The rise of the raccoon (*Procyon lotor*) in Flanders, Belgium: chronicle of a predicted evolution

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Abstract: As a non-native species, the raccoon (*Procyon lotor*) has been present in the wild in Europe for about a century, and the expectation seemed justified that it would establish itself also in Belgium. A meticulous recording and interpretation of all possible raccoon sightings in Flanders (northern Belgium) over the past 30 years shows that this was not the case during the first two decades of this period. In contrast, a clear increase in the number of registrations has occurred in the last decade. Necropsy of collected roadkills also shows that reproduction in the wild is occurring throughout the region, a finding confirmed by the increasing use of camera traps. The raccoon has been included in the Union List of Non-Native Species of Concern since 2016 through the EU Regulation, and addressing its further population development in Europe is currently the subject of international consultations. This study aims to provide a documented baseline for Flanders on the raccoon population status, while also making some considerations regarding the need for systematic intervention.

Keywords: raccoon, wasbeer, *Procyon lotor*, invasive species, management, Flanders, Belgium.

Introduction

The issue of wild-living non-native species is now a standard concern in efforts to preserve biodiversity. Alongside ecological impacts, there are often additional worries, such as the risk of zoonotic disease transmission or damage to property and economic interests. These risks are influenced by whether the species is invasive and the extent of its population growth in new environments.

Within this broader context, non-native predatory mammals, such as raccoon (*Procyon lotor*), raccoon dog (*Nyctereutes procyonoides*) and American mink (*Neogale vison*), have received attention for many years in Flanders, the northern part of Belgium. Their potential population development has always been followed with suspicion or curiosity, within the nature sector but often also in a broader public context, with regular press coverage. All three of the species mentioned have become established in various European countries and the fear or expectation that these species would soon settle in Flanders too seemed justified for several years. However, to date, this appears to be the case only recently with raccoons, while the presence of American mink and raccoon dogs in Flanders still remains limited to isolated sightings so far, according to the carnivore database of the Flemish Research Institute for Nature and Forest (INBO).

In Flanders, raccoons are covered by the Species Decree (2009), partim alien species. Introduction into the wild was therefore already prohibited. Since August 2016, EU Regulation No. 1143/2014 has also prohibited the private keeping or trading of raccoons. These restrictions were added to the implicit ban that already

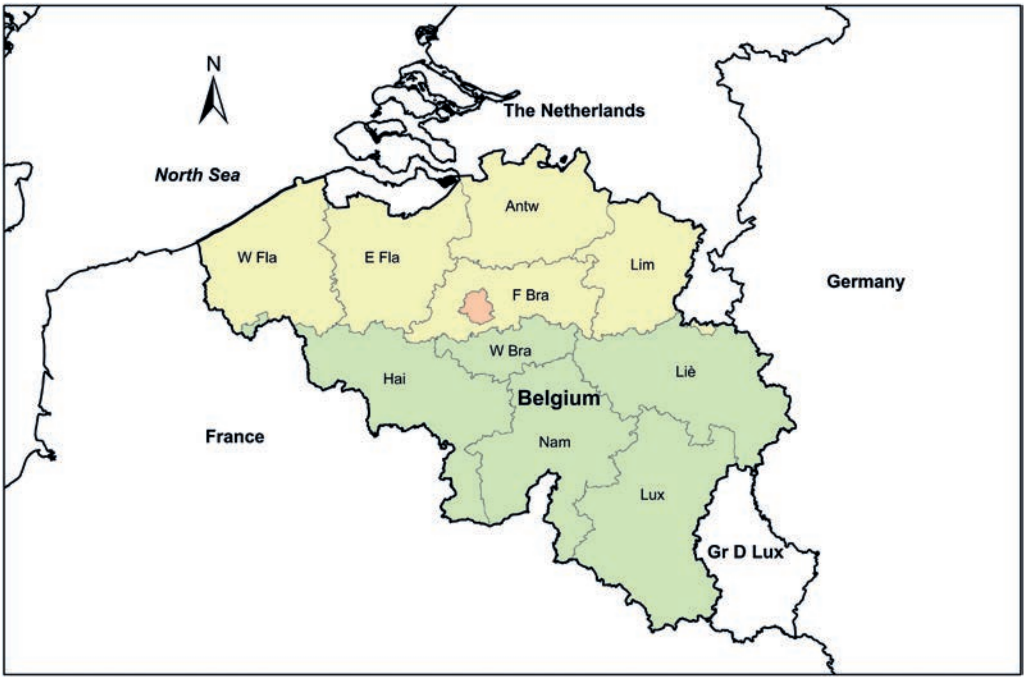

Figure 1. Location of Flanders in federal Belgium, with an indication of the regions (yellow: Flanders, green: Wallonia, orange: Brussels) and the provinces (W Fla: West Flanders, E Fla: East Flanders, Ant: Antwerp, F Bra: Flemish Brabant, Lim: Limburg, Hai: Hainaut, W Bra: Walloon Brabant, Nam: Namur, Liè: Liège, Lux: Luxembourg).

applied on the basis of the Belgian 'Positive List of Mammals', which does not include raccoons.

This paper aims to synthesize validated raccoon data to present an overview of both the recent past and the current population status of this species in Flanders. It does not aspire to provide a comprehensive risk analysis or practical management recommendations for raccoon populations. First and foremost, this overview can serve as a reference point for monitoring future developments. However, a number of critical considerations inevitably arise, with more questions being raised than definitive answers can be given at present.

Materials and methods

Study area

Flanders, the northern region of Belgium (Figure 1), covers approximately 13,500 square kilometres with an altitude ranging from 0 to 288 m. The temperate maritime climate is characterized by a mean annual precipitation of 780 mm and a mean annual temperature of 10.1 °C. The landscape is predominantly flat, with a network of rivers and canals shaping its hydrology. Flanders is among the most densely populated and industrialized regions in Europe (Jaeger et al. 2011). Forest coverage is only 10%, and urban expansion, intensive agriculture, and infrastructure development have significantly altered the natural environment (Statbel 2020). Native carnivore species that are widespread in the area include red fox (*Vulpes vulpes*), Western polecat (*Mustela putorius*), stoat (*Mustela erminea*) and weasel (*Mustela nivalis*), while badger (*Meles meles*), otter (*Lutra lutra*) and pine marten (*Martes martes*) are irregularly distributed (Van Den Berge & Gouwy 2021, Van Den Berge et al. 2021). Since 2018, the wolf (*Canis lupus*) has also settled in the area with (at least) one territory (Van Den Berge 2018, Van der Veken et al. 2021).

