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Wolves Among Us

The Societal and Ecological Implications of the Wolf's *(Canis lupus)* Comeback to the Netherlands

Bachelor's Thesis Life Sciences

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Date of issue: 27 July 2023

Content

Abstract

With the revival of the wolf (*Canis lupus*) in the Dutch anthropogenic landscape, human-wolf conflicts are increasing. Livestock is attacked frequently and initiates societal debates in the country. Because of their protected status in Europe, wolves cannot be killed or captured, only in exceptional cases. The species will in all likelihood be part of Dutch nature for a while. The consequences of the wolf's comeback for nature and society will be addressed in this paper. By comparing data about Dutch wolves and case studies from other countries about wolf preferences, activity and ecological impacts, I aim to get a better understanding of the potential effects on the Dutch landscape and society. For this, I made use of the Dutch website Bij12.nl, which gathers data about wolves in the Netherlands, and related papers about wolf impacts on other countries. I found that positive ecological effects have been observed in these countries. For the Dutch situation, ecological effects are probably highly dependent on regional differences in habitat. I expect human-dominated regions, which are abundant in the Netherlands, to notice little ecological effects from wolf presence. Meanwhile, my expectation is that these same regions will likely suffer more from livestock predation and thus have more wolf-human conflicts. In contrast, for larger unfragmented woodland areas, such as the Veluwe, I predict more ecosystem changes due to wolf presence, provided wildlife management is regulated. After reviewing data about current precautionary measures in the Netherlands, I consider it below desired levels. Improvements in this aspect are in my opinion crucial for increasing positive ecological effects and decreasing wolf-human conflicts, consequently ensuring successful coexistence and conservation of the species in the Netherlands.

Introduction

Up until 9 March 2015, the wolf's image was probably largely based on fairy tales and movies. Wolves had not wandered our lands for almost 150 years (Dufresnes et al., 2018, Drenthen, 2015). For many centuries, human populations in Europe grew rapidly. Suitable wolf habitat was quickly converted into farmland. Besides, wolves and humans competed for the same food resources, resulting in large scale hunting of wolves, starting in the middle ages and probably even earlier (Dufresnes et al., 2018). What once was the most widely distributed mammal on our planet, had been driven to extirpation in almost all of Western Europe by the end of the 19th century (Dufresnes et al., 2018). The last wolf in The Netherlands was killed somewhere around the year 1869 and with the extirpation, Dutch nature lost one of its last apex predators. Only in the most remote areas in the southern and eastern parts of Europe, wolves were able to withstand human influences and maintain small, yet viable populations (fig. 1) (Drenthen, 2015).

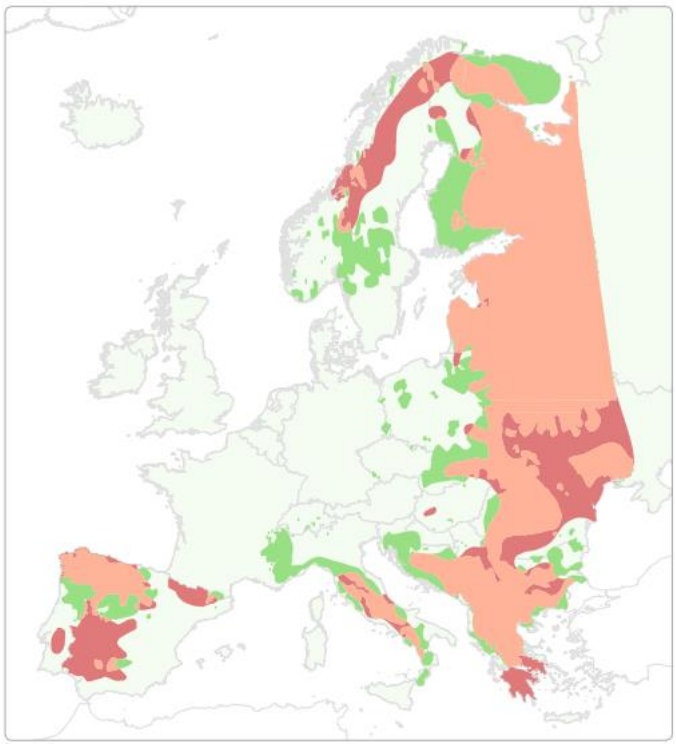

Figure 1: Wolf dispersal in Europe from 1960-2008. Green is expansion, orange is persistence, red is extraction. Retrieved from *Wildlife comeback in Europe – The recovery of selected mammal and bird species*

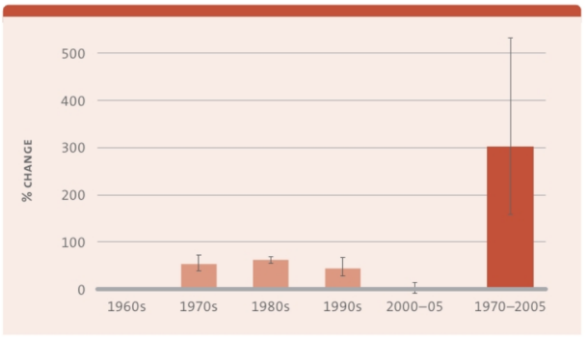

Figure 2: Relative growth of wolf numbers across Europe from 1960s until 2005.
Retrieved from *Wildlife comeback in Europe – The recovery of selected mammal and bird species*

