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NINA Report

Wolf attacks on humans: an update for 2002–2020

John D. C. Linnell, Ekaterina Kovtun & Ive Rouart



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European wolf, in captivity © John Linnell

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Abstract

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The degree to which wolves pose a threat to human safety has been a central part of the public controversy surrounding wolf recovery in Europe for the last three decades. This report seeks to update our knowledge for the period 2002 to 2020. We searched the peer-reviewed literature, technical reports, online news media sources and contacted regional experts to gather as much information as possible. Our coverage for Europe and North America is likely to be high, but for the rest of Eurasia we have at best found a good sample of events, especially for the period after 2015. We identified relatively reliable cases involving 489 human victims. Of these 67 were victims of predatory attacks (9 fatal), 380 were victims of rabid attacks (14 fatal), and 42 were victims of provoked / defensive attacks (3 fatal). Attacks were found in Canada, USA, Croatia, Poland, Italy, Iran, Iraq, Israel, India, Kirgizstan, Turkey, Kazakhstan, Ukraine, Belarus, Moldova, Russia, Mongolia, Armenia, Azerbaijan, Tajikistan and Saudi Arabia. In addition, we found an almost equal number of cases that we could not include because of poor documentation as well as cases that we could clearly reject based on evidence, for example where the attack was actually caused by dogs.

The distribution of attacks by rabid wolves closely follows the distribution of rabies cases in humans and other wildlife species. As such this represents a very low risk for Europe due to the near eradication of rabies. The predatory attacks had move diverse etiology. Some clusters, such as those from western Iran, appeared to be linked to landscapes with low wild prey density, high density of humans living in poor socio-economic conditions, and where livestock were the main prey of wolves. A single case appeared to be due to an injured wolf in poor health. A range of other cases though were associated with situations where wolves had been demonstrating fearless behaviour and had been utilising anthropogenic food sources over time before the attacks. Such cases represent a close parallel to the risk factors that are known from other large canids like coyotes in North America and dingoes in Australia. Finally, a single and well-documented fatal attack from Alaska involved a group of healthy wolves in an area with no previous history of fearless wolves or feeding.

There is an urgent need to learn more about the behaviour of “bold” or “fearless” wolves and understand at what point a harmless degree of habituation to humans (which is necessary to live in human-dominated landscapes) can lead to potentially dangerous behaviour. There is also a need to develop clear management procedures to both prevent dangerous situations from developing (i.e. feeding) and to react to such situations when they appear. Finally, there is a need for increased communication and awareness raising in this area, both to the public and to medical, veterinary and wildlife management institutions. As our understanding of wolf attacks increases there appears to be a high degree of convergence with the much better understood risks associated with bears, which allows for a more consistent multi-species communication strategy.

While being aware of the potential risks associated with wolves it is also crucial to place this into context. In Europe and North America we only found evidence for 12 attacks (with 14 victims), of which 2 (both in North America) were fatal, across a period of 18 years. Considering that there are close to 60.000 wolves in North America and 15.000 in Europe, all sharing space with hundreds of millions of people it is apparent that the risks associated with a wolf attack are above zero, but far too low to calculate.

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Sammendrag

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I hvor stor grad ulver utgjør en risiko for mennesker har vært en sentral del av kontroversen rundt tilbakekomsten av ulv i Europa de siste tre tiårene. Denne rapporten forsøker å oppdatere kunnskapsnivået for dette temaet i perioden 2002-2020. Vi søkte etter ulveangrep på mennesker i vitenskapelig litteratur, nyhetssaker på nett og kontaktet regionale eksperter for å samle så mye informasjon som mulig. Dekningen vår for Europa og Nord-Amerika er trolig høy, men for resten av Eurasia har vi i det beste funnet et godt utvalg av tilfeller, særlig for perioden etter 2015. Vi identifiserte 489 offer fra saker som vi anså som relativt troverdige. Av disse var 67 offer for predatorangrep (ni døde), 380 var utsatt for rabiesangrep (14 døde) og 42 var offer for provoserte/forsvarsangrep (3 døde). Ulveangrep på mennesker ble funnet i Canada, USA, Kroatia, Polen, Italia, Iran, Irak, Israel, India, Kirgisistan, Tyrkia, Kasakhstan, Ukraina, Hviterusland, Moldova, Russland, Mongolia, Armenia, Aserbajdsjan, Tadsjikistan og Saudi-Arabia. I tillegg fant vi mange saker som vi ikke kunne inkludere på grunn av dårlig dokumentasjon eller saker som vi kunne avises basert på beviser, for eksempel når det var hunder som faktisk stod bak angrepet.

Fordelingen av angrep fra rabiesulver følger fordelingen av rabiestilfeller hos mennesker og dyr. Derfor representerer disse angrepene en veldig lav risiko i Europa siden rabies nærmest er utryddet her. Predatorangrepene hadde en mer variert etiologi. Noen angrep, slik som vest i Iran, ser ut til å være knyttet til områder med lav tetthet av ville byttedyr, høy tetthet av mennesker som lever under dårlige sosioøkonomiske forhold og hvor husdyr er de viktigste byttedyrene for ulv. Et enkelt tilfelle var antagelig fra en skadet ulv i dårlig kondisjon. En rekke andre tilfeller var knyttet til situasjoner der ulvene hadde vist fryktløs adferd ovenfor mennesker og hadde utnyttet menneskelig matkilder, for eksempel søppelfyllinger, over tid før angrepet skjedde. Disse tilfellene er en nær parallell til risikofaktorene som er kjent fra andre store hundedyr, som prærieulver i Nord-Amerika og dingoes i Australia. Vi fant ett enkelttilfelle av et dødelig ulveangrep som kom fra en frisk ulveflokk i Alaska, og som ikke hadde vist fryktløs adferd ovenfor mennesker tidligere. Dette tilfellet var godt dokumentert.

Det er et stort behov for å lære mer om adferden til «fryktløse» ulver («bold wolves») og forstå når en harmløs grad av tilvenning til mennesker (som er nødvendig for å leve i menneskedominerte landskap) kan føre til potensielt farlig adferd. Det er også et behov for å utvikle tydelige forvaltningsprosedyrer for å forhindre at farlige situasjoner utvikler seg (f. eks fôring) og for å reagere når de oppstår. Til slutt er det et behov for å øke kommunikasjonen og bevisstheten rundt dette temaet, både for offentligheten og for medisin-, veterinær- og naturforvaltningsinstitusjoner. I det vår forståelse om ulveangrep øker, ser det ut som at det kan være stor likhet med bjørneangrep. Bjørneangrepe er mye bedre forstått enn risikoen assosiert med ulv. Det kan derfor være mulig å oppnå en mer konsistent kommunikasjons- og tiltaksstrategi som er rettet mot flere rovdyrarter samtidig. I forbindelse med å være oppmerksom på risikoen assosiert med ulveangrep er det også viktig å sette dette i kontekst. I Europa og Nord-Amerika fant vi bare bevis for 12 ulveangrep (med 14 ofre) over en 18 års periode, hvor to (begge i Nord-Amerika) endte med dødelig utfall. Når vi tar hensyn til at det er rundt 60 000 ulver i Nord-Amerika og 17 000 i Europa, hvor alle deler landskapet med flere hundre millioner mennesker er det opplagt at sannsynligheten for et ulveangrep er over null, men altfor liten til å bli beregnet.

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Foreword

While the underlying premise of large carnivore management in Europe may well always be a subject of controversy and disagreement because of the diversity of values and interests that exist in our societies it is clearly an advantage if stakeholders can agree on the underlying scientific basis concerning the ecology and behaviour of the species. One of the topics that is often hotly debated concerns the potential risks that wolves pose for human safety. This review was funded by the World Wide Fund for Nature, the International Fund for Animal Welfare and NABU (Nature and Biodiversity Conservation Union) e.V. in order to improve the scientific understanding of the risks that wolves pose for human safety. It is intended to provide an update to a previous report that was released in 2002, and covers the period up to 2020.

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John Linnell
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1 Introduction

Since the low point in the mid-20th century Europe's wolf populations have dramatically expanded to reoccupy large parts of the continent (Boitani & Linnell 2015, Chapron et al. 2014). This includes returning to areas from which they were totally exterminated like Finland, Norway and Sweden in the north, Germany, Denmark, the Netherlands in the west, and across the entire Alpine arc of northern Italy, France, Switzerland, Austria and Slovenia in the centre of the continent. They have also expanded their ranges in other countries like Spain, Portugal, and peninsular Italy where they had been reduced to small fragments. There are currently (i.e. 2016) an estimated 17.000 wolves in Europe, not counting Russia, Ukraine and Belarus. Viewed from the lens of wildlife conservation this represents one of the great success stories of the last 50 years. However, the return of the wolf has not been welcomed by everybody. Their return has also been associated with the revival of a wide range of ancient conflicts and the appearance of others that are unique to our time. The tendency of wolves to depredate on livestock — like sheep, goats, cattle, horses, semi-domestic reindeer and domestic dogs is well documented elsewhere (Butler et al. 2014; Linnell & Cretois 2018). In addition to these very tangible impacts are a range of less tangible, but very important, social conflicts (Bisi et al. 2007, Moore 1994, Redpath et al. 2013, Skogen et al. 2017) that, if not adequately addressed, typically express themselves as a clash of attitudes, values, or knowledge between different stakeholders or sectors of the public.

One of the dominant discussions in the media, social media, and public debate concerns the potential danger that wolves represent for human safety. This translates into widespread expressions of unease, limitation of freedom, and outright fear. In the early decades of wolf conservation that started in the 1960's and 1970's there was a widespread belief among wolf conservationists, especially North Americans, that wolves were not potentially dangerous and had never attacked people. This overtly optimistic view did not agree with the historic or present day reality from other parts of the world, but barriers of language and discipline had hindered the development of a unified consensus on the issue. The end of the 20th century and the first years of the 21st century saw a surge of scholarship on this topic, with biologists, wildlife managers, historians, mythologists, veterinarians, doctors, and forensic examiners all contributing case reports, results from research projects, and insights that began to paint a much more complex and more representative global picture of the relationship between wolves and humans. In 2002, Linnell et al. (2002) produced a report on the state of knowledge concerning wolf attacks on humans that summarised as much of the available information as this team of 18 authors could gather from across the globe. McNay (2002a,b) independently summarised North American cases. The major results of these studies are summarised in Box 1.

In the subsequent 18 years the public discourse around the danger from wolves has ebbed and flowed, but has never gone away (Linnell & Alleau 2015). Europeans have acquired almost two decades more experience of sharing their continent with thousands of wolves. The global level of professional and scientific knowledge about the risks of sharing space with wolves and other large predatory species has developed considerably. It was therefore felt that it was timely for an update to see if the main conclusions from 2002 still stand today. This report provides that update.

Box 1: Summary of main findings from the 2002 reports.