Surveying method

In 1998 a network of volunteers and professionals (such as forest rangers) was established at INBO, as part of the research on carnivores, especially mustelids (martens). This 'Marternetwerk' (Marten Network) aimed at centralizing all possible information about the presence of carnivores in Flanders into a specific carnivore database. Unlike neighbouring countries, Flanders does not have hunting statistics for most predators, as hunting these species has been closed for years. However, many carnivore species are often victims of traffic accidents, and such animals collected by the network provide reliable information about their presence and, through necropsies, insight into population parameters such as reproductive status, age distribution, and health. This helps distinguish between established populations and wandering individuals, which is especially important for rare, declining or emerging species. From the moment the Marten Network became operational, explicit attention was also drawn to the exotic predator species that could potentially be present in Flanders. After all, these species can lead to species confusion in the case of superficial assessment or damaged carcasses (e.g. badger versus raccoon or raccoon dog), while at the same time, *avant la lettre*, the problem of alien species was explicitly raised (Van Den Berge 1998).

In 2008, the online platform Waarnemingen.be became available through the private nature organisation Natuurpunt, which gradually took over the collection of sightings, while the collection of dead specimens became a complementary activity of INBO. The most robust data comes from collected dead animals, but all other sightings (live animals, tracks, etc.) from all kinds of sources (broader than waarnemingen.be, e.g. also from captures, press articles) are also integrated in the INBO-carnivore database, with careful attention to avoid double-counting. Strict reliability criteria are applied when assessing observations that are not linked to concrete evidence (photographs, collected dead specimens, etc.), e.g. via a cautious, exploratory questioning of observers. The data retained is divided into four categories, namely 'certain', 'very probable', 'possible' and 'undetermined'. Recently, the widespread use of camera traps by volunteer nature researchers provided a strong new tool for detecting highly elusive species, such as most mammalian predators, including raccoons.

Necropsy

Prior to necropsy, the collected specimens are frozen in an ultra-freezer (-80 °C) for 8 days for safety reasons with regard to possible parasitic infections. After thawing, a number of standard biometric measurements are recorded externally, including the total weight and the weight after removal of all internal organs. In some cases, the latter allows for a better comparison between specimens, as animals collected as roadkill are often no longer intact and no 'total' weight can be recorded. A general physiognomic assessment is also recorded, such as possible lactation in females, any coat lesions or an obvious juvenile stage. Evidence or strong indications of reproduction in the wild are considered very important in the context of a possible population development.

During the internal autopsy, in addition to taking various tissue samples (e.g. for genetic testing) and analyzing the stomach contents, attention is focused primarily on a number of characteristics relating to reproductive status and age. In females, the uterus is assessed for weight and any signs of pregnancy (embryos, placental scars). In males, the baculum is dissected, measured and weighed, and referenced to the age classification according to

Table 1. Overview of necropsy results from the collected raccoons with a view to determining possible reproduction in the wild – see text. (Information on origin or date in brackets may not be entirely precise and is subject to reserve).

Location	Date	Sex	Wt	We	HBL	Cra	Mol3cl	Mol2cl	Can	UtW	Gest	BacW	BacL
Denderleeuw	15/10/2000	M	-1	-1	-1	-1	-1	-1	-1			-1	-1
Peer	29/09/2001	M	4126	-1	57.5	-1	-1	-1	-1			1.608	91.9
Erpe-Mere	20/05/2002	F	3848	-1	54.5	2	2	2	3	1.04	NBP		
Willebroek	20/09/2002	F	6342	5304	56.5	-1	-1	-1	-1	3.1	NP		
Harre	3/08/2010	M	5234	-1	55.7	-1	-1	-1	-1			1.936	84.3
Laakdal	26/01/2011	M	-1	4776	-1	-1	3	2	3			2.844	95.6
Bertem	30/08/2012	M	4472	3824	55.5	3	2	2	3			2.732	95.9
Houston (USA)	1/2014	M	3446	3056	56	2	2	1	1			2.497	95.8
Dilbeek	2/2015	F	4202	3440	54	3	2	2	3	6.02	BP		
Dilbeek	6/2015	M	4118	3432	52.7	1	1	1	1			1.327	81.1
Dilbeek	6/2015	F	4912	4622	53.3	3	2	2	3	1.79	BP		
Hoeilaart	29/07/2015	M	2122	1758	46	1	1	1	1			0.31	50.4
Lille	23/09/2015	F	3010	2316	47.2	2	1	1	1	0.54	NBP		
Tervuren	30/07/2016	M	-1	3416	56	-1	2	2	2			1.938	90.5
Maasmechelen	17/10/2016	M	6664	5614	58.7	3	2	2	3			3.583	91.1
Lede	24/10/2016	M	6122	4958	58.5	3	3	2	3			3.232	92.5
Zottegem	19/02/2017	M	8120	6812	60.8	-1	3	2	3			5.162	99.1
Hasselt	18/01/2018	F	7646	5836	59	3	2	2	3	9.06	BP		
Hasselt	2/11/2018	M	7950	4578	57	-1	2	2	3			1.702	85.9
Duffel	11/02/2019	M	6048	5368	58	2	2	2	3			2.756	102
Maasmechelen	10/03/2019	M	5896	4530	54	-1	2	2	1			1.795	92
Voeren	13/11/2019	M	5732	4966	38	-1	1	1	1			1.238	80.7
Halen	6/02/2020	M	6418	4984	60	2	2	1	2			2.3	94.3
Herselt	18/02/2020	F	4910	4360	51.5	-1	2		3	7.47	P		
Oudsbergen	22/10/2020	M	4636	3670	53	-1	1	1	1			0.99	74.1
Schoten	21/07/2021	M	4078	3538	52.7	2	2	2	2			2.09	95.1
Bierbeek	(1/09/2021)	M	4234	3976	59	2	2	2	3			2.177	98.8
Westerlo	20/10/2021	M	4592	3760	54	1	1	1	1			0.946	77.7
Hasselt	19/06/2022	M	4010	3400	57.7	2	2	2	3			1.977	89.8
(Peer)	(1/08/2022)	M	4876	4400	-1	3	2	2	3			3.168	99.9
Diest	18/12/2022	F	4920	4920	57	-1	1	1	2	-1	-1		
Hasselt	5/10/2023	M	-1	3580	48.7	2	2	1	1			0.66	68.9

Schwery et al. (2011). For both sexes, the skull is inspected for closure of the cranial sutures and characteristics of the teeth, more specifically the degree of wear of the molars and the degree of closure of the canine root apical foramen (Grau et al. 1970), on the basis of which a distinction between juvenile and adult animals can be made with reasonable certainty.