However, in more recent decades, awareness rose regarding the loss of biodiversity and conservation problems. European governments and policymakers have increasingly adopted policies aimed at nature conservation and biodiversity. The International Union for Conservation of Nature (IUCN) created an endangered species list to prevent the loss of species that were on the verge of extinction (Evans, 2012). Natura2000 areas were assigned to protect valuable natural habitat. In addition, efforts were made to reconnect formerly fragmented habitats to promote migration, gene flow and biodiversity (Proceedings of the Conference on Wilderness and Large Natural Habitat Areas, 2009). As a result, many species began to reinhabit their formerly abandoned habitat. For example, beavers, lynx, wild boar and bison are expanding their territory (Drenthen, 2015). This is partly a consequence of rewilding projects, in which locally extinct species are reintroduced to former environment (Drenthen, 2015).
The wolf is also one of the species undergoing a resurgence (fig. 2). During the last few decades, Eastern European wolves have been expanding their range further and further to the West (fig. 3).

Around 2000, the first wolf pups were born in Germany and in 2013, camera footage showed wolf presence very close to the Dutch-German border (Lelieveld et al., 2016). It was clear that a comeback of wolves in the Netherlands was not merely a fantasy. And thus, on 9 March 2015, the first wolf, "Wanderwolf" crossed the border in search of a new territory. It travelled over 200 kilometres before arriving in the Dutch province of Drenthe (Drenthen, 2015). The wolf made many headlines and Dutch society showed diverging opinions. Nature enthusiasts were delighted to see a large carnivore returning, but more negative voices could be heard from the sceptical agricultural industry, which was concerned about its livestock. Policymakers started thinking about ways in which society could co-exist with wolves in such a densely populated area. After 4 days of wandering, the wolf headed back to Germany (Drenthen, 2015). Nevertheless, after more and more sightings, it seemed inevitable that the wolf would settle in the Netherlands.

In July 2023, an estimated 30 to 35 wolves live in the Netherlands (Bij12.nl). They are divided over 8 packs or pairs and wandering individuals looking for a territory.

Figure 3: Arrows indicating direction of expansion of wolves in Europe in recent decades.
Retrieved from *Wildlife comeback in Europe – The recovery of selected mammal and bird species*

Since the wolf's comeback to the Netherlands, many wolf attacks on livestock were reported. Killing or capturing wolves in Europe is still illegal in most cases, so farmers and shepherds watched in dismay as their livestock was attacked. Very recently, even a shepherd was attacked by a wolf, amplifying the societal issue even more. This all leads to increased societal and political debates whether such an anthropogenic area as the Netherlands is suited for sustaining a wolf population. It also clarifies the need for a clear and uniform approach on how to deal with the wolf's comeback. These attacks often made it to the media and augmented the already negative image many Dutch people have on wolves. Yet, there might also potential positive effects of the presence of wolves.
In this paper, I will focus on the effects of wolves on Dutch society and its different natural areas and how to maximize prosperous coexistence between wolves and humans in the Netherlands.

Approach

By combining i.e. much literature, case studies and data about wolves and their dispersal, as well as ecological characteristics, trophic cascades and Dutch landscape, I aim to get an overview of the effects the wolf will have on Dutch landscape and society. Dutch website Bij12.nl provided me with much data on wolves in the Netherlands. Moreover, 'ecological effects of wolves', 'trophic cascades', 'livestock predation by wolves' were examples of search terms used to get a better understanding of the effects of wolves can potentially have in this country. This resulted in many, mostly foreign, studies that have been carried out on various wolf aspects: ecological roles, diet composition and habitat preference for example. Yet, research on wolves in the Netherlands is still in its infancy, since

the wolf has only settled for several years. Consequences for the Dutch ecosystems will be reviewed, along with societal effects to gain more insight and understanding of the place and role the wolf has in the country and how we can improve our co-existence with the species.

Results

Preferred Wolf Habitat

At first sight, Dutch nature does not seem to be tailor-made for wolves. I found that preferred wolf habitat predominantly consists of forest and woodland areas with preferably low human population density (Jędrzejewski et al., 2004). High forest coverage is linked to high prey abundance and enough sites for a den. Multiple studies on wolves in Poland and North America showed most frequent occurrence in areas with 50-80% of forest coverage and 1.5 person/km^2 (Mladenoff et al., 1995, Jędrzejewski et al., 2004). With only 10% of total forest coverage in the Netherlands and a mean population density of 523/ km^2 (CBS.nl), the Dutch landscape seems unsuited from a geographical point of view. However, wolves have shown to be a very tolerant species when it comes to habitat selection. The species even occurred at forest coverages of 11%. In areas with relatively low forest coverage, the wolf's habitat consisted of a mosaic of forest fragmentation and farmland, as long as there was sufficient prey abundant (Jędrzejewski et al., 2004). Prey abundance, mainly ungulates, thus is a more important factor in being suitable wolf habitat (Glenz et al., 2001). Yet, not only abundance, but also prey diversity is of big influence on areas being fitting wolf habitat. A multi-prey system with different prey species causes less fluctuations in the ecosystem and thus a more stable prey density (Glenz et al., 2001).

Current Wolf Dispersal in the Netherlands

The distribution of wolves in the Netherlands reflects the preference for low-anthropogenic, wooded areas. The highest abundance can be seen on "The Veluwe", a large nature area in the eastern part of the country (fig. 4). Here, 6 wolfpacks or pairs and a varying number of roaming individuals occupy the territory. Two other packs can also be found in northern provinces of Drenthe and Friesland and in the southern province of Noord-Brabant, close to the Belgian border. Furthermore, an unknown number of individual wolves are roaming the eastern provinces.
Of all wolf territory, in particular the Veluwe possesses the most fitting geographical and ecological characteristics for suitable wolf habitat: relatively low human population density and relatively high forest coverage and wild prey densities.