At the time the Linnell et al. (2002) report was released there was a widespread claim among wolf advocates that wolves were not responsible for any attacks on people. This was in part based on a simplification of a statement in Mech (1970) which added many conditions to the statement, most important of which was that it concerned “healthy wolves”, “in North America” and “in the 20th century”. The 2002 report cast a far wider net across Europe and Asia and incorporated events from the 30 years after Mech’s classic work. This included both documented recent events and the results of historical scholarship. In parallel, an Alaskan researcher was compiling a review of wolf attacks on people from North America (McNay 2002a). Some of the information that was quoted from unpublished sources or technical reports in the Linnell et al. (2002) report has subsequently found its way into the peer reviewed literature (e.g. Linnell et al. 2003, Linnell & Alleau 2015, McNay 2002b, McNay & Mooney 2005) making them more accessible to a wider audience.

The result of these two reports portrayed a slightly different picture of the relationship between wolves and humans than the claim in Mech (1970). Historically, from Europe and Russia, there was overwhelming evidence of many cases of wolves attacking people. In addition, there was considerable contemporary data concerning wolves attacking, and killing people from Europe, Asia and North America. For example, in the period from 1950 to 2002 for Europe (excluding Russia) and North America (where data is more complete) we found reports of 37 victims of attacks by rabid wolves (of which 4 were fatal), and 31 predatory / defensive attacks (of which 4 were fatal). Data from Russia and Asia was too fragmentary to summarise easily, but we found reports of >1300 victims of attacks by rabid wolves and >300 victims of predatory attacks.

Based on an analysis of these cases Linnell et al. (2002) recognised three categories of attacks. Firstly, a very large proportion of attacks appeared to be due to wolves with rabies. Historical descriptions from historical Europe and medical / veterinary descriptions from present day Eurasia portrayed a very similar picture of dramatic nature of a rabid wolf attacking people and livestock. Secondly, a small number of cases were categorised as investigative / defensive, mainly consisting of cases where wolves bit people in self-defence or where apparently naïve wolves bit people as a way of “testing” their suitability as prey. Finally, there were many cases that could only be described as predatory, where humans, mainly children, were clearly killed by wolves. These accounts were spread across historical Europe, and contemporary south Asia, and to a large extent tended to fall into discrete clusters in space and time. Most of them tended to be associated with rather specific social-ecological conditions, including areas with almost no wild prey and poor, vulnerable, human communities. In addition to these categories of cases involving wild wolves, there are reports of attacks by captive wolves.

The publications of these two reports in 2002 (Linnell et al. 2002, McNay 2002a) created a change in our understanding of the potential dangers that wolves represent. Although the reports contained thousands of cases of attacks, it must be born in mind that they were distributed across almost 400 years of history and the entire range of wolves in North America, Asia and Europe. In fact, this new understanding simply brought wolves into the same frames that we use to consider the potential risks posed by all large predators, like polar, black, brown and sloth bears, lions, tigers, leopards and cougars, and sharks and crocodiles.

2 Methods

A very specific topic like wolf attacks on people is neither a conventional field of scientific investigation nor an area where national or international bodies routinely collate data. Therefore, any attempt to generate an overview of the topic requires a lot of detective work, gathering pieces of information from many different sources. Because of the political nature of the topic there is also a great deal of mis-reporting and deliberate fake news such that each report needs to be evaluated and subject to a credibility check.

We started our search for peer-reviewed literature in the scientific databases (Web of Science) using a range of relevant keywords, placing special attention to include a diversity of disciplinary sources including medicine, veterinary science, forensics, history, anthropology, wildlife management, conservation biology and ecology. This was complimented with searches of Google Scholar. We then used snowball sampling and explored the reference sections of papers and reports that we found. We then searched through Google and Google Scholar for technical reports and other “gray” technical literature. As well as searching for data on wolf attacks we also included coyotes and dingoes because of the comparative insights that are possible for these species. This search of the scientific and technical literature was mainly done using English search terms.

We then conducted a systematic search of online media reports and a review of wolf attack cases listed on the Wikipedia site (https://en.wikipedia.org/wiki/List_of_wolf_attacks) dedicated to maintaining a list of claimed wolf attacks. This search included multiple languages, facilitated by Google Translate. For Russian language cases we used a native Russian speaker. For each case found, efforts were made to verify the accuracy of the case by conducting targeted searches for further media coverage, supporting technical reports and / or by contacting the relevant authorities. This focused heavily on the countries that have Russian language media, including Belarus, Ukraine, Russia and Central Asian and Caucasus countries. Turkey and Iran were also carefully screened. These countries were focused on because of their geographic proximity to Europe, and the fact that there is a lot of European media focus on claimed events from the region. This survey produced 75 cases that we could accept as being “verified” wolf attacks. Of these 44 were attributed to rabid wolves, 15 were regarded as being predatory, 7 were classified as defensive / provoked, and 9 were not possible to clarify although the evidence strongly points to a wolf attack. An additional 16 cases were rejected because either nobody was injured in the attack or investigations revealed that the attack was not due to a wolf. For a final 51 cases it was not possible to determine if an attack had happened or not from the descriptions available. This media search was most intensive for the period 2015 to 2018 (limited due to resources). A full list of the media sources and underlying documentation is available from the first author on request.

Finally, we consulted with a wide contact network of experts from Europe, Asia and North America to follow up leads on specific incidences and check for any missed cases.

The resources available did not permit a complete coverage of all cases, all areas and of the entire period from 2002 to 2020. For Europe and North America we are confident that we have picked up almost all serious cases and most minor incidents, however, for the rest of Eurasia / Asia it is clear that we have only accessed a sample of what is reported, and it is clear that many cases do not ever make it into the online accessible media. However, we believe that we have sampled enough to build up a good picture of the overall situation. Rather than simply listing cases, this update mainly seeks to further our understanding of the underlying magnitude of the problem, the patterns, the various risk factors, and the potential need for management responses. Some key examples are given in the text and in tables, with more information available in appendices.

In addition, we conducted a targeted review of the scientific literature that focuses on the drivers of “bold” behaviour in mammalian carnivores because of its importance in a lot of the current media / public debates about wolves.

3 Results — New historical knowledge about wolf attacks

At the time of the 2002 report historians were just beginning to investigate archival sources in Europe and Russia to look for insights into historical wolf-human relationships. Some of these investigations revealed considerable numbers of reports of wolves, both rabid and non-rabid, attacking people (e.g. Cagnolaro et al. 1992, Comincini et al. 1996, de Beaufort 1988).

Since 2002, there has been a dramatic increase in this form of historical scholarship conducted by both professional and amateur historians. Furthermore, our literature search has found a small number of sources that were overlooked in the 2002 report. Combined, there is now a wealth of new historical evidence from countries as diverse as France (Alleau 2011, Moriceau 2007, 2014, Sobrado 2008), Italy, Portugal (Flower 1971, Petrucci-Fonseca 1990), Norway (Furuset 2005), Sweden (Linnell et al. 2003), Finland (Lappalainen 2005), Russia (including the present day Baltic States and Belarus; Graves 2007, Hindrikson et al. 2017, Rootsi 2003), the United Kingdom (Harting 1994), and even the Netherlands (Geraerds 1981). Some of this information has even been published in English, making it more accessible to a wider audience. Moriceau (2014) and Alleau & Linnell (2015) provide accessible discussions of the process by which historians process archival information to assess the reliability of sources. In general, the sources quoted above represent serious historical scholarship, and while it is always possible to question the veracity of each individual episode the sheer volume and richness of the record indicates that wolf attacks have repeatedly occurred throughout the last 400 years in Europe. The new evidence supports the existence of both rabid and predatory attacks throughout the period covered and reinforces the understanding of associated factors that were identified in Linnell et al. (2002).

4 Results — Overview of new cases of wolf attacks

4.1 North America

There have been two relatively well documented fatal predatory attacks in North America since 2002. In addition to these cases where people were killed, there have been multiple locations where people have been injured by wolves.

Points North Landing, Saskatchewan, Canada 2005. The first involved the death of an adult male (22 years old), Kenton Carnegie, on November 8th, 2005, near Points North Landing in northern Saskatchewan, Canada. Carnegie was working at a remote mining camp, went for a walk in the evening and didn't return. His partly consumed body was found later that evening. While there was no doubt that he was killed by a predator, there was some confusion about if it was due to a black bear, or wolves. Initial reports implicated a black bear (despite the absence of any bear tracks at the scene), but later review of the material favoured the interpretation of wolves as the culprits (McNay 2007) which was reinforced by the presence of multiple wolf tracks at the site. The coroner's verdict in 2007 concluded that death from wolf attack was the most likely cause of death. The mining camp had an open garbage dump that was frequented by wolves which showed no fear of humans, and there were multiple reports of close encounters with these wolves in the period leading up to the attack.

Media report two other incidents in similar settings; remote mining camps in northern Saskatchewan with open landfill garbage disposal sites. One case from December 31st, 2004, described an attack on an adult male, Fred Desjarlais, near Key Lake and the other from August 2016 describes an attack on an adult male, Andrew Morgan, near Camerco's Cigar Lake mining site. Both were attacked by wolves, in cases where there was no provocation. In both cases, other workers intervened to rescue the victims who survived.

Chignik Lake, Alaska 2010. The second high profile case involved the death of an adult female (32 years old), Candice Berner, on March 8th, 2010, near Chignik Lake in southwestern Alaska, USA (Butler et al. 2011). Berner was a teacher in the local community and went for a jog in the evening after work. Her body was found less than an hour later by local residents who observed blood stains in the snow along the road she was jogging along. The attack was carefully investigated using robust forensic approaches and eight wolves were killed in the surrounding area in subsequent weeks. The combination of the autopsy results, analysis of tracks in the snow around the kill site, and DNA matching between saliva on the body and one of the shot wolves allowed a clear conclusion that multiple wolves had been involved in the attack. They had apparently encountered her face to face as they were travelling in converging directions along the road. The attack was sudden and persistent. Wolves dragged the body after killing it, even returning to the body to drag it further followings its initial discovery. Although two of the wolves killed were emaciated, the other six were in good condition, including the adult female with the clearest DNA match. The wolves were not suffering from rabies. There had been no sightings of wolves showing unusual behaviour in the area prior to the attack, and there were no food attractants. Overall, this case represents one of the best documented cases of a predatory attack by wolves.

Lake Winnibigoshish, Minnesota, USA 2013. A 16-year-old boy was bitten by a wolf on 24th August 2013 at a campground near lake Winnibigoshish in north central Minnesota. The boy was lying on the ground outside preparing to sleep when a wolf bite him on the head. He managed to chase away the wolf and get help. The wound required staples, but was not life-threatening. A wolf was trapped at the campground two days later. DNA analysis confirmed it was the same individual. An autopsy revealed that the wolf did not have rabies, but that it had major deformity to its jaws and brain, probably caused by a traumatic injury which had healed. The injuries were likely to have greatly affected its ability to hunt wild prey. There had been reports of the same wolf scavenging food and entering tents at the campground in the days before the attack (Schwablander et al. 2016).