Table 1 provides the following information:

- Origin, Date: reference of the necropsied specimen
- Sex: gender, M/F
- Wt: total weight in grams
- We: eviscerated weight (i.e. without entrails) in grams
- HBL: head-body length (i.e. from tip of nose to anus) in centimetres
- Cra: closure of the sutures of the bones of the skull (cranium); 1 = none, 2 = partial, 3 = complete closure
- Mol3cl: degree of wear on the molars in three classes; 1 = none, 2 = limited, 3 = advanced

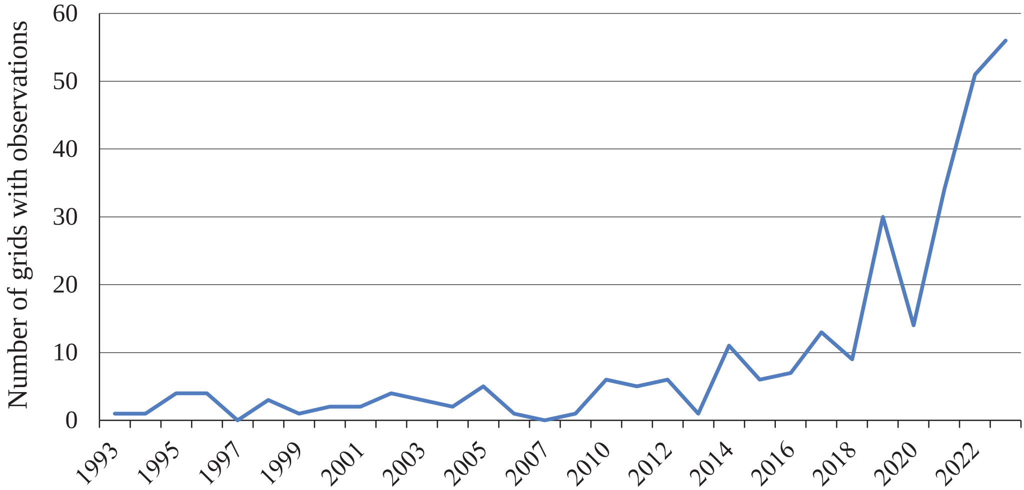

Figure 2. Number of UTM-grids (1x1 km²) with raccoon observations in Flanders.

wear
- Mol2cl: degree of wear on the molars in two classes; 1 = none, 2 = wear present
- Can: closure of the canine root apical foramen; 1 = open, 2 = closing, 3 = closed
- UtW: weight of the uterus in grams
- Pregnancy: P pregnant, BP recently been pregnant (with placental scars), NP not pregnant, NBP not been pregnant
- BacW: weight of penis bone (baculum) in grams
- BacL: maximum length (A2 see Schwery et al. 2011) of penis bone in mm

In addition to the findings from autopsies on collected specimens, the likelihood of reproduction in the wild could also be estimated based on the information associated with other data types, i.e. observations. Specifically, this may involve verified images of living or dead specimens, well-argued sightings of living or dead animals, and catch results.

Results

Raccoon presence

With the oldest validated data dating back to the early 1990s, the INBO carnivore database contains more than 350 observations of raccoons in Flanders validated as 'certain' or 'very probable' for the period up to mid-2024. Figure 2 shows the trend in the number of UTM-grids with raccoon observations over the years. During the first two decades, the numbers fluctuated around a low value, while in the last decade they have increased rapidly and undeniably. This trend is also clear when comparing the corresponding map representations. For the periods 1993-2003 (Figure 3) and 2004-2014 (Figure 4), the coloured grid cells are sparsely distributed and, with a few exceptions, do not overlap. During these periods, no high density of sightings was recorded anywhere. For the period 2015-2024 (Figure 5), the picture is very different, with multiple clustered grid cells and frequently a higher density of observations.

Reproduction

An overview of a series of necropsy results from the collected raccoons with a view to determining possible reproduction in the wild is given in Table 1. As mentioned above the focus is on the reproductive status of the

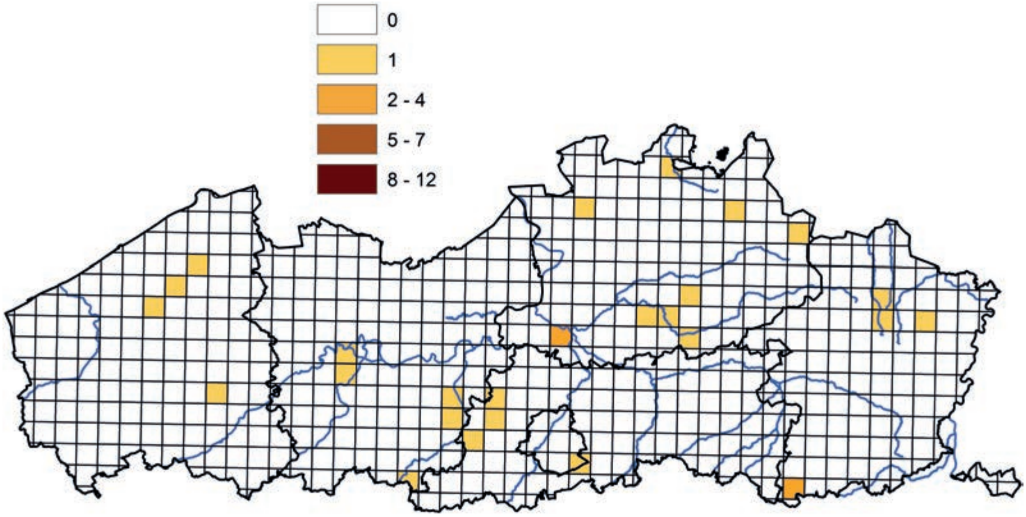

Figure 3. Validated data ('very probable' and 'certain') on raccoon presence in Flanders for the period 1993-2003 based on the 5x5 km² UTM grid.