Figure 4: current wolf dispersal in the Netherlands in July 2023. Coloured areas indicate territories where a pack or pair of wolves has settled. Retrieved from *Kaart verspreiding wolf - Voortgangsrapportage wolf 28 juni 2023.*

Wolf Territory in Dutch Landscape

The territories of wolves often stretch dozens of square kilometres (Jędrzejewski et al., 2007). Countries close to the Netherlands, such as Germany, have already been able to do research on wolves for several years. I found that their studies about wolf territory showed average ranges of roughly 200 km2 (Jansman et al., 2021). Territory size was dependent on multiple factors, including ungulate density or competition with neighbouring wolfpacks for prey. Social status also affects territory size: packs require more area than solitary individuals (Jansman et al., 2021). The scale of these wolf territories make it almost inevitable that a big part of wolf habitat in the Netherlands will be a mixture of natural areas (forest and moorland) and agricultural lands, since more than half of the country consists of farmland (CBS.nl). Only the Veluwe is potentially large enough to host a territory with very little agricultural coverage.

Livestock Predation by Wolves in The Netherlands

Wolf habitat in a mixture of natural area and farmland will consequently increase the risk of livestock damage, especially if livestock is more easily accessible than wild prey (Sidorovich et al., 2003).
A study by Sidorovich et al. in 2003 performed in Belarus, pointed out that, in times when wild prey abundance was at its lowest, 38% of consumed biomass by wolves consisted of domestic animals. Still, the majority of prey was wild. This, nevertheless, is a fairly high percentage compared to times when ungulate density was at its peak. This resulted in livestock contributing 4-6% in wolf diet. This shows the need of sufficient wild prey to avoid wolf-human-livestock conflicts as much as possible. Consequently, artificially reducing the population of wild boar, red deer and fallow deer, by shooting a big part of their populations, may be a factor influencing the number of wolf attacks on livestock in the Netherlands.

This potential damage to livestock is not coincidental the main critique on the revival of the wolf in the Netherlands. The wolf's arrival can expect little support from the agricultural sector. Conservation policies regarding the wolf in Europe and the Netherlands secure the preservation of wolves by making it illegal to kill, capture or disturb the species in most cases. The only legal options farmers and shepherds have to protect their livestock, is in taking precautionary measures. Electric fences and guard dogs are examples of measures taken to keep wolves at a distance. In areas with much wolf activity, farmers and shepherds can locally apply for subsidy to accommodate those precautionary measures. Yet, since the return in march 2015, 2275 domestic animals were killed during a total of 659 reported deadly attacks on livestock by wolves (Bij12.nl).
Every year, the number of attacks grows together with the increase in wolf population. The majority of casualties are sheep, but also cows, ponies and goats have fallen victim to wolves (Bij12.nl). Policy in the Netherlands ensures that farmers and shepherds who lose livestock in a proven wolf attack receive compensation. The Dutch government has, up until July 7th 2023, paid over 634.000 Euros in compensation for wolf damage (Bij12.nl).
It goes to show that human conflicts with wolves are rising. Is this purely a result from increasing population or are there other factors playing a role? Do wolves in the Netherlands have a preference for livestock over wild prey and is there something to change the attack rate on livestock?

Potential Causes for Livestock Predation by Wolves

I found many case studies about livestock predation by wolves, suggesting that there seem to be multiple factors that might influence the amount of livestock predation in an area.
Various studies indicate that wolves have a preference for wild prey over livestock when present in similar abundance (Newsome et al., 2016). Data from Germany (Saxony) and Belgium (Limburg) about wolf diet amplifies this: the majority of prey consists of middle and large-sized ungulates as deer, wild boar, red deer and fallow deer (fig. 5) (Jansman et al., 2021). Livestock contribution to the wolf's diet is respectively 1.6% and 12.9% for Germany and Belgium (fig. 5 and 6, Vee=Livestock). Although in both cases, the majority of prey is wild, livestock is roughly 8 times more predated in the Belgian area than in the German area. I do have to mention relatively small sample sizes in this study but it may be worth comparing.
Such an elaborate research on wolf diet has not yet been done about wolves in the Netherlands.
For the Dutch situation, these results from neighbouring countries cannot be extrapolated one on one, but they do give a fairly good indication since we can still see some similarities in habitat characteristics which may explain the local difference in livestock predation.

The study by Jansman et al. in 2021, which provides these data, states that the studied German landscape can be compared to that of the Veluwe. The studied Belgian landscape is more similar to the wolf's territory in Noord-Brabant and possibly also comparable to the Drenthe/ Friesland wolf habitat.

If we look at the diversity in these landscapes we can already see profound differences: The Veluwe is a large nature area with high forest cover and relatively little farmland and urbanisation. Many big ungulates (red deer, wild boar, fallow deer) are present in the area. The high coverage of forest and moorland on the Veluwe consequently limits the agricultural land cover in this area. This is also caused by the fact that the Veluwe is a Natura2000 area and is thus protected.
As mentioned earlier, the Belgian situation resembles the territory in Noord-Brabant and probably also the wolf territory in Drenthe and along the Drenthe-Friesland border. This implies a more fragmented landscape with a mosaic of woodlands, moorland and farmland. The lower population sizes or even lack of big ungulates, such as red deer, form also clear differences between these wolf territories. Connecting this to the contribution of livestock to wolf diets might give more insight into why and where livestock is preyed upon to a larger extent**:** The extent to which unfragmented forest area is available may play a role in livestock predation. Increased cover of farmland mixed with natural areas, may furthermore induce higher livestock predation. Also, the lack of sufficient numbers of large ungulates, related to the absence of unfragmented natural areas possibly influences the attacks on livestock.