Port Edward, British Columbia, Canada 2020. On May 27th, 2020, a man in his 70's was attacked by a wolf at the entrance to his house after walking home from a party at a neighbour's house. The house was on a suburban street on the edge of the forest, and the man was under the influence of alcohol. The wolf, which apparently had been lying in bushes near the house, knocked him over and grabbed his leg, removing significant muscle mass. Neighbours responded to his screams and managed to chase the wolf off. However, the wolf remained nearby, circling the responders as they administered first aid, and even returned to the area after the victim had been taken away. The victim was flown to hospital and was checked out after approximately 3 weeks of treatment. The attack was clearly a predatory attack. In the subsequent days Conservation Officers investigated the circumstances and it became apparent that there had been many sightings and incidents involving severely habituated wolves in the Port Edward / Prince Rupert area in the preceding months. Several wolves had been frequenting the towns' landfill garbage disposal site (c. 4 km away) where staff had claimed that the wolves fed on food even during daytime and showed no fear of humans or of vehicles. Although the landfill site was fenced with bear-proof electric fencing, the wolves were able to crawl under the lower wires. Wolves had also been involved in attacks on dogs, both on and off the leash, and were also apparently attracted to a significant population of stray / feral domestic cats in the Port Edward neighbourhood. Workers on the nearby grain depot reported sightings of wolves walking across the railway bridge between the islands. In response, a total of six wolves were killed, 1 nearby, and 5 on the landfill site. A DNA match identified one of these as the one responsible for the attack. It was an adult male, large and in good condition, and tested negative for rabies. (Sources: media reports, interview with Inspector Cam Schley, BC Conservation Officer Service, and technical reports obtained from BC Government).

Ramparts Creek Campground, Banff National Park, Alberta, Canada. On August 9th, 2019, a wolf tried to force entry into a tent on a campground at night with a family sleeping inside. While the father of the family tried to scare the wolf away, it bit him multiple times on the hands and arms, dragging him from the tent. Neighbouring campers assisted and by kicking the wolf and throwing stones at it were able to get the family to safety, although the wolf remained nearby, following them as they retreated to a car. Later that day a wolf was shot 1 km nearby and DNA tests confirmed it was the wolf responsible for the attack. Reports described the wolf as being old and in poor condition. Because of the presence of grizzly and black bears in the area there were no food attractants in the tent (Sources: Media). Media also report that the national park authorities had issued "aggressive wolf warnings" in 2016 following a pack approaching a ski-slope worker who was on a snowmobile.

Anderson Island, British Columbia, Canada 2007. A 31-year-old male kayaker was attacked and bitten by a wolf while he was camping on a beach. According to reports, the man managed to stab the wolf until it gave up. The injured animal was later found and shot, and tested negative for rabies but was reported as being in poor body condition.

Pacific Rim National Park and Reserve and surroundings, Vancouver Island, Canada 1999-2003. A single attack by a wolf on a camper on Vargas Island in 2000 was listed in the 2002 reports. However, Windle (2003) provides a summary of events in the same area over a longer period. From 1999 to 2003 he summarises 51 close interactions between wolves and people and / or their dogs. The cases range from wolves entering tents, playing with or stealing campsite equipment, growling at people, approaching or following people, taking food handouts, approaching dogs, and even killing dogs. Several of the closest interactions were documented on Vargas Island in the months before the July 2000 attack, which remains the only episode where a person was hurt. Media searches reveal that the situation with habituated wolves displaying bold behaviour has continued, with dogs being attacked, even when on a lead (Bower et al. 2017, MacKinnon 2017). Research has been conducted to study how visitors react to the risk from wolves and the need for restrictions on their behaviour (Bower et al. 2017, Smith 2006).

Yellowstone National Park, USA. After many decades of absence wolves were reintroduced into Yellowstone National Park in 1995 and 1996. Wild Canadian wolves were used as the source, and animals were only exposed to minimal human contact before release. Since their release the population has rapidly expanded, and wolves have been surprisingly visible to tourists from the park's road network. With over 4 million visitors a year the wolves of Yellowstone must be among the wolf populations in the world with the highest exposure to humans. Most wolves display a high degree of tolerance to humans, especially those on the road, but most do not approach people, and will keep a distance if people approach. Since reintroduction a total of 55 wolves have displayed behaviours that park authorities refer to as "habituated" (Anon 2003), implying that they approach people or do not move away when approached. Of these, 17 only displayed the behaviour on a single occasion. 38 others were subject to hazing, or aversive conditioning, actions that ranged from loud noises to rubber bullets and cracker shells. In almost all cases this hazing changed the behaviour of wolves such that problems ended. For two wolves however the park had to intervene and shoot them. Both appeared to have become food habituated, associating humans with food, with one wolf ripping open some hikers' backpack to access food and another chasing a bicycle. Most of the wolves which needed hazing were yearlings, a life cycle stage when individuals are most prone to learning new habits. Despite the large wolf population and the huge numbers of visitors there have been no attacks on people (Smith et al. 2020).

Denali National Park and Preserve, Alaska, USA. Although located in Alaska, Denali receives over 600,000 visitor days per year, mainly during summer. Road access is generally very limited and mainly closed to private vehicles, such that most visitors spend time in the back-country. During the period 2000–2007 over 250 events were logged where wolves displayed behaviour that was viewed as being habituated or bold. In most cases this consisted of curious approaches or failure to run away, although there were cases of damage to camping equipment in 7 of the 8 years. None of these episodes involved injury to people, although people had to aggressively frighten the wolves away on multiple occasions. Most events were associated with a single pack that tended to den close to the park's only road and near two campsites. The park responded by hazing wolves and by closing campsites for several years, and by developing a plan of action (Anon 2007). No further events have been reported in recent years (Bridget Borg, pers. comm.).

4.2 Europe

Poland. In June 2018 three people were bitten by a wolf in the town of Wetlina in southeast Poland, an adult on June 12th and two children, aged 8 and 10 on June 26th. A wolf was shot after the second attacks. Genetics indicated it was a pure wolf, and it tested negative for rabies. A wolf had been seen frequenting the village and images posted on social media in the preceding days showed a wolf that was not afraid of people, tolerating their close approach.

In August 2018 a wolf was reported having bitten a person in the Notecka Forest in western Poland during a barbeque party. Apparently, the wolf had been visiting the village since March 2018 and was being fed frequently by villagers. Episodes of attacks on dogs were reported. The attack occurred at a site where the wolf was accustomed to being fed. A wolf was subsequently shot, which was found to be in good body condition and did not have rabies.

Croatia. On 22nd March 2009 a 67-year-old man was attacked by a wolf in his backyard in north-east Croatia. He suffered major damage to his hands, arms, leg and face. The victim received post-exposure treatment and reconstructive surgery and survived. The wolf was shot the same day while attacking a police officer, and laboratory analysis confirmed the presence of rabies (Lojkic et al. 2010).

North Macedonia. On 29th January 2016 a 58-year-old man encountered a wolf that had got into his sheep barn. When the man entered the barn, he tried to remove the wolf, apparently by grabbing its tail, which triggered an attack with the wolf biting his arms and face. With the help

of his wife he managed to kill the wolf with an axe. He was taken to hospital and recovered. It was apparently not rabid (Media and Dime Melovski, pers. comm.).

Kosovo. In July 2019 media in Kosovo reported a number of stories about wolf attacks in the Hani i Elezit region of southern Kosovo. According to the media one attack on a five-year-old child resulted in bite injuries that required hospital treatment. A second event a few weeks later in the same region was focused on two children who had to fight off the wolf, and apparently escaped unharmed. Media also reported that a wolf was observed in the region on several occasions and that livestock had been attacked. No verification was possible.

Italy. In June 2020 a bold wolf was repeatedly seen near the city of Otranto in the Apulia region of southern Italy over many days, and tourists were reported as having fed the wolf. Social media reported videos of people approaching it, and it assuming a playful behaviour. The wolf was reported to having attempted to bite a 6-year-old girl and wounded a jogger. A team from Majella National Park and the Forestry Corps were asked to intervene for removing the animal. It was caught on the second attempt. A collar mark in the fur around its neck provided evidence that it had been held in captivity, explaining its bold behaviour. Genetical analysis indicated that it was a wolf, but with some signs of introgression with dogs from at least 3 generations previously. It is now kept in captivity in a rescue centre (Source: press release from the Italian National Institute for Environmental Protection and Research).

4.3 Russia, Ukraine, Belarus and Moldova

Our media survey revealed 16 cases of attacks (38 victims) by rabid wolves from this region in the period 2015–2018 (**Table A1**). These reports were particularly well documented, with detailed media accounts and official documents / press releases produced by health and agricultural authorities imposing rabies quarantine rulings on the districts. Rabies is common in Russia, including in wolves (Sidorov et al. 2010). Most wolves were also formally tested for rabies. In addition, Shkvyria et al. (2018) report an additional 14 attacks by wolves on 48 people during the period 2002–2015 in Ukraine. Rabies was confirmed in 8 of these cases and suspect in the others. All victims survived. In 2009, Russian media carried a story about a fatal predatory attack on a child who was playing in the forest. While the media reports appear consistent and credible, we were not able to verify the event with external sources as it fell outside the period of our most intensive follow-up.

4.4 Caucasus and Middle East

Hamedan province, western Iran. In a set of papers Behdarvand (Behdarvand et al. 2014, Behdarvand & Kaboli 2015) describes a series of 53 wolf attacks on people in the period 2001 to 2012. The data is based on face-to-face interviews with survivors or witnesses of attacks that led to compensation claims in official reports. Most attacks (n=33) were directed at children. A total of 5 attacks resulted in the death of victims, all were children aged from 3 to 6 years old. The authors characterised 68% of the attacks as predatory, with the rest being described as pet-related, investigative and defensive. Although rabies is widespread in the west of Iran, including among wolves (Gholami et al. 2014, 2017), it was excluded from this dataset of attacks. The landscape is very agricultural, with only small areas of natural vegetation, and a high human density (88 per km²). Wild ungulate prey are essentially absent from the landscape. Subsequent studies (Mohammadi et al. 2019) have shown that wolves in the landscape subsist on a diet of anthropogenic food. Livestock being the most important (both scavenged and depredated), but also with frequent consumption of garbage and poultry from farm dump-sites. Overall, these feeding habits will constantly bring wolves into the immediate vicinity of people in the rural landscape. Further episodes of attacks on children (5 non-fatal, 1 fatal) were reported from the same province in the media in 2015 and 2016 (see **Table A1**).

Zanjan and Kermanshah provinces, western Iran. Media reports provide detailed accounts of 14 people injured in attacks in the neighbouring province of Zanjan during the period April 2016 to January 2018. Two episodes involved rabid wolves in which 3 and 7 people were injured, respectively. Two attacks on children appeared to have been predatory in nature, while two attacks on adult men have so few details that it is impossible to determine the circumstances (**Table A1**). There are also details of a fatal predatory attack on a 3-year-old boy in the neighbouring Kermanshah province in 2017.