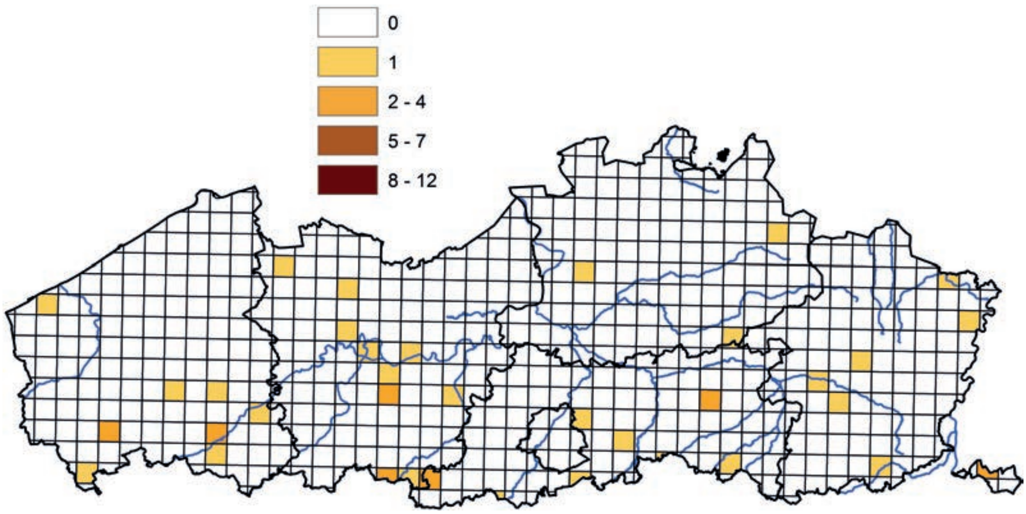

Figure 4. Validated data ('very probable' and 'certain') on raccoon presence in Flanders for the period 2004-2014 based on the 5x5 km² UTM grid.

females and on an approximate age determination with a distinction between juvenile and older (subadult and adult) animals. The values marked in yellow in the table are characteristic of juvenile and subadult animals, i.e. with an age of up to approximately six months and between approximately six months and approximately one year, respectively. The cells marked in green indicate females that are pregnant or have reproduced in the recent past.

Figure 6 shows the locations in Flanders where reproduction in the wild has been observed or can at least be strongly suspected. In fact, reproduction has now been demonstrated in every province; in the Province of West-Flanders there is one location, in East-Flanders there are four locations, in Antwerp

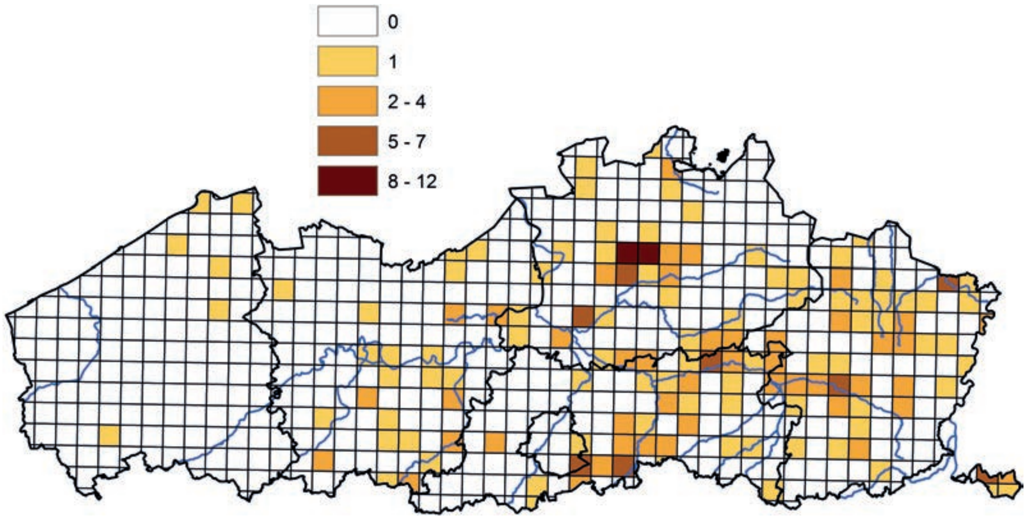

Figure 5. Validated data ('very probable' and 'certain') on raccoon presence in Flanders for the period 2015-mid 2024 based on the 5x5 km² UTM grid.

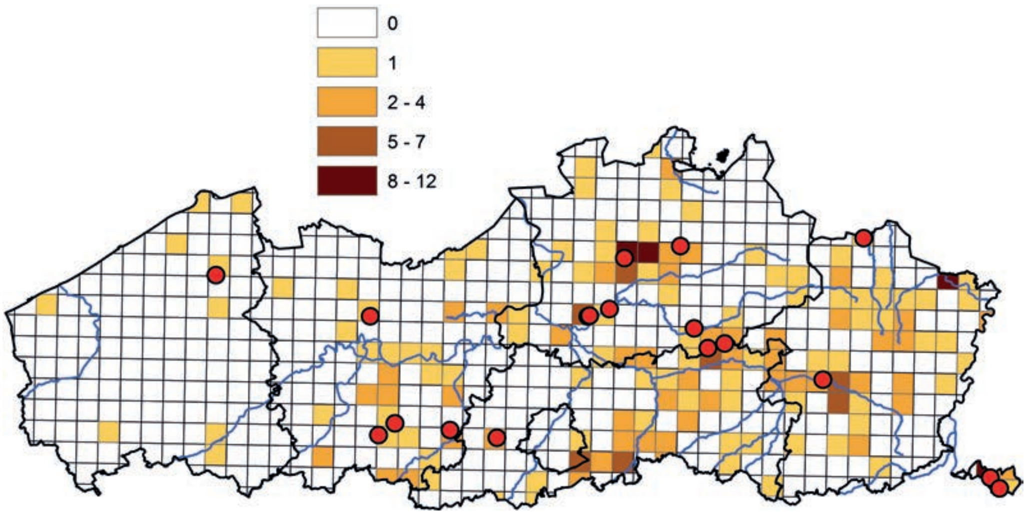

Figure 6. Locations of (very probable) raccoon reproduction (red dots) referenced to all validated data ('very probable' and 'certain') of raccoon presence in Flanders for the period 2010-2024 based on the 5x5 km² UTM grid.

there are seven locations, in Flemish Brabant there is one location, and in Limburg there are four locations. In addition, reproduction was observed in some locations for more than one year.