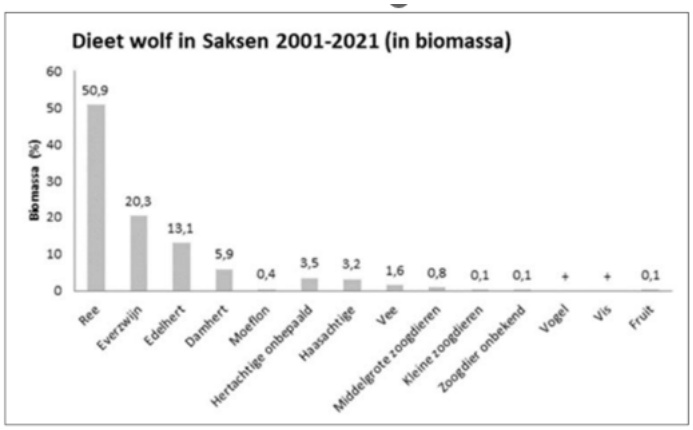

Figure 5: Wolf diet in Saxony, Germany, in percentage of biomass *(Jansman et al., 2021)*

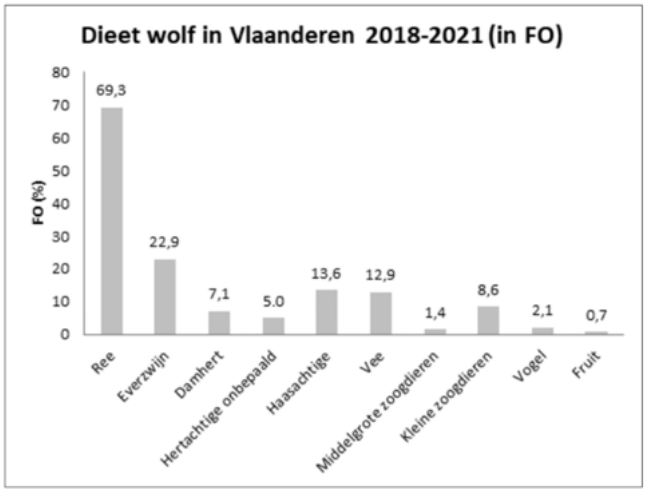

Figure 6: Wolf diet in Limburg, Belgium, in percentage of biomass *(Jansman et al., 2021*)

Yet, there are multiple other factors that might be involved in the extent to which wolves attack livestock, including health condition, social status and livestock vulnerability. Solitary and/ or unhealthy wolves may be more inclined to attack livestock during their passage, looking for an easy meal. Something that was also remarkable, were certain peaks in livestock predation. In the Belgian

region, during autumn, livestock predation peaked up to almost half of the diet (Jansman et al., 2021). The expectation is that this is caused by packs with semi grown up pups. In an attempt to keep up with their rapid growth, the packs probably make use of easier prey during these periods. A similar situation was also observed on the Veluwe, where sheep were attacked excessively in the period of pups. (Jansman et al., 2021).
Vulnerability of livestock also greatly influences predation by wolves (Janeiro-Otero et al., 2020). Unattended livestock (absence of fences, shepherds or guard dogs) was one of the main motives for wolves to attack (Janeiro-Otero et al., 2020). Additionally, the size and density of the herd was a factor in areas where the livestock could roam in open fields in relatively small numbers (less than 20 individuals/ km2). Then, there was more risk for wolf predation (Janeiro-Otero et al., 2020).

Local Differences in Livestock Predation in The Netherlands

Because of a good monitoring of wolf attacks on Dutch livestock, it is possible to compare livestock predation in the wolf areas in the Netherlands. With regards to livestock predation in this paper, the focus will be on the three areas with settled wolf presence: The Veluwe (Gelderland), Drenthe/Friesland and Noord Brabant. Drenthe and Friesland have been combined since attacks in Friesland are almost certainly from the same packs/ individuals as in Drenthe. These 3 regions are also the regions in which most wolf attacks on livestock are registered (Bij12.nl). Looking at the dispersal map of wolves in the Netherlands (fig. 4), the highest abundance is clearly on the Veluwe, the large woodlands area in the province of Gelderland. In this region, 4 packs are settled and multiple solitary individuals also make use of the territory. The presence of about 17 wolves is registered on the Veluwe in the last few months. Moreover, 4 individuals without pack or fixed territory were observed in Gelderland. In the provinces of Drenthe and Friesland, where two packs have also settled for a while now, 7 wolves were shown to occupy the territory. Here too, roaming individuals scan the environment for territory one of which was registered. Yet, the number of packs with settled territory is two. The last region in which a wolf with fixed territory is present is Noord-Brabant. Here, around 4 wolves are in the area but it is unknown whether these wolves have formed packs.
Common sense would tell us that in areas with more wolves, more attacks on livestock were to be expected. Nevertheless, looking at the distribution of wolf attacks over the period 2015-2023, the areas of Drenthe/ Friesland and Noord-Brabant exhibit higher overall registered livestock attacks even though they have lower wolf numbers (figure 7 and 8).