Rabies in Iran and Iraq. Our survey of media reports revealed a series of attacks by wolves with rabies that led to 52 people being injured in Iran and 4 in Iraq in the period from 2015 to 2018. This high frequency indicates that such attacks are widespread.

Turkey and southern Caucasus. Wolves are widespread in Turkey (Ambarli et al. 2016). Recent scientific articles have provided an overview of attacks by wolves in Turkey. Ambarli (2019) surveyed Turkish online media and evaluated cases for veracity in the period 2004 to 2016 for all cases of human-wolf conflict. Within this dataset were 58 episodes where 107 people were injured and 12 killed by wolves. 88% of the injuries and 75% of the deaths were associated with rabid wolves. None of the non-rabies attacks were viewed as predatory, being attributed to defensive or provoked categories. The medical literature verifies several of the cases (Kuvat et al. 2011, Turkmen et al. 2012), including a case where a patient died of rabies despite receiving post-exposure prophylaxis. Our survey of more recent media also revealed multiple reports from Turkey, two of which could be verified as being due to rabid wolves (**Table A1**).

Media also revealed multiple cases of attacks by rabid wolves in Armenia and Azerbaijan in the period 2015–2018. Six of these could be verified (**Table A1**). Although 20 of the victims survived, two children from a case in Azerbaijan died of rabies despite having been given post-exposure treatment.

Saudi Arabia. Our media survey picked up 7 cases that reported a wolf attack on humans. One of these was reported in sufficient detail that we could accept it as being a “verified” case, involving a shepherd who was injured while defending his sheep flock against an attacking wolf. The other six cases involved reports of wolves attacking people close to farmhouses, but were not reported in sufficient detail to permit an evaluation of their veracity, or of the circumstances (rabies or predatory).

Judean Desert, Israel. Between May and September 2017 there are reports of 10 children being attacked by wolves in two popular tourist locations in Israel’s Judean Desert. The locations are Masada National Park and the Ein Gedi Reserve, only 20 km apart. Information is fragmented with details only available from media, but the events have been verified by two biologists who interviewed some of the victims’ families (Haim Berger and Amos Bouskila, pers. comm.). In all cases the families describe a wolf calmly approaching them at campsites, in car parks or other outdoor areas and trying to grab a child (ages from 1.5 to 6-years-old). Although the children were bitten and scratched in these attacks none of them suffered serious harm because adults were able to rapidly intervene and rescue the children. Some attacks were preceded by observations of a totally fearless wolf approaching them, or entering their tent. There were also rumours of tourists feeding wolves. Although authorities were slow to act, they initially responded with hazing (paint balls) but finally removed at least one wolf after which the attacks appear to have stopped. An older media account describes a similar case from Masada in 2008 when a 3-year-old girl was grabbed next to her parents, but was rescued. Media also report 2 cases of rabid wolves biting people in the Golan Heights region. Other media accounts report different cases resulting 6 people being bitten by rabid wolves in the Golan Heights region of northern Israel.

4.5 South Asia

Wolf attacks in India. India has often been in the centre of cases about wolf attacks on people, although solid data on verified cases remains hard to find. Predatory attacks in India were well documented in the 1980's and 1990's (Jhala & Sharma 1997, Rajpurohit 1999, Yadav 2000). Since then we have not been able to find concrete evidence of similar episodes although media reports from December 2018 and January 2019 describe a series of 4 predatory attacks (two of which were fatal) by wolves on children over the course of two months in a limited area in the Sambhal district of Uttar Pradesh state. Khan (2017) presents a medical case study of the treatment of a 12-year-old boy from the Indian Himalayas who suffered massive facial injuries resulting from an animal attack that was attributed to a non-rabid wolf.

A survey was conducted of Forest Department records for the 2 years 2006–07 and 2007–08 concerning people injured or killed by wildlife (see annex reports in Thomassen et al. 2011). Responses were received from 622 divisions (of 804 contacted) from 25 (of 28) Indian states. The survey received reports of 608 deaths and 5832 injuries caused by wildlife where the species responsible was identified. Wolves were identified as being responsible for 12 deaths (1 in Uttar Pradesh, 7 in Madhya Pradesh, 3 in Maharashtra, 1 in Jharkhand) and 167 injuries. In contrast elephants killed 286 people, leopards killed 109, sloth bears killed 65 and tigers 41. Interestingly Nabi et al. (2009) used similar sources to survey human attacks by wildlife in the state of Jammu and Kashmir for a partly overlapping period (2005–2007). They found additional records of 2 people killed and 5 injured by wolves (leopards killed 16 people and black bears killed 2).

Unfortunately, neither of these surveys could identify what proportion of cases were due to rabid wolves. Attacks by rabid wolves are commonly reported by the media in India, although scientific documentation remains rare, see Isloor et al. (2014) for an exception describing an attack where 3 people were bitten in a single attack in the state of Karnataka. Belsare & Vanak (2011) describe 5 attacks that led to 24 people being bitten by rabid wolves (of which 4 died) in the districts of Ahmednager and Solapur in Maharashtra state in the period 2005–2009. Indian media provide a detailed description of two episode in September 2010 in Chittoor district in Andhra Pradesh where rabid wolves bit 40 and 25 people respectively. To provide context, cats and dogs are responsible for 98% of India's approximate 20,000 annual cases of human rabies (Mani et al. 2016, Sudarshan et al. 2007).

4.6 Central Asia

Our media survey identified multiple cases of attacks by rabid wolves across central Asia, including 1 attack each in Mongolia and Kazakhstan and four in Kyrgyzstan, with a total of 12 victims. One of the Kazakh cases was lethal where an adult male died of rabies despite having post-exposure treatment. Media also report predatory attacks in Kyrgyzstan and Tajikistan. The Kyrgyz case involved an 11-year-old boy attacked outside his house. He survived because his father came to the rescue and shot the wolf, which tested negative for rabies. The Tadjik case involved a child between 2 and 3-years-old who was grabbed in a field while playing with his older sister. He was carried several hundred meters. By the time rescuers found him he was already dead.

4.7 Captive wolves, fake news, misrepresentation and mistaken identities

The media landscape concerning wolf attacks is highly charged and contains multiple reports that can potentially misrepresent the dangers posed by wolves. For example, there is a Wikipedia page on wolf attacks that uncritically lists all manner of reports, including those that are verifiable with those that are not, and many that can be easily rejected. Multiple media cases report cases

where people reported a wolf attack even though nobody was injured and where the wolf did not have contact with the victim. In such cases it is often impossible to know what would have happened if the people had not managed to escape, or defend themselves. Because it is very hard to standardise what people perceive as an attack or verify such events including these cases as attacks risks misrepresenting the situation. However, it is important to keep track of such events as they may represent early-warning signs of a problematic situation where action is needed, for example as in the case of wolves in Yellowstone, Denali or the Pacific Rim National Parks in North America, or with dingos on Fraser Island in Australia.

Media cases also report cases of the bodies of people that have died outdoors and then been scavenged by predators, including wolves. In such cases it is impossible to know what the original cause of death was – i.e. natural causes or predator attack, or which predator was responsible. Again, there is a grave risk of misrepresentation if these cases are uncritically listed as attacks.

Finally, there are multiple cases where other species were to blame, including domestic dogs or other predators like foxes or jackals.

Combined, the uncritical confounding of cases with different causes and different degrees of documentation contribute to public confusion and controversy over the issue. The causes of this uncritical misrepresentation are not always evident, but at least in Europe and North America it is evident that certain individuals and groups go to great lengths to actively inflate the dangers posed by wolves (Linnell & Alleano 2015).

Kolmården Zoo, Sweden 2012. On June 17th, 2012, a 30-year-old female zoo keeper was killed inside an enclosure where 8 male wolves were kept. The wolves had been socialised to humans (bottle-fed as pups) so that tourists could be taken into the enclosure together with a zoo keeper for a close encounter experience. On the morning of her death the zoo keeper had entered the enclosure alone (information collected from Swedish media).

Rodope prefecture, Greece. On 21st September 2017, a 63-year-old British tourist called her family in the United Kingdom to report that she was being attacked by stray dogs. When the telephone connection was broken the family reported her missing which triggered a search. The remains of her body were found 36 hours later, very heavily consumed, with much of the skeleton disarticulated. The initial assumption in the media and by local people interviewed all supported the belief that dogs were responsible. This was because of the location of the attack, next to a livestock camp where there were a large number of free ranging livestock guarding dogs which were reported as being aggressive. However, the coroner quickly came to a conclusion that the victim was killed by wolves or jackals because of the degree of consumption and the breaking of bones which was viewed as being impossible for dogs. This decision did not in any way account for the possibility that wolves could have fed on the victim even if dogs had killed it. There is an ongoing legal proceedings to challenge this conclusion. Evidence against it is based on her last phone call that claimed she was being attacked by dogs, the presence of a large number of free-ranging dogs (11 recorded in camera traps a few weeks later), the time of the attack (17:00 — before wolves become active), and the low number of wolves in the area (2 recorded on camera traps). Overall, the evidence strongly supports the idea of dogs being to blame for her death, although wolves and jackals may have also helped consume the remains (Yorgos Iliopoulos and Christos Astaras, unpublished field report on the case, 2018).

Other cases from Greece. There are some more reports of wolf attacks that appeared in national media. Apart from the victims' claims there was no further investigation from authorities to verify / confirm those claims (i.e. genetic analysis) as far as we know, making it impossible to judge their veracity. Rabies is not endemic to Greece anymore so this can be excluded as a cause (the outbreak in 2012–2013 was successfully treated with aerial vaccination of foxes from authorities, no rabid animals were found after 2014 and the main vector in the wild was red foxes

with no known wolf cases). Greece is known to have problems with free-ranging dogs that can occur in packs. Some examples of these cases are listed below.

On August 1st, 2017, in Kastoria, northern Greece, an old woman claimed that she was attacked and injured by a wolf when she visited a small sheep pen to feed her animals. The wolf was already there when she arrived trying to kill one of the sheep. She was injured (bitten) and went to the hospital for emergency treatment.

Parnassos mountain, central Greece. On November 14th, 2017, a shepherd claimed that while his flock was attacked by a large pack of wolves he was attacked by wolves. He claimed that while he was trying to scare away the pack, one of the wolves bite him on the hands. He made a picture of his wounds and posted it in the internet. There were some very minor scratches resembling nail marks rather than bite marks. He also claimed that the pack had a size of 20 animals (there are no other evidence for such large packs either in Greece or the rest of Europe).

Ieromnimi, Ioannina, western Greece. On April 4th, 2018, four Immigrants (3 Syrian and one Iraqi) called authorities (emergency call) for help and claimed that they were attacked by a pack of wolves. One of them was injured in the foot and was transferred to the hospital for first aid treatment.

Kavala, northern Greece. On July 21st, 2018, a farmer claimed that he was attacked by a wolf in an unprovoked way (from behind) and was slightly injured in his leg. He managed to scare the animal away with his son and he went to the hospital for first aid medical treatment. Later on his son claimed that he saw a fearless wolf following him at a short distance in the same area.