West-Flanders
Around 20 June 2019, a mother animal with three young was spotted in a garden in Assebroek (Bruges) on a summer evening. After that, no further sightings were reported for that region.

East-Flanders
On 19 February 2017, i.e. in the middle of the mating season, an adult male was collected as a roadkill victim in Grotenberge (Zottegem). A few days earlier, presumably the same spec-

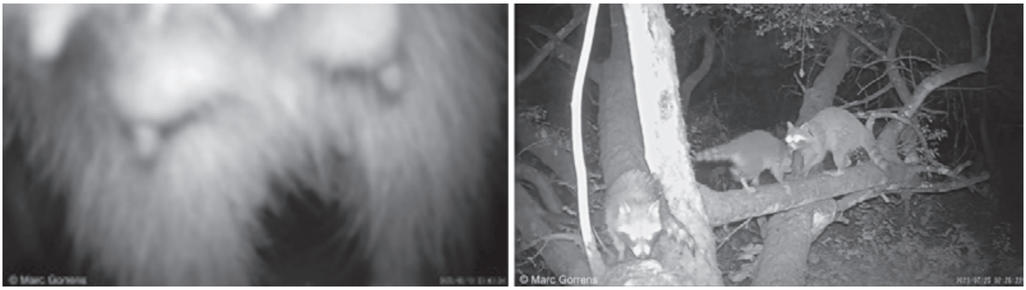

Figure 7. Lactating female raccoon (left) and juveniles (right) in Oelegem (Ranst), respectively on 19/6 and 25/7/2023. *Photos: Marc Gorrens.*

imen was photographed in a garden about five kilometres away. The distance between the two sightings is too great to consider the animal locally resident, but it is quite conceivable that a rutting male (as a ‘floating male’) could cover such a distance in a still sparse population (Van Den Berge 2017). The animal had a large bald patch on its rump, which is a typical rubbing mark for animals in mating mode.

In late spring 2018, a (obviously) young animal was seen as a roadkill victim on the busy N28 motorway near Ninove. At the beginning of July of the same year, a second and third roadkill victim were found on approximately the same stretch of road.

In Oostakker (Ghent), a recently lactating female was found as a roadkill victim near the harbour area on 10 August 2019. Given that mother animals are normally accompanied by their already fairly large young in the summer, it is unlikely that this was a recent ‘stowaway’ from a ship.

Antwerp

On 23 September 2015 a young animal was collected (Table 1) as a roadkill victim in Wechelderzande (Lille).

In June and early July 2019, a total of five young animals were captured in Duffel after they had been widely reported in the local press, while a few months earlier adult animals had also been recorded (two on camera, one poisoned).

In Herselt, an early-pregnant female was collected as a roadkill victim on 18 February 2020, and on 20 October 2021 a young male was collected in Westerlo (Table 1). On 9 October 2022, a young specimen was captured in Lier.

In Oelegem (Ranst), a nursing female and later (at least) three young were recorded in the summer of 2023 in an extensive series of camera trap recordings (Figure 7).

Flemish Brabant

In the first half of 2015, an entire family of raccoons was captured and killed in Schepdaal (Dilbeek) (Gouwy et al. 2015, 2016). The family consisted of a subadult male, two adult females, one of which was lactating (Figure 8) and one that must have had cubs in the previous year, and two cubs (Table 1).

On 29 July 2015, a first-year cub was found dead in Hoeilaart. The animal was noticeably thin and had probably been orphaned for some time (Table 1; Gouwy et al. 2015).

A subadult specimen was captured in Averbode (Scherpenheuvel-Zichem) on 3 January 2020, and on 18 December 2022 one was collected as a roadkill victim (Table 1) in Schaffen (Diest). Not far from there, a juvenile was photographed on 19 June 2023.

Limburg

In Hasselt, on 18 January 2018, a female was collected as a roadkill victim that apparently had young in the previous year; on 5 October 2023, a subadult male was collected as a roadkill victim in the immediate vicinity (Table 1).

In Oudsbergen, a young male was collected

Figure 8. Lactating female raccoon, killed in Schepdaal (Dilbeek) in June 2015. *Photo: INBO*.

as a roadkill victim on 22 October 2020 (Table 1), and on 2 August 2022, a mother and two young were observed in Neerpelt.

In Voeren, at two locations, a nest with young was captured in 2021, 2022 and 2023.

Discussion

Population history

Based on the earliest documented introductions, i.c. in Germany (Lutz 1984), raccoons have been present in Western Europe as a wild species for almost a century. Various releases and escapes led to permanent and successful establishment in several regions, initially mainly in Germany and France (see, among others, Salgado 2018). Long-term attempts in Germany to eradicate the species through intensive hunting failed, and the species has remained permanently present in a number of regions for some time (Lammertsma et al. 2008, van der Grift et al. 2016), while also giving rise to a continuous flow of dispersing animals to new regions.

The first documented mention of a free-roaming raccoon in Belgium dates back to 1986 (Libois 1987) and concerned a road-kill found in Amel (Sankt-Vith, Province of Liège). Its appearance in Belgium, close to the German-Dutch border, was not interpreted as a surprise, quite the contrary ("*La présence en Belgique du raton laveur était, à vrai dire, attendue depuis belle lurette*", and "*il est même surprenant que ce carnivore n'ait pas franchi nos frontières avant 1986*"), given that the species was already considered to be regularly occurring in the German and especially Dutch (South Limburg) border areas at that time.

Nevertheless, the question arises, especially in relation to current knowledge about the time frame of further population development and its genetic framework (see below), whether this was actually a 'wild' (dispersing) specimen or just an animal from captivity. Apart from a series of skull measurements (apparently an adult), no supporting information is provided, and neither the sex nor the reproductive status is mentioned. Incidentally, the Royal Saint Hubert Club of Belgium (Koninklijke Sint-Hubertusclub van België 1971) reported a raccoon caught by a gamekeeper in Sart-Eustache (Province of Namur), which also cites a communication with the Royal Belgian Institute of Natural Sciences about another isolated case of a killed animal in the vicinity of Spa (Province of Liège) around 1964. At the time, it was decided that such cases must involve escaped animals, as no pair or family of wild raccoons had ever been observed in Belgium.

For Flanders, the first records relate to the north of Limburg, dating back to the first half of the 1980s (Holsbeek et al. 1986): a specimen shot in 1982 in Molenbeersel-Bree, and a sighting in 1985 in the military domain of Leopoldsburg. However, the species was not (yet) considered to be permanently present at that time, with the individual cases being regarded as possible artefacts (relocated animals).