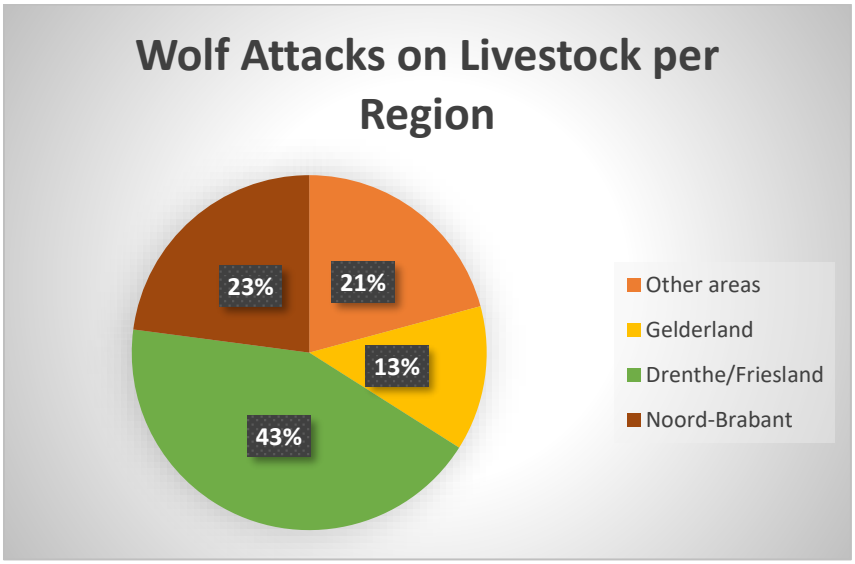

Figure 7: Wolf attacks on livestock in Dutch wolf habitat regions from 2015-2023 in relative numbers. Total attacks was 659.
Retrieved from: *Wolvenschade melden en overzicht van de meest recente schademeldingen. (2023, June 22). BIJ12.*

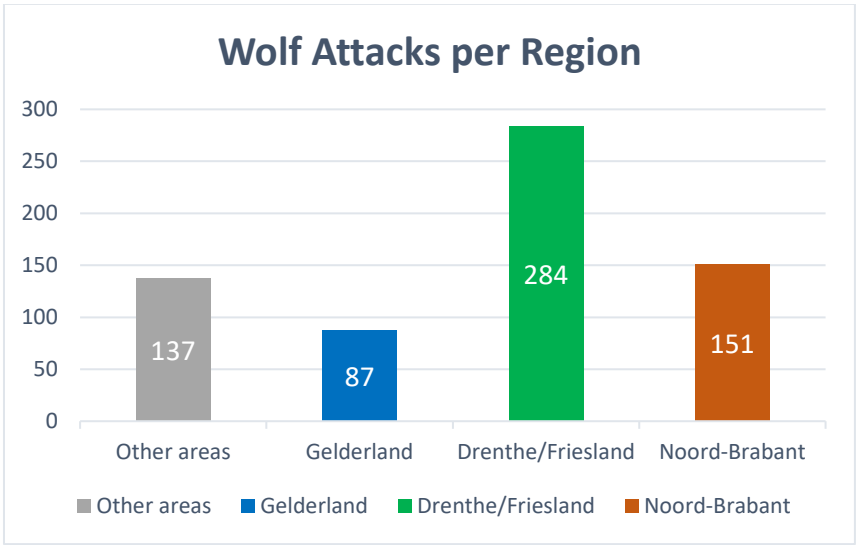

Figure 8: Wolf attacks on livestock in Dutch wolf habitat regions from 2015-2023 in absolute numbers. Total attacks was 659
Retrieved from: *Wolvenschade melden en overzicht van de meest recente schademeldingen. (2023, June 22). BIJ12.*

This uneven distribution of total wolf presence compared to the amount of attacks on livestock support the view of different circumstances in the various wolf habitats in the Dutch landscape.
Lower forest coverage and more patches with farmland may be explaining factors. Besides, (big) ungulate population/density differences might force wolves in Noord-Brabant and Drenthe/Friesland to predate more on livestock. Detailed diet composition of Dutch wolves should bring clarification, but a strong tendency regarding increased livestock predation in the aforementioned provinces, may already be visible.

Precautionary Measures to Fend Off Wolves

Vulnerability of the livestock is also one of the wolf's main drives to feed on livestock. This is a non-ecological factor which might influence livestock predation. Good attendance in the form of electrical fences, guard dogs and shepherds is crucial (Janeiro-Otero et al., 2020). Implementing one or more prevention measures might decrease wolf predation on domestic animals. As a result, harmony between wolves and humans could be partly restored (Janeiro-Otero et al., 2020).
Nonetheless, precautionary measures to fend off wolves are to be applied correctly. Experts in Germany advice to meet at least 3 requirements when installing a wolf fence: 1) the lowest wire must not be higher than 20 cm above the ground, since wolves prefer to dig under fences rather than jump over it. 2) the fence should be at least higher than 90 cm. 3) a minimum voltage of 2500 Volt is required (Poerting, 2023). Only if these 3 requirements are met, German farmers qualify for compensation for livestock damage (Poerting, 2023). Additionally, it is desirable to have at least 5 wires with electrical current and add visual repellent objects to the fence (Poerting, 2023).