Bulgaria. Bulgarian media have carried a few stories claiming wolf interactions with people. Unfortunately, they have never been verified. In November 2018 an old lady who was herding her livestock claims to have been bitten by a wolf in Bukovo, southeastern Bulgaria. Media reported that she was treated in hospital for bites on her arms, but no forensic evidence was available to confirm that they were caused by a wolf. Wolves do occur in the area, and attacks on livestock have been reported. Other reports only describe the close approach by animals believed to be wolves.

Italy. In June 2015, a man claimed to have been attacked by wolves while picking mushrooms in the northern Apennines. DNA analysis of saliva from his clothing and bites later indicated that it was due to a dog, which the man then confessed to being true (Caniglia et al. 2016). This example illustrates the importance of critically investigating wolf attack claims.

Estonia. In July 2019, Estonian media carried a story about a wolf attack on an adult lady on the island of Hiiumaa. Follow-up field investigations and interviews by the Estonian wildlife management authorities found no evidence of a wolf attack.

Iran. In January 2016, an Iranian news portal, Farda News, ran a story about a non-fatal wolf attack and showed photographs of the victim's injuries. The photographs actually came from Canada and show the victim of polar bear attack from the 1990's. Incidentally, the same images have previously been falsely claimed to represent a brown bear attack in Slovenia during the 1990's.

Russia. In September 2011, Russian media ran a story about a mushroom picker who claimed to have had two fingers bitten off by a wolf, although it turned out to be due to a mining accident. In April 2016, another story from Russia reported a man injured by a wolf, but from the images in the media it appears that this was a husky type dog.

5 Results — New overviews of knowledge on other species

The phenomena of wildlife that attack people have attracted considerable interest in recent years. This has mainly come from the wildlife conservation discipline, with some limited engagement from medical and public health disciplines. There have been a number of cross species reviews of attacks (Kelly et al. 2019, Löe & Røskaft 2004, Penteriani et al. 2017a,b, Quammen 2003, Quigley & Herrero 2005, Torres et al. 2018) as well as reviews that focus on more specific taxonomic groups, like snakebites (Chippaux 2012, Chippaux et al. 2013, Kasturiratne et al. 2008, Mohapatra et al. 2011), bear attacks (Bargali et al. 2005, Bombieri et al. 2019, Clark et al. 2012, Herrero et al. 2011, Gustafsson & Eriksson 2015, Miller et al. 2016, Støen et al. 2018), large cat species (Athreya et al. 2011, Barlow et al. 2013, Dhanwatey et al. 2013, Garrote et al. 2017, Gurung et al. 2008, Mattson et al. 2011, Neto et al. 2011, Packer et al. 2005, 2019), crocodilians (Pooley 2015), sharks (Clua & Linnell 2019) or on specific settings such as urban environments (Bombieri et al. 2018).

This literature has firmly put the topic on the conservation agenda within the field of human-wildlife conflicts. For species groups like bears and cougars these analyses have begun to identify patterns within the data that shed light on the circumstances and mechanisms behind the attacks which can inform wildlife management and inform guidelines on how to respond (e.g. Brown & Conover 2008, Mattson et al. 2011). Our understanding of the mechanisms behind attacks by large canids (coyotes, wolves, and dingoes) lags behind these other species, although there have been many recent advances. We summarise the emerging insights from canids below.

5.1 Dingo attacks

Fraser Island, Queensland, Australia. Fraser Island is a 1670 km² island off the coast of eastern Australia. It is heavily visited (350.000 visitors per year) and home to 100–200 of the most genetically pure dingoes in Australia. The dingoes are very visible to visitors and can generally be described as being extremely habituated in areas where the interactions are frequent (along the beach and at campgrounds). The island has long been subject to controversy because of repeated attacks on people. These peaked in 2001 when a 9-year-old boy was killed by dingoes (see Linnell et al. 2002). Attacks have continued. Appleby et al. (2017) summarised 160 category E interactions (where dingoes make contact with people) for the period 2001 to 2015. These interactions included many incidents where dingoes bit people. Although 83% of cases resulted in only minor injury, 10% required medical treatment and 6% required hospitalisation. The most recent cases are from 2019, where one baby was snatched from a camper, but was rescued by its father. Responses have varied. The fatal episode in 2001 resulted in a heavy cull of over 30 dingoes in the immediate aftermath, and a continued use of culling with a total of 110 being killed in the period 2001–2013. Although still practiced, selective culling of specific dingoes remains controversial (O'Neill et al. 2017). Hazing has been tested, but generally is not believed to be effective. Otherwise, the main effort is used on education concerning tourist behaviour, patrolling and enforcement of behavioural regulations, and fencing of campsites (Tapply 2018).

There is a growing trend for dingoes to colonise suburban environments, in a parallel to that seen by urban foxes or urban coyotes for example. This opens up a whole new interface for human-dingo interactions and potential conflicts (Allen et al. 2013). Although it is hard to find details, there are media and other reports (Anon 2004) concerning dingo attacks on people (as well as on pets) in these settings. There are also reports of non-lethal attacks on workers at outback mining camps, associated with feeding (Hughes & Carlsen 2008).

5.2 Coyote attacks

Coyotes have a massive interface with people in North America, occurring in all ecosystems, including increasingly in urban and sub-urban settings (Gehrt et al. 2011). It is well documented that coyotes are responsible for attacks on people in North America, although the vast majority of such attacks are minor, consisting of simple nips or bites. There have been multiple overviews of the topic in recent years focusing on different regions (Poessel et al. 2013 for Denver, Colorado, Lukasik & Alexander 2011 for Calgary, Alberta, White & Gehrt 2009 for North America, Alexander & Quinn 2011, 2012 for Canada). The most recent overview (Baker & Timm 2017) has summarized the available knowledge on the topic from 1970 to 2015. They compiled multiple sources, including those from other publications, media accounts and records kept by various state, provincial or protected area management authorities. In total they found evidence for 367 attacks by non-rabid coyotes, where an attack is defined as physical contact being made between a coyote and a human and where the coyote initiated the contact. These attacks led to 327 injured people. Only two attacks were fatal: a 3-year-old girl in California, USA, in 1981 and a 19-year-old woman in Nova Scotia, Canada in 2009 (see below). 60% of attacks were on adults.

Most attacks appear to be associated with urban green-space or sub-urban residential settings or with protected areas (Poessel et al. 2013, Carbyn 1989, Lukasik & Alexander 2011). Many of the attacks seem to have been predatory or investigative in nature (White & Gehrt 2009), especially those directed at children. A common element in all these cases seems to be situations with coyotes that are strongly habituated to the presence of people. This is typical in urban, sub-urban and protected area settings where coyotes are constantly exposed to humans with only neutral or positive associations. The presence of food associations with humans makes matters worse. Baker & Timm (2017) have developed a scale of behaviours that are intended to reflect a gradient of habituation, and recommend intervention in the form of lethal removal of specific coyotes when coyotes begin to openly attack pets or approach people in day time. Otherwise, the focus is on preventing food habituation, limiting access to anthropogenic food-sources, stopping people from feeding coyotes and other non-lethal interventions such as hazing.

However, it is important to bear in mind that coyotes are very widespread in North America and are found in most protected areas and many cities (Gehrt et al. 2010, 2011). This implies that vast majority of coyotes that regularly encounter people are never involved in attacks.

Cape Breton Highlands National Park, Nova Scotia, Canada. On October 28th, 2009, a 19-year-old woman, Taylor Mitchell, was attacked by coyotes while hiking alone on a popular trail in Cape Breton Highlands national park. Other hikers heard her scream. When they followed the sounds, they found her being attacked by two coyotes. It required the efforts of four people to get the coyotes to stop the attack, although they remained nearby. Finally, a shotgun shot by a police officer caused the coyotes to leave the area. Although she was alive when found, she later died in hospital. It was apparent that she had been fighting off the coyotes while trying to retreat to a toilet building. Six coyotes were shot or trapped in the vicinity in the subsequent days, and forensic evidence linked several of them to the attack. None appeared to be in bad condition, or infected with rabies (Porter 2013, Power 2015, Sponarski et al. 2015a,b,c). The park has had multiple cases of apparently habituated or fearless coyotes being observed in the period 2003–2016, with 16 reports of aggressive behavior and at least one other case of a bite (Porter 2013). Two coyotes had been seen walking past hikers on the same trail minutes before the attack. One issue to bear in mind is that coyotes in the maritime provinces of eastern Canada contain a high degree of genetic introgression from wolves (either *Canis lupus* or *Canis lycaon*) and tend to be larger than normal western coyotes (Way & Lynn 2016).

5.3 Red foxes

Red foxes have moved into urban settings in recent decades in many European cities. Although their ecology is widely studied there has been little systematic study of any conflicts resulting from this colonization. Bridge & Harris (2020) provide a preliminary media-based survey of events and documents multiple episodes of where urban foxes are involved in biting people, mainly children. The small size of foxes implies that injuries are minor, and in western Europe rabies is absent, so the conflict is not that serious. However, there is clearly an opportunity to learn parallel lessons from this species that may be relevant for dealing with habituation issues in other, larger, canids (Parsons et al. 2020).

6 Discussion

Our survey of available sources unearthed multiple cases of wolf attacks on people in the period from 2002 until 2020. Of these cases that involved 489 victims (with the highest degree of veracity and enough information to categorise them; **Table 1**), we categorised 67 as predatory attacks, 380 as rabid attacks, and 42 as provoked / defensive attacks. The cases fitted into the broad categories that were identified in 2002 (Linnell et al. 2002). Firstly, we identified a small number of cases where wolves bit people in response to direct provocation, typically when shepherds tried to kill a wolf without firearms, or tried to manually separate a wolf from their flocks. Secondly, we uncovered many cases of attacks by wolves with rabies across Eurasia. Finally, we also found evidence of a small number of predatory attacks, a few of which were fatal. Considering that the global wolf population numbers in the 100's of thousands (<https://www.iucnredlist.org/species/3746/163508960>) and their overlap with 100's of millions of rural people our finding of less than 10 lethal cases of predatory attacks across almost 20 years illustrates how small the risks are. In the next sections we shall explore these categories in detail and outline some implications for wildlife management, human safety and wildlife conservation policies.

Table 1. Overview of wolf attacks on people (expressed as number of victims) found from the period 2002–2020, with special focus on 2015–2018. Data comes from multiple sources and includes only those cases for which we judged the veracity to be high, and where we had enough information to attribute the attack to a category. Coverage for Europe and North America is good for the whole period 2002-2020, but for other countries the numbers are only minimums.

Attack type	Outcome	Number	Distribution
Predatory	Fatal	9	Canada 1, USA 1, Iran 6, Tajikistan 1
	Non-fatal	58	Canada 3, USA 1, Poland 4, Italy 1, Kosovo 1, Iran 36, Israel 10, India 1, Kyrgyzstan 1
Rabies	Fatal	14	Turkey 9, India 4, Kazakhstan 1
	Non-fatal	366	Croatia 1, Ukraine 57, Belarus 9, Moldova 2, Russia 20, Turkey 94, India 88, Mongolia 2, Iran 52, Iraq 4, Armenia 5, Azerbaijan 16, Kazakhstan 1, Kyrgyzstan 9, Israel 6
Defensive / provoked	Fatal	3	Turkey 3
	Non-fatal	39	North Macedonia 1, Iran 17, Turkey 11, Kyrgyzstan 3, Kazakhstan 2, Ukraine 1, Russia 3, Saudi Arabia 1

6.1 Attacks by rabid wolves — summary of new knowledge

Our new survey indicates that attacks by rabid wolves continue to be a regular occurrence in Eurasia, southern Asia and the Middle East. From the technical literature we found new evidence of attacks in countries as diverse as Belarus (Mishaeva et al. 2007), China (Wang et al. 2014), India (Isloor et al. 2014), Iran (Gholami et al. 2014, 2017, Simani et al. 2012), Mongolia (Odontsetseg et al. 2009), Turkey (Ambarli 2019, Ambarli et al. 2016, Kuvat et al. 2011, Tug 2005, Turkmen et al. 2012), and Ukraine (Shkvyria et al. 2018). In addition, there was one record of an attack within the present day boundaries of the European Union, in Croatia (Lojkic et al.

2010. Our survey of recent media cases found robust evidence of attacks by rabid wolves in Armenia, Azerbaijan, Belarus, Iran, Iraq, Kazakhstan, Kyrgyzstan, Moldova, Mongolia, Russia, Israel, Turkey, and Ukraine (see **Table A1**).

In contrast to historical times when a bite from a rabid wolf was almost inevitably fatal, rapid post exposure treatment presently means that most victims now survive. However, some people are killed outright by trauma in the attacks, and some may die of rabies when treatment is withheld, arrives too late, was not provided correctly, or if the bite was in the head or neck region so that the disease develops before the post-exposure treatment has time to take effect (Ambarli 2019, Ambarli et al. 2016, Mishaeva et al. 2007, Simani et al. 2012, Turkmen et al. 2012).

Table 2. Overview of estimated number of annual human deaths from canine (domestic dogs) rabies (both from Hampson et al. 2015), numbers of wolves diagnosed with rabies for European countries in period 2002–2020 (www.who-rabies-bulletin.org), and reports of attacks by rabid wolves on humans for the same period (this report).

Country	Estimated annual number of human deaths from canine rabies	Attacks by rabid wolves on humans	Number of wolf rabies cases
India	20.847	Yes — multiple	na
China	6.002	Yes	na
Iran	37	Yes — multiple	na
Russia	33	Yes — multiple	168
Turkey	24	Yes — multiple	59
Iraq	24	Yes	na
Tadjikistan	16	No	na
Kazakhstan	14	Yes — multiple	na
Kyrgyzstan	7	Yes — multiple	na
Georgia	5	No	6
Azerbaijan	5	Yes — multiple	na
Ukraine	2	Yes — multiple	169
Belarus	1	Yes — multiple	85
Romania	1	No	25
Armenia	0	Yes	na
Mongolia	1	Yes	na
Moldova	1	Yes	na
Israel	0	Yes	na
Bosnia & Herzegovina	0	No	6
North Macedonia	0	No	4
Poland	0	No	4
Lithuania	0	No	4
Latvia	0	No	3
Croatia	0	Yes	3
Montenegro	0	No	3
Bulgaria	0	No	2
Albania	0	No	1
Serbia	0	No	0
Switzerland	0	No	0
Norway	0	No	0
Rest of mainland EU*	0	No	0

*Slovenia, Austria, Hungary, Germany, Denmark, Sweden, Finland, Italy, Spain, Portugal, France, Czech Republic, Slovakia, Belgium, Netherlands, Luxemburg, Estonia, Greece.

The distribution of attacks by rabid wolves closely matches that of the distribution of cases of wolf rabies and canine transmitted cases of human deaths (**Table 2**). Turkey, Russia, Ukraine and Belarus are the sources of 89% of confirmed cases of wolf rabies in the wider “European” zone as monitored by WHO for the period 2002–2019. They also represent the countries where we found most evidence of attacks on people. Rabies controls in Europe continues to push back the disease to the eastern edges of the continent (Hampson et al. 2015, Müller et al. 2015). The implication is that while attacks by rabid wolves will continue to be an issue across eastern Eurasia and the Middle East, the risks in Europe will decrease to almost zero, with the possible exception of border zones to countries where rabies persists. Unfortunately, there is no easily accessible comparable data on wolf rabies for countries in the Middle East, the Caucasus or Central Asia because of poor surveillance. However, rabies is known to be widespread throughout these regions, as indicated by the cases of human rabies (Hampson et al. 2015). The extent to which rabies cases leads to death is directly linked to the availability of healthcare in the country, which explains why India has such a massive proportion of the global rabies deaths, in contrast to countries like Iran for example that have a well-established rabies response within their healthcare system.

It is important to put these results into context and bear in mind that probably 99% of human rabies cases are transmitted from domestic animals, especially cats and dogs (Hampson et al. 2015). Even among wildlife it is the smaller and more common species like foxes and jackals that are responsible for the vast majority of transmissions. There are many details lacking in our understanding of the linkages between wildlife and domestic animal rabies cycles, and where wolves fit into these systems. However, ongoing efforts to vaccinate wildlife and domestic dogs (e.g. the WHO’s Zero-by-30 campaign <https://www.who.int/rabies/news/RUA-Rabies-launch-plan-achieve-zero-rabies-human-deaths-2030/en/>), control dog populations (Dalla Villa et al. 2010) and improvements in availability of human post-exposure treatments should lead to a progressive decline in the risks posed by rabid wolves, and a restriction of this risk to smaller geographic areas.

6.2 Predatory attacks — summary of new knowledge

Although predatory attacks appear to be widespread in the historical sources, they are relatively rare in contemporary situations. Some of the best documented cases mentioned in the 2002 report stemmed from India (Jhala & Sharma 1997, Rajpurohit 1999). We have uncovered an additional source that refers to a series of attacks that reportedly killed 17 children in the Indian state of Madhya Pradesh in 1985–86 (Yadav 2000). We have not found any evidence of these persistent and localised incidences in recent times. However, wolves are still identified as being responsible for multiple isolated deaths across India, although the documentation does not permit the separation of rabies or predatory attacks.

In contrast, two recent papers provide reports of a series of attacks in western Iran (Behdarvand et al. 2014, Behdarvand & Kaboli 2015). Between 2001 and 2015 they gathered reports of 53 attacks of which 5 were fatal. They were mainly focused on children, with all victims of fatal cases between 3 and 6 years old. Although rabies is known to be present in the region (Gholami et al. 2014, 2017), it was excluded in these cases which were interpreted by the authors as being mainly predatory. Media cases report further attacks, both lethal (n=1) and non-lethal (n=6) from the wider region of western Iran in subsequent years. Our media survey identified one similar case from Tajikistan from 2017 where a 2-year-old child was grabbed and carried away by a wolf and killed. The socio-ecological situation is rather similar to that of the Indian cases from the 1980’s and 1990’s (see above) and many of the historical cases of clustered attacks, with poor rural communities, landscapes with few wild prey, and wolves that depend on consuming garbage, carrion and livestock. Such situations bring wolves into frequent and close contact with people where children are often vulnerable and exposed. Under these circumstances it appears that a very small minority of wolves may test the potential of children as prey, and that this may

reoccur in an even smaller proportion of cases. With ongoing changes in global development across Eurasia it is likely that these circumstances will become increasingly rare.

Two high profile cases occurred in North America where an adult male (in Canada in 2005) and an adult female (in Alaska in 2010) were killed by wolves in predatory attacks. In addition, there have been several well-documented cases of people bitten by wolves in the United States (Minnesota), Canada (British Columbia, Saskatchewan and Alberta), Poland, and Israel, in what appear to be predatory attacks. These are all associated with very different socio-ecological conditions, i.e. situations with relatively developed societies, low to medium human densities, and relatively abundant wild prey populations. The Minnesota case had a clear explanation in the form of a wolf with severe injuries (Schwablander et al. 2016). The Alaska case stands out from all others in that there were no warnings or underlying risk conditions (Butler et al. 2011). The other cases were however, associated with situations in which wolves were frequently seen close to people, were demonstrating an extreme lack of shyness, and in many cases where they were accustomed to using anthropogenic food sources or killing pets on a regular basis. Many, but not all, of these cases occurred in protected areas or in landscapes with low hunting pressure on wolves. These wolf cases are very similar to those with coyotes and dingoes described earlier. Although the vast majority of large canids in these situations never attack people, there are enough indications pointing to risks that it is important to explore what we know about these processes associated with habituation. This is especially so because these are circumstances that are likely to increase in the future in the western world (Newsome et al. 2017) and because the risks associated with wolves that are “bold” or “fearless” has become a central part of controversies and public debates around the dangers posed by wolves across the western world (Linnell & Allean 2015).

6.3 What do we know about habituation, boldness and aggression in carnivores?

Because of the paucity of wolf-specific data the following discussion is built on a broad comparison of data from canids, namely wolves, dingoes, coyotes and red foxes because the underlying behavioural processes are similar.

Habituation is the process by which individuals reduce their response to certain external factors and thereby learn to tolerate them, including raising their tolerance for the proximity of anthropogenic influences. Bolder or more explorative animals are likely to habituate faster because they are likely to have greater exposure. There is a general understanding that most carnivores living in human-dominated landscapes have achieved a high degree of habituation (Baker & Timm 2017). For example, Yellowstone wolf packs that are most exposed to human road traffic show the greatest degree of tolerance to it (Anton et al. 2020). Dispersal age wolves are also more tolerant of anthropogenic structures, and the exposure to this during dispersal may make them more tolerant of these features as adults (Barry et al. 2020). But the processes leading to habituation are complex.

The study of animal behavioral traits that reflect “animal personality” has accumulated decades of experience from species in captivity, however, the study of animal personality in the wild lags behind (Blumstein 2016, Fagen & Fagen 1996, Sol et al. 2013, Wolf & Weissing 2012) due to the massive logistical challenges involved. Individual behavior is shaped by multiple aspects. Multiple studies in many species have shown that behavioural traits are partially inherited, creating a genetic predisposition to certain personalities. However, this predisposition is then subject to being modified by multiple factors, including (1) the individuals own experiences, (2) teaching from parents, (3) the behavior of siblings and litter-mates, (4) body condition, (5) age, (6) sex and even (7) pre-natal maternal effects (epigenetics). This complexity means that it will be almost impossible to identify the specific drivers behind any individual personality. There are also strong selective reasons to maintain a diversity of behavioural types, even within litters (Wolf et al. 2007).