For the Netherlands, Hoekstra (1983) concludes that, from 1965 onwards, there was also an influx of dispersing raccoons from Germany. It was assumed that the earlier records (dating back to the beginning of the last century) must all have originated from zoos, travelling circuses, fur farms, private individuals, as well as Allied army units that carried raccoons as mascots.

In France, apart from scattered reports from across the country (and therefore most likely all animals originating from captivity), a strong population centre developed in the northern department of Aisne from 1966 onwards, based on specimens that had escaped from an American military base (Léger 1999). For the border region of Nord-Pas-de-Calais, an isolated sighting (capture) in 1992 led to the long-awaited conclusion that "*Le raton laveur est arrive*" (B. 1992). However, this was in all likelihood an escaped animal and, years later, there is still no evidence of a local occurrence of the species (cf. Léger 1999).

In the Flemish Mammal Atlas, Van Den Berge & De Pauw (2003) consider the raccoon to be mainly first-generation escaped animals, with no evidence of local reproduction. The same analysis remains valid in subsequent years, although at the same time it could not be ruled out that there may also have been a few cases of distant dispersers from neighbouring countries (Van Den Berge 2008, Van Den Berge & Gouwy 2009). Somewhat remarkable is an observation in Gingelom (Province of Limburg), where in February 2003, during an (illegal) fox hunt, two raccoons were found together in a burrow, possibly indicating mating.

In a number of cases, the information accompanying a specific report – sometimes an extensive story, often accompanied by press articles – indicates that there is evidence or at least strong indications that these are recent, first-generation escaped animals. Sometimes these indications are obvious, such as when the animals are microchipped or tame, but behaviour alone does not always provide a definitive answer. An interesting report in this regard concerns the recapture of an (individually recognisable) specimen after it had, apparently, lived in the wild for five months without any problems, travelling a distance of at least approximately 35 km and becoming relatively shy in the meantime (De Meulemeester 1995, Van Den Berge & De Pauw 2003). In principle, such cases can therefore give rise to a series of sightings spread over a relatively long period (months). If, every now and then, a specimen escapes 'quietly' from a nearby source, such as an animal dealer and his local clientele, over a period of several years, this can quickly give rise to the suspicion that wild specimens have settled locally. Such a combination of events was probably – given the subsequent discontinuity of data – at the root of a series of observations in the Nete Valley as described by De Smet & Vandewalle (1995).

As mentioned above, the overall appearance of map representations for the periods 1993-2003 (Figure 3) and 2004-2014 (Figure 4) shows a fairly similar picture of scattered, irregular presence. Furthermore, with a few exceptions, the coloured map squares are all different in both time periods and no high density of sightings was recorded anywhere. This suggests that there is little or no connection between the data from these periods and that this data probably refers to random observations, such as escaped and wandering animals.

In contrast, the picture for the period 2015-mid 2024 (Figure 5) is clearly different with multiple clustered grid cells and a higher observation density, confirming the trend previously identified by D'Hondt et al. (2023) for a shorter period of time. So, it's obvious that raccoons became widespread in Flanders during the last decade, as evidenced also by a recent increase in (collected) roadkill (see also Table 1) and camera recordings. The recent upward trend in Flanders can be logically explained in the context of developments in neighbouring regions. On the Dutch side, Akkermans & Mulder (2016) – contrary to Hoekstra's (1983) prediction – stated that the raccoons present at the time did not yet form a self-sustaining population, but that the front of the German source population was gradually approaching the Dutch border. A few years later, La Haye et al. (2021) noted that this front was still some distance away from the border in (Dutch) Limburg, but that a local population could now develop from captivity. In France, and more specifically in the north-eastern departments, a spectacular expansion was taking place (Léger & Ruette 2014, Larroque et al. 2023). Subsequently, large parts of Wallonia were seamlessly colonised within a few years (Schockert 2017).

Reproduction in the wild

As mentioned earlier, determining reproduction in the wild is a classic criterion for distinguishing between the random occurrence of individual animals (stray animals, escaped specimens, etc.) and the possible establishment of a species in a (nascent) population.

In principle, some reservations should always be made regarding the interpretation of the biological characteristics that have been established. For example, the discovery of a nursing female as a roadkill victim does not necessarily mean that the animal's previous reproductive cycle also took place in the wild. It is possible, for example, that a pregnant female escaped from captivity and gave birth to her young in the wild some time later. It is also possible that a mother animal could escape with some of her young, or that one or more young could escape separately. Therefore, local circumstances should also be taken into account as far as possible, such as the proximity of a known location where exotic animals are or were recently kept, or when it appears that (live-captured) animals are exhibiting unnatural tame behaviour.

For the cases examined here, it was not always possible to reach a clear-cut conclusion regarding the certainty of reproduction in the wild. However, through a critical evaluation of the circumstances of each of these cases, it was possible to conclude for the vast majority of them that this was (in all likelihood) indeed the case. Almost all of them were 'surrounded' by numerous other sightings in the more or less immediate vicinity, either in the preceding years or later. Moreover, with the exception of one possible sighting in 2003, all cases date from the last decade. Conversely, the mere observation of raccoons in a particular area for several consecutive years, and certainly when there are occasional indications of reproduction, logically argues for an (emerging) established population core. So, for rapidly expanding species, necropsy findings or other 'hard evidence' can even quickly become outdated compared to field reality.

Trend reversal

Although invasive raccoon expansion has been feared and warned about for several decades in Western Europe, it has only become an issue relatively recently. Since the mid-

1990s, a clear dynamic has emerged in the former strongholds, with the species (only then) beginning the steep part of the classic S-shaped population growth curve and numbers subsequently increasing exponentially (Salgado 2018). Accurate information on European distribution is available via the reporting mechanism of the EU Regulation. Raccoon is the most widespread species in the EU Regulation based on the number of 10x10 kilometre grids in Europe (>6500 grids, Tsiamis et al. 2017). The expansion front has now reached Flanders.

It is remarkable how the raccoon population trend fits in with the analogous trend that has occurred among various native carnivores in recent decades (cf. Van Den Berge & Gouwy 2021). Whereas native predator species are in a recovery phase after a long period in which the respective species had become locally or quasi extinct, an alien species such as the raccoon is, of course, experiencing a new emergence. The causes of these apparently prolonged slowdowns, despite their widespread and latent presence prior to the respective recent population breakthroughs, are not precisely known. A general change in environmental and nature policy, including an international ban on the use of non-humane (but efficient) hunting and control methods such as certain types of traps and heavy poisons, has at least facilitated this general trend reversal – if not caused it.