The data concerning prevention measures in the Netherlands show worrying results in my opinion. Out of the 659 proven wolf attacks on livestock, in merely 70 cases, the fence conditions were sufficient according to German requirements (max. 20 cm from the ground, minimum height of 90 cm and voltage minimum of 2500 V) (Bij12.nl). This is a best-case scenario since the registration of prevention measures differs per case. In most cases, only a maximum height and voltage was noted. In these cases, it was not clear whether the lowest part of the fence was lower than 20 cm. When looking at the data critically, there was only 1 case in which all the 3 requirements were met and clearly registered.
Considering these situations, it is clear that there is enough room for improvement.

Potential Positive Impact on Dutch Ecosystems

At the same time, there are also reasons that the Dutch government accepts financial losses and societal debates due to wolf conflicts. Its return can have major impacts on ecosystems. This can happen through so-called trophic cascades.
The wolf is a species that, if present, can be found at the top of the food chain. Such species, apex predators, play majorly important roles in the ecosystems' food web (Ripple et al., 2016).
By predating on the lower trophic levels, the highest trophic levels start a domino effect that resonates all the way from the top to the bottom of the food web. Top predators are said to be crucial in the stabilisation of the food web (McCann et al., 2005). With the removal or absence of these apex predators, the well balanced trophic pyramid might be disrupted. As a result, the new version of the ecosystem without the top tier predators is often a simplified form compared to the old ecosystem (Paine, 1980). In many cases biodiversity will decrease, since large grazers can graze and browse limitless, reducing vegetation regeneration and diversity, which consequently will affect other species too.
Large predators are especially suggested to impact ecosystems. Their relatively large bodies enable them to cover long distances and thus connect communities and food webs (Terborgh, 2010). Yet, decades of human activity has impacted the abundance of large carnivores. As said before, this happened in the Netherlands but also on a global scale (Atkins et al., 2019). Consequently, large herbivores, the main prey of big carnivores, have become overabundant in many global communities (Terborgh, 2010). This is also the case in Dutch ecosystems. Numbers and distribution of ungulates, which include fallow deer, wild boar, red deer and deer, have been rising for the last 50 years (Bruinderink, G. & Van der Grift, E., 2015). Hence, herbivory by these ungulates is an extensive problem in some Dutch natural landscapes. In areas with more herbivory, vegetation has a harder time to grow and regenerate, affecting the amount of biodiversity. Directly, by reducing the variety of vegetation and indirectly by influencing habitat and niches for other species. In an attempt to promote

biodiversity and decrease damage to agriculture, Dutch policy has, to a certain extent, approved the shooting of wild ungulates. Merely on the Veluwe, 3000 ungulates were shot in the last two years (Faunabeheereenheid Gelderland)
Artificially reducing animal populations in areas with relatively low human activity might disturb ecological processes. Human sounds alone are already enough to cause ecological effects.(Suraci et al., 2019) .Shooting sounds thus can be triggers for disrupting these ecological processes.
Wolf presence can be a potential solution for the reduction of ungulate species in a more natural way. A prime example is the case of Yellowstone National Park, Wyoming , USA. Wolves were reintroduced in 1995 after many decades of absence (Ripple et al., 2004). Large ungulates, such as elk, did not have many natural predators and populations boomed, leading to much overgrazing and limited biodiversity (Ripple et al., 2004). The reintroduction of wolves marked the transformation of the landscape because of their presence. Elk abundance decreased and consequently, herbivory pressure did too, starting a whole series of cascading effects. Increased vegetation created many new habitats and niches for birds, beavers and other species. Rising beaver numbers in turn created new environments for various aquatic species. It was not just the fact that wolves kill prey, but simply their presence that may be enough to alter the ecosystem by fear-mediated effects. Prey species possibly adjusted their behaviour and dispersal as a result of wolf presence (Ripple et al., 2004).
Distribution of prey species focussed more and more towards areas with possibilities for escape and with few obstacles around. Steep valleys and riverbanks for example experienced less grazing and thus an uplift in plant cover, since these areas were avoided by ungulates for their lack of escape routes (Ripple et al., 2004). The large increase in vegetation even stabilised the riverbanks and caused rivers to flow in a straighter path (Ripple et al., 2004). Therefore, large numbers of wolves to induce ecosystem changes are not necessarily needed, since not merely the killing of herbivores leads to reduced grazing.

However, these studies were mainly performed in low anthropogenic areas. Can such ecological effects also be witnessed in Dutch nature? It is obvious that these wolf initiated trophic cascades will be visible to a lesser extent with increased livestock predation. Livestock has little influence on natural grazing regimes and removing them will not affect herbivory pressures on natural areas. As previously mentioned, high abundance of wild ungulates strongly reduces risks of livestock attacks (Imbert et al., 2016). The situation in the Netherlands is from this point of view quite positive, since the number of deer have been growing all over the country every year since the 1930's (fig. 9) (Kenniscentrum Reeën)

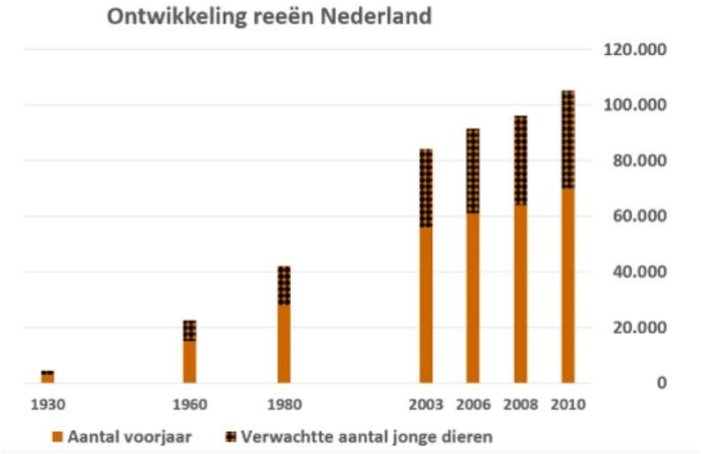

Figure 9: absolute numbers of ungulates in the Netherlands from 1930-2010. Orange in the amount of adults in spring and the dark dotted colour represents the expected calves that period.
Retrieved from: *De populatie reeën in Nederland is groter dan 70.000 dieren. (n.d.).*

In addition, red deer and wild boar populations are considered to be too large on the Veluwe by Stichting Wildbeheer Veluwe, a party that manages the wildlife in that area. For a fairly small wolf population, wild prey abundance might be considered sufficient, at least on the Veluwe. For the other wolf territories in the Netherlands, it is questionable if wild prey abundance is satisfactory. Combined with the mosaic landscape of agriculture and woodland, there is higher chance of excessive livestock predation and hence less ecological impact might be expected.
Direct human activity is also a factor which might impact the extent of ecosystem changes by large carnivores, including wolves. First of all, in highly anthropogenic landscapes, carnivore populations often cannot reach levels to be ecological functional (Kuijper et al., 2016). This is due to the fact that carnivore numbers and distribution are highly affected by human activity, more so than with ungulates, causing changes in predator-prey interactions (Kuijper et al., 2016). On top of that, wildlife management by humans such as shooting or additional feeding of prey populations disturb the natural processes and reduce potential carnivore effects (Kuijper et al., 2016). Thus, density mediated trophic cascades are harder to achieve in densely human populated areas. Since, behavioural-mediated ecosystem changes do not require high predator densities, this possibility is more likely to occur in anthropogenic landscapes (Kuijper et al., 2016).

Possible Side Effects of Wolf Arrival

Road safety

A high human population density means large networks of infrastructures, which are often part of the wolf's territory. Ever since the wolf returned to the Dutch landscape, 15 individuals have been killed in traffic accidents (Bij12.nl). No real studies have been performed on the subject of road safety regarding wolves. Yet, the impact on road safety is thought to be negligible, compared to the amount of deer that get hit in traffic (Jansman et al., 2021). The indirect effects of wolves on road safety are possibly a little stronger, although whether this turns out positive or negative for the number of traffic accidents is doubtful (Jansman et al., 2021). Indirect road safety effects of wolves are the effects caused by altering ungulate density and behaviour. With density-mediating effects, the amount of ungulates will be brought down, which might reduce road traffic accidents caused by deer and wild boar. However, the other option is that behavioural-mediated effects are more pronounced, which is more likely in anthropogenic areas. Wolves will mainly avoid human presence and infrastructure as much as possible. If prey species associate infrastructure with reduced wolf abundance, this could result in more activity of deer in surrounding infrastructure (Jansman et al., 2021). Still, due to lack of research, all of this controversial.

Ecotourism

Asking Dutch people about their opinion on the wolf will yield divergent results. For now, no real effects are found on visiting numbers in national parks such as the Veluwe since the return of the wolf (Jansman et al., 2021). In Yellowstone National Park (USA), effects are detectable. From 1979 until 2017, visiting numbers experienced a big growth, going from 1.9 to 4.1 million visitors per year, with most increase in the last 25 years (Anton et al., 2020). A large part of the new visitors were hoping to get glimpses of wolves in their natural habitat. Such an impact has not occurred yet in Dutch parks, but with a more positive image of wolves and less fear in society of the species it can be an economic

opportunity. A side note should be that increased tourism potentially leads to habituation, which is absolutely undesirable since it can affect wolf behaviour and increase conflicts.

Conclusions

Due to increased awareness of nature conservation and better conservation resulting therefrom, the wolf has expanded its range from fragmented areas in eastern and southern Europe back into the Netherlands after 150 years of absence. Our highly human dominated landscape has had some trouble with its arrival, resulting in many wolf-human conflicts and heated societal debates. This paper tries to understand the consequences of the comeback of the wolf in the Dutch landscape and society and provide solutions to improve the co-existence of wolves and humans in the Netherlands as much as possible.

Geographically and ecologically, the Netherlands does not seem ideal wolf habitat. The mosaic of fragmented nature mixed with farmland do not match the preferences of 50-80% forest coverage. Furthermore, the high human population density make the area very anthropogenic. Still, wolves are ultimately flexible in habitat choice and inhabit quite a few areas apart from the Veluwe, which geographically seems the best wolf habitat. Accordingly, many of the wolf regions in the Netherlands consist of fragmented landscape with a mixture of forest coverage and farmland.

Since the wolf's return, the number of reports of livestock attacks have been increasing each year. Livestock predation and related human conflict is the main cause for the controversy over the wolf's presence. It is thus of high necessity to avoid this scenario as much as possible in order to improve the harmony between wolf and society and increase support for wolf conservation.

Multiple studies argued that ungulate densities have big impacts on livestock predation rate. Wolves possess a natural preference for wild prey over livestock. As long as abundance of wild prey species is sufficient for the wolf population and easily available, livestock predation risk is significantly lower than in areas where there is a lack of ungulates. Furthermore, fragmented woodlands with relative high cover of agricultural lands increase chances for livestock predation. Social status, stable packs or roaming individuals also influence the livestock attack rate, where stable packs decrease the risk of livestock predation. Also, the presence of rapidly growing young wolves in all certainty will result in more domestic animals being killed, since these packs often need more prey than normal and livestock is considered an easy meal. Lastly, livestock vulnerability and density have consequences on livestock predation. Lower densities make predation easier for wolves as the herd has a harder time defending itself. The absence of adequate precautionary measures such as electric fences and guard dogs is probably one of the biggest factors.
German and Belgian wolf diet studies gave insight in composition of predated animals. The German case showed little livestock predation. This area was best compared to the Veluwe situation, whereas the Belgian case had 8 times more livestock predation. This Belgian region showed more similarities with wolf territory in Drenthe/Friesland and Noord Brabant. The data of livestock attacks per region in the Netherlands also confirm this trend. Disproportionate numbers of attacks on livestock were reported from Noord-Brabant and Drenthe/ Friesland than were to be expected from the number of wolves present compared to the Veluwe area. Here, the abundance of wolves was much higher and still the attack rate on livestock was remarkably lower.

Ecologically, the wolf has proven to be a potential ecosystem engineer. Case studies argued that the presence of apex predators such as wolves in the ecosystem have strong positive effects on ungulate densities. In large natural environments with low human influence, this happens both behavioural

mediated as density-mediated. The latter means a direct decrease of ungulate abundance by predation. This is possible if the wolfs population can exploit its full ecological potential. Behavioural-mediated effects occur by predator-fear of prey species. This alters their activity pattern and dispersal. In more anthropogenic regions, behavioural mediated effects have higher chances of initiating cascade reactions than density-mediated effects.
Both behavioural and density-mediated effects consequently release or shift grazing pressures and this benefits vegetation. More and different plant species have higher survival chances, which has snowball effects through multiple trophic layers of the system and causes increased biodiversity.

Since Dutch wolf habitat has quite some different contrasting characteristics, the wolf's effect on the Dutch landscape will not be universal in all areas. The Veluwe, which hosts the bulk of Dutch wolves, has the benefit of being a largely unfragmented woodlands area with relatively little human influences and agricultural cover. Consequently, positive influences on the ecosystem are expected to occur in this area. However, if it will be to this extent in, for example Yellowstone National Park, is doubtful. The high abundance of big ungulates also contributes to this expectation. Although shooting of excessive numbers of these species will also release grazing pressures, I expect it to have double negative influences: 1) It will increase unwanted human activity in the area and disturb ecological processes on wolves and prey, attenuating the wolves ecological effect. 2) It will decrease ungulate densities, which in turn can affect the livestock predation rate. If this increases, ecosystem effects will be weakened and, additionally, unwanted wolf-human conflicts will rise. Current shooting policies will thus need to be re-considered and, if needed, changes need to be applied to adjust ungulate abundancies for the perfect wolf habitat.

For the remaining wolf habitats, Drenthe/ Friesland and Noord-Brabant, I expect considerably less ecological effects. The main reason for this statement is the relatively high anthropogenic character of the landscape, especially compared to the Veluwe. First of all, grazing pressures in these area are not as big of a problem since big ungulates are lacking. Secondly, the human activity levels are much higher in Drenthe/ Friesland and Noord-Brabant and probably also amplify reduced ecological effects of wolves
Finally, this lack of ungulates and increased coverage of farmland may intensify livestock predation and hence diminish the ecological effects on the area. This excessive livestock depredation may be remedied by attempting to intensify ungulate densities, or perhaps even releasing big ungulate species in these areas. However, although it might reduce livestock depredation, I think the presence of these large ungulates may create increased damage to crops and increase traffic accidents in these anthropogenic areas.

In my opinion, the most important aspect in prosperous coexistence are precautionary measures. These reduce livestock predation and thus diminish negative influences and simultaneously might strengthen the positive impact of wolves on nature. This applies for all wolf habitat regions, but mainly anthropogenic areas as the Netherlands. The data regarding these measures in the Netherlands have shown to be far below the desired level in terms of requirements compared to for example Germany. A lot of improvements can be made in this aspect. Vulnerability turned out to be one of the main factors for increased livestock predation. Reasonable measures, which meet certain requirements to fend off wolves will likely have strong effects. I argue for the approach they use in Germany, where certain requirements are set for electrical fences. Compensation for livestock damage is only given if the precautionary measures are sufficient, this forces livestock owners to meet the requirements. Probably, the finances to realise this are much higher than current local budgets. Yet, if applied properly, the outcome has double benefits with decreased wolf-human conflict and increased ecosystem benefits. Additional wolf repellent measures such as guard dogs are in my opinion strongly recommended. Besides, there should be extra caution in the season with growing wolf pups in order to decrease livestock predation.

All in all, if European policies will not change regarding the protected status of the wolf, Dutch society will inevitably need to live with the wolf in its landscape, although it is not the best suited wolf habitat. Readjustments will need to be made regarding wildlife management. Ungulate densities need to be high enough to avoid too much livestock depredation. This means artificially reducing big ungulate populations will need to diminished or even stopped totally. Besides, enhanced livestock protection is desired. National, or maybe even European agreements on wolf fence requirements may help in reducing livestock predation. Germany's requirements are already based on professional advice, but more research for optimal fencing may be helpful so that wolf-human conflicts can be avoided. Furthermore, alternative options in fending off wolves need to be examined. This could be guard dogs, visually repellent objects or artificial human sounds in the proximity of livestock for example. The best options for reducing livestock predation need to be taken. Decreased livestock depredation would mean diminished human-wolf conflicts and in turn mean that the wolf's positive influence on ecosystems can be amplified to make the best out of the difficult societal situation.

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