Ethologists recognize five main gradients along which individual animals are located. These are (1) shyness / boldness, (2) explorative / avoidance, (3) aggression, (4) sociability, and (5) activity. Of main concern for the study of wolf attacks on humans are the shyness - boldness and the explorative - avoidance gradients. There is evidence that these trait groups exist in domestic dogs and captive wolves (Svartberg & Forkman 2002, Wheat et al. 2019a,b), although there are subtle differences between dog breeds, and between dogs and wolves in general. It is unlikely that aggression is related to predation, because aggression is normally viewed as an intra-specific behaviour not associated with prey. However, it may play a role in wolf attacks on domestic dogs (Butler et al. 2014) in circumstances where this is driven by dominance or a perception of dogs as being wolves.

There is a broad research base documenting that individuals of multiple species with bolder or more explorative behaviour are those likely to be favoured in human-dominated landscapes (Sol et al. 2013). When considering wolf conservation in the Anthropocene it is clear that wolves will need the behavioural traits that allow them to inhabit human-modified and human-dominated landscapes. Studies have demonstrated that urban coyotes show a greater degree of boldness and exploratory behavior than rural coyotes (Breck et al. 2019), and that young coyotes raised by habituated parents become more habituated themselves (Schell et al. 2018). Heritability for certain traits and selection for them can lead to evolutionary processes akin to domestication (see Newsome et al. 2017 for a discussion, and Parsons et al. 2020 for a case study of urban red foxes). Although the extent to which this is happening to wolves is unknown, the issue of how humans are imposing a “domesticating” selective effect on wildlife is a growing topic of research (Myrsterud 2010).

Irrespective of the relative roles of innate genetic predisposition or acquired experience, high degrees of habituation are likely to bring individual wolves into closer contact with human-dominated landscapes, human habitations, and humans, as well as facilitate the testing of novel, anthropogenic food sources. Combined, these are factors that increase the risk for conflicts, including the risk of predatory attacks on people. However, the mere fact that wolves can tolerate being in human-dominated landscapes and the proximity of human disturbance does not imply that they are automatically a danger to humans. Rather these traits are a necessity for survival in the Anthropocene. The situations which are more concerning are those where wolves (1) begin to show tolerance for the close proximity of humans (i.e. within 30–50 m), (2) begin to directly approach people, and (3) when they begin to associate humans directly with food. Even these situations do not automatically imply that wolves will attack, but they are circumstances associated with many of the attacks documented in this report.

Baker and Timm (2017) have developed a scale of habituation for coyotes based on decades of study of urban, sub-urban and rural populations. They view low levels of habituation as essential to allow coyotes to share space with humans, but recommend taking action against coyotes when habituation passes stages associated with individuals approaching or being fearless with humans at short distances and in daylight. Most of the cases identified above where predatory attacks occur were associated with advanced degrees of habituation in which wolves were openly being seen by people in daytime, or when they actively approached them. Although such situations will not escalate in the majority of situations, public safety concerns suggest that it may be appropriate to react in a precautionary manner. The question then remains as to which reactions are appropriate?

6.4 Managing risk in human-dominated landscapes

There are a range of options available to respond to wolves showing undesired behavior, which can be viewed along a gradient of invasiveness, and from proactive to reactive.

6.4.1 Remove food sources.

Excluding wolves from food sources that are directly associated with humans is both an important proactive measure and a first line reactive measure. This implies both food sources in close spatial proximity to humans and food sources that permit an association of food with humans. This includes actions like fencing garbage dumps and land-fills, and ensuring proper disposal of carcasses from farms. The most important action is to prevent the deliberate feeding of wolves by photographers or those acting out of a misguided desire to “help” wolves. A special case concerns areas where food is mainly provided for bears either to photograph (e.g. in Finland) or to reduce conflict and facilitate hunting (across the Balkans and Carpathians) and where wolves may also obtain food (Kavcic et al. 2013, Penteriani et al. 2017b, Steyaert et al. 2014). These feeding activities are highly controversial for multiple reasons, however they probably do not facilitate habituation greatly because of their remote locations and the general absence of any direct association with humans or areas of habitation.

6.4.2 Hazing.

The principle of hazing is to provide a negative stimulus that can be associated with the presence of humans or their structures which can change wolf behavior. In other words, to undo the effects of habituation. As such it constitutes a form of aversive conditioning (Smith et al. 2000). There is a very large degree of uncertainty concerning the effectivity of hazing at inducing greater shyness in wild canids (Snijders et al. 2019). Most published experience comes from studies with dingoes and coyotes, both in the wild and in captivity (Appleby et al. 2017, Darrow & Shivik 2009, Edgar et al. 2007, Smith et al. 2020, Young et al. 2019). Based on the published data from canids and other species it is possible to draw the following preliminary conclusions:

- (1) Mild negative stimuli like water-pistols, whistles, horns and lights have minimal effects, although combinations work better than single stimuli. The cases that report success used rubber bullets or shotgun propelled bean bags.
- (2) There is massive individual variation due to personality type and the degree of habituation.
- (3) It is important to react early in the process.
- (4) It is harder to treat animals that are food conditioned than those that are simply accustomed to the presence of humans.
- (5) Multiple treatments may be necessary.
- (6) It is important to administer the hazing in the specific situations that you wish to discourage.

In other words, experience is mixed with there being good examples of successful hazing and examples when it doesn't work. A key aspect concerns the logistical practicality of detecting the unwanted behavior early enough and being able to administer a targeted hazing activity often enough to achieve the desired effect. The apparent success of hazing in situations like for wolves in Yellowstone National Park, or some urban coyote settings, is possible because of the extreme visibility of animals. In other words, their habituation to the general presence of people in the vicinity makes it easier to use hazing to discourage more specific behaviours. For shyer animals it may be almost impossible to deliver targeted and frequent hazing. Several North American cities have attempted to use “citizen hazing” where residents and park users for example are encouraged to try and haze urban coyotes whenever they see one. Although there has been success in the uptake of the idea among citizens the effect on coyote behavior seems to be mixed (Bonnell & Breck 2017, Breck et al. 2017, White & Delaup 2012).

Overall, there is still a huge amount of uncertainty surrounding the utility of hazing, and there is clearly a need for much more data collection and systematic study of canid behaviour and their response to humans (e.g. through approach studies Wam et al. 2014). However, there is enough experience to say that in some situations it can work, and that in other situations it is not sufficient. The only other option that exists is to remove the animal.

6.4.3 Selective animal removal.

In cases where individual wolves display undesired or unacceptable behavior and where hazing has either failed or is not practical the only option is to remove the individual animal from the wild. Live capture is a theoretical possibility but is exceptionally time-consuming, expensive, and difficult. Furthermore, there is the question of what to do with the animal once captured. Clearly it cannot be released back into the wild because there are no locations without human presence, so the only option is to keep it in captivity for life. Introducing a wild-born wolf into a captive environment represents considerable practical and animal welfare challenges, and involves enormous costs. Overall, the only realistic option in most situations will be to shoot the wolf in the field. Lethal control is quicker, more efficient, far cheaper, and arguably more humane. Lethal control is by far the most commonly employed measure used in response to attacks on people or in situations where animals are identified as being threats to human safety. This includes within protected areas such as Yellowstone, Banff, Cape Breton Highlands, Pacific Rim, Fraser Island and Masada National Parks. When unwanted behaviours can be linked to specific individuals, it is obvious that removing the individuals will at least temporarily remove the threat, and provides an opportunity to initiate measures to minimize the chances that the unwanted behaviours resume when new individuals recolonize the same territories. Breck et al. (2017) have conducted one of the few studies on the utility of lethal control (on urban coyotes) and document that it produces significant, and lasting, benefits. However, they underline that while lethal control can address issues once they arise, a sustainable wildlife management strategy must also invest in proactive actions to prevent the development of problematic behaviour in new individuals.

6.4.4 Wolf hunting.

There is a lot of public discussion concerning whether routine hunting of wolves serves to reduce the risks of habituation and attacks on people. It is important to consider by what mechanism it can have an effect. Potentially, it could work via several mechanisms.

- (1) Population reduction, which is based on the assumptions that the risk of problematic behaviour is density dependent and that hunting lowers the population.
- (2) Learning, which is based on the assumption that the disturbance caused by hunting induces shyness in wolves.
- (3) Selection, which is based on the assumption that certain wolves have a genetic predisposition to problematic behaviour and that hunting can disproportionately remove these animals.

Some of the predatory attacks described in this report occur in areas where wolf populations are subject to hunter harvest and / or trapping (e.g. the fatal attacks in Alaska, Saskatchewan, Tajikistan, and the non-fatal attack in Port Edwards). Although many of the other cases appear to be associated with protected areas where there is no hunting of wolves, these protected areas are small "islands" of protection in wider landscapes where wolves are subject to hunting and / or persecution. It would therefore appear to be unlikely that there is a strong population level benefit operating through selection against a genetic predisposition to boldness. Furthermore, Wolf et al. (2007) present arguments as to why there should be a strong selection to maintain multiple personality types within populations. In contrast it is possible that hunting could remove individuals that begin to show extreme habituated behavior and / or that the disturbance caused by the process of hunting could serve as a form of hazing. At present it is impossible to conclude on this issue. However, there is a real need to obtain robust scientific data on this issue from field studies of wolves under different management regimes.

6.4.5 Management protocols.

Wolf management will always be highly controversial among both professionals and the public, especially when lethal control is discussed (Lute et al. 2018, Donfrancesco et al. 2019). It is therefore very important to establish clear management guidelines in advance that detail how authorities will respond to different situations, with the actions scaled according to the level of

threat posed by the animal. For example, such guidelines exist for Yellowstone, Denali and Fraser Island National Parks as well as for Germany (Anon 2003, Anon 2007, Anon 2013, Reinhardt et al. 2018). The Large Carnivore Initiative for Europe (a Specialist Group within the International Union for the Conservation of Nature) has built on these to generate a broad set of guidelines, summarized below in **Table 3**. Reactive guidelines also need to be accompanied by clear guidance on prevention measures, especially related to the feeding of wolves. A final aspect is to clarify issues of legal liability (Stringham 2013), especially important in protected areas.

Table 3. Assessment of wolf behavior and an assessment of the risk it may pose for human safety with recommendations for action based on Reinhardt et al. 2018 and guidelines drawn up by the Large Carnivore Initiative for Europe.

Behavior	Assessment	Recommendation for action
Wolf passes close to settlements in the dark.	Not dangerous.	No need for action.
Wolf moves within sighting distance of settlements / scattered houses during daylight.	Not dangerous.	No need for action.
Wolf does not run away immediately when seeing vehicles or humans. Stops and observes.	Not dangerous.	No need for action.
Wolf is seen over several days <30m from inhabited houses (multiple events over a longer time period).	Demands attention. Possible problem of strong habituation or positive conditioning.	Analyze situation. Search for attractants and remove them if found. Consider aversive conditioning.
Wolf repeatedly allows people to approach it within 30m.	Demands attention. Indicates strong habituation. Possible problem of positive conditioning.	Analyze situation. Consider aversive conditioning.
Wolf repeatedly approaches people by itself closer than 30m. Seems to be interested in people.	Demands attention / critical situation. Positive conditioning and strong habituation may lead to an increasingly bold behavior. Risk of injury.	Consider aversive conditioning. Remove the wolf if appropriate aversive conditioning is not successful or practical.
Wolf attacks or injures a human without being provoked.	Dangerous.	Removal.

6.4.6 Communication.

The messaging associated with the risk posed by wolves is complex. On one hand it is important to communicate that the risks posed by wild wolves is so small that it cannot be calculated, especially in European and North American settings, so as to reduce fear. On the other hand, it is important to communicate that this risk is not zero, in order to prepare the public for the possible need of reactive measures and to gain acceptance for proactive actions / restrictions. The understanding of the risks from wolves is growing, and it increasingly appears that wolves are broadly similar to bears where the risks are much more widely understood, i.e. most individuals are not dangerous, but that there are risks from habituated and especially food-conditioned individuals, and on some rare occasions unpredictable and unprovoked incidents will occur. This should permit a more unified and coherent messaging. Wolves also have the advantage that information on how to react to an eventual close encounter or attack are similar to how people should respond to encountering free-ranging domestic dogs which are familiar to most people. It is also a challenge to communicate the details of what constitutes risky behavior. The mere presence of a wolf in a human-dominated landscape is not a cause for concern. The presence of a wolf passing a house or walking along a road is not an issue. Seeing a wolf at a distance is not a risk. The problem arises if there are repeated episodes of sightings of wolves at short distances where the wolf does not react with caution or where wolves are regularly consuming food of anthropogenic origin in proximity to people or houses.

Such information needs to be carefully designed and communicated and again can be modelled on the more widespread information concerning attacks from other species like bears and

cougars (Brown & Conover 2008, Penteriani et al. 2017a, Smith et al. 2012) and it is highly beneficial if such information campaigns are scientifically designed and monitored to allow continual improvements (see Sponarski et al. 2016a,b, 2018, 2019 for a good example).

6.4.7 Forensic and documentation procedures.

If an attack by a wolf is reported it is essential that the cases are properly investigated using formal forensic procedures. This is because of the risk of confusing dog attacks for wolf attacks, either deliberately (Caniglia et al. 2016) or by mistake (Fonseca & Palacios 2013). Many of the reports that we list in the previous sections remain unverified because there was no follow up of the attacks. Dog attacks are massively more common than wolf attacks (Cornelissen & Hopster 2010, Horisberger et al. 2004, Golinko et al. 2017, Rosado et al. 2009). There is a growing body of forensic evidence describing the characteristics of attacks by wolves, dogs and other carnivores (e.g. Butler et al. 2011, De Munnynck & Van de Voorde 2002, Heinze et al. 2014, Gudmannsson & Berge 2019, Gustafsson & Eriksson 2015, Khan 2017, McNay 2007, Salem & Marinescu 2008, Santoro et al. 2011, Tsokos et al. 2007 and older references in Linnell et al. 2002), which needs to be synthesized and made available to medical staff, first responders, law enforcement and wildlife management staff (Dietrichs 2016). Wolf and dog attacks are broadly similar, so it is essential that DNA samples are secured from bite wounds and from the surface of skin and clothing surrounding bites. This is essential to both unambiguously identify the right species and to identify if the correct individual has been caught or killed after the attack.

6.4.8 Knowledge needs.

There are very many gaps in our knowledge concerning bold / fearless / habituated wolves and the reactions to humans in human-dominated landscapes. These behaviours are logistically challenging to study in the field and their interactions with humans are very rare. One approach that exists is to better log ongoing incidents to accumulate a larger body of detailed case reports that will provide insights over time (Huber et al. 2016). It is also necessary to better record experience with different interventions, such as hazing or lethal control such that it is possible to better document the efficacy of different actions. However, really detailed insights will have to come from the analysis of movement and behavioural data from GPS-collared wolves to study how they react to human disturbance (e.g. Barry et al. 2020). One interesting approach is to use intensive GPS data to study fine scale movements close to houses (Odden et al. 2018) or to study how wolves react to deliberate approaches by people. This experimental design has been used a little with wolves (Wam et al. 2014) and intensively with bears (Moen et al. 2012, 2019, Ordiz et al. 2019). This systematic approach can be repeated in different situations to understand factors explaining differences in wolf response to humans.

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8 Appendix

Table A1. List of cases of wolf attacks that were identified as being reliable (“verified”) found by systematically searching media and online sources during the period 2015–2018. This period was chosen as being recent, and was limited by our resources. Verification is based on the level of detail provided, the sources cited, as well as the availability of official documents. The main focus was on Russian speaking countries with a secondary focus on those of the eastern Mediterranean and Middle East. An asterisk (*) indicates victims which were not killed directly by a wolf but died of rabies. Note that other cases found through more ad hoc approaches and searches of the scientific literature are only listed in the text. Details of media and other sources are available from the authors on request.

Date of attack	Country	Region	Victims		Type of attack
			Injury	Death	
August 29 th , 2016	Canada	Saskatchewan	1	—	predatory
June 12 th , 2018	Poland	Podkarpackie province	1	—	presumably predatory
June 26 th , 2018	Poland	Podkarpackie province	2	—	predatory
January 29 th , 2016	North Macedonia	Skopje statistical region	1	—	unknown
February 16 th or 17 th , 2015	Russia	Astrakhan region	5	—	rabid
September 8 th , 2015	Russia	Kabardino- Balkar Republic	3	—	rabid
October 4 th , 2015	Russia	Rostov region	3	—	rabid
January 2016	Russia	Rostov region	2	—	defensive
February 16 th , 2016	Russia	Vologda region	1	—	presumably defensive
February 17 th , 2016	Russia	Rostov region	2	—	rabid
July 6 th , 2017, or earlier	Russia	Rostov region	1	—	rabid
December 10 th , 2017	Russia	Krasnoyarsk region	4	—	rabid
January 31 st , 2015	Ukraine	Zhytomyr region	1	—	rabid
February 4 th , 2017	Ukraine	Chernihiv region	3	—	rabid
February 16 th , 2017	Ukraine (Russia)	Autonomous Republic of Crimea	1	—	presumably defensive
December 9 th , 2017	Ukraine	Donetsk region	1	—	presumably rabid
January 4 th –5 th , 2018	Ukraine	Chernihiv region	3	—	rabid
January 7 th , 2018	Ukraine	Rivne region	1	—	rabid
January 19 th , 2015	Belarus	Gomel region	3	—	rabid
July 7 th , 2016	Belarus	Gomel region	4	—	rabid
January 2 nd , 2018	Belarus	Gomel region	2	—	presumably rabid
October 16 th , 2018	Moldova	Camenca district	2	—	rabid
January 11 th , 2015	Iran	Kurdistan province	4	—	rabid
July 6 th –7 th or 7 th –8 th , 2015	Iran	Hamadan province	2	—	predatory
November 28 th –29 th , 2015	Iran	Gilan province	6	—	rabid
December 8 th , 2015	Iran	Gilan province	1	—	unknown
February 20 th , 2016	Iran	Qazvin province	1	—	unknown
April 2 nd , 2016	Iran	Ardabil province	5	—	rabid
April 17 th , 2016	Iran	Zanjan province	1	—	defensive / rabid
June 3 rd , 2016	Iran	Hamadan province	1	—	predatory
October 31 st , 2016	Iran	East Azerbaijan province	10	—	presumably rabid
mid-April to mid-June 2017	Iran	Zanjan province	1	—	unknown
April 18 th , 2017	Iran	Zanjan province	1	—	predatory
May 5 th , 2017	Iran	Zanjan province	1	—	predatory
May 27 th , 2017	Iran	Qazvin province	7	—	rabid

June 12 th , 2017	Iran	Zanjan province	7	—	rabid
c. June 24 th , 2017	Iran	Ardabil province	1	—	presumably rabid
July 18 th , 2017	Iran	Kermanshah province	—	1	predatory
October 17 th , 2017	Iran	Isfahan province	4 or 5	—	rabid
January 11 th , 2018	Iran	Zanjan province	3	—	rabid
August 25 th , 2018	Iran	Qazvin province	4 or 6	—	presumably rabid
January 13 th , 2018	Iraq	Al-Qādisiyyah governorate	4	—	presumably rabid
June 20 th , 2015	Turkey	Çorum province	2	—	presumably rabid
April 1 st , 2017	Turkey	Erzurum province	4	—	rabid
March 24 th , 2015	Armenia	Vayots Dzor province	5	—	presumably rabid
March 21 st , 2016	Armenia	Vayots Dzor province	1	—	unknown
October 25 th , 2015	Azerbaijan	Agsu district	2	—	unknown
November 29 th , 2015	Azerbaijan	city of Mingecvir	1	—	unknown
May 30 th , 2016	Azerbaijan	Ismaili district	1	—	defensive / rabid
February 21 st , 2017	Azerbaijan	Salyan district	1	—	unknown
July 20 th , 2017	Azerbaijan	Salyan district	1	—	defensive / rabid
July 25 th , 2017	Azerbaijan	Aghstafa district	1	—	rabid
August 6 th , 2017	Azerbaijan	Agsu district	2	—	rabid
May 28 th , 2018	Azerbaijan (Republic of Artsakh / Nagorno-Karabakh)	Khojavend district (Hadrut province)	2	2*	rabid
November 28 th –29 th , 2018	Azerbaijan	Lankaran and Astara districts	9	—	rabid
November 18 th , 2017	Saudi Arabia	Aseer region	1	—	defensive
beginning of May 2017	Israel	Southern district	1	—	predatory
c. May 29 th , 2017	Israel	Southern district	1	—	predatory
May 31 st , 2017	Israel	Southern district	1	—	predatory
May 31 st , 2017	Israel	Southern district	1	—	predatory
May 9 th , 2015	Syria / Israel	Al Qunaitra governorate / Northern district	5	—	rabid
July 31 st , 2015	Syria / Israel	Al Qunaitra governorate / Northern district	1	—	presumably rabid
c. November 2016	India	«Indian Himalayas»	1	—	predatory
March 21 st , 2016	Mongolia	Ulaanbaatar	2	—	rabid
January 13 th , 2015	Kazakhstan	East Kazakhstan region	1	1*	rabid
December 15 th , 2016	Kazakhstan	Atyrau region	1	—	defensive
October 14 th , 2017	Kazakhstan	West Kazakhstan region	1	—	unknown
December 22 nd , 2015	Kyrgyzstan	Naryn region	2	—	unknown
January 28 th , 2016	Kyrgyzstan	Osh region	2	—	rabid
November 8 th , 2016	Kyrgyzstan	Naryn region	1	—	predatory
February 5 th , 2017	Kyrgyzstan	Issyk-Kul region	2	—	defensive
March 15 th , 2017	Kyrgyzstan	Osh region	1	—	defensive
June 15 th , 2017	Kyrgyzstan	Jalal-Abad region	1	—	rabid
November 7 th , 2017	Kyrgyzstan	Issyk-Kul region	1	—	rabid
October 23 rd , 2018	Kyrgyzstan	Batken region	5	—	rabid
July 1 st , 2017	Tajikistan	Gorno-Badakhshan autonomous region	—	1	predatory

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