Stricter European environmental standards, including the ban on the production and use of PCBs since 1985, have probably also played an important role here. These substances are particularly toxic in terms of reproductive disruption and genetic abnormalities (He et al. 2021). For several decades, the bioavailability of these substances and other fat-soluble toxic contaminants (dieldrin, heavy metals, etc.) in the Western European food web has been declining (see, for example, de Boer et al. 2010). For semi-aquatic predators such as otters and American minks, such pollutants have long been considered genuinely harmful (see, for example, Jensen et al. 1977, MacDonald & Mason 1994, Van Den Berge et al. 2019). These substances may also have been the reason why no wild population of American mink was able to develop in Flanders (and the Netherlands) (Van Den Berge & De Pauw 2003, Dekker 2012). The raccoon, whose diet consists largely of aquatic organisms, is also one of the species considered to be particularly sensitive to PCB concentrations in the environment (U.S. Environmental Protection Agency n.d.).

In addition, more generic aspects of habitat improvement may also have played a facilitating role in population development. For example, the trend towards more nature-oriented forest management, including attention to ageing trees and more dead wood (Pro Silva Europe s.d., Forest Europe 2020), will have led to an increase in good shelter and nesting sites. The recovery of aquatic biodiversity (Haase et al. 2023), including an increase in macroinvertebrates, will have led to more food. The widespread occurrence of alien species, in this case crayfish, often in high densities, is also linked to the emergence of the raccoon (Salgado 2018).

Genetic context

Ongoing genetic research – for which INBO also provided samples, see Frantz et al. (2013), Fischer et al. (2015), Maillard et al. (2020) and Larroque et al. (2023) – has now shown that the origin of local animals is often more complex than previously assumed. In addition, for the wider Western European region, there are indications or findings of relatively recent (i.e. in the last few decades) multiple new inputs of raccoons of different genetic origins from captivity. Noteworthy in this context is also the finding by Maas et al. (2021) that the Dutch raccoons in South-Limburg could be characterised as a largely separate genetic group (at least until a few years ago), originating locally from captivity.

Currently, the respective, originally isolated Western European areas are becoming interconnected through both steady expansion at the periphery and, in some cases, long-distance dispersal (up to 200-300 km, Michler 2018, Larroque et al. 2023) of individual animals. Belgium occupies the geographical centre between the original French and German areas and thus forms the contact zone between them. In this context, it can be assumed that the increasing genetic mixing associated with this will also promote the genetic fitness of the species in Western Europe. This, in turn, may reinforce the purely mathematical effect of the exponential growth phase in which the population currently finds itself – or at least limit the risk of a possible (temporary) slowdown in growth due to potential inbreeding effects.

A remarkable, albeit (perhaps very) exceptional occurrence concerns the possible introduction of new and originally indigenous genetic material via animals that are transported as 'stowaways' by ship. In 2014 (Gouwy et al. 2014) and 2021 (D'hondt et al. 2023), for example, a raccoon was found in the ports of Antwerp and Zeebrugge respectively on a ship that had departed from the United States.

Afterthoughts

Double standards?

It may be taken for granted that no one concerned with nature conservation and biodiversity will welcome the arrival and establishment of a new non-native species. However, with regard to non-native carnivores, a warning should be issued about the risk of applying an overly nuanced double standard. Most native carnivore species have also recently made, or are in the process of making, a remarkable comeback, without existing communities (or the prevailing perception thereof) being 'prepared' for it. The return or population recovery in Flanders of species such as the fox and stone marten (just a few decades ago) or the pine marten, badger, otter, and wolf (currently) was or is generally welcomed with great enthusiasm by nature conservationists, as the final element of rich communities. The question then arises as to what the specific problem is with regard to non-native carnivores, and, in other words, what is not an issue with native species.

Classically, a whole range of undesirable characteristics are cited regarding the raccoon, all of which call for drastic intervention. These range from predation on domestic animals and vulnerable wild prey species, the spread of zoonoses, to damage and nuisance in buildings. These 'adverse characteristics' however, all apply equally to native predator species. Regarding native species, we generally advocate a completely different approach, partly due to the special position of predators as keystone species in ecosystems (see, for example, Agentschap voor Natuur en Bos 2014). Chickens, pigeons, and sheep should be protected from being killed by foxes, martens, or wolves with appropriate fencing. Predation on nests of, for example, black woodpecker (*Dryocopus martius*) and honey buzzard (*Pernis apivorus*) by pine marten is 'part of the game', and there is now a broad consensus that important breeding sites of meadow birds can be protected from excessive predation by terrestrial predators, mainly by fencing (see, among others, White & Hirons 2019, Teunissen et al. 2020). Regarding the risk of transmission of the fox tapeworm (*Echinococcus multilocularis*), one of the most threatening parasitic challenges in the European Union (EFSA & Zencanaro 2019), from foxes (or wolves) to humans, we limit ourselves to focusing on basic hygiene and the sometimes very low local prevalence of the parasite. Regarding damage and nuisance in buildings, we expect (potential) victims to take the necessary preventive measures to prevent stone martens from entering or accessing buildings. It should be noted that once a marten can no longer get in somewhere, this will certainly not be possible for the larger raccoon either.

Essential in considering potential problems and nuisance caused by predators is the message that the correct handling of them is not dictated simply because, in the case of native carnivores, they are protected species. After all, a species' legal status is the subject of a societal choice, and therefore nothing more than the result of a human decision. It is not this legal status, and therefore not the prohibition on capture or killing, that is the cause of potential problems or inconveniences, but (literally) the nature of the creature. In other words, the recommended solutions are not forced alternatives to control (killing) because they concern protected species: they simply offer the most realistic, sustainable, and effective solution. Anyone who kills a fox or wolf to protect their chickens or sheep cannot avoid the risk that sooner or later a new fox or wolf will appear, which will in turn attack the unprotected chickens or sheep. Anyone who captures a stone marten after the roof insulation of their home has been destroyed can very likely expect a recurrence of the incident if martens continue to have free access. Controlling foxes to reduce the risk of fox tapeworm can be counterproductive (see, for example, Comte et al. 2017).

Is culling recommended?

Previous analyses (see Van Den Berge & Gouwy 2021 for an overview) have explained that for year-round territorial predator species, with their generally naturally capped low densities, indiscriminate culling of individuals would only be meaningful if control leads to (near) extermination of the species across a very large area. However, with currently permitted – humane and selective – means and methods, this often proves impossible in practice once the species has established a population. While eradicating native predator species is no longer a viable objective, the question remains whether it is even possible for non-native species, using (solely) humane and selective means (cf. Smith et al. 2022). Documented significant impact on biodiversity should be the basis for such a decision (Davis et al. 2011). Moreover, if the proposed objectives prove difficult or impossible to achieve, for example, due to compensatory population demography, the ethical aspects of the applied management become all the more pressing. The systematic killing of (highly developed) animals can then hardly be justified solely on the grounds that a non-native species is involved.

Despite successful examples of near-eradication of nascent raccoon populations (e.g. Mazzamuto et al. 2020), it is unrealistic, in this phase of growth and within the given geographical context, to prevent further expansion and establishment of raccoons in Flanders. Given the geographic position relative to immediately neighbouring, already occupied areas in northern France and Wallonia, as well as in Germany, continued recolonization can be expected. In this context, D'hondt et al. (2022) already point out that comprehensive management on a Flemish scale is not evident due to the problematically low perspective for action, which is based on, among other things, the high risk of recolonization from neighbouring countries and regions (Adriaens et al. 2019).

A critical yet comprehensively argued analysis of the current standard raccoon control policy (in the Netherlands) is provided by Mulder (2008, s.d.). In it, virtually all the prevailing motives for raccoon control are refuted or, in their broader context, significantly nuanced (including the public health risk associated with the raccoon roundworm *Baylisascaris procyonis*). At the same time, explicit reference is made to the previous, extensive, but ultimately unsuccessful control efforts in Germany, from where the raccoon range is expanding unstoppably towards the Netherlands. The final message is that it will be a matter of learning to live with the raccoon as a new species, whether one wants to or not.

Staying focused

An interesting point of attention within this issue remains the raccoon's further population dynamics, coupled with its complex social organization. Somewhat unlike our native medium-sized predator species, the raccoon sometimes appears to live in loose groups with conspecifics: clusters of females and 'coalitions' of males (Michler 2018). In rural areas, densities can potentially be reached that are two or three times higher than those of our native species, although, so far, this has only been observed in the native range. In urban areas, numbers sometimes reach (very) high densities (Fischer et al. 2016). While this could be an argument against allowing it to get to this point, this inherent population plasticity could also fuel the argument that comprehensive (expensive) control measures (only using humane means and methods) will have little effect in practice.

In certain cases, temporary and localized management may be appropriate, with prevention of nuisance and impact being the primary management drivers, and control measures implemented only as a last resort, aimed at safeguarding specific natural values. This can potentially save time locally, for example, by reducing the vulnerability of a potentially endangered prey species through appropriate habitat restoration. Habitat restoration generally requires sufficient time, assuming that it is effectively implemented in the meantime. The latter generally remains the foundation for nature restoration and therefore requires the necessary commitment and budgets.

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Samenvatting

De opkomst van de wasbeer (*Procyon lotor*) in Vlaanderen: kroniek van een aangekondigde evolutie?

Het voorkomen van de wasbeer als uitheemse soort in West-Europa wordt al enkele decennia met bijzondere aandacht gevolgd. Via het Marternetwerk van het Instituut voor Natuur- en Bosonderzoek (INBO) wordt in Vlaanderen sinds 1998 werk gemaakt van een systematische opvolging van wasbeeraanwezigheid in het wild. Daarbij is gebleken dat het bij de waarnemingen uit de jaren 1980, 1990 en beginjaren 2000 zo goed als allemaal om eerste-generatie ontsnapte of door mensen getransporteerde dieren moet zijn gegaan. Nergens kon spontane vestiging, met voortplanting in het wild, worden aangetoond. Sinds zowat een decennium is daarin overtuigend verandering gekomen. Op basis van de integratie van alle waarnemingen met bijhorende informatie, waaronder ook de bevindingen omtrent de voortplantingstoestand van ingezamelde verkeersslachtoffers, blijkt dat de populatieontwikkeling zich verspreid over geheel Vlaanderen reeds in een gevorderd stadium bevindt. Deze nieuwe toestand is het logische uitvloeisel van een opgemerkte dynamiek, die sinds het midden van de jaren 1990 in het vroegere Duitse en later ook Noord-Franse bolwerk op gang is gekomen. Actueel is de Waalse regio bezuiden de Samber-Maaslijn naadloos vanuit de Franse en Duitse grensregio's als het ware 'dichtgevloeid' met wasberen, en spreidt deze kolonisatiegolf zich geleidelijk aan verder uit over Vlaanderen en Henegouwen. Deze trendbreuk is opmerkelijk maar niet uitzonderlijk in West-Europa. Zij spoort samen met een analoog gebeuren bij meerdere (middel)grote (zoog)diersoorten als een gecombineerd effect van afgenomen actieve doding (jacht, bestrijding) en toegenomen habitatkwaliteit, waaronder o.a. afname van zwaar-toxische contaminanten in de voedselketen en gerichte natuurherstelmaatregelen. Als niet-inheemse soort is de wasbeer in principe ongewenst in de natuur. Specifiek voor de soort zelf worden daarbij verschillende redenen aangehaald: het betreft een predator die mogelijk een bedreigende invloed uitoefent op de biodiversiteit, regelmatig pluimvee doodt en gebouwen beschadigt, en drager kan zijn van een voor de mens niet-ongevaarlijke parasitaire worm. Over de werkelijke draagwijdte en impact van deze negatieve eigenschappen bestaat in wetenschappelijke kringen discussie. Uit langjarige beheerervaring en dito -onderzoek in Duitsland is gebleken dat wasberen zich, eens stevig gevestigd, heel moeilijk efficiënt laten bestrijden en terugdringen. Het is dan ook de vraag of, en zo nodig hoe, wasberen (nog langer of opnieuw) systematisch dienen bestreden te worden in West-Europa. Los daarvan kan ingrijpen in specifieke situaties wenselijk zijn om, lokaal en tijdelijk, een acuut natuurbehoudsprobleem te helpen milderen of te vermijden. Dit artikel is gebaseerd op het eerder verschenen INBO-rapport van Van Den Berge et al. (2024).

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