Social and environmental factors influencing contemporary cases of wolf aggression towards people in Poland

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Received: 29 April 2020 / Revised: 18 November 2020 / Accepted: 26 December 2020 / Published online: 12 July 2021
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Abstract

Understanding factors and mechanisms causing large carnivore aggression towards people is crucial for their conservation in modern human-dominated landscapes. We present detailed descriptions of wolf attacks on people in early summer 2018 in two areas of Poland, analysis of behaviour, fitness and origin of individuals responsible for the attacks and management actions undertaken by local communities as well as governmental bodies and non-governmental organisations. We show that attacks were caused by yearling wolves (13-month-old male and 14-month-old female) originating from local packs, which appeared near households several months prior to incidents. Both individuals were positively food-conditioned and showed increasing habituation caused by irresponsible behaviour of people such as long-lasting intentional feeding or illegal keeping. Post mortem necropsy revealed obesity and serious abnormality of spleen (polysplenia) in the problem female wolf that negatively impacted her fitness and was the most likely reason for her presence near households and feeding on leftovers. Despite prolonged observations of these wolves very close to human settlements (less than 30 m), no mitigation actions were undertaken until the attacks, after which both individuals were killed. We provide several recommendations to avoid aggressive human-carnivore encounters.

Keywords *Canis lupus* · Human safety · Animal attacks · Habituation · Food conditioning · Conflict management

Introduction

Conservation of large carnivores is often justified by their key role in ecosystems (Steneck 2005; Kuijper et al. 2013), and delivering important ecosystem services to humans (Braczkowski et al. 2018; O'Bryan et al. 2018). Nonetheless, their presence in nowadays human-dominated landscapes is inevitably connected with a wide array of issues, including

threat to human safety (Löe and Röskft 2004). Despite global decreases in the abundance of large carnivores (Estes et al. 2011), in some regions, their range and number grow (Chapron et al. 2014) increasing opportunities for human-carnivore interactions. The growing frequency of encounters with large carnivores is additionally provoked by the intense recreational activities of people in natural habitats, intentional feeding to attract wild animals, expansion of human settlements, growing adaptation of carnivores to anthropogenic landscapes and even climate change (Penteriani et al. 2016, 2017b; Wilder et al. 2017; Bombieri et al. 2018a; Kumar et al. 2019).

Compared with other species (Langley and Morrow 1997; Forrester et al. 2018), large carnivores rarely attack people (Linnell and Alleeu 2016; Penteriani et al. 2017a). However, if such cases occur, they often receive excessive media attention (Löe and Röskft 2004; Bombieri et al. 2018b; Chandelier et al. 2018), which may undermine long-term efforts for their conservation (Gore and Knuth 2009; Bruskotter and Wilson 2014). Therefore, understanding mechanisms affecting large carnivore aggression towards people is crucial for the effective management of conflicts (LCIE 2019).

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Although bears and big cats are responsible for most fatalities caused by large carnivores worldwide (Bombieