two management options remain: A. Intensive control on a local scale (a few km<sup>2</sup>) in places where an impact is expected, 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.

# 1. Introduction

In October 2007 the Dutch Government published its policy on invasive species (Document 20071012-dn-2007-2899.pdf). In its definition an invasive species is an organism which arrives from elsewhere with the aid of humans (by transport or infrastructure) and which is a successful colonizer (by reproduction and population growth). In accordance with the agreements in the Convention on Biological Diversity (Rio de Janeiro, 1992) the successive policies are: prevention of the arrival, eradication if populations are still small, and isolation and control management if populations have grown too large to eradicate. However, the intensity of control measures depends on the (expected) harmfulness of the invasive species with respect to biodiversity and human health and safety. In the Netherlands the Team Invasive Species (TIE) of the Ministry of Economy, Agriculture and Innovation has the task to advise the Minister on all issues of invasive species. The TIE collects and publishes information, makes risk analyses for invasive species and recommends, on the basis of a risk analysis, measures for prevention, control and management of species. This report contains the risk analysis of the raccoon dog for the Netherlands, commissioned by the TIE. It consists of three parts: an overview of the available knowledge, the present (as of January 2010) situation of the raccoon dog in the Netherlands, and the risk analysis itself.

Two earlier publications have dealt with the raccoon dog in the Netherlands and its possible risks (Oerlemans & Koene, 2008; Dijk & Koning, 2009). These reports 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.

## 2. Biology and introduction history in Europe

### 2.1. The species

The raccoon dog (*Nyctereutes procyonoides* Gray, 1834) is called 'wasbeerhond' in Dutch. It is taxonomically quite an isolated species in the *Canidae*, the dog family. The nearest relatives would be the members of the genus *Dusicyon* (Clutton-Brock et al., 1976), a group of South-American fox like canids. However, more recent DNA-analysis showed that the African Bat-eared fox *Otocyon megalotis* may be its nearest relative (Wayne et al., 1997).

On the continent of Asia a total of seven different subspecies have been described in the raccoon dog. Corbet (1978) however lumped all seven continental subspecies into one subspecies: *N. p. procyonoides* Gray, 1834. Two other subspecies occur on different Japanese islands: *N. p. viverrinus* Temminck, 1844 on Honshu, Shikoku and Kyushu, and *N. p. albus* Beard, 1904 on Hokkaido.

Several important differences exist between the raccoon dogs from Japan and those from the mainland populations. Japan has been separated from the mainland since about 12.000 years, and the Japanese raccoon dog may have evolved in a different direction than the mainland population. Japanese raccoon dogs have 38 chromosomes, those from the mainland (and Europe) 54. Mainland raccoon dogs are larger, able to accumulate more fat for the winter period, and have thicker fur than Japanese raccoon dogs. Mainland raccoon dogs (at least in Europe) appear to be strictly monogamous, whereas Japanese raccoon dogs may live in groups (several authors cited by Kauhala et al., 1998a). Kauhala et al. (1998a) themselves found clear differences in skull and tooth size and relative dimensions between Japanese (Honshu) and Finnish populations. This suggests, that results from Japanese studies may not be valid for the European raccoon dog. Therefore, the literature on the Japanese raccoon dog has been used selectively and to a small extent only, in this study.

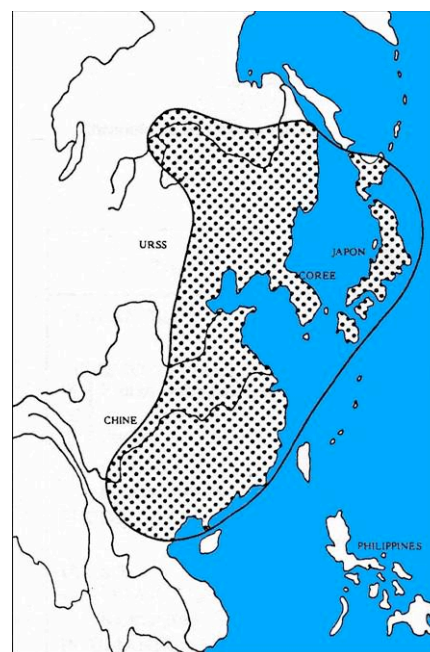
Between the different islands of Japan the raccoon dog populations seem to differ also, especially in behaviour. Although they have plenty of opportunity to do so, raccoon dogs on Hokkaido (the northern island) hardly leave the forest to forage on agricultural fields. The local people often are not aware of their presence. On Honshu, where raccoon dogs frequently appear in rice fields, croplands and residential areas, people are very familiar with the species (Abe et al., 2006).

The raccoon dogs which have been introduced into Europe originate from the Amursk-Ussuria region, north of Wladiwostok; they belong to the (former) subspecies *N. p. ussuriensis* (Nowak, 1993) and are adapted to a cold climate with severe winters (Kauhala & Kowalczyk, 2011). Judging from their epigenetic variability, the European raccoon dogs nowadays differ considerably from the raccoon dogs in the Amursk region, from where they originate. This is most likely a consequence of the complete reproductive isolation during 60 years, as well as of the repeated founder effects in the European pioneer populations. Comparing a number of European populations amongst each other, also a clear difference in epigenetic variability was found between Finnish-Bialowieza populations on the one hand, and German populations on the other hand. This may have been the result of the much earlier colonization of Finland and Bialowieza, already during the first expanding phase directly after the Second World War. Germany was colonized decades later, and these animals most likely have come from another source than the Finnish and Bialowieza animals (Ansorge et al., 2009). Interestingly, a study of mitochondrial DNA variation revealed a (weak) difference between Finnish and German populations as well (Pitra et al., 2010).

## 2.2. Original range

The raccoon dog has its original distribution in the far eastern part of Asia (fig. 1), in the woodland zone from south-eastern Siberia to northern Vietnam, as well as on the Japanese islands (Nowak, 1984). The climate in the original distribution area varies from the subtropical regions of Japan, northern Vietnam and southern China to a harsh continental climate with cold winters in Mongolia and southeast Siberia. Accordingly, raccoon dogs in different areas have adapted to different climates, habitats and diets, which can be seen in their body size, fat reserves, thickness of fur, and their behavioural and dental characteristics (Kauhala & Kowalczyk, 2011).

*Figure 1. Original range of the raccoon dog in East Asia. After Nowak, 1984.*



## 2.3. Introduction history in Europe

From 1928-1957 approximately 9100 animals, mostly from captive bred stock, were released in more than 70 areas of the former USSR, mainly in the European part (Lavrov, 1971; Helle & Kauhala, 1995). The aim was to enrich the fauna with a valuable fur animal. The raccoon dog spread rapidly, with an average speed of about 40 km/year (Lavrov, 1971). Introductions in very cold climates (Irkutsk, Transbaikal, Novosibirsk) and in mountainous areas (Caucasus, Transcaucasia, Central Asia) failed. To illustrate the rapid increase in favourable areas: in the period 1948-1952 the total number of animals shot in Ukraine was already 11.000 (Nowak & Pielowski, 1964). Several measures favoured the introductions, such as a thorough selection of habitats, provision of artificial earths and food, and keeping a reasonable number of animals in captivity for breeding (Duchene & Artois, 1988). Later, raccoon dogs were captured and translocated from successfully settled populations to new areas. The history of its colonization of Europe is given in figure 2.

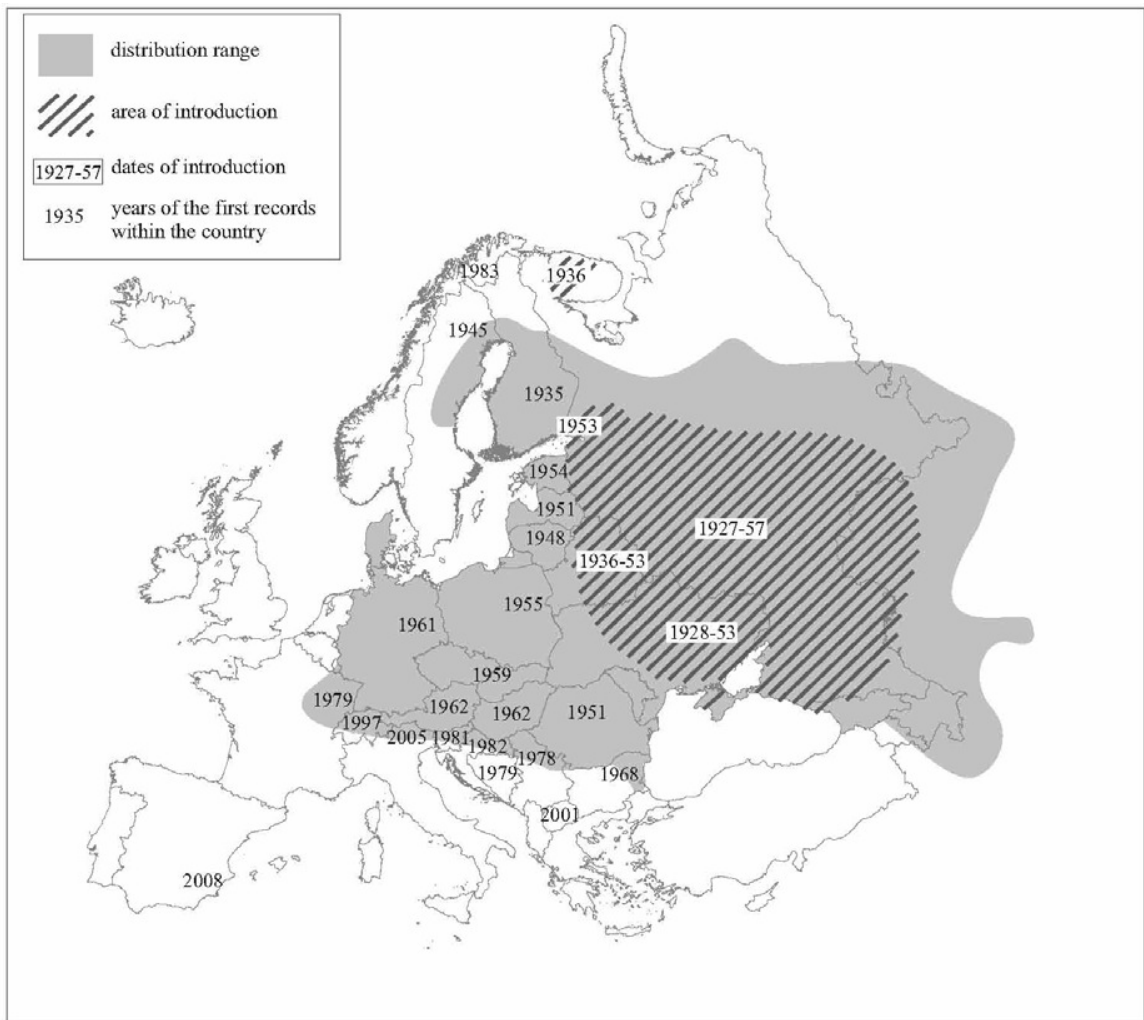


Figure 2. Areas of reintroduction, first observations in different countries and present distribution of the raccoon dog in Europe. From Kauhala & Kowalczyk, 2011.

In 1935 the first raccoon dog was found on Finnish territory, and by 1953 raccoon dogs had reached the northern regions of Finland (Siivonen, 1953). However, the real phase of increase lasted from 1965 to 1985. Since then the population slightly declined (Helle & Kauhala, 1991). Sweden and Norway were colonized from Finland, around the Botnic Gulf; the first raccoon dog in Sweden was found in 1945. In subsequent years the species mainly inhabited the low lying coastal regions in the north-east of the country. Management is implemented here in recent years, in an effort to stop or contain the influx from around the northern end of the Gulf of Bothnia. Raccoon dogs are trapped, neutered and released with a radio collar. These so-called 'Judas animals' are used to trap or kill the mates they find (Dahl, 2009). Until now the distribution in Sweden is almost limited to the northernmost province (Hallin, 2009).

In 1948 it was first observed in Lithuania, and twelve years later the raccoon dog was found in the whole of the country. In Poland colonization started in the early 1950s. The Bialowieza Forest in eastern Poland was invaded by the species in 1955; it nowadays is more common there than any native species of medium-sized carnivores (Kowalczyk et al., 2009).

In the north-east corner of Romania, especially the delta of the Danube, the first raccoon dogs were observed in 1952-1953; they came from Moldavia, which itself had been colonized in 1940-1945. The raccoon dog was used as a fur animal. By 1956 it was rather common in the Danube delta. After fifteen years, around 1967, it was considered a problem animal (Barbu, 1972).

Slovakia was reached by raccoon dogs in 1959, and Hungary in 1961. In 1962 three raccoon dogs were shot there (Bruchholz, 1973). The first raccoon dogs in Germany were observed in 1964 in the north-east, in Mecklenburg-Vorpommern (Nowak & Pielowski, 1964). In Brandenburg the first two raccoon dogs were shot in 1967, along the Spree south-east of Berlin (Bruchholz, 1973). It was expected that central Europe might be invaded rapidly (Ansorge, 1998), but apparently the colonization speed decreased. The first raccoon dogs reaching the Dutch border, 480 km distant from NE-Germany, were observed around 2001 (section 3). Expansion speed through the north of Germany thus was about 13 km/year. Until the early 1990s the number of raccoon dog observations in Germany remained low, but subsequently the number of animals killed increased exponentially. Since the hunting season of 2005/2006 between 27.500 and 35.000 animals have been shot each year (fig. 3) in the whole of Germany (Drygala et al., 2008b). Figure 4 depicts the German municipalities where at least one raccoon dog was reported until 2009 (Anonymus, 2010).

The introduction history of the raccoon dog in Europe has been dealt with in more detail by Kauhala & Kowalczyk (2011).

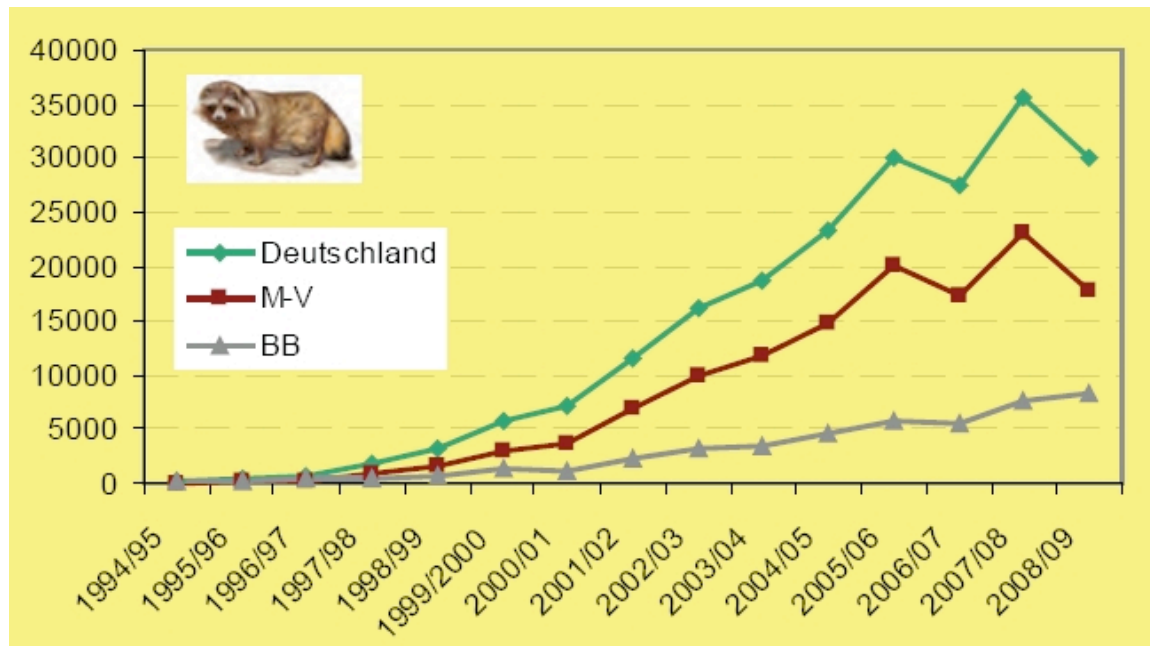


Figure 3. Hunting bag of the raccoon dog in the whole of Germany (green), in Mecklenburg-Vorpommern (brown) and in Brandenburg (grey). ([http://medienjagd.test.newsroom.de/broschuere\\_wild\\_2009\\_web.pdf](http://medienjagd.test.newsroom.de/broschuere_wild_2009_web.pdf) )



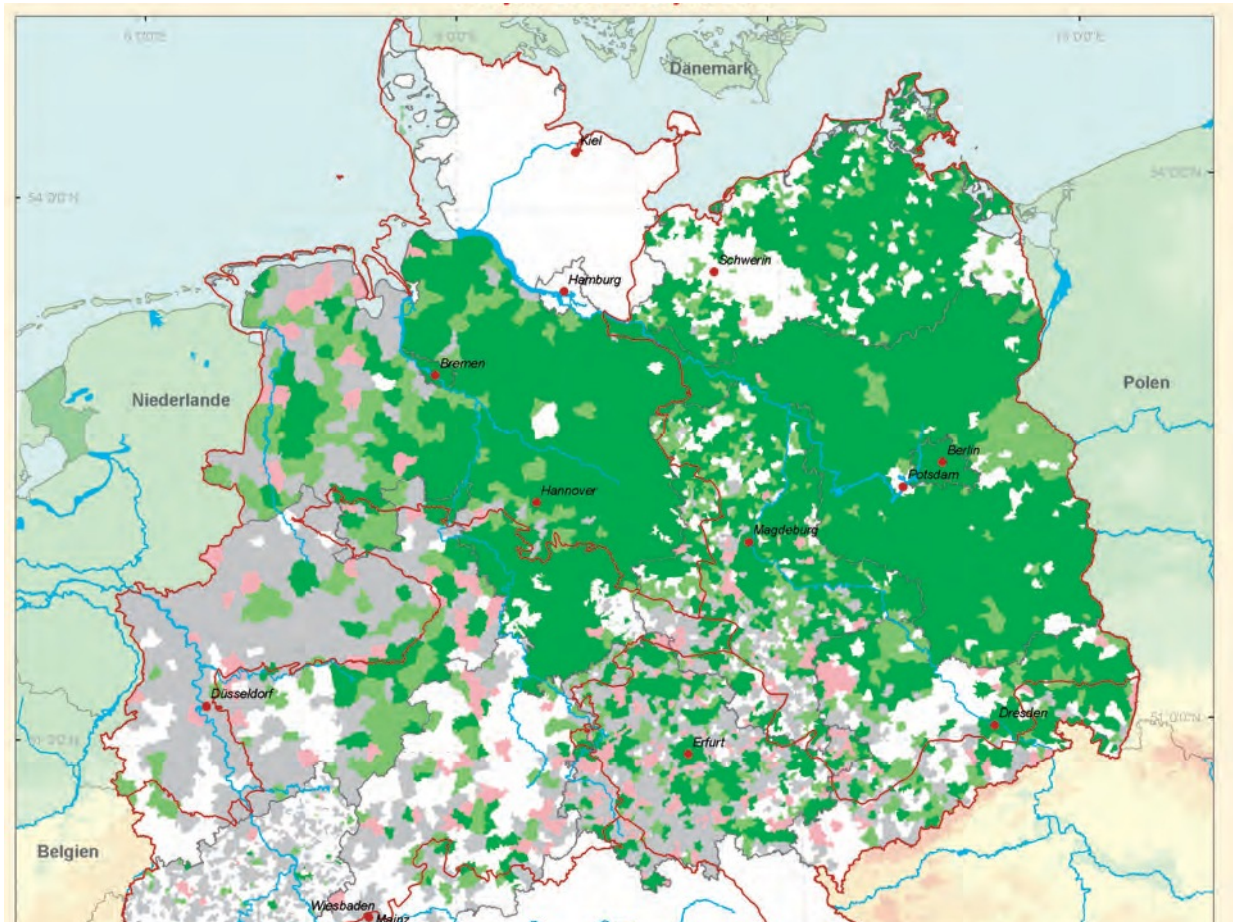


Figure 4. Distribution of the raccoon dog in Germany, per municipality, according to a repeated inquiry among hunters, the German project WILD. Color legend: pink: at least one observation in 2006 only; dark green: idem in 2006 as well as in 2009; light green: idem in 2009 only; grey: no observations; white: no data. ([http://medienjagd.test.newsroom.de/broschuere\\_wild\\_2009\\_web.pdf](http://medienjagd.test.newsroom.de/broschuere_wild_2009_web.pdf)).

## 2.4. Appearance, size and tracks

The raccoon dog is a small and stocky medium-sized predator. It has a characteristically long fur (guard hairs up to 12 cm) with a mixture of black, grey, brown and white colours. Especially in the long winter coat its face is striking: black eye-pads, whitish nose in between (the most important difference with the face of the raccoon) and long whitish side-whiskers. The tail is short (15-22 cm), not reaching the ground, mostly somewhat light coloured with a blackish tip. From nose to tail base the raccoon dog measures 50 to 85 cm. The legs are short and black. Footprints are small and more rounded than those of the red fox, which leaves more elongated footprints. Like in the fox the nails are always visible in the prints. Because of its broad body and short legs, the raccoon dog does not place its footprints in an (almost) straight line as the fox does: the prints of left and right legs are rather widely separate. The short legs, broad body and long hair give the animal sometimes the appearance of a badger, especially in winter. Its height is only 37 to 39 cm. In Finland females are on average somewhat smaller and weigh less (except when pregnant) than males; however, the differences are not statistically significant (Kauhala, 1993). Ansorge (1998) did not find a sexual dimorphism in skull dimensions.

In Finland the body weight of raccoon dogs fluctuates considerably through the year. In late autumn it may be 50-70% higher than in spring (Kauhala, 1993). Polish males from September to January weighed 8.63 kg on average (6.10 -11.00 kg, n = 53), females from the same months 7.40 kg (5.50-8.90, n = 34) (Wlodek & Krzywinski, 1986). Weight decreases during winter, and starts to increase in March or April, reaching maximum values in August to November (Nowak, 1993). However, in areas with mild winters the weight fluctuations throughout the year are much

less pronounced. In the Danube delta male raccoon dogs weighed about 6.5 kg in autumn and winter, and about 6.0 in spring (Barbu, 1972). Young of the year reach adult weight on average in November-December in Finland. Weight gain of juveniles depends on spring temperature and snow depth, but small mammal abundance also is an important factor (Kauhala, 1993).



Footprints of a raccoon dog. Photo N. Stier.



Raccoon dog. Photo J. Helder

## 2.5. General biology

The present knowledge about the biology and more specific the ecology of the raccoon dog, has been accumulated through a series of studies, mainly in the east and north of Europe. For reference purposes, the location of each of these studies, of which the results are used in the following sections, is indicated on the map in figure 5.

The raccoon dog is the only member of the canid family showing winter lethargy in areas where winters are harsh (Kauhala & Saeki, 2004a). It then accumulates large fat reserves before winter. If snow depth exceeds 20 cm, raccoon dogs usually stay in their hiding place (Heller, 1959). During winter (see section 2.6) and when rearing pups (see section 2.10) raccoon dogs prefer to use dens. At other times of the year a den is used only occasionally (Kauhala et al., 1998c). When active, raccoon dogs like to stay in cover as much as possible. During the day they usually rest in cover as well. In Poland raccoon dogs were found in a variety of above-ground resting places throughout summer and early autumn. Of 225 reported observations, 21% were in reed beds, 18% in maize, 15% under fallen trees, 13% under piles of wood, 9% under piles of branches, 8 % in wild boar 'nests' and 7% under cover of hanging fir branches. The remaining 9% resting places in the reports were in haystacks, in high grass, in peat stacks and in culverts (Wlodek & Krzywinski, 1986).

Raccoon dogs move relatively slow, they walk in a quiet gait and are less able to run fast. When disturbed, they seek cover in a fast trot, or take to water to escape swimming. They may even dive (Nowak, 1993). An island three km off the coast of the Danube delta was reached swimming by a pair of raccoon dogs. Still they may drown, for instance during floods in the Danube delta (Barbu, 1972). Hunting dogs easily outrun them. Raccoon dogs tend to keep in cover, often keep very still when approached and may pretend to be dead when in danger. Deep, fresh snow hinders them greatly. They hardly climb, only easily accessible trees are sometimes ascended to reach nests in bird colonies (Nowak, 1993). A simple one meter high fence is enough to keep them in captivity (Stier, 2006b). In contrast to foxes and especially badgers, raccoon dogs have little tendency to dig burrows; during foraging they may dig small pits while searching for small prey (Nowak, 1993). When leaving a burrow, they are very cautious and take several minutes of investigating the safety, before they effectively leave (Wlodek & Krzywinski, 1986).

Raccoon dogs live pairwise in home ranges, of which only the core areas seem to be avoided by neighbours (see section 2.7). Except when they have small cubs in a den, the members of a pair rarely stray far from each other (Kauhala et al., 1993a; Kauhala & Holmala, 2006; Drygala, 2008a). Members of a pair tend to hibernate together (in 84% of 106 cases); in summer they spend less days sleeping together in a den, but still a considerable proportion: 67% of 106 cases (Kauhala & Holmala, 2006). The raccoon dog is the only canid with this behaviour and





Figure 5. Location of raccoon dog research areas in Europe. Colors indicate different vegetation zones. Associated literature:

1. Southwestern, southern and northwestern Finland (Kauhala, 1993; Helle & Kauhala, 1995)
2. Southern Finland (Helle & Kauhala, 1993; Kauhala et al., 1998b)
3. Virolahti, southeastern Finland (Kauhala & Holmala, 2006; Kauhala et al., 2006)
4. Evo, central-south Finland (Kauhala, 1996c; Kauhala et al., 1998c)
5. Central, east and south Finland (Helle & Kauhala, 1995)
6. Białowieża Primeval Forest (Reig & Jedrzejewski, 1988; Selva et al, 2003; Kowalczyk et al., 2008; 2009)
7. Ueckermark (Stiebling et al., 1999; Ansorge & Stiebling, 2001)
8. Lewitz (Stier, pers. comm.)
9. Mecklenburg-Vorpommern (Drygala et al., 2008; 2009; 2010; Stier, 2006)
10. Oberlausitz (Ansorge, 1998; Ansorge & Stiebling, 2001)
11. Lithuania (Baltrunaite, 2005; 2006; 2010)
12. Vitebsk, northern Belarus (Sidorovich et al., 2000; 2008)
13. Brandenburg (Sutor, 2008; Sutor et al., 2010; Sutor & Schwarz, 2011)
14. Danube-delta (Barbu, 1972)

such a narrow pair bond. The partners criss-cross their territory together to forage. Raccoon dogs have large litters which are born relatively late in the year (see section 2.10); however, the pups are quickly independent and start to disperse early, when not even fully grown (see section 2.11).

## 2.6. Activity

### Seasonal activity

In Finland the seasonal activity of raccoon dogs was studied by radio-tracking, in two different areas, a coastal area with a relatively mild climate and a more inland site with a harsher climate (Kauhala et al., 2007). Raccoon dogs moved fastest in late winter (March-April) and slowest in autumn (September-November). The area covered per tracking night was largest in March, did not change from April to June but decreased with lengthening nights from July to November. Only in March a difference between the sexes was apparent: males were moving more often than females. In winter the activity of raccoon dogs was correlated with day length and temperature (positively), and snow depth (negatively). The animals were usually inactive when the temperature was below -10 °C, snow depth was higher than 35 cm and day length was less than 7 hours. They were usually active when temperatures were higher than 0 °C, when there was no snow and when day length exceeded 10 hours.

### Circadian activity

In a study area in central south Finland circadian activity of raccoon dogs was studied by regularly listening to the signals of transmitters, equipped with activity sensors. The animals were more active during dark hours than in daytime. In winter the activity level was lowest before midday. During the breeding season raccoon dogs often seemed to rest early in the evening, around 18:00 hr, whereas later in the summer they usually rested in late afternoon, around 16:00 hr. In late summer a difference between males and females was apparent, with males being more active than females, especially before noon (Kauhala et al., 2007). Rather much activity during daylight hours, usually in thick vegetation, has also been found by Drygala et al. (2000) in Germany and by Ward & Wurster-Hill (1989) in Japan.

### Winter

In Poland, where winters are rather severe, raccoon dogs preferred unoccupied badger setts over fox dens for winter dormancy. They are lethargic from December to February or March, depending on the weather (Jędrzejewska & Jędrzejewski, 1998). From October onwards the burrows were cleaned out and refurbished with dry grass and leaves. Dormancy started when the temperature dropped below -8 to -10 °C. In large badger setts only two or three entrances were used, the remaining were closed up (Wlodek & Krzywinski, 1986). Winter dens were usually situated in the centre of the home range (Kauhala et al., 1993). Mostly two raccoon dogs (a pair) share an earth during winter dormancy, sometimes small groups of juveniles (Judin, 1977). Of 12 wintering sites of radio-tracked raccoon dogs, 9 (75%) were found in main badgers setts and 3 in hollow trees in Białowieża Primeval Forest (Kowalczyk et al., 2008). Sometimes other, more open places were used for winter dormancy, especially in milder winters: reed beds, piles of branches, open holes under roots of fallen trees and wild boar 'nests'. Only 8% of 200 burrows used during winter seemed to be dug by the raccoon dogs themselves. During warmer periods of the winter, raccoon dogs sometimes left their burrows but never strayed further away than about 50 m. December and January were the only months in which no tracks of raccoon dogs were found on the regular feeding places of wild boar (Wlodek & Krzywinski, 1986, all field observations).

A study in Finland, with radio collars, showed that raccoon dogs on average used 3.3 different dens (range 1-9) during winter, and changed dens on average 3.0 times. There was no difference in behaviour between the sexes (Kauhala et al., 2007). Radio transmitters with activity sensors indicated, that winter dormancy may not be very deep; animals stay in their dens during harsh weather, but often move within the den, falling into deep sleep only for short periods. There are often footprints in the snow outside the dens, indicative of regular weather inspections by the animals. If the snow cover is hard and it is not too cold, raccoon dogs may walk longer distances and change dens, for instance (Kauhala et al., 2007). Their small paws do not allow them to walk in deep, soft snow, however, and are sensitive to frost bite. When they fall into deep sleep, their body temperature drops a few degrees and the metabolic rate decreases with 25% (Heptner & Naumov, 1974). In Germany, with milder winters and less snow, raccoon dogs are known to be active throughout the winter (Stier, 2006a).

## 2.7. Home range

Abe et al. (2006) radio-tracked raccoon dogs in Central Hokkaido, near Sapporo, in mixed conifer-hardwood forest with many small streams. Home ranges inside the forest were  $1.25 \pm 0.71 \text{ km}^2$  (June and July only) ( $n=3$ , 2 of which formed a pair). Home range size on Hokkaido is rather small (see below), and may not be comparable to European home ranges, since the Japanese raccoon dogs differ in many aspects from those of the mainland and are considered a different subspecies (*N. p. viverrinus*).

In southern Finland (fig. 5, nr 1) Kauhala et al. (1993a) were the first to study the home range and behaviour of raccoon dogs in Europe. In an area with coniferous forests interspersed with clearcuts, small streams and pine swamps, 23 raccoon dogs were radio-tracked for periods of a few months to three years. The average maximum home range was 950 ha (Harmonic mean method, Dixon & Chapman, 1980). The 85% utilization core area was 340 ha, the 60% core area only 130 ha. Maximum home ranges were larger in autumn than in summer, core areas were similar in size between seasons. Core areas (85%) of adjacent pairs did not overlap in the pup-rearing season (summer) and to some extent only in autumn; the peripheral areas of the maximum home ranges, however, overlapped considerably. Home ranges of male and female of a pair were almost identical.

In South-East Finland (fig. 5, nr 3) Kauhala et al. (2006) followed 17 raccoon dogs with radio-collars. The average total individual home range (over all years and seasons, 95% fixed kernel, Worton, 1989) was  $3.90 \pm 1.42$  (SD)  $\text{km}^2$ , the 50% core area  $0.80 \pm 0.51 \text{ km}^2$ . Seasonal home ranges ( $n=32$ , 3 seasons a year, no winter data) were smaller and covered on average  $2.60 \pm 1.35 \text{ km}^2$  (95%) and  $0.40 \pm 0.26 \text{ km}^2$  (50%). This study area consisted mainly of managed coniferous forests (68%), fields (18%), and seashore, reedbeds and other wetlands (together 12%). In summer the core areas of members of a pair overlapped for  $75 \pm 3.5\%$  ( $n=2$  pairs), whereas the core areas for adjacent pairs overlapped for only  $1 \pm 3\%$  ( $n=7$ ) in summer.

Drygala et al. (2008a) radio-collared 74 raccoon dogs in an area in north-eastern Germany (Mecklenburg-Vorpommern), about 50 km from the Polish border (fig. 5, nr 9). The research period fell about ten years after the start of the rapid increase (see section 2.17) in raccoon dog sightings in the area, and the population was supposed to not yet be saturated. From 12 males and 14 females sufficient data were obtained to calculate home range sizes. Of these animals, 62 independent and stable seasonal home ranges were obtained, for some animals during several years in succession. Four seasons were distinguished: oestrus and gestation (March-April), parturition and cub rearing (May-July), intensive foraging and fat accumulation (August-October) and reduced activity and winter burrow associated activity (November-February). Home ranges were calculated from the 95% kernel distribution of locations and are thus comparable to the data of Kauhala et al. (2006) as dealt with above. Home range size fluctuated through the year. During oestrus and gestation home ranges were small, around  $1.60 \text{ km}^2$ , during fat accumulation much larger, around  $5.40 \text{ km}^2$ . The overall year means were  $3.82 \pm 2.97 \text{ km}^2$  for 30 seasonal ranges of females, and  $3.52 \pm 3.13 \text{ km}^2$  for 32 seasonal ranges of males. The large standard deviation indicates huge differences between pairs, some having small and others very large home ranges. There are no clear differences between males and females. The reason is, that male and female of a pair keep close together during foraging. Only when having small cubs, the parents split up and one of them stays with the cubs. Overlap between the home ranges of members of a pair was 85 to 93%; only during cub rearing the overlap was less, 69% on average, as a result of the separate foraging activities of partners. Home ranges were smaller in an agricultural landscape ( $2.39 \pm 2.14 \text{ km}^2$ ) compared to a forest landscape ( $3.13 \pm 4.40 \text{ km}^2$ ) (see section 2.8).

Although the raccoon dog home ranges appeared to be rather evenly spread over the research area (fig. 6), raccoon dogs did not seem to be very territorial in behaviour. Adjacent home ranges overlapped to a considerable extent, with a maximum in the August-October season of about 30% on average, and a minimum of about 3% during winter. In March-April overlap was 16%, during cub rearing 12% on average. Core area (85% Kernel distribution) overlap was least during cub rearing, suggesting at least avoidance if not territoriality and defence of the breeding den vicinity. Similar results were obtained by Kauhala et al. (1993). Adjacent radio-collared adults never visited the vicinity of breeding dens of their neighbours. Figure 7 shows 100% and 85% harmonic mean home ranges in southern Finland in summer and autumn 1991 (Kauhala et al., 1993).

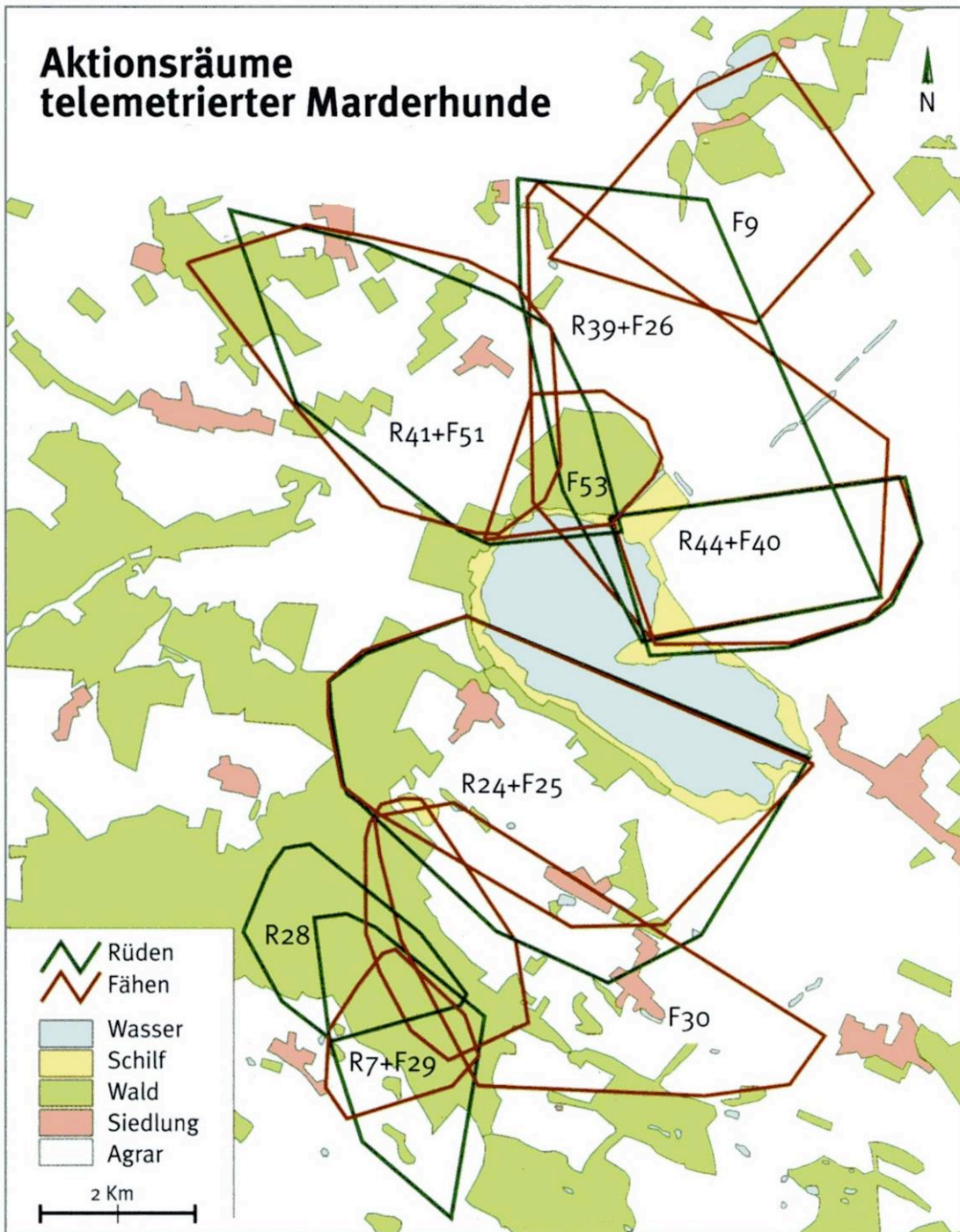


Figure 6. Home ranges of raccoon dogs in the study site in Mecklenburg-Vorpommern, Germany. R = male, F = female. Wasser = water; Schilf = reeds; Wald = woodland; Siedlung = village; Agrar = fields and meadows. From Stier, 2006a.

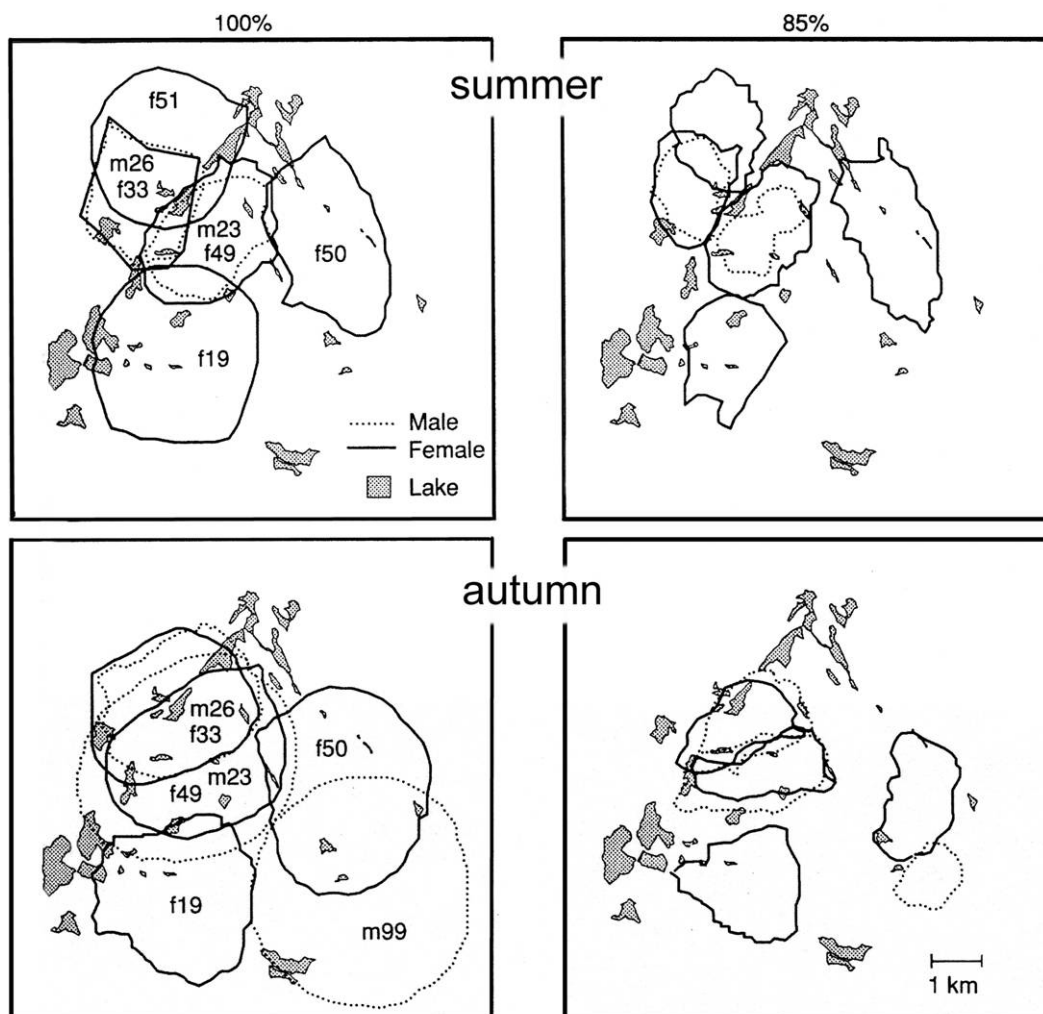


Figure 7. Home ranges of raccoon dogs in Southern Finland, according to the harmonic mean distribution of radio-locations, in summer and autumn. To the left 100% of all locations included, to the right 85% of locations included: core areas. From Kauhala (1991).

In Southern Brandenburg, also in northeast Germany (fig. 5, nr 13), Sutor & Schwarz (2011) followed 9 raccoon dogs with radio-collars in a mixed agricultural landscape, and obtained similar results. The yearly average home range sizes were  $1.83 \pm 1.54 \text{ km}^2$  (95% fixed kernel). Core areas (50% fixed kernel) measured  $0.50 \pm 0.49 \text{ km}^2$ . The authors distinguished the same four seasons as Drygala et al. (2008a), see above, and also found the autumn ranges to be the largest. In winter the home ranges were the smallest of the year. Again, the core areas of the home ranges did not overlap in the pup-rearing season.

In conclusion, the raccoon dog in Finland and eastern Germany is monogamous, with a probable lifelong pair bond, not defending an exclusive territory but respecting and avoiding neighbouring core home range (Drygala et al., 2008a; Kauhala et al., 1993; Kauhala et al., 2006).



## 2.8. Habitat use

The raccoon dog mainly lives in landscapes with moist or wet habitats and deciduous and mixed forests with dense undergrowth, in moors and wet grasslands with clumps of trees, and in reed beds along lakes and streams. Large scale agricultural areas and large scale coniferous forests are less preferred. In east and central Europe it prefers the lower elevations; it is hardly found above 800 m (Nowak, 1993).

In Europe two extensive studies of habitat use of radio-collared raccoon dogs have been published. Kauhala (1996c) studied the activities of 12 adult raccoon dogs (3 pairs plus 6 individuals) in the boreal zone of central-southern Finland (fig. 5, nr 4), about 35 years after the start of the colonization of Finland by this species. The study area was characterized by industrial forests, small pine swamps and many small lakes and streams. Raccoon dogs hibernate here for several months. Their habitat choice was determined in the snow-free part of the year, divided into three seasons: early summer (May-June; pup-rearing), midsummer (July; pups begin to forage with their parents) and autumn (August-October; young disperse, adults prepare for winter). The distribution of radio-fixes (except those in the surrounding of the dens) was compared to a large sample of random locations in the study area. Available habitats were: clear cuts (4% of random locations), young forests (10-30 yrs, 13%) and old forests (>30yrs, 40%) on moist heath (productive soils), and clear cuts (1%), plantations, young forests (10%) and old forests (19%) on barren heath, mostly lacking undergrowth. Shore zones made up 7% of random locations. The remaining, non-used areas (water and built up areas) amounted to 6% of the random locations.

Raccoon dogs preferred shore areas in all seasons, and more so during early summer (30% of fixes) than during midsummer (19%) or autumn (17%). Along shores and in shallow water frogs are abundant and easily caught in early summer. During midsummer and autumn shores of lakes and streams provide shelter in the form of dense undergrowth. In addition, safety may play a role: raccoon dogs have the habit of escaping into water when chased or attacked.

In Russia, raccoon dogs are frequently found near water and in damp meadows and swamps. Dense reedbeds and bushes were preferred. In one study area 50% of their tracks were located on river banks, although this habitat constituted less than 10% of the area (Nasimovic & Isakov, 1985, as cited by Kauhala, 1996c).

In the Finnish study area moist heaths were favoured in autumn, probably because of their abundant supply of berries: raccoon dogs are fattening up on berries for the winter dormancy. In Finland bilberries (*Vaccinium myrtillus*) and cow- or lingonberries (*V. vitis-idea*) and to a minor extent raspberries (*Rubus idaeus*) are important, elsewhere also cranberries (*Vaccinium oxycoccus*). In Japan berries and fruits were also found to be important in autumn (Ikeda, 1985) and sometimes migration of raccoon dogs towards areas with abundant fruits and berries was observed (Nasimovic & Isakov, 1985, as cited by Kauhala, 1996c). Kauhala (1996c) concludes that the habitat use of raccoon dogs is affected by the availability of food, shelter and suitable den sites. It lives in Europe in habitats which are not found in its original distribution area, such as coniferous forests, steppe and semi-deserts. In the Russian far east the raccoon dog favours open landscapes, especially damp meadows and agricultural land and avoids dark forests (Judin, 1977; Nasimovic & Isakov, 1985, as cited by Kauhala, 1996). In all areas, however, the raccoon dog is very often found near water, and forages on fruits and berries in autumn.

The second large study on habitat use was conducted by Drygala et al. (2008b) in North-eastern Germany (fig. 5, nr 9). The study area was part of a vast agricultural landscape, more or less similar to the general landscape in the east and south of the Netherlands, with many maize fields, interspersed with reed beds, swamps, mixed forests, streams, ditches and lakes. The three main habitats were meadows (33%), arable land (28%) and forests (27%). A total of 12 males and 14 females, all residents, were tracked for a period of one month to four years. Four seasons were distinguished: Oestrus and gestation (March-April) - Parturition and pup rearing (May-July) - Intensive foraging and fat accumulation (August-October) - Reduced activity and winter-burrowing (November-February). Winter lethargy is less pronounced than in Finland and depends on the severity of the winter. In total 62 individual seasonal home ranges with at least 29 locations each (avg. 65±23) were available for analysis.

Of all the available radio locations 43% were in deciduous forest, 31% in meadows or pastures and only 10% in arable land. The home ranges of the animals could be divided into two types: an agrarian type with 82% of the area in agricultural land and less than 5% in forest, and the forest type with at least 50% forest, on average 68%. Both contained less than 14% of other habitat. In

their activity the raccoon dogs did not show a preference for forests (except in autumn), reeds, small woods and hedges. They tended to avoid open farmland (except during the pup-rearing period), open meadows, large water surfaces and settlements (villages and farms).

A study in Lithuania (fig. 5, nr 11), based on snow track abundance in February-March, found that raccoon dogs avoided meadows and pastures, as well as pine forests, in winter. They preferred swamps, deciduous and mixed forests, spruce and mixed coniferous forests, and to some extent arable land (Baltrunaite, 2006; 2010).

## 2.9. Population density

Estimating population density of raccoon dogs is difficult because of their secretive behaviour. The two main methods are the results of a radio-telemetry study, and the distribution and number of litters (Stiebling et al., 1999). On the basis of a large telemetry study Drygala et al. (2008a) calculated the pre-breeding population density in North-Eastern Germany as 0.95 adults/km<sup>2</sup>. In Brandenburg, Eastern Germany, Sutor & Schwarz (2011) estimated the pre-breeding population density as 1.1 adults/km<sup>2</sup>. In South Eastern Finland maximum population density was about 0.77 adults/km<sup>2</sup> (Kauhala et al., 2006). In Białowieża Primeval Forest raccoon dog density was 0.17 - 0.5 adults/km<sup>2</sup>, as compared to 0.25-0.35 foxes and 0.13 - 0.21 badgers (Kowalczyk et al., 2008). According to Jędrzejewska & Jędrzejewski (1998) and Kowalczyk et al. (2003) raccoon dogs in Białowieża reached densities of 0.7 adults/km<sup>2</sup>. In Suwałki Landscape Park in north-eastern Poland raccoon dog density was estimated to be 0.37 adults/km<sup>2</sup> (Goszczyński, 1999).

## 2.10. Reproduction

Raccoon dogs reach sexual maturity at the age of 8-10 months. Pairs are formed in autumn. The timing of the mating season fluctuates with the length of winter; in Russia and in Finland it lasts from the end of February to the beginning of April, in the Danube delta from mid February to mid March (Nowak, 1993; Helle & Kauhala, 1995). Older females breed earlier than young females (Helle & Kauhala, 1995). In North-Eastern Germany mating season is at the end of February and the beginning of March. Females are in oestrus for about 4 days. Pregnancy lasts 59-65 days, so in NE-Germany the pups are born at the end of April or the beginning of May (Stier, 2006a) and in Finland in May or the first half of June (Kauhala, 1993). In Białowieża Forest the average date of birth is 25 April (Kowalczyk et al., 2009).

### Litter size

The raccoon dog produces a relatively large litter, larger than expected for a medium-sized carnivore species (Kauhala, 1996b). It usually consists of 6 to 9 pups, with a recorded maximum of 19 pups. In the original range average litter size varies from 7.2 - 9.8 pups (Judin, 1977, cited by Ansoerge & Stiebling, 2001). In North Eastern Poland 8 pregnant females were caught alive, between 1975 and 1980, which had their litter in captivity between 30 April and 16 May. The number of cubs was 5 to 14, on average 8.75. Between 1976 and 1986 the size of 37 litters in Poland was recorded in the field: on average 6.4 cubs, range from 2 to 11 (Włodek & Krzywinski, 1986). More recently litter size was recorded in Białowieża at, or shortly after birth in 21 litters. It ranged from 4 to 12, on average 8.4. Over time litter size decreased: three months after parturition litter size ranged from 2 to 6 only, on average 3.3, giving a mortality of 61% of cubs in their first three months (1996-2006, Kowalczyk et al., 2009). In Finland average litter size at birth was  $9.5 \pm 3.2$  (SD) in SW Finland and  $7.0 \pm 2.6$  in NE Finland (combined  $n = 371$ ). Embryonic litter size, however, was  $10.4 \pm 3.1$  and  $9.0 \pm 3.4$  respectively (combined  $n = 430$ ). Intra-uterine mortality thus amounted to 9 and 22% respectively. Litter size was positively correlated with body condition (Kauhala & Saeki, 2004b). Litter size at birth ranged from 2 to 16 pups. Three to five year old females had the largest litters (Helle & Kauhala, 1995). Sixteen females from eastern Germany had litters with a mean of 7.8 (Ueckermark) and 10 (Ober-Lausitz) pups (Ansoerge & Stiebling, 2001). Mean weight of raccoon dog pups at birth in Finland was 122 g (Kauhala, 1996b). Maximum average weight in a Finnish litter was 139 grams (Kauhala, 1993). Mean total litter weight was 21% of the mean weight of the female (Kauhala, 1996b). Investment in reproduction thus is relatively high in the raccoon dog; the weight of a fox litter is only 10-13% of the mean weight of the female (Kauhala, 1996b).

Raccoon dogs have a high reproductive potential, not only because they reproduce already when one year old, as most canid species, and have large litters, but also because of the high proportion of reproducing females. On average 81% of the females reproduced in Bialowieza Forest (7 out of 11 first year females reproduced, and 10 out of 10 females older than 1 year) (Kowalczyk et al., 2009). In Finland the proportion of reproducing females averaged 78% and increased with age; productivity (number of young per female) increased from 5.5 at 1 year of age to 8.2 at more than 3 years of age. However, productivity may have been enhanced by the high hunting pressure, possibly keeping the population below the natural carrying capacity (Helle & Kauhala, 1995). In Eastern Germany the percentage of reproducing females in samples of killed animals was likewise high, varying from 75 to 100% (Ansorge & Stiebling, 2001).

## Reproductive behaviour

Females come into oestrus after awakening from winter lethargy, in Finland usually in March, in north-eastern Germany at the end of February. Raccoon dogs bring dry grassy vegetation into the den, sometimes already from mid October, to make a nest (Stiebling et al., 1999; Wlodek & Krzywinski, 1986). Pups remain in the den for about six weeks. They start to take solid food from week 3 or 4 onwards and are weaned after 40 to 50 days (Nowak, 1993).

Kauhala et al. (1998c) intensively radio-tracked five pairs of raccoon dogs during parturition and subsequent care for the pups, in southern Finland (fig. 5, nr 4). Likewise Drygala et al. (2008c) studied parental behaviour in north-eastern Germany (fig. 5, nr 7) in detail, by continuously radio-tracking (for one day a week) three raccoon dog pairs for six weeks after parturition, and by video-surveillance of one den, from before parturition to seven weeks after. Before parturition the daily distances covered and the daily range were similar for both members of a pair. The video observations at a breeding den showed, that in the two weeks before parturition the male and female always arrived and went together, spending about 33% of the 24 hr away from the den (Drygala et al., 2008c). Also in Finland the parents were at the den simultaneously, during the day for 37% and during the night for 23% of the time (Kauhala et al., 1998c). On the day of parturition the female and the male left for 3.18 and 0.33 hours respectively. The time away from the den increased for both parents in the following weeks, but the female always was absent considerably more of the time than the male (fig. 8; Drygala et al., 2008c).

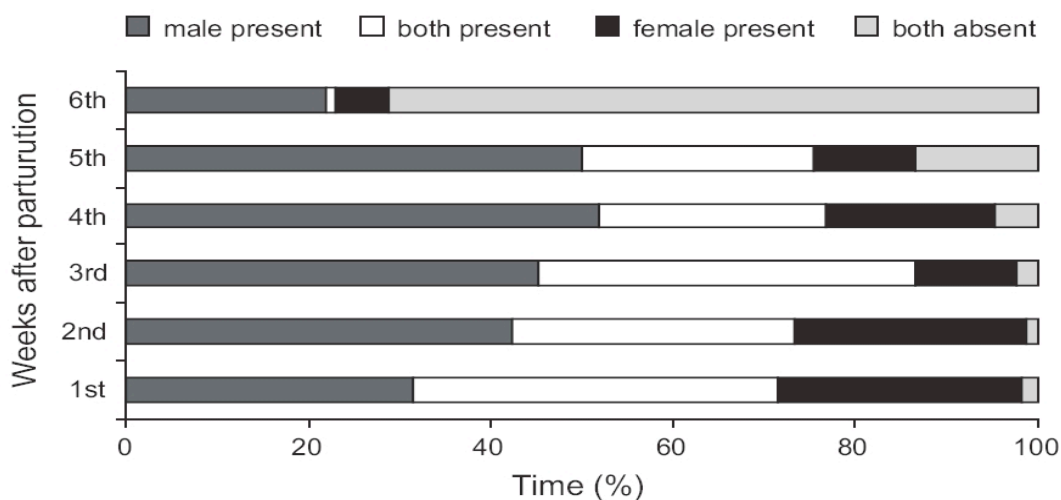


Figure 8. Time allocation of male and female to pup rearing (Drygala et al., 2009c).

Shortly after parturition, the ranges of male and female were very small. The daily range of the female increased from week to week, to about 1.50 km<sup>2</sup> in the sixth week, but the range of the male continued to be small (about 0.15 km<sup>2</sup>) and centred around the den. Its distance to the den was on average only 94 ± 17 (SD) meter during the first five weeks (Drygala et al., 2008c). The pups were seldom left alone during their first month of life; on average 2.6 ± 1.6% of the time



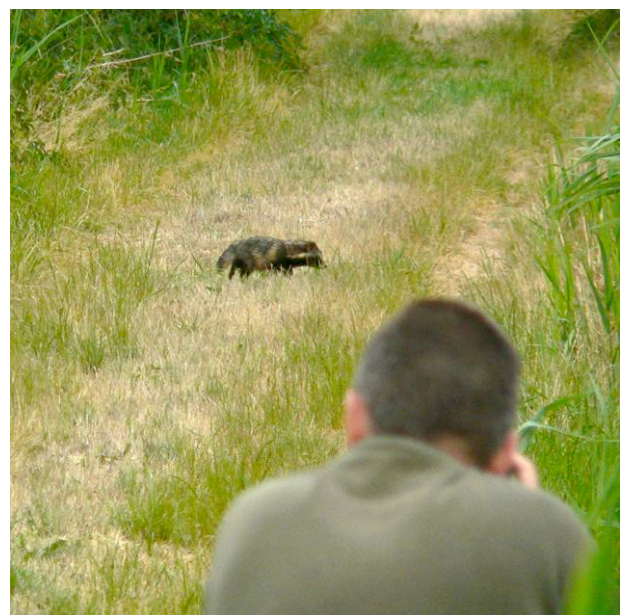
only in north-eastern Germany, and 15% (range 7-34%) of the night as well as 7% (range 2-12%) of the day in Finland. Video recordings showed, that often the attending parent left as soon as the other returned from a foraging trip. In the fifth week both parents were absent for  $13.5 \pm 12.0\%$  of the time, and in the sixth week even  $71.2 \pm 39.6\%$ . Males spent more time alone at the den (40%) than females (16%); together they spent 27% of the time attending the pups, during the 36 days of 24 hr continuous radio-tracking. In Finland females were absent 40% and 50% of the time during the day and during the night respectively, in week 1 to 5, males 23% and 39% respectively (Kauhala et al., 1998c). The important part the male plays in guarding the pups, enables the female to spend much time foraging, both during the day and during the night. This way she can compensate for the high energy demands of nursing, of milk production (Kauhala et al., 1998c). In the sixth week after parturition the den was abandoned and the pups started to rest above ground and to travel around; the male's daily range started to increase from then on (Drygala et al., 2008c). In Finland pups start to move with their parents usually in late June or early July. During a few weeks family groups of up to 12 raccoon dogs may be encountered, travelling together.

As is the case in the red fox, parents of raccoon dogs have never been observed to regurgitate food for their pups, not in the wild and not in captivity (Drygala et al., 2008c; Yamamoto, 1987). Since prey remains are rarely found at breeding dens, it was assumed that pups were entirely fed with milk. However, permanent video recordings at a breeding den in north-eastern Germany showed, that the male carried prey to the den, to provide for the female as well as for the pups. It took him on average  $88 \pm 70$  minutes after leaving to come back with a food item. The list of food items recorded at this particular den included 14 grass snakes, 7 small mammals, 4 frogs or toads, 2 legs of a roe deer, 2 roe deer fawns, 1 passeriform bird, 1 egg of chicken size, 1 mole and 12 unidentified items. No prey remains were found at the den, except for hooves and legs of the roe deer. Pups were recorded at the age of 19 days in the entrances of the den for the first time, chewing on solid food (Drygala et al., 2008c). In Bialowieza it was observed that pups started to forage on their own rather quickly; at the end of May and the start of June some were already found at a distance of 800 meters from the den (Wlodek & Krzywinski, 1986).

Usually the male guarded the litter inside the den, and the female slept outside, beside the entrance. Both parents carried the pups back to the breeding den during the first four weeks. From the fifth week onwards, the female only approached to nurse the pups for a couple of minutes, until 45 days after parturition when the whole family left the den. The pups were not yet weaned at that time (Drygala et al., 2008c). However, according to Kauhala & Saeki (2004a) pups are weaned at an age of four to five weeks.

Guarding the pups so closely during the first weeks of their life, may serve a dual purpose. First of all, predation by badgers and foxes is a real threat for the pups. A guarding raccoon dog was observed to successfully chase a badger away from a breeding den (Stier, 2006a). Secondly, permanently attending the pups may be necessary to prevent hypothermia, especially in the colder regions of the raccoon dog's range (Drygala et al., 2008c).

Although usually in badger and fox earths, raccoon dogs in Bialowieza are also born in lairs in fallen hollow trees and in dense vegetation (Kowalczyk et al., 2009). Open lairs with pups are common in areas where no dens are available, for instance in moors; showers of rain and hail may in these situations lead to a high pup mortality (Barbu, 1972).



*Raccoon dog pup, 7 or 8 weeks of age, now travelling around with its parents, 23 June. Photo H. Weber*

## 2.11. Dispersal

The high dispersal capacity of the raccoon dog was already observed early in the introduction history in Europe. In 1957 an ear-tagged animal was found in Central Poland, which had been released in 1953 in Western Ukraine; it had dispersed about 500 km (Nowak 1973). Systematic dispersal studies have only been conducted in eastern Germany. Dispersal is defined as the movement of animals from their natal range to the place where they settle and (will) reproduce (Howard, 1960). In field studies it is, however, usually unknown whether the marked animals, reported back by hunters for instance, have already settled and started to reproduce.

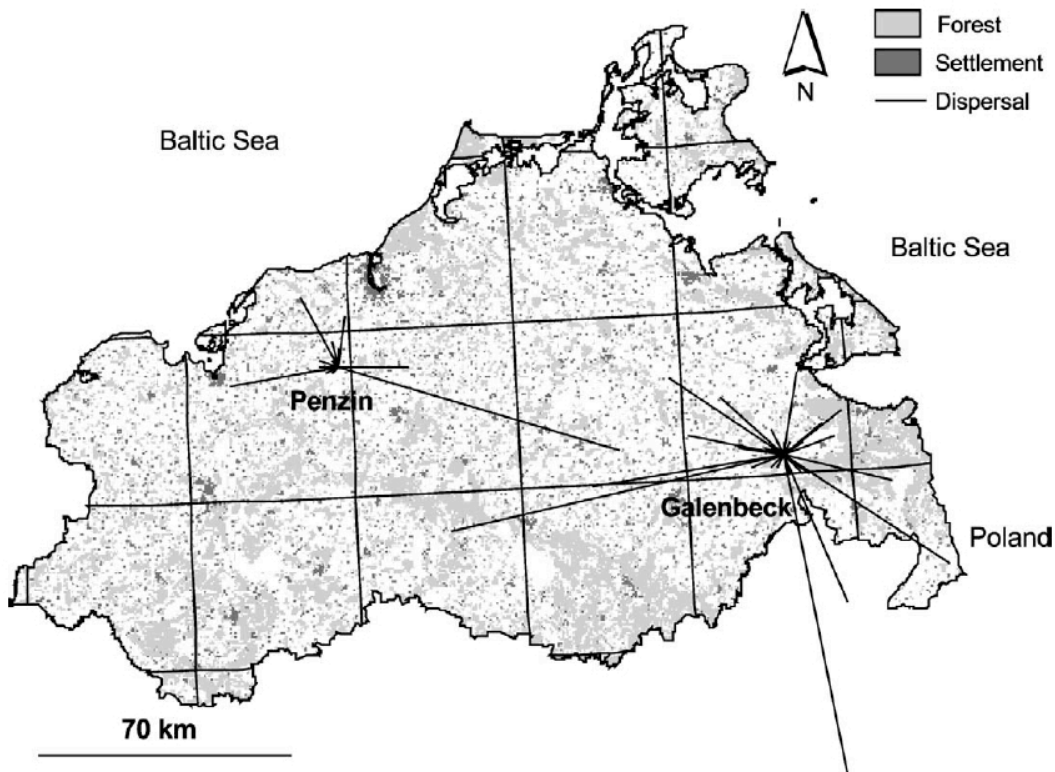


Figure 9. Dispersal of earmarked young raccoon dogs from two study areas in Mecklenburg-Vorpommern. From Drygala et al., 2010.

Drygala et al. (2010) fitted 48 young raccoon dogs in Mecklenburg-Vorpommern with radio-collars, and ear-tagged a further 88 pups. A total of 43% of the marked animals were reported back, with a mean distance from the marking point of  $13.5 \pm 20.1$  km and a maximum of 91 km (fig. 9). Most animals were reported within 5 km of their marking point, only 8.5 % travelled more than 50 km. However, regarding only individuals which were reported back at an age of  $> 1$  year, of which thus safely can be assumed that their dispersal process had been completed, dispersal distance was  $17.8 \pm 23.4$  km ( $n=18$ ). All of the 48 radio-collared young raccoon dogs left their natal range. However, in another dispersal study, in southern Brandenburg 3 of the 11 ear-tagged juveniles which were recovered after more than a year, were reported from the vicinity of their marking place (Sutor, 2008). The four longest distances covered by dispersing raccoon dogs in this study ranged from 58 to 108 km. Mortality rate among young tagged raccoon dogs was 69% during the first year (Drygala et al., 2010). Hunting (55%) and traffic (27%) were the major causes of death. Domestic dogs killed 8% of the young raccoon dogs. The radio-collared individuals dispersed between July and September, in a variety of movement patterns. Some departed from one day to the next, some made several excursions before finally departing for good. Some travelled many times between their natal range and a second range, before eventually settling there. Some roamed the landscape, some walked for days on end in the same direction (covering average daily distances of 5 - 12 km) before establishing a home range somewhere. Human settlements were avoided during dispersal. Almost no dispersal was apparent during winter. Two individuals (males)

established a temporary home range during winter, but started to disperse again in April, the mating season. A striking characteristic was the lack of difference between males and females, contrary to in most other canid species, both in average distance covered during dispersal and in time of dispersal (fig. 10). This implicates, that reproduction can start quickly in newly invaded areas; in most other canids the males disperse over much longer distances than the females (Drygala et al., 2010).

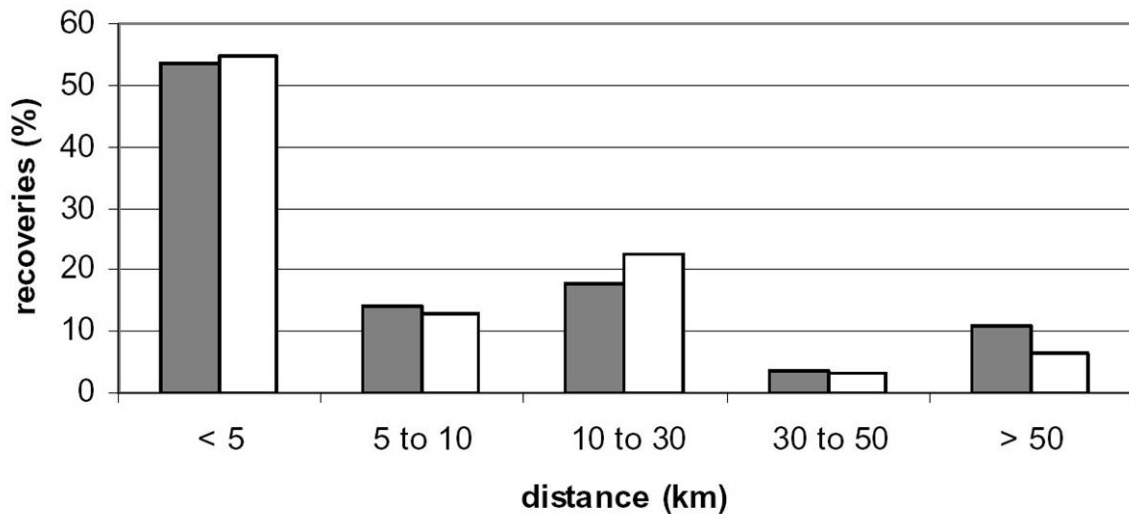


Figure 10. Distribution of recovered earmarked young raccoon dogs, according to sex and distance. Grey columns: females; white columns: males. From Drygala et al, 2010.

## 2.12. Mortality and age

Within three months after birth 61% of the pups in Bialowieza Forest disappeared, as deduced from the negative relation between litter size and age of the pups (Kowalczyk et al., 2009). Mortality among young raccoon dogs during their first year amounted to 89% in Finland (Helle & Kauhala, 1993). Pups may be killed by other predators, such as foxes and badgers with which raccoon dogs often share dens, or die from diseases such as sarcoptic mange (Nowak, 1993; Kowalczyk et al., 2009). In Poland golden and white-tailed eagles take raccoon dogs and their pups (Wlodek & Krzywinski, 1986). In the Danube delta many pups in open lairs die as a result of rain and hail showers (Barbu, 1972).

Of 82 dead raccoon dogs recorded in the Bialowieza Forest, at least 55% died of natural causes: 27% by predation by wolves and dogs, often in the vicinity of predator kills, and 27% by diseases such as sarcoptic mange and rabies, mainly in August to November. When killed by predators, raccoon dogs were rarely consumed. 40% of the recorded dead animals were killed by humans, the majority of them by cars. 18 out of 20 traffic victims were juveniles. 16% of the recorded deaths were due to hunting and poaching, although there is no hunting in the central reserve of the Bialowieza Forest. A sample like this probably does not constitute a reliable representation of the real mortality, because it is affected by observer bias, in contrast to a study with radio-collared animals (Kowalczyk et al., 2009). The same bias applies to an earlier account of causes of death, in Poland. Of 1214 dead raccoon dogs recorded between 1974 and 1984, 276 were killed by dogs, 218 were beaten to death by man, 210 were killed by traffic (mainly between August and October), 121 by poachers, 115 by rabies, 83 by harvest machines, 29 by wolves and 19 by other causes; of 143 raccoon dogs the cause of death was uncertain (Wlodek & Krzywinski, 1986). At present rabies has been eradicated from most of Poland (see section 2.16), thus no longer constituting a major mortality factor in raccoon dogs.

In Bialowieza, among 17 radio-tracked individuals, all older than 5 months, the annual mortality was 62%. A life table, constructed on the base of age at death of radio-collared animals and all other recorded deaths, suggests a mortality of 82% in the complete first year of life and 50 to 68% in the years 2 to 5; maximum recorded life span was 7 years. Pairs of the raccoon dogs live and

move around very closely together; they also often die together (especially when killed by predators or hunters,  $n=2$ ) or a short time (8 to 114 days,  $n=3$ ) after each other (Kowalczyk et al., 2009). Sex ratio in samples of dead raccoon dogs always is equal (for instance Helle & Kauhala, 1993), contrary to in other carnivores. Apparently, males and females run the same risk to die, being shot or killed on the road, for instance. This is most probably the result of their similar life style, activity, home range size and dispersal distance, which in other carnivore species generally differs considerably between the sexes (Ansorge & Stiebling, 2001).

Life tables from southern Finland (where a high hunting pressure prevails) indicate an annual average mortality rate of 80%: 52% for adults and 88% for juveniles. Mortality rate was lowest among 2-4 year old raccoon dogs and increased after 5 years of age. Maximum life span seemed to be 7-8 years. Almost 1300 raccoon dogs, collected between 1986 and 1990, were used in this analysis (Helle & Kauhala, 1993). In a sample of 328 raccoon dogs from Eastern Germany (mostly shot), the oldest individuals were 6 years old; 70% were maximum 1 year old, 14% 2 years old and 9.5% 3 years old, while the older classes comprised only 1-2 % each (Ansorge & Stiebling, 2001). Age structure in the original East-Asian range and in several recently occupied European countries is similar, according to the authors probably because of a similar hunting pressure (Ansorge & Stiebling, 2001).

Raccoon dogs are vulnerable for predation for several reasons. Pups are easily accessed by badgers and foxes which use the same (type of) burrows, and also by larger predators (wolf, lynx and bear) when in more open lairs. Adult raccoon dogs may profit from carcasses left by larger predators; in some areas scavenged meat is a very important part of their diet (Jędrzejewska & Jędrzejewski, 1998; Sidorovich et al., 2000, 2008). However, use of carcasses by raccoon dogs is risky because the raccoon dogs may become prey themselves when carcasses are revisited by wolves or lynx, or utilized by large birds of prey. Kowalczyk et al. (2009) recorded three such kills, one by a white-tailed eagle and two by wolves. Its behaviour makes the raccoon dog also vulnerable: when approached they usually remain still without escaping. They are easily caught with dogs or even with hand held nets (Kowalczyk et al., 2009). In late autumn their mobility is reduced by excessive fat reserves. Their body mass then is 50-70% higher than in spring (Kauhala, 1993).

## 2.13. Relations with native predators

Sidorovich et al. (2000) studied the dietary overlap between all generalist predators in the natural forest landscape of northern Belarus: brown bear, lynx, pine marten, badger, red fox, raccoon dog and polecat. In the warm season (April - October) there seems to be little resource competition between the different predators, because of the wide food spectrum of most species. However, in the cold season food availability is much more limited, both in abundance and diversity: fruits, small mammals and especially carrion. Wild ungulate carrion (elk and wild boar) is intensively used by most species in winter; only badger and lynx use them to a lesser extent. Especially in late winter, when snow conditions make it energetically costly to forage, carrion is often the only food available. In that period raccoon dogs are not active, being dormant in their dens. However, in late autumn and early winter they have fed considerably and effectively on the available carrion, depleting this resource substantially. During late winter this might severely affect the native predators in the area (Sidorovich et al., 2000). Especially the polecat seems to be affected: as measured by track counts, a significant negative correlation was found between abundance of raccoon dogs and polecats in the two study areas in a 14-year period, from 1985 to 1998: polecat decreased, raccoon dog increased in this period. In one of the two study areas a negative correlation was also found with red fox, pine marten, badger and brown bear. Deep snow as well as poor soils (few masting trees) and therefore much less small mammals living under the snow are factors that may enhance late winter food competition in northern Belarus (Sidorovich et al., 2000), as compared to the situation of the more southern forest of the Białowieża Primeval Forest (Jędrzejewska & Jędrzejewski, 1998), which does not grow on poor glacial soils.

### Badger

In Finland and in the Białowieża Forest in Poland raccoon dogs have now become more common than foxes and badgers (Ansorge et al., 2009). Kowalczyk et al. (2008) postulate a positive effect of badgers, and especially of their setts, on raccoon dogs, facilitating their success. Burrows are an important resource for badgers, foxes and raccoon dogs, for reproduction, winter rest (or lethargy), and for daytime shelter. Use of badger setts by these three medium-sized predators may lead to negative (predation, interference competition) and positive (facilitation) interactions among the three species. Communal denning has always been a common phenomenon between badgers

and foxes in Europe, and now the raccoon dog joins these two species in their interest in burrows. Kowalczyk et al. (2008) studied the three species in Bialowieza Primeval Forest by radio-tracking and by badger sett monitoring, from 1997 to 2002. Cohabitation of setts was very common in winter: in 88% of 71 'sett-winters' badgers shared a sett with raccoon dogs, in 4% with foxes, in 4% with both species and in only 4% they were the sole species in the sett. In summer cohabitation was much less: of 49 'sett-summers' badgers lived alone in the setts in 80% of the summers, sharing with raccoon dogs and foxes in only 10% for each species of the summers. Occupation of badger setts by raccoon dogs or foxes never led to the departure of badgers. Different species sometimes used the same entrances to come and go, but used different parts of the sett to rest below ground. In all the years of research, only five times raccoon dog pups were present in an active badger sett. In three of those cases there were no badger cubs present, in two cases it was not known if the badgers reproduced. Also five cases of red fox reproduction were found in active badger setts, and in only one case there also was a badger litter present. Foxes always used an entrance at the edge of the sett, an entrance which was not used by badgers. Once a fox cub was found dead on a sett, killed by a badger, and once two raccoon dog cubs. Several dead adult raccoon dogs and foxes were found on and in badger setts, which may have been killed by badgers. In winter the raccoon dog may benefit from badgers, with higher winter survival. In summer however, the costs of sharing a sett may be higher than the benefits, due to predation of pups. No evidence of aggression of raccoon dogs or foxes against badgers was found. However, remains of a badger cub have been found in raccoon dog scats in Bialowieza Primeval Forest (Jędrzejewska & Jędrzejewski, 1998).



*A corner of a badger sett, with a latrine produced by raccoon dog cubs. Photo J.L.Mulder*

So, badger setts were a very important resource for raccoon dogs in Bialowieza Forest. Through ecosystem engineering, badgers improve unfavourable habitats for raccoon dogs by providing them with predictable, long lasting refuges from stress (cold) and predation, as well as comfortable reproduction sites. Elsewhere badger setts were important for raccoon dogs as well: In a Latvian nature reserve, in winter, 41% of badger setts were occupied by raccoon dogs (Zoss, 1992). In a Lithuanian nature reserve, in spring, 8% of badger setts were used by raccoon dogs for reproduction (Ulevicius, 1997). In South Eastern Finland radio-collared badgers and raccoon dogs were detected wintering or resting together on 24% of 135 simultaneous locations in winter and 12.5% of 124 locations in summer (Kauhala & Holmala, 2006).

The invasion of raccoon dogs did not result in a decrease of densities of badgers in de Bialowieza Primeval Forest or in other European localities (Kauhala, 1995; Kowalczyk et al., 2000; Sidorovich et al., 2000). It appears, that these two species can coexist and utilize available resources with minimal competition (Jędrzejewska & Jędrzejewski, 1998).



## Red fox

It has been argued that the number of foxes started to decline as soon as the raccoon dog appeared. Relative predator population size usually is assessed from the number of animals killed by hunters. In north-eastern Germany this 'bag record' indeed decreased during about four years (2000-2004) after a rather long period of gradual increase; the decline coincided with the first part of the expanding phase in the raccoon dog population (fig. 11). However, since 2004 the bag record of the fox is more or less stable again, although with strong fluctuations. So if the arrival of the raccoon dog has had some impact on fox numbers, it has not been very strong. In its original range, the raccoon dog has always coexisted with the red fox (Zoller, 2006). In Lithuania the increase in the abundance of the raccoon dog did not result in a distinct decline of native medium-sized predators, also suggesting a weak or absent competition between them (Baltrunaite, 2010).

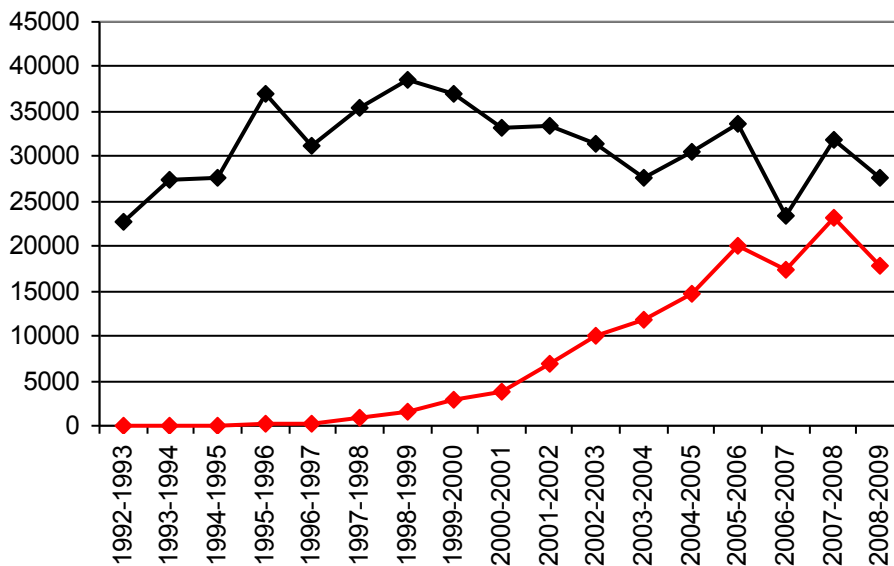


Figure 11. Hunting bag of red fox (black) and raccoon dog (red) in Mecklenburg-Vorpommern, NE-Germany, from 1992 to 2009. After Rackwitz & Hellwig, 2010.

Baltrunaite (2006) concluded that the impact of raccoon dog on red fox (and pine marten) in Lithuania was insignificant, because of differences in diet, hunting tactics, specific use of some habitats and its relatively low abundance. However, because fox and raccoon dog population indices correlated negatively during a five year predator removal experiment, Kauhala (2004) thinks that competition between these two species is possible and, if the hunting pressure towards one of them is high, the other species may benefit and increase in numbers. Competition is possible, because foxes and raccoon dogs have a large overlap in diet (Kauhala et al., 1998b). Both species have been observed to kill cubs of the other species (Stier, 2006b) but adults killing each other is unlikely, because raccoon dogs do not seem to avoid foxes (Kauhala, 2004) and are more or less the same size and strength. A third process in the possible competition between raccoon dog and red fox may be an enhanced mortality in the red fox by sarcoptic mange after the arrival of the raccoon dog, due to a higher incidence of mange in this species than in the red fox (section 2.16).

Cannibalism is occasionally reported in raccoon dogs. The male of a captive raccoon dog pair pulled almost all the 3-4 weeks old cubs of the raccoon dog pair in the next cage through the fence and ate them (Stier, 2006a). How common such cannibalism is in the wild, remains unclear.

## 2.14. Diet

Sutor et al. (2010) studied the diet of raccoon dogs in eastern Germany, and reviewed 81 other food studies from 9 countries, both from Europe and from its native range in continental eastern Asia. Everywhere the raccoon dog can be typified as a 'gatherer' rather than a 'hunter', with a very broad spectrum of food items: an opportunistic omnivore. It profits from all available food sources, both temporary and permanent, which must have contributed to its successful colonization of Europe. Important food items in virtually all studies were small mammals, insects, plants (cereals, maize, fruits and berries) and carrion. In wet habitats a large proportion of its diet consists of amphibians and fishes; in one German study area amphibians were found in about 50% of the stomachs and fish in 11% (Sutor et al., 2010).

In northern Belarus (fig. 5, nr 12), in the transition zone of boreal coniferous forest and deciduous forest, raccoon dog diet varied with season and habitat, and not individually, i.e. between different pairs successively occupying the same home range. The main factors influencing the composition of the food consumed by raccoon dogs, were: type of top soil (clay = rich or sand = poor), proportion of lakes and marshes and proportion of berry-rich pine stands, mostly on poor soils. On rich soils more reptiles, amphibians, small mammals and medium-sized mammals were eaten. With many lakes and marshes in the area more birds were consumed, fish and mollusc consumption increased with higher lake abundance as did berry consumption with higher proportions of berry rich pine stands. During periods with snow cover the consumption of small mammals decreased and the amount of carrion increased in the diet. In years with a good berry crop raccoon dogs ate much more berries than in years with a poor crop. All these results suggest that the raccoon dog is a generalist predator with an opportunistic feeding behaviour. Its diet reflects the availability of easy to get food categories (Sidorovich et al., 2008). To the same conclusion came Baltrunaite (2005) after studying the diet of raccoon dogs in three different landscapes of Lithuania. In spring and summer the diet was more varied than in autumn and winter, and availability of food determined diet composition.

A striking aspect in all diet studies is the lack of hares and rabbits. In the red fox, which is of similar size as the raccoon dog, these lagomorphs always make up an important part of the consumed food, if they are present in the environment. This illustrates that raccoon dogs are not typical hunters, but subsist upon food items for which speed and agility are not important.

There are many examples of the opportunistic feeding behaviour of the raccoon dog. It has been seen following the plough in the twilight (to catch voles?); to turn up cow-dung to eat insects; to eat the scats of lynx; to follow the line of dredged sludge along a waterway, to eat molluscs and other food items; to search the high water mark along the Baltic sea for fish and molluscs; to pick up potatoes after the harvest and to eat from carrots and beets on the field; to climb in fishermen's vessels to eat the discarded small fishes; to visit campsites for edible waste; to walk long distances to orchards for the fallen fruit (Wlodek & Krzywinski, 1986).

The male raccoon dog carries prey to the den with pups, to provide for the female and the pups. With video observations at a den in North-Eastern Germany 44 such food items were recorded. The list included 14 grass snakes, 7 small mammals, 4 frogs or toads, 2 legs of a roe deer, 2 roe deer fawns, 1 passeriform bird, 1 egg of chicken-egg size, 1 mole and 12 unidentified items (Drygala et al., 2008c; see also section 2.10).

Where carrion is available (from wolf or lynx kills, or hunting waste (entrails), or natural death of ungulates) it is intensively used. Dead bison in the Białowieża Primeval Forest were revisited by raccoon dog pairs very often, especially when lying in cover; carcasses lying in the open were rarely visited (Selva et al., 2003). Scavenging on carcasses may be a tricky business: raccoon dogs often become victims of large predators (wolves) at carcasses (Jędrzejewska & Jędrzejewski, 1998). Raccoon dogs also profit from the food provided by hunters for wild boar (maize, offal, fruit, etc). Similar to the case of large carcasses, many are being shot on these feeding grounds (Stiebling, 2000). Other temporary and locally available abundant food sources are sometimes feasted upon: fish when fish ponds dry up, eggs when a colony of black headed gulls is present (Nowak, 1993).

Remains of egg shells are rarely reported from studies of raccoon dog stomachs. Sometimes shells of domestic chickens were found, probably from feeding places for wild boar (Stier, 2006a). In most food studies eggs are not mentioned at all (Kauhala, 2009). The extent of egg consumption by raccoon dogs is not known.

## Relevant diet studies

For the future situation in the Netherlands, the various German diet studies are the most important, plus wetland studies elsewhere. Up till now three German studies have been published (Stier (2006a), in north-eastern east Germany; Ansorge (1998) and Sutor et al. (2010), both in south-eastern east Germany). Only one study from a wetland situation is available, from the Danube delta (Barbu, 1972). Table 1 contains the results of these studies, relevant for the Netherlands.

*Table 1. Diet composition (%) in some relevant food studies. Several studies are listed two or three times, with a different method of calculating the importance of food-items, different seasons or different study areas.*

*Methods: FO = Frequency of occurrence, i.e. percentage of stomachs in which the item occurred (sum of percentages > 100%); PB = percentage of total biomass (adds up to 100%). Percentages within brackets form part of a more general category.*

author:	Barbu, 1972	Barbu, 1972	Ansorge, 1998	Ansorge, 1998	Stier, 2006a	Sutor et al., 2010	Sutor et al., 2010	Sutor et al., 2010
area:	Danube delta	Danube delta	SE-East-Germany, Saxonia	SE-East-Germany, Saxonia	NE-East-Germany	SE-East-Germany, Brandenburg	SE-East-Germany, Brandenburg	SE-East-Germany, Saxonia
main habitat	marsh	marsh	agri-culture	agri-culture	agri-culture	agriculture	agriculture	agri-culture
season:	summer	winter	year	year	year	summer	winter	year
n stomachs	85	40	27	27	306	232	58	37
method:	FO	FO	FO	PB	PB	FO	FO	FO
invertebrates						69.4	29.3	95.0
leeches	8.2	-			-			
earthworms			7.4	2.1	2			
molluscs	-	2.5			1			
insects	50.6	-	59.3	0.8	2			
fishes	3.5	2.5	7.4	10.9	13	1.7	0	10.8
amphibians + reptiles						19.0	13.8	54.1
amphibians	44.7	12.5	18.5	5.2	17			
reptiles	15.3	5.0	7.4	4.0	1			
birds	17.6	20.0	18.5	10.3	14	7.5*)	13.8*)	8.1*)
bird eggs	8.2	-			-			
small mammals			33.3	5.3	9	27.2	24.1	37.8
rodents	21.2	35.0	(25.9)	(3.9)				
insectivores	4.7	5.0	(7.4)	(0.2)				
carrion	2.4	5.0	25.9	36.1	27	15.5	19.0	8.1
compost						1.3	5.2	2.7
plants	32.9	32.5	51.9	24.3	15			
fruit/berries				(17.8)	(9)	25.4	22.4	43.2
maize			(11.1)	(5.0)	(5)	18.1	32.8	21.0

\*) including eggs



Some details per project (table 1):

Barbu, 1972. Summer. The 'summer'-period comprises spring, summer and autumn in this case, the 'warmer' seasons of the year. Data are given in frequency of occurrence, so one small insect gives the same score as one bird or mammal. In 'summer' insects and amphibians were the most common prey, followed by rodents, birds and reptiles. Amphibians: a total of 32 individual newts, 55 toads, 5 tree frogs and 161 other frogs (*Rana*) were counted. The reptiles constituted 11 lizards and 8 grass snakes. Bird-eggs were found in more than 8% of the stomachs, but considering only the stomachs from April and the first half of May, the percentage of stomachs containing bird eggs amounted to 28.5%. Plants scored very high in the stomachs, but mostly represented accidentally (with other prey) ingested material. In only 4.8% of the stomachs fruit was present, and in 2.3% maize.

Barbu, 1972. Winter. In winter (December to February) rodents (mostly water voles *Arvicola terrestris*) with 35% and birds (20%) predominated in the diet. Birds were mainly ducks, coots *Fulica atra* and moorhens *Gallinula chloropus*. The author states that in winter many corpses of these species are available in the field. In mild winters the raccoon dog may to some extent (12.5% and 5% in different winters) feed on amphibians and reptiles.

Ansorge, 1998. A study on just 27 stomachs. Carrion and fruit constituted the two main categories in the diet. This study was repeated later as part of the study by Sutor et al., see below, with somewhat more stomachs (n=37).

Stier, 2006a. This study is an extension of the studies published earlier by Drygala et al. (2000 and 2002). In 80% of the stomachs insects were present, but in biomass they represented only 1.6% of the total stomach contents. Cultivated fruits (mainly plum, cherry, apple and pear) and maize were present with 4% in winter, 15% in spring, 17% in summer and 23% in autumn. Since maize was present in stomachs throughout the year, most of it must have come from feeding sites for wild boar. Raccoon dogs had no problems (unlike foxes) with consuming shrews, moles and hedgehogs. These insectivores were the most common mammal category, followed by voles. The more agile species of mice (e.g. wood mouse, harvest mouse) were the least consumed mammal category. At least a part of the birds in the stomachs must already have been dead, when eaten by the raccoon dogs, because raccoon dogs do not climb and are too slow to surprise birds like buzzards and thrushes. Radio-collared raccoon dogs were observed to search the verges of roads for hours on end, to eat traffic victims (insects, molluscs, amphibians, small mammals, birds). Carrion amounted to more than 40% in winter and was mostly hunting waste, left in the field: entrails of roe deer and wild boar. Although a large number of stomachs were collected in the spring season, bird eggs were found only twice; both were chicken eggs, probably eaten at a wild boar feeding place.

Sutor et al., 2010. In the Saxonian study area there are many fish ponds, resulting in a greater presence of amphibians and fish in the raccoon dog diet there, than in Brandenburg. Some stomachs in this study contained only one type of food, e.g. maize in winter, frogs or grasshoppers in summer. The category small mammals mainly consisted of the voles *Microtus spec.* and *Arvicola terrestris*, but also some shrews (*Soricidae*) were consumed. About 10% of the invertebrate samples consisted of earthworms and molluscs. About 90% of the amphibian-reptile category consisted of amphibians (of them 18% were toads and 82% frogs) and 10% of reptiles. Consumed fruits were mainly apples and pears. The birds in the stomachs were mainly (74%) small *Passeriformes*, mainly skylarks *Alauda arvensis* and their nestlings. Five stomachs contained thrushes, two contained parts of mallards *Anas platyrhynchos*. Only in a negligible small number of stomachs remains of bird eggs were found. Carrion mainly consisted of hunting waste; especially in the Brandenburg study area this was abundantly available from October to January.

## 2.15. Predation and impact on prey species

In southern Finland 1% of raccoon dog faeces (n=206) collected in May and June (the breeding season for birds) contained remains of waterfowl, and none contained remains of gallinaceous birds (Kauhala et al., 1993b). However, in the same study, in 63 stomachs from southern and central Finland, dating from spring and summer, 10 times (in 16% of the stomachs) remains of gallinaceous birds were found and none of waterfowl. Most of the gallinaceous birds were introduced pheasants (*Phasianus colchicus*) but some black grouse (*Tetrao tetrix*) and hazel grouse (*Bonasia bonasia*) also occurred (Kauhala et al., 1993b). However, grouse populations started to decline in southwest Finland as early as in the 1960s, i.e. before the raccoon dog invaded the area (Helle & Kauhala, 1991). In Poland, Reig & Jedrzejewski (1988) found that, while red foxes

frequently prey on birds, raccoon dogs do so only occasionally. Naaber (1971) concluded that raccoon dogs have little impact on grouse or hare populations in Estonia. In fact, the raccoon dog is a rather slow and very clumsy predator and most probably has great difficulties in catching fast prey like adult birds or hares (Kauhala et al., 1993b).

In a large scale predator removal experiment in southern Finland (removal in 55 km<sup>2</sup>, control in 48 km<sup>2</sup>), during a five year period, no evidence was found that the non-native raccoon dog had a negative impact on the breeding success of dabbling ducks (Kauhala, 2004). Either predator removal was not successful enough in this experiment (see section 2.18) or raccoon dogs did not have a noteworthy effect on the breeding success of waterfowl. The positive correlation between the raccoon dog index and the breeding success of dabbling ducks in this experiment suggests that the latter alternative is true. However, removing mainly one predator, like the raccoon dog, may not have the desired effect on the breeding success of birds, because both the numeric and functional response of other predators, like the fox, may increase and lead to compensatory predation (Kauhala, 2004). In Latvia, of 1059 duck nests destroyed by predators on a eutrophic wetland, only 0.6% were attributed to raccoon dogs; the main predators were marsh harrier (53.7%), corvids (14.7%) and American mink (9.0%); 13.6% of the depredations could not be attributed to a specific predator (Opermanis et al., 2001).

Another, much more limited Finnish experiment (two removal areas of 2.0 and 3.5 km<sup>2</sup>) focussed on raccoon dog removal in wetlands near Helsinki (Väänänen et al., 2007). A first year with no removal was followed by two years of raccoon dog removal and some fox removal. Two other areas of unknown size acted as control areas with no predator removal during all three years of the experiment. Relative densities of raccoon dogs and red foxes were estimated from sign post indexes. In the control areas predator densities were constant, in the removal areas raccoon dog densities decreased during the experiment. Red fox density decreased considerably during the first removal year in one area but was constant (and low) in the other (opus cit., Table 1). Breeding success of four species of waterfowl in the two removal areas increased in the second year of the experiment, but decreased again to the original level (with no raccoon dog removal) in the third year (opus cit., Table 3). The results of this removal experiment are thus rather inconclusive. The strong decline in the red fox index in one of the experimental areas from first to second year may also have influenced the improved breeding results in the second year. For removal experiments of predators scale is important. Since home ranges of raccoon dog and red fox in southern Finland are several km<sup>2</sup> each (Kauhala et al., 2006), removal areas of 2 and 3.5 km<sup>2</sup> constitute at most one home range (= family) of each species. Nevertheless, each year 20 to 31 raccoon dogs were killed in each area in this experiment (Väänänen et al., 2007, Table 2), indicating that dispersing animals were constantly entering the removal areas. Such small experimental areas are insufficient for a sound predator removal experiment.

Also in Germany much discussion, especially among hunters, has been devoted to the role of the raccoon dog in the predation of (nests and chickens of) ground breeding birds. However, according to Langgemach & Bellebaum (2005), real data are mostly lacking. The impact of raccoon dogs on breeding success of ground breeding birds is considered rather small, compared to that of foxes (Langgemach & Bellebaum, 2005). Sutor et al. (2010) state: "Potentially predation pressure by the raccoon dog on widespread bird species is low, but a negative impact on small and isolated bird populations - for example the residual population of great bustard [*Otis tarda*] in Germany - cannot be excluded".

Although there are indications that raccoon dogs do predate on nests of ground breeding birds, there has been no sound research into its effect on the population level, as yet. A low reproduction result and a population decline are two different things, which are not necessarily connected. Much of the reproductive effort of a species may get lost, to predation for instance, without effects on its population size. The trends in wetland breeding birds in Germany for instance do not reveal a clear downward trend in breeding populations since the arrival of the raccoon dog. Of all the duck species only the pochard *Aythya ferina* declined in numbers. One vulnerable wetland bird species has even strongly increased in numbers, especially in north-east Germany where raccoon dogs are now common: the crane *Grus grus* (Sudfeldt et al., 2009; <http://www.dda-web.de/index.php?cat=service&subcat=vid>). A study on coot population and breeding success in a Polish wetland is, however, suggestive of an influence of raccoon dogs on coot population size (Rek, 2009). Coots were studied in 1980-1982 and again in 2002-2003. In the first period non-native mammalian predators were still absent, whereas the number of hooded crows was several times higher than in the second period. In the period between the two research periods raccoon dog and American mink established themselves in the area, and shortly before the second period also the raccoon *Procyon*

*Iotor* arrived. From the 1980 to 2002 the number of coot breeding pairs more than halved, but breeding success increased. The author: "In 2002–2003 hooded crows were the main coot predators during incubation [despite their much lower numbers, JLM]. Other predators, such as the raccoon dog or American mink, were of little importance". Notwithstanding these research results, the author argues in his discussion that raccoon dog and American mink can be responsible for the population decline, thereby basing himself purely on the correlation between coot decline and appearance of these predators in the area. However, other possible changes in the twenty year period (water quality, food availability for coots, etc) are not discussed at all.

Kauhala & Kowalczyk (2011) reviewed the literature on all aspects of the invasion of raccoon dogs in Europe, including their impact on prey species. In this respect they state, based on expert judgement: "Hunters in particular have suspected that raccoon dogs destroy the nests of game birds (Lavrov, 1971). According to Naaber (1971, 1984), raccoon dogs robbed 85% of waterfowl nests in some areas of Estonia. Ivanova (1962) found remains of birds (mainly water birds) in 45% of raccoon dog scats collected in a river valley in Voronez [500 km south of Moscow; JLM]. When the raccoon dog population increased rapidly in Russia, it was thought to be very harmful but, according to Lavrov (1971), this was not based on fact. Raccoon dogs were accused of causing the decline of grouse populations even in areas where raccoon dogs did not occur (Lavrov, 1971). Even today robust scientific studies, clearly demonstrating that raccoon dogs cause damage to native birds, are scarce."

In island situations breeding bird populations are in general more vulnerable to predation by raccoon dogs, especially if mammalian predators were lacking before. If raccoon dogs reach such islands, their impact may be considerable (Kauhala, 1996a). As reported by Kauhala & Auniola (2001), in summer 2–67% of raccoon dog faeces from the Finnish archipelago contained waterfowl (mainly eider) remains, but most probably a major part of them had been found as carcasses. The raccoon dogs were estimated to kill only 1.2–3.5% of the nesting female eiders each year. Rather many scats (11–40%) contained egg-shells. More egg-shells were found in the scats in July (after eider chicks had hatched) than earlier in spring. The predatory impact may differ from area to area, depending on food availability and the local fauna composition (Kauhala & Auniola, 2001).

Prey species other than breeding birds may be affected by the newly arrived raccoon dog. Especially on small islands, frog populations may become threatened. Frogs have indeed vanished from some islands off the southwest coast of Finland after raccoon dogs arrived in the 1970s, but frog populations have not declined on the outer islands where raccoon dogs are not found (Nummelin, pers. comm. in Kauhala, 1996a). Recently the remnant and reintroduced populations of the European pond turtle *Emys orbicularis* in north-east Germany have become endangered by non-native mammals. Raccoon dogs (and wild boar) eat eggs and newly hatched turtles in the nests, but more importantly for turtle population survival, raccoons *Procyon lotor* catch young and adult turtles in shallow water (Schneeweiss & Wolf, 2009). Sutor et al. (2010) fear for an impact of the raccoon dog upon the fire bellied toad *Bombina orientalis* which occurs in small isolated populations in Germany, but present no data.

So, in conclusion: raccoon dogs can have an effect on the breeding success of ground nesting birds, mostly in wetland areas and especially in bird colonies. They eat the eggs and chicks, but only rarely the breeding adults. However, from population trends there is no evidence yet for an impact on population size of ground breeding birds, and well designed studies into predation on ground nesting birds are still lacking. Raccoon dogs may be a serious threat for small isolated populations of amphibians, and probably also for turtles.

## 2.16. Infectious diseases and public health

The raccoon dog can play a role in the transmission of several infectious diseases, including parasitic diseases, to other species and/or to humans. New species in an area may import new diseases, act as new vectors for diseases (transmitting the disease to other animals or humans) and/or act as new reservoirs for diseases (Tackmann et al., 2003). However, as far as is known, there are no new diseases or parasites imported by raccoon dogs to Europe, but they may act as reservoirs for several pathogens already present in Europe. Here, these pathogens and their diseases will be discussed.

## Rabies

Rabies, caused by the classic rabies virus, is an important disease in canids. The raccoon dog is one of the canids that can be an important reservoir and vector of rabies. Until the introduction or invasion of the raccoon dog, the red fox was by far the main reservoir and vector of rabies in Europe. That situation has 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 the raccoon dog was the main vector and victim, with 73% of all reported rabies cases (Westerling, 1991). In north-eastern Europe the raccoon dog was the main vector of rabies as well; in the 1990s, from 7 to 50% of all rabies cases in Poland and the three Baltic states were raccoon dogs (Mol, 2005; Kowalczyk, 2007). Also in Lithuania the raccoon dog has surpassed the red fox in number of rabies cases in recent years (Zienius et al., 2007). Raccoon dog rabies showed a peak in late winter (Westerling, 1991; Reinius, 1992, WHO 2003, 2004), suggesting an efficient spread of the disease during mild nights in late winter, when raccoon dogs may be active and moving about. Another peak is in autumn, when juveniles disperse; this peak must indeed be caused by juveniles, because adults decrease their activities towards autumn (Kauhala et al., 2007). In Lithuania there was one peak in rabies cases in raccoon dogs only, from September to December (Zienius et al., 2007).

The introduction and secondary colonization of raccoon dogs in areas with foxes and badgers increases the overall density of rabies susceptible mammals, because raccoon dogs co-exist with foxes and badgers (Holmala, 2009). Higher densities of susceptible animals might facilitate the spread of infectious pathogens after accidental introduction (Holmala, 2009). The threshold value for rabies epizootic, calculated for Western Europe, is about 0.63 susceptible foxes/km<sup>2</sup> (Kauhala et al., 2006). Only in northern Europe such low fox densities exist; red fox rabies never reached far north. Since the arrival of the raccoon dog the combined density of susceptible animals has been about doubled, thus shifting the possible rabies limit considerably to the north.

Many countries in western Europe are rabies free as a result of oral vaccination campaigns. Currently the front of rabies and rabies vaccination campaigns runs from eastern Poland to north-eastern Italy. Until the arrival of the raccoon dog the red fox was the only important vector of rabies. In the new situation in Europe, with two main rabies vectors, the vaccination campaigns may not be as effective as before; rabies could persist in the community, even if the disease was not spreading in an individual vector species due to low density (Holmala & Kauhala, 2006; Kauhala & Kowalczyk, 2011). However, Poland has in fact been largely freed from rabies with vaccination campaigns between 2000 and 2010, when raccoon dogs were already as common as foxes (<http://www.who-rabies-bulletin.org/Queries/Maps.aspx>). Apparently the oral vaccination campaigns were as effective for raccoon dogs and foxes together, as they were for foxes alone. The foraging strategy of raccoon dogs probably makes them even more prone to find and eat the distributed baits than foxes (see section 2.14). In the same period (2002-2004) a survey of 227 raccoon dogs from eastern Germany (bordering on Poland where rabies was still present) yielded no rabies cases (Sutor, 2007). Figure 12 gives a map of all the reported wildlife rabies cases (except those in bats) in Europe in 2010 and the first half of 2011.

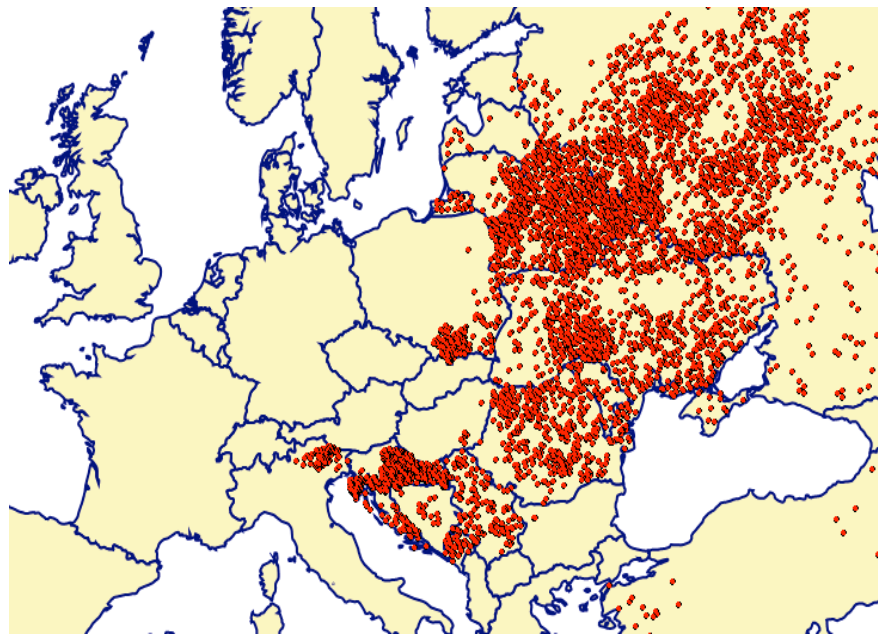


Figure 12. All cases of sylvatic rabies (excluding bats and domestic animals) in Europe between 1 January 2010 and 1 June 2011. Map generated with <http://www.who-rabies-bulletin.org/Queries/Maps.aspx>

## Canine distemper

Like in other canids, canine distemper caused by canine distemper virus (paramyxo-virus), an important disease in domestic dogs, has been observed in the raccoon dog as well. Recently it has become rather widespread in eastern Germany (pers. comm. N.Stier). An outbreak of canine distemper in 1991 near Tokyo killed about 70% of the local 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 sooner be infected by non-vaccinated domestic dogs, than vice versa ([http://en.wikipedia.org/wiki/Canine\\_distemper](http://en.wikipedia.org/wiki/Canine_distemper)).

## Parasitic infections

Three parasites are of importance in raccoon dogs. Raccoon dogs may be carriers of *Trichinella sp.* (Oivanen et al., 2002); in Finland 53 to 72% of the examined raccoon dogs were infected (Mikkonen et al., 1995) and in eastern Germany 5.8% (Thiess, 2004). In Finland also 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 increased along 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 a rare disease in Western Europe (Giessen, pers. comm.). Trichinellosis is caused by nematodes of the genus *Trichinella spp.* and the disease is the result of eating raw or undercooked meat from infected domestic pigs (mostly if they have access to outdoor pens) or game animals. Several carnivore or omnivore wildlife species (red fox, raccoon dogs, wild boar, rats, other rodents) can be carriers of *Trichinella*, and if pigs eat their bodies, they get 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 myocardium may get affected, with death as a potential result.

Sarcoptic mange (*Sarcoptes scabiei var. vulpesi*, a mite) is rather common in raccoon dogs (Shibata & Kawamichi, 1991; Ninomiya & Ogata, 2005; Stier, 2006b). 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, making few victims. Raccoon dogs seem to be more often infected with mange than foxes (N. Stier, pers. comm.). At present mange is rare among red foxes in the Netherlands, and the arrival of the raccoon dog may boost its occurrence (cf Stier, 2006b), especially in the fox population, but other species may be affected as well. Humans may get infected by the sarcoptes scabiei mite of dogs, and also of foxes, although the mite is not able to finish its life cycle in humans.

The most important parasite in raccoon dogs (and foxes) is the small fox tapeworm *Echinococcus multilocularis*. It may cause a severe infection in humans, and if not diagnosed and treated properly the infection may lead to death. The parasite is very small (max. 4 mm) 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 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 the own dog. In the Netherlands *Echinococcus multilocularis* is found in the provinces Groningen and Limburg (Giessen et al., 2004a and 2004b).

Thiess et al. (2001) demonstrated the presence of *Echinococcus* in raccoon dogs in Europe for the first time; in Japan the parasite has been known already for a very long period. Thompson et al. (2006) studied the development of *Echinococcus* in foxes, raccoon dogs, domestic dogs and cats in an experimental setting. Fifteen animals of each species, 13 to 15 weeks of age, were infected once with *E. multilocularis*. After one, two and three months five animals of each species were killed and their intestines investigated. The results showed, that cats are poor hosts and probably not important in transmitting the parasites to humans. Foxes, raccoon dogs and domestic dogs however are excellent hosts. They all shed *Echinococcus* eggs during the whole three-month period and possibly beyond. In foxes and raccoon dogs the mean worm burden decreased after two

months, in domestic dogs it did not decrease. Data from field studies suggest that exposure to infection in young, sub-adult foxes may generate a partial immunity in their adult life (Hofer et al., 2000). For raccoon dogs such data are not yet available.

In table 2 the results of several recent studies on *E. multilocularis* in raccoon dogs are summarized. The maximum percentage of infected animals was 10.7% in Europe, but the studies have been limited in scope and number, so far.

Table 2. Various surveys of the presence of *Echinococcus multilocularis* in raccoon dogs

Area	years	nr analyzed	nr infected	% infected	author
Poland	< 2002	25	2	8	Machnicka-Rowinska et al., 2002
Germany, north western Brandenburg	2000?-2003?	12	1	8	Tackmann et al., 2003
(North)eastern Brandenburg	1998-2000	74	2	3	Thiess, 2004
Northern Brandenburg	2000-2008	966	60	2.6 - 10.7	Schwarz et al., 2011
Southern Brandenburg	2000-2008	286	0	0	Schwarz et al., 2011
Japan, Hokkaido	1999	13	3	23	Yimam et al., 2002

The risk of infection with *Echinococcus* depends for instance on the rate in which raccoon dogs consume voles. Since the proportion of voles in the diet of raccoon dogs is generally lower than in the diet of foxes, raccoon dogs will probably be less important vectors than foxes (Tackmann et al., 2003). On the other hand, raccoon dogs like to forage in wet habitats, where (at least in foxes) the risk of infection with *E.m.* has been proven to be higher (Staubach et al., 2001). However, so far thorough studies of the prevalence of *E.m.* in raccoon dogs are still lacking. Although nothing is known about the exact infection routes of *E.m.*, the risk for humans of infection from raccoon dog excrements can be hypothesized to be lower than via fox faeces, since raccoon dogs tend to avoid human settlements and deposit their faeces in a few latrines only (Tackmann et al., 2003; Drygala, 2009). Foxes on the contrary spread their faeces over the whole area of their territory, thus making a chance encounter between man (and his dog) and the parasite more likely.

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.



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

## 2.17. Colonization capacity

The population characteristics of the raccoon dog, with respect to reproduction and age structure, are not different between populations in the original range and in the recently occupied European range, suggesting that the expansion in Europe is not the result of some kind of newly adopted 'expansion strategy' (Ansorge & Stiebling, 2001). However, the situation in western Europe is ideally suited for further colonization, because of the lack of rabies and large predators, the two main mortality factors (Kowalczyk et al., 2009). Its high rate of reproduction, even higher than expected given body size, food habits and reproductive system, enables a high colonization potential. Other canids of corresponding size usually have litters of 4 to 6 pups (Kauhala, 1996b). The colonization of Finland, as an example, proceeded very rapidly. The species spread through the southern and central parts of the country in two decades after the mid-1950s, although 88% of the juveniles died in their first year; litter size was 9 (Helle & Kauhala, 1991, 1993, 1995; Kauhala, 1996b). Average life time production per adult female is about 15 young, which is relatively high for mammals. If adult mortality is low, the species has a high capacity for increase and dispersal (Helle & Kauhala, 1995).

Several factors contribute to the high reproductive capacity of raccoon dogs. Firstly, the monogamous mating system with a clear division of labour in the rearing of young: while the female feeds to build her energy for suckling young, the male tends the young and guards the den. Presence of helpers, or regurgitation by the male has not been reported. The second factor is their omnivorous diet, and the third is a period of winter lethargy where necessary. These factors contribute to a good physical condition of females. Omnivory makes the raccoon dog independent of any specific food items or prey species, whereas winter lethargy makes the animal almost entirely independent of food availability during the most unproductive period of the year. This way their physical condition is independent of winter weather. Body condition is important for the reproduction capacity in the population, especially for the juvenile females. Early born females, in years with abundant food supply, will reproduce in the same rate as adult females. In western Europe, where winters are mild, reproductive capacity will therefore probably be even higher (Helle & Kauhala, 1995).

Dispersal is another factor contributing to a high colonization capacity in raccoon dogs. All juveniles of both sexes disperse, there is no role (as 'helpers') for one-year-old individuals in the population, contrary to in many other canid species. Mean dispersal distance is rather high, and some individuals travel tens of kilometres before settling (see section 2.11). This leads to a high rate of expansion, with an average speed of 40 km, in some areas at first even 120 km per year (Lavrov, 1971; Helle & Kauhala, 1987). Its opportunistic habitat use, well adapted to agricultural and forested areas, adds to its success; food, water, daytime shelters and den sites are almost everywhere available and are important habitat components for the raccoon dog (Drygala, 2009).

The pattern of colonization of new territory has been similar in several European countries: a relatively long period with individual, more or less sporadic sightings, without indication of reproduction, followed by a relatively short phase of rapid (probably exponential) increase and population saturation. This has elegantly been documented for the Czech Republic by Mrštný et al. (2007). The first sightings in the country date from the mid-fifties. Until 1989 the sightings had a sporadic character. In the period 1990-1994 the raccoon dog was recorded in 7% of the area of the country, but permanent occurrence of this species was suspected in only 0.2% of the country. Then the increase really took off. The next five years the species was recorded already in 32% of the country, with permanent occurrence in 1%. In the period of 2000 to 2004 the raccoon dog was recorded in 66% of the country, with permanent presence in 12% of the area. So after a period of about 30 years with sporadic sightings, the Czech Republic was colonized by the raccoon dog in only 15 years (fig. 13). A similar course of time was observed in Finland with first sightings in the thirties and a rapid increase from 1965 onwards (Helle & Kauhala, 1991), and in eastern Germany, with the first sightings in the sixties and a rapid increase around 1990 (Drygala et al., 2002).



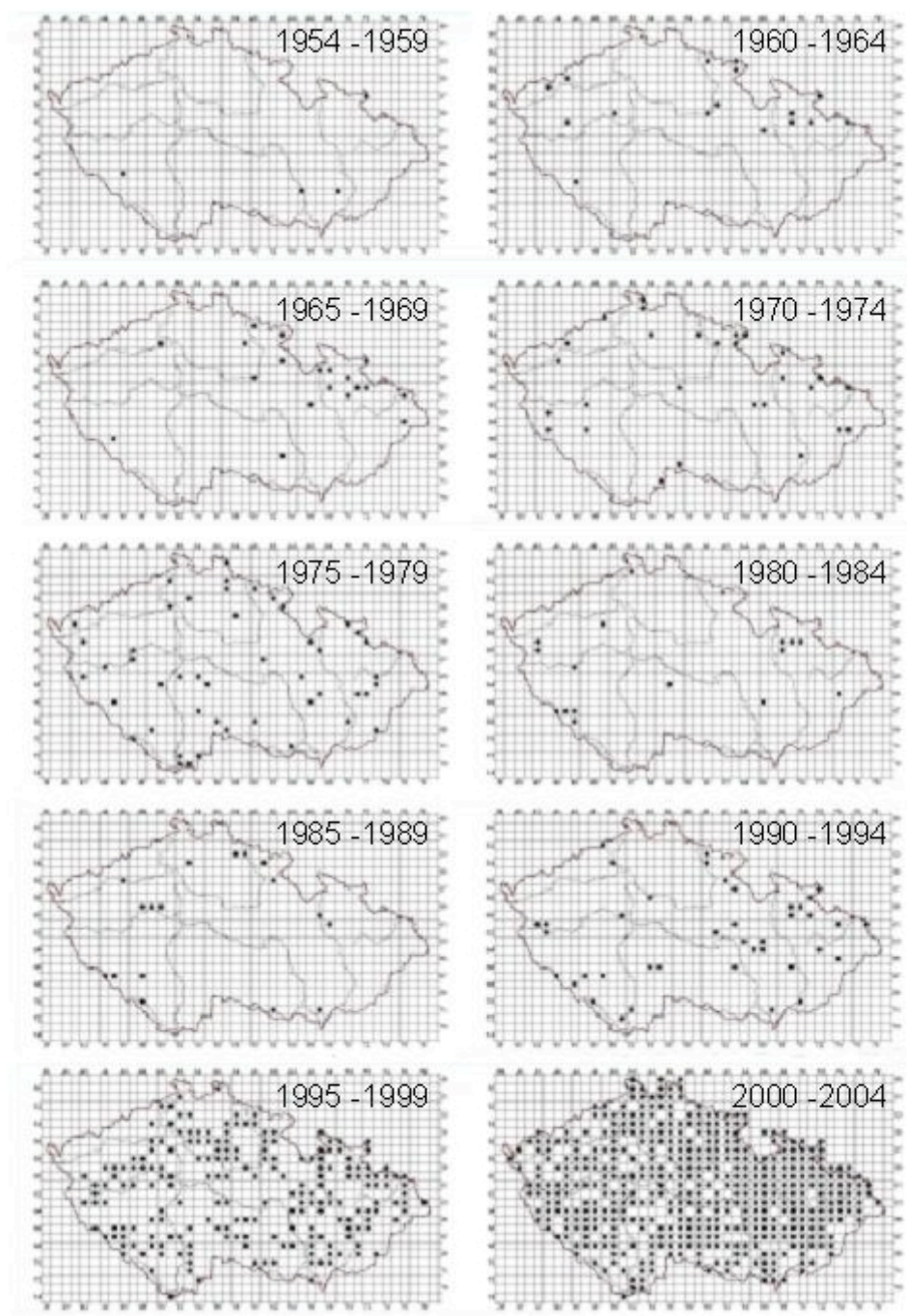


Figure 13. Records of the raccoon dog in de Czech Republic, per period of five years. After Mrštíný et al., 2007.



## 2.18. Management options

In many countries the killing of raccoon dogs is permitted year round (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 (Kowalczyk, 2006; Kauhala & Saeki, 2008). In Denmark hunting is not allowed unless there is a negative impact on game animals (Kowalczyk, 2007). In Germany the different countries (Bundesländer) have different rules; in most of them raccoon dogs can be hunted year round. Exceptions are: in Niedersachsen and Nordrhein-Westfalen adult raccoon dogs are protected from March to August, and in Schleswig-Holstein from March to June; in Hamburg adult and juvenile raccoon dogs are protected from May to August; in Bremen and Saarland raccoon dogs are protected year round (<http://www.schonzeiten.de>, consulted dd 14 August 2010).

Kowalczyk (2006) discussed the hunting intensity in Europe: "In Finland, the annual hunting bag varied between 75,000-130,000 in 1998-2003 (Kauhala & Saeki 2004a, Kauhala, pers. comm.), c.a. 20,000 in Germany (S. Schwarz, pers. comm), 6,000-10,000 in Poland (data of Research Station of Polish Hunting Society in Czempień), 4,000-5,000 in Estonia, 3,500-4,000 in Lithuania (L. Baltrūnaitė, pers. comm), and 2,000 in Latvia. In other countries raccoon dogs are hunted occasionally. In Norway farming of non-native animals demands an exemption from regulations in the Wildlife Act, and no such permits are yet given for raccoon dogs (Erik Lund, pers. comm.). Finland prohibits catching raccoon dogs from the wild for transportation to the fur farms due to the risk of rabies (Kaarina Kauhala, pers. comm.). 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 3 (section 2.3) shows the bag record of the raccoon dog between 1994 and 2009 for the whole of Germany. Since 2006 the exponential rise in the numbers seems to have stopped, although the expansion to western parts of Germany is still going on. What this means, the future will learn. In Germany most raccoon dogs are being shot more or less by coincidence, while the hunters sit and wait near a feeding ground for wild boar or roe deer. Raccoon dogs are attracted to the bait (mainly maize) used to lure wild boar, but also visit feeding places for foxes, and are being shot there as well. Some hunters specially target raccoon dogs and use dogs to corner them or to find them in burrows, from which they are subsequently dug out. Many raccoon dogs are shot in autumn, when they leave maize fields during the harvest. When fish ponds are being drained for the harvest, they work as magnets for raccoon dogs (and their hunters). Hunters have learned to wait some time, when a raccoon dog has been shot: the chances that its partner will come and have a look, are high. Like with the fox, traps do work for juvenile animals but are ineffective for adults (Stier & Joisten, 2006).

Stier (2006b) argues that the high hunting bag in eastern Germany may look impressive, but that a two- to three-fold intensification of the hunting pressure should be needed to even start reducing the breeding population of the raccoon dog. One major natural cause of death has disappeared recently, rabies, increasing the raccoon dog's expansion potential; however, another cause slowly returns: the wolf. In his calculations Stier assumes rather conservatively a 300% annual potential increase (2 adults getting 6 pups), and a mortality by other causes than hunting (traffic, diseases, etc) of 50%. In view of the favourable circumstances in habitat and food availability, such an intensification of hunting is not feasible and not realistic. Therefore Stier (2006b) advises to manage possible problems, such as predation in 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 the target area (which should not be too large) for a good result.

In southern Finland raccoon dogs and other medium sized predators (fox, pine marten, American mink) were killed by shooting and capturing in a 'removal area' of 55 km<sup>2</sup>, in order to study the effects of these predators on the breeding success of ducks (Kauhala, 2004). In a similar control area (48 km<sup>2</sup>) the numbers of medium-sized predators were not controlled. The experiment lasted five years. Raccoon dogs were killed from 1 August to 31 April each year, by voluntary hunters. An index of raccoon density was obtained using 50 scent stations each spring. A total of 280 raccoon dogs were killed, i.e. 0.73 to 1.36 ind/km<sup>2</sup> each year. Notwithstanding this effort, no significant decrease in the raccoon dog index was observed. One reason behind this may be the fact that most raccoon dogs were caught in autumn and were juveniles that would have died anyway (Kauhala, 2004). It is clearly not easy to substantially reduce a population of raccoon dogs.

A local intensive culling effort, again from 1 August to 30 April, has been practised in another experimental research in some relatively small wetlands (0.3 to 5.0 km<sup>2</sup>) near Helsinki (Väänänen et al., 2007). A citation: "The number of bagged raccoon dogs in our experimental wetlands was much higher than we expected before predator removal. The raccoon dog hunting bag/km<sup>2</sup> decreased when the hunting area increased. This indicates that raccoon dog immigration to the removal area is more effective in small hunting areas than large ones. Overall, the number of raccoon dogs [shot, not necessarily settled as reproducers, so this number includes dispersers; JLM] in semi-urban wetlands can be surprisingly high. [...] Even in semi-urban wetlands it is possible to decrease raccoon dog densities considerably, but considerable effort is needed to achieve that goal."

Väänänen et al. (2007) used four experimental wetlands (and two control areas with no predator control), in which there was no predator control in the first year and an intensive control in the two successive years. Their results were rather erratic. In two intermediate sized areas (2.0 and 3.5 km<sup>2</sup>) they could achieve a bag of 8.6 to 11.0 raccoon dogs/km<sup>2</sup>, and in a small area (0.3 km<sup>2</sup>) a bag of 90 (!) ind/km<sup>2</sup>. In the third and largest area (5 km<sup>2</sup>) hardly any signs of raccoon dogs could be found, still a bag of 4.4 ind/km<sup>2</sup> was achieved in one year and of zero in the second year. Most importantly, there was no relation between the intensity of hunting (ind. killed/km<sup>2</sup>) in the winter season and the change in index of raccoon dog presence between years. Considering the pre-breeding density of the raccoon dog in southern Finland, which is in the order of only 0.5 - 1.0 ind/km<sup>2</sup> (Kauhala et al., 2006), this lack of correlation between both parameters (killing effort and change in raccoon dog breeding density) must, as in the case of the aforementioned experiment, be the result of the timing of the culling, mainly in the months in which the juveniles disperse. In conclusion, it is only feasible to reduce raccoon dog density in spring, if intensive hunting is performed after the period of dispersal, i.e. from November or December onwards. Such a strategy can only be applied on a local scale, and probably only by professional instead of voluntary hunters.

The situation in Sweden and Norway is a special case. The raccoon dogs only have a narrow corridor to enter Sweden and Norway, along the coast of the Gulf of Bothnia; some distance to the north the climate is too harsh for them. In Sweden a policy is recently introduced to prevent the colonization of Sweden and Norway by raccoon dogs. Raccoon dogs are life trapped, neutered and radio-collared, and used as 'lures': because of their close association with a mate, these mates can be easily shot after radio-tracking of the 'lure'. After some time a new mate turns up and is killed as well. It is estimated that a permanent 'population' of about 100 radio-collared animals should be sufficient to contain the invading population (Dahl, 2009). In these special circumstances this policy might have success, although keeping it up permanently (which is necessary) may be a costly affair. More recently this management option has been introduced in Denmark as well (Steinar, 2011).

### 3. The raccoon dog in the Netherlands

To describe the raccoon dog history and present situation in The Netherlands, all records of raccoon dogs were collected and screened as available from scientific literature, hunting journals and from various databases (e.g., Alterra, Dutch Mammal Society, Telmee.nl, Waarneming.nl, Yvette van Veldhuijsen, Royal Dutch Hunters Society, Foundation AAP). Efforts were made to collect observations hitherto not reported, via hunting journals and the internet. Many of the original observers were contacted by telephone or email, and questioned. The vast majority of the records could thus be validated in four categories: 'certain', 'probable', 'possible' and 'not likely'. The records which could not be verified with additional information, were placed in the category 'possible'. The resulting database has been submitted to the National Authority for Data concerning Nature.

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. 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 because it lasted ten years before the next raccoon dog was recorded in the Netherlands. This second animal was found dead along a road east of the town of Groningen (NE-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 often kept as pets, usually in a kennel outdoors. They are rather easy to keep, eat virtually anything, make hardly any noise and deposit their faeces in one spot only. In animal journals and on the internet advertisements are not uncommon, offering young or adult raccoon dogs. 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 fence of one meter high is enough to contain raccoon dogs, it appears that escaping animals are not rare, mostly through negligence of the owners. Seven of such cases have been documented (Appendix 1), all seven cases regarding two animals each. Four of these seven cases of escaping raccoon dogs were associated with a road killed raccoon dog, and one with an animal shot by a hunter. This last animal certainly was the escapee, for it was a white sterilised female. As far as we know, the five recovered raccoon dogs were found within 0.5 to 9 km and within 1 month of the escape; one was even killed on the road in the same night in which it escaped.

Escaped raccoon dogs may blur the pattern of colonization in the Netherlands. Isolated observations, far away from the bulk of the other observations, may indicate such escapees. Proof is, however, rarely available. Sometimes it is obvious from the behaviour of a raccoon dog that it is an escapee: no fear for men, approachable to within a few meters or even less, etcetera. If such behaviour had been reported, or the connection with a known escape was clear, the record was labelled 'escapee'. After validation the database with all observations of raccoon dogs until 1 January 2011 contained 139 records (excluding the category 'not likely'), of which 62 were certain, 31 were probable and 46 were possible. In the three categories a total of 11, 5 and 1 records respectively were considered escapees. Figure 14 shows a map of the Netherlands with all raccoon dog observations. The majority of observations were made in the north eastern part of the country, very well in line with the raccoon dog distribution in Germany (section 2.3, figure 4). All records outside this area might pertain to escaped animals too. Especially the Veluwe area (white oval in figure 14) is interesting in this respect. Raccoon dogs started to be reported from the Veluwe already rather early (1993) and continued to do so. As judged from their behaviour, at least three of the observed animals clearly were escaped animals. Furthermore, several people in the region were known to have raccoon dogs as pets. Since the Veluwe is separated from the north eastern part of the country by the river IJssel, the early appearance of raccoon dogs in this region is suspect; I therefore consider all the raccoon dog records from the Veluwe (until now) as observations of escaped animals.

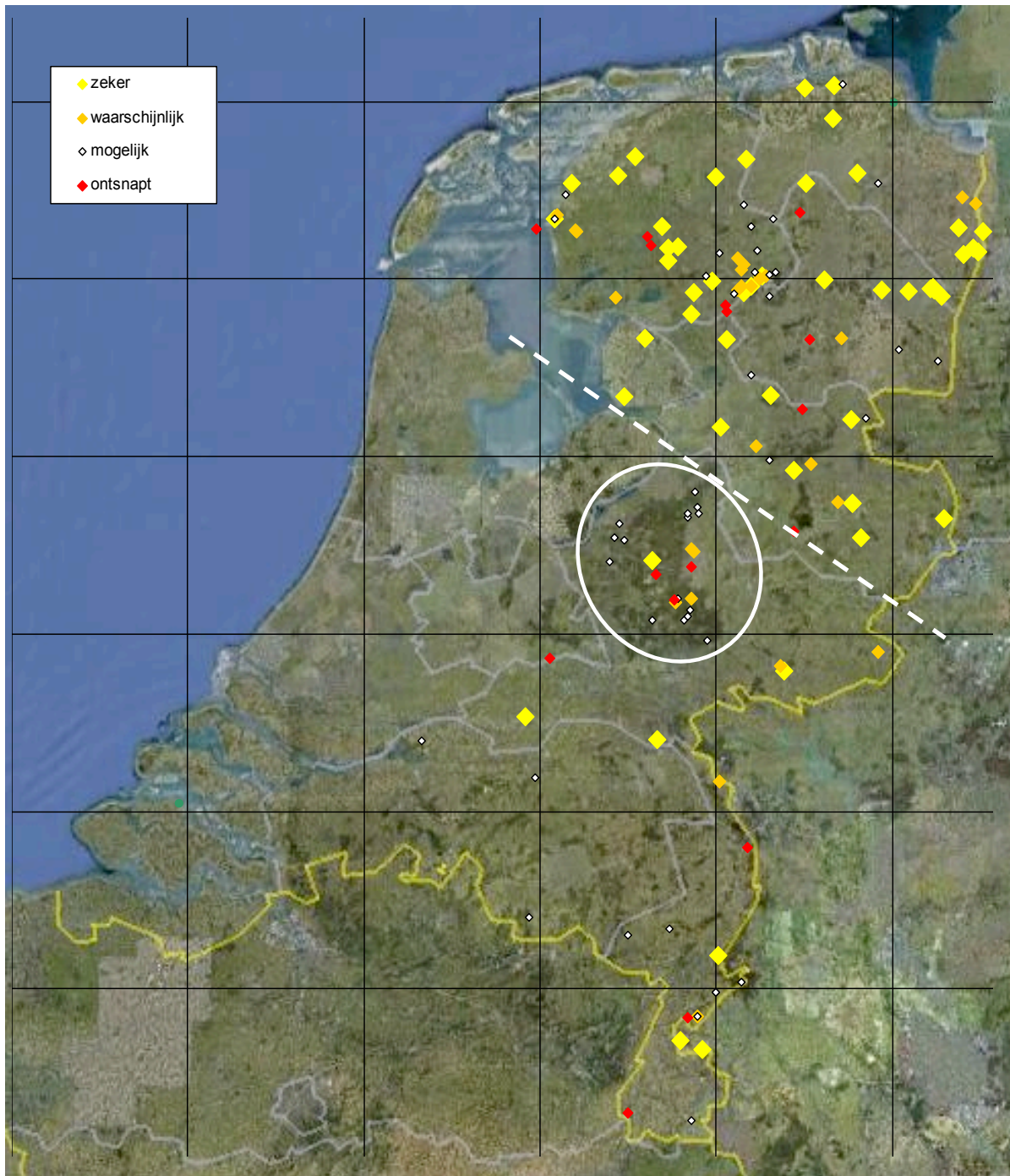


Figure 14. All records of raccoon dogs in the Netherlands until 1 January 2011. The observations from within the white oval (Veluwe) are all considered escapees from captivity. The records northeast of the dashed line are in majority considered the natural situation and have been used in figure 15. The records southwest of the dashed line are all considered to be escaped animals. Legend: large yellow square: certain; smaller orange square: probable; small white dot: possible; red square: certainly or most probably an escaped animal.

Excluding all records from the Veluwe, as well as clear escapees elsewhere, 102 records remain, of which 50 are certain, 22 probable and 30 possible. Focussing on the north-eastern corner of the country only (with 44 certain, 18 probable and 20 possible observations) the pattern of raccoon dog observations in time becomes clear (figure 15).

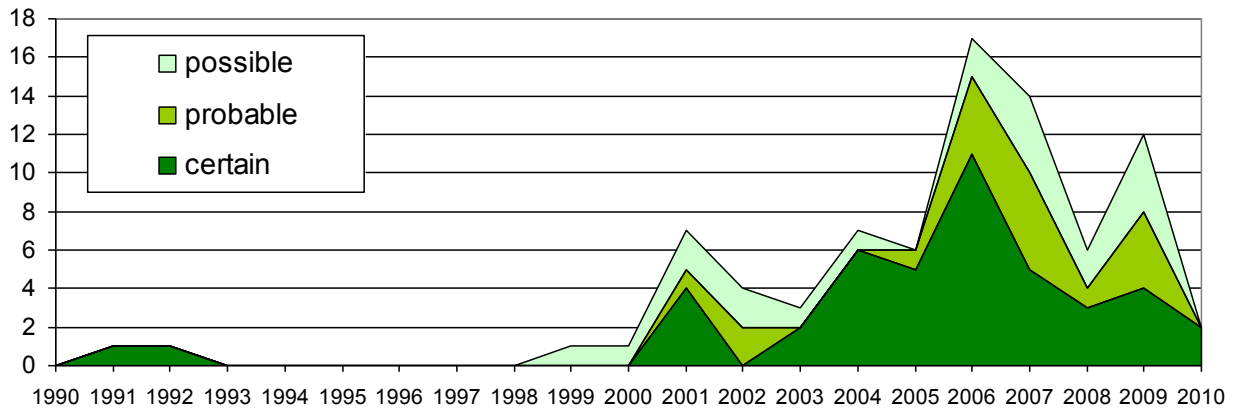


Figure 15. All observations of raccoon dogs in the northeastern part of the Netherlands (Provinces Groningen, Friesland, Drenthe, Overijssel, plus Noordoostpolder, see figure 14) in three categories of certainty, between 1991 and 2010. Clear escapees have been excluded.

After two isolated observations in the early 1990-ties, the years with continuous observations of raccoon dogs started in 2001. Since then each year roughly 3 to 8 raccoon dog observations have been recorded, with a maximum of 11-15 in 2006. The Netherlands apparently has reached the stage of irregular, sporadic but steady observations of raccoon dogs, which in other countries lasted 20-30 years before the population started to grow exponentially (section 2.17). This is in keeping with the apparent lack of reproduction in the Netherlands so far: no indications of reproduction from post-mortem research and no field signs of raccoon dog litters in badger setts as yet (own data). Based on the time pattern of raccoon dog colonization in other countries, we may expect the start of exponential growth in the Netherlands around the year 2025.

Most of the reliable records of raccoon dogs are traffic victims.  
Photo J.L.Mulder





## 4. Risk assessment of raccoon dog in the Netherlands

### 4.1. 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 dispersed most likely from Germany occurred in 1991 and no reproductive individuals have been found yet. Considering the present colonization speed of the raccoon dog in Germany, the lack of possible barriers (i.e. mountain ranges) and the presence of suitable habitats in the Netherlands, it is likely that the raccoon dog will proceed with its westward colonization by dispersal and eventually become established in the Netherlands. Raccoon dogs have a high dispersal and reproduction potential, which is not expected to be adversely affected by predators and diseases in the Netherlands. 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 is expected to be a truly invasive alien species. Already now each year several raccoon dogs are recorded in the country. This phase of sporadic sightings started around 2000 and may last 20 to 30 years, as it did in other European countries (see section 2.17). That means that the first records of reproduction are to be expected within five to eight years, and the phase of rapid population increase will start around 2025. Based upon the history in other parts of Europe, we may predict the raccoon dog to be a common inhabitant of the Netherlands by the year 2035.

Apart from the natural dispersal from Germany, the establishment of the raccoon dog in the Netherlands might be accelerated by individuals which escaped from captivity. The number of raccoon dogs kept in captivity is unknown, but it must be considerable. A minimum of seven cases of escaped animals have been documented already, regarding at least 14 individuals (Appendix 1). From time to time individuals turn up in areas where it is unlikely that they have arrived from Germany, for instance in the Veluwe area in the centre of the Netherlands (see fig. 14). Moreover, from the lack of shyness, reported by several observers, it can be concluded that the raccoon dogs they saw must have been escapees.

### 4.2. Future distribution

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, in contrast to in some places in Japan, where raccoon dogs recently appeared in urban areas (Saeki, 2001). To date, research results in Europe indicate that resident raccoon dogs avoid settlements and have never been observed to cross villages, even when these were located in the middle of their home range (Drygala, 2008b). Especially the numerous wetlands in the low lying north and west of the Netherlands will probably harbour a dense population of raccoon dogs in the future, as well as wet areas in the rest of the country. Areas where higher grounds with badger populations adjoin marshy areas with lots of dense cover (reeds, willow and alder thickets) will probably constitute the optimal habitat, with a maximum of 2 adults/km<sup>2</sup> locally in the most varied landscapes (Kauhala et al., 2006). Less favoured habitats will be large forests with predominantly pine and fir 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 all 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<sup>2</sup>.

A changing climate will not make a difference for the future distribution and density of the raccoon dog in the Netherlands. For areas with harsh winters however, where raccoon dogs do hibernate (sometimes for long periods), climate change may be beneficial for the raccoon dog. Melis et al. (2010) postulate that the raccoon dogs in those areas will benefit from climate warming, because of a longer plant growing season. However, they also state that increased spring precipitation in the form of snow at higher latitudes might compensate for this effect, and restrict the distribution of raccoon dogs in harsher environments. In lowland Europe, where winters are mild, the southern limit of its distribution is relatively far south, running from mid-Romania through mid-Hungary to southern Germany. So, if the climate warms and the southern regions of the present raccoon dog's distribution may become too warm and/or dry, and thus not suitable for the species any longer, it is not likely that the southern limit of its distribution will shift so far north that the Netherlands will become unsuitable as well. Most likely the raccoon dog will live in the whole of the country in the future.



### 4.3. Impact on biodiversity

The ecological impact of the raccoon dog includes:

1. Impact on native predators;
2. Impact on prey species;
3. Import or enhancement of diseases and parasites in the native fauna;
4. Risk of genetic effects;
5. Impact on ecosystems as a whole.

#### 4.3.1. Impact on native predators

The raccoon dog is an omnivorous, medium sized predator of which the ecology shares aspects with several native and non-native predators: badger, red fox, polecat and American mink. 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 the badger, the red fox and the polecat. Impact through competition can be interference competition or resource competition (Pianka, 1978). Direct interference of raccoon dogs with badgers seems to be rare (see section 2.13). Only one example was found in the literature: the remains of a badger cub have been found in raccoon dog scats in Białowieża Primeval Forest (Jędrzejewska & Jędrzejewski, 1998). More often badgers kill raccoon dog pups (Kowalczyk et al., 2008). Once an adult raccoon dog was observed which had died of wounds, inflicted on its back parts by most probably a badger (Drygala, 2009). Interference with foxes probably is much more common and both species occasionally kill cubs of the other species. In northeast Germany fox numbers (measured as 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 enhanced infection rate with sarcoptic mange, 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, leading to the significant decrease of either of the 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, red fox and brown bear in one of the two study areas. The mechanism behind this possible negative impact of raccoon dogs on other generalist predators is thought to be the effective exploitation of the 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 not very likely, except perhaps locally 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 being generalist predators, have a clear preference for amphibians, and the polecat might thus be negatively affected in the future by the presence of raccoon dogs.

#### 4.3.2. 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, rarely the adult breeding bird (see section 2.15). 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.

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

Its preference for amphibians may lead to local declines of more or less isolated populations of 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, gathering an easy meal from the buckets (Puffpaff, 2008).

#### 4.3.3. Import or enhancement of diseases and parasites in the native fauna

The raccoon dog is not known to have imported East-Asian diseases into Europe (see section 2.16). In its newly established European range it carries the same diseases and parasites as native predators like the red fox. However, raccoon dogs seem to be more susceptible to sarcoptic mange than red foxes and may enhance the frequency of mange occurrence in wild animals, leading to a higher mortality especially among foxes. Raccoon dogs are important vectors for (and victims of) rabies. In countries where rabies is still present, raccoon dogs are often the most numerous species infected. However, wildlife rabies has been successfully combated in western Europe with oral vaccination campaigns. Currently rabies only occurs east of a line running from eastern Poland to northeastern Italy. The chances of a raccoon dog arriving in the Netherlands after dispersing from an area where rabies is still endemic, i.e. from a distance of at least 900 km, are nil. Colonization by raccoon dogs will consequently not enhance the risk of rabies returning to the Netherlands.

The fox tapeworm *Echinococcus multilocularis* will be dealt with in section 4.5.

#### 4.3.4. Risk of genetic effects

The raccoon dog is quite an isolated species in the canid family, and hybridisation with other dog species is unknown, even in captivity. There is, therefore, no risk of genetic effects on native species.

#### 4.3.5. Impact on ecosystems as a whole

Except for some small island situations, it is not likely that raccoon dogs will have a substantial impact, directly or indirectly, on ecosystems as a whole, e.g. by disrupting the existing food webs.

### 4.4. Economical and social impact

It is unlikely that people will have negative experiences with raccoon dogs. To date, there is no record of an economical or social impact in other European countries. Raccoon dogs are shy and clumsy and avoid the vicinity of people and their infrastructure. Direct damage to property is not known, as is competition with economically important animals. They do not climb (a fence of one meter high is enough to keep them out, Stier, 2006b) and do not normally predate on pets or poultry. Raccoon dogs might have some economical impact (although there are no data about it as yet) by eating from commercial crops of low hanging fruit (strawberries, blueberries, bramble etc), and maize.

### 4.5. 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. Raccoon dogs can be carriers of diseases and parasites harmful to people, i.e. the rabies virus and the fox tapeworm *Echinococcus multilocularis*. Kauhala & Kowalczyk (2011) consider this the most severe risk of the colonization of Europe by the raccoon dog. Rabies has been eradicated in western Europe and it is highly unlikely that it will return with the arrival of the raccoon dog (see section 4.3.3). The risk of rabies in western Europe now mainly comes from imported pets (dogs and cats) and from a few bat species. However, the rabies control measures in Europe should be scrutinized 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. In the small scale studies carried out up till now the prevalence of the tapeworm was rather low in raccoon dogs, at maximum 10.7 %, but more extended research may reveal a higher incidence in the future. Before the arrival of the raccoon dog, the red fox was the only vector of *Echinococcus*. It is unknown whether the raccoon dog will in the future show the same prevalence of *E.m.* as the red fox does. In the Netherlands the distribution of the small fox tapeworm is restricted to two areas, the northeast corner and the southeast corner of the country (Giessen et al., 2004a; Giessen et al., 2004b). At present a new survey is ongoing. It is expected that the distribution of *E.m.* 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 are larger in raccoon dogs than in foxes, it is to be expected that the distribution area of *E.m.* will expand slightly faster than with the fox as the only vector, thus exposing more people to the risk of infection over time.

Since raccoon dogs will live next to the already present foxes, the density of potential *E.m.*-carriers will increase and might double in the future. This implicates that infection risk in endemic areas may increase as well. Red foxes spread their faeces diffusely over their whole territory, while raccoon dogs defecate in a few latrines only. Raccoon dogs thus contaminate the environment with *E.m.* in a few confined areas only, with a corresponding lower risk for infection of people than the way foxes contaminate the environment. The only known method to combat *E.m.* in order to diminish the risk for humans, is the permanent application of anthelmintic baiting, targeting foxes and raccoon dogs: baits containing the worm-killer Praziquantel are distributed in the field (Hegglin & Deplazes, 2008).

To assess the health risks of the raccoon dog (and other invasive species) in more detail and depth, a separate risk analysis is recommendable.

#### 4.6. Overall assessment

Several methods for risk assessment for invasive species have been developed. Branquart (2007) and co-workers devised a simplified hazard assessment for the ecological impact for Belgium: Invasive Species Environmental Impact Assessment protocol (ISEIA). A number of aspects receive a score of 1, 2 or 3, low, medium and high respectively, and the sum of scores leads to a classification in three categories: A, 'black list', i.e. high environmental risk, B, 'watch list', i.e. a moderate environmental risk, and C, species that are not considered a threat for native biodiversity and ecosystems.

If we are scoring the raccoon dog according to this assessment, on the basis of this study, it leads to the following result:

Aspect	sub-aspect	risk	score	max.score
Dispersion potential		high	3	3
Colonization 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

An ISEIA score of 4-8 corresponds with category C, of 9-10 with category B (watch list) and 11-12 with category A (black list). The raccoon dog, with an ISEIA score of 9, thus falls in category B, representing a 'moderate environmental risk'. The main factors responsible for this score are its high dispersion and colonization potential.

In Australia Bomford (2003) developed a protocol to score the risks of exotic vertebrate species. The protocol is meant to be a basis for setting appropriate import and keeping restrictions for Australia. In this model three main risk scores are calculated: 1. The risk that individual animals harm people. 2. The risk that a species will establish a wild population. 3. The risk that an established population of the species will cause harm, become a pest. The three risk scores are then combined, leading to assignment of the species to one of four threat categories: extreme, serious, moderate or low. The model, like the ISEIA-protocol, does not assess the risk that the import of exotic vertebrates will introduce diseases.

Applying this Australian risk assessment model to the raccoon dog in Europe, the following values for the three risk scores are achieved: 0 (not dangerous), 13 (extreme establishment risk) and 14 (moderate pest risk). Combining these scores according to the rules of the model, results in threat category 'extreme' for the raccoon dog (details of the scoring in Appendix 2). This result differs from the outcome of the ISEIA protocol. The reason behind this discrepancy is, that the Australian model more strongly focuses on the risk of an exotic species arriving in the country and establishing a population. The raccoon dog scores 13 of the 14 possible points on this aspect: it is certain to arrive in the Netherlands and to establish a population here (cf section 4.1). The ISEIA protocol is originally designed only for the species already established in Europe.

#### 4.7. Future management

At the moment (December 2011) the raccoon dog in the Netherlands is placed in a category of species of which the populations 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, to be enabled to use firearms in the control of these species, a separate decision of each province is necessary. Such a decision has been issued only in the province of Friesland.

In all or most of the European countries where raccoon dogs are living today, they have been hunted from the moment of their arrival. The information on population trends in the various countries is based on hunting bags. Despite high numbers of raccoon dogs killed by hunters, their expansion has nowhere been halted 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 reality in the areas where the raccoon dog has become common now (Stier, 2006b), and the 'usual' shooting of raccoon dogs will at the most decrease their expansion rate a little. To prevent the raccoon dog from establishing in the Netherlands, if at all possible, should at least require an effort and professional organisation such as exists for controlling muskrats *Ondatra zibethicus* and coypu *Myocastor coypus* (Broekhuizen, 2007).

This means that two management options remain:

- A. Intensive hunting on a local scale (a few km<sup>2</sup>) 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.

## Acknowledgements

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Lastly I thank Dr. Sim Broekhuizen for critically reading a draft version of this report, which considerably helped improving the final report.

## Samenvatting

De wasbeerhond *Nyctereutes procyonoides* 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 Europa verspreid. De soort wordt beschouwd als een invasieve exoot, omdat hij door mensen is geïntroduceerd, zich succesvol voortplant en zich verder verspreid. Het beleid in Nederland met betrekking tot invasieve exoten is, om de risico's in te schatten voor de biodiversiteit met aandacht voor de impact op dier- en volksgezondheid en economie. Dit rapport bevat een uitgebreide samenvatting van de huidige kennis van de biologie en de ecologie van de wasbeerhond, een overzicht van zijn huidige voorkomen in Nederland en een analyse van de ecologische, veterinaire en sanitaire risico's.

De wasbeerhond (die door jagers ook wel marterhond genoemd wordt, naar het Duits) is ongeveer zo groot als een vos, maar heeft kortere poten en een kortere staart. In de herfst vet hij sterk op, en in koude winters gaat hij in winterrust. Bij het foerageren loopt hij langzaam en blijft hij meestal in dekking van vegetatie. Hij graaft en klimt nauwelijks. Voor de voortplanting gebruikt hij bij voorkeur de holen van das en vos, buiten die tijd slaapt hij bovengronds. Wasbeerhonden zijn monogaam en een paartje trekt gewoonlijk gezamenlijk op. Elk paar leeft in een vast activiteitsgebied, waarvan het centrum door de burens wordt gerespecteerd maar waarvan de randen overlappen met die van de burens. In gemengde biotopen ligt de voorjaarsdichtheid gewoonlijk tussen de 0.5 en 1.0 ind/km<sup>2</sup>.

Wasbeerhonden hebben een voorkeur voor oevers, vochtige gebieden en loofbos, en mijden liever naaldbossen en open agrarisch gebied. Ze gebruiken echter wel degelijk alle biotopen in hun activiteitsgebied in zekere mate. De wasbeerhond is een alleseter en meer een 'verzamelaar' dan een 'jager'. In het brede voedselspectrum zijn vooral amfibieën, kleine zoogdieren, dode dieren, vruchten en maïs belangrijk. Hoewel hij ook eieren van grondbroeders kan eten, worden ze bij voedselstudies erg weinig aangetroffen. Tot nu toe is er geen goed opgezet onderzoek verricht naar de invloed van de wasbeerhond op de populaties van grondbroeders. Er zijn vooralsnog geen aanwijzingen dat soorten zijn achteruitgegaan in gebieden waar de wasbeerhond zich heeft gevestigd. Alleen op eilanden heeft de komst van de wasbeerhond geleid tot het lokaal uitsterven van amfibie-populaties, en tot predatie in broedvogelkolonies.

Rond eind april vindt de geboorte plaats van relatief grote worpen, meestal bestaande uit 6 tot 9 jongen. De jongen worden vrijwel voortdurend bewaakt door tenminste één van de ouders. Al zes weken na de geboorte verlaat de hele familie het hol en gaat in het activiteitsgebied rondtrekken. Vanaf juli gaan de eerste jongen, nog slechts halfwas, op zoek naar een eigen leefgebied, waarbij

ze meer dan 100 km kunnen overbruggen. De meeste blijven echter binnen 30 km van hun geboorteplek.

De wasbeerhond heeft geen nieuwe ziektes meegebracht naar Europa, maar zou wel het voorkomen van reeds aanwezige ziektes en parasieten kunnen bevorderen: hondsdoelheid, hondenziekte, *Trichinella*, schurft en de vossenlintworm *Echinococcus multilocularis*. Hondsdolheid is echter uit west Europa verdwenen door orale immunisatie-campagnes. De belangrijkste problemen voor de volksgezondheid worden waarschijnlijk gevormd door *Trichinella* en de vossenlintworm.

Ongeveer tien jaar geleden werden in Nederland de eerste wasbeerhonden waargenomen die zich vanuit Duitsland verspreid hebben. Het patroon van die kolonisatie wordt echter verstoord door het regelmatig voorkomen van uit gevangenschap ontsnapte dieren. Tot 2011 werden 'wilde' wasbeerhonden 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 fase waarin we nu zitten, 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 lijkt onvermijdelijk dat de wasbeerhond heel Nederland gaat koloniseren, 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. Sommige ziekten en parasieten zouden vaker of intensiever kunnen gaan voorkomen, zoals *Trichinella* en de vossenlintworm. Er zijn nauwelijks mogelijkheden om die laatste in het veld te bestrijden.

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 op de voorjaarsstand. Er zijn twee beheeropties voor het tegengaan van mogelijke problemen:

A. Intensieve bestrijding op een lokale schaal (max. enkele km<sup>2</sup>) 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-)hekkwerk, rond poelen met zeldzame amfibieën of broedvogelkolonies, bijvoorbeeld.



## References

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## Appendix 1. Escaping raccoon dogs

Raccoon dogs are easy to keep as pets. They don't need much attention, are house-trained (defecate in one spot only), are not noisy and eat anything. In the Netherlands the number of people keeping raccoon dogs, sometimes in their white (not albino) form, probably is considerable. On the internet advertisements can often be found in which animals are offered for sale. As judged from the number of visitors to these advertisements, there is a lot of interest with the public.

Although raccoon dogs are easy to keep in a pen (they hardly climb or dig) escapees are not rare. Until now we have documented seven cases of escaping raccoon dogs, all seven regarding two animals each (Table 3). It must be the tip of the iceberg. Four of these seven cases of escaping raccoon dogs were associated with a road killed raccoon dog, and one with an animal shot by a hunter. This last animal most certainly was the escapee, for it was a white sterilised female. As far as we know, the five recovered raccoon dogs were found within 0.5 to 9 km of the place of escape and within 1 month; one was even killed on the road in the same night in which it escaped.

*Tabel 3. Known cases of escaping raccoon dogs. Sources: Yvette van Veldhuijsen (third and fourth case) and own research. Data until 1 July 2011.*

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). After some weeks with a private person they were returned to the original children 's farm.
2001	Gangelt (D), Zoo Hochwild Freigehege, adjacent to the Dutch border, east of Sittard.	Adult male and female	Unknown	Male was killed on the adjacent road in the night of the escape
August 2002	Private person 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 person 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 the 12th of October 2002 a young female was found as a roadkill near Wijk bij Duurstede. During the autopsy it was suspected of being an escapee. Distance 9 km, other side of the river Rhine.
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 within 800 m and within a few days, on 26 april 2010.
Autumn 2010	Animal rescue asylum It Schildhus, Goengarijp, Friesland, specialised in turtles	White sterilized adult female and normally coloured neutered adult male. Had been kept by private person in Utrecht province before.	Were kept in a stable	The white female was shot on 13 November at a distance of 5 km. The male was probably spotted on 11 November at a distance of 2-3 km
ca 10 June 2011	Private person in Egmond-Binnen, Noord-Holland. Did keep raccoon dogs already 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 at 800 m distance on 17 June 2011. The other was seen on 20-21 August in Heiloo, in a chicken coop, at ca 3 km distance

## Appendix 2. Bomford scoring

To assign the species to a VPC Threat category, the scores from the score sheet (see below) are translated as follows:

Risk to public safety posed by captive or released individuals (A):

- A = 0 not dangerous
- A = 1 moderately dangerous
- A ≥ 2 highly dangerous

Risk of establishing a wild population (B):

For birds and mammals:

- B < 7 low establishment risk
- B = 7–8 moderate establishment risk
- B = 9–10 high establishment risk
- B > 10 extreme establishment risk

Risk of becoming a pest following establishment (C):

- C < 9 low pest risk
- C = 9–14 moderate pest risk
- C = 15–19 high pest risk
- C > 19 extreme pest risk

VPC Threat Category

A species' VPC Threat Category is determined from the various combinations of its three risk scores (according to Table 6 in Bomford, 2003).

**Table 4: Score sheet for risk assessment model.**

Factor	Score for raccoon dog
A1. Risk to people from individual escapees (0–2)	0
A2. Risk to public safety from individual captive animals (0–2)	0
<b>A. Risk to public safety from captive or released individuals: A = A1 + A2 (0–4)</b>	<b>0</b>
<b>i.e. Not dangerous</b>	
B1. Degree of climate match between species overseas range and Australia (1–6)	5
B2. Exotic population established overseas (0–4)	4
B3. Taxonomic Class (0–1)	1
B4. Non-migratory behaviour (0–1)	1
B5. Diet (0–1)	1
B6. Lives in disturbed habitat (0–1)	1
<b>B. Establishment risk score: B = B1 + B2 + B3 + B4 + B5 + B6 (1–14)</b>	<b>13</b>
<b>i.e. Extreme establishment risk</b>	
C1. Taxonomic group (0–4)	4
C2. Overseas range size (0–2)	1?
C3. Diet and feeding (0–3)	1
C4. Competition with native fauna for tree hollows (0–2)	0
C5. Overseas environmental pest status (0–3)	1?
C6. Climate match to areas with susceptible native species or communities (0–5)	5?
C7. Overseas primary production pest status (0–3)	0
C8. Climate match to susceptible primary production (0–5)	0
C9. Spread disease (1–2)	2
C10. Harm to property (0–3)	0
C11. Harm to people (0–5)	0
<b>C. Pest risk score for birds, mammals, reptiles and amphibians:</b>	
<b>C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 (1–37)</b>	<b>14</b>
<b>i.e. Moderate pest risk</b>	
<b>A, B and C combined, VPC threat category: extreme !</b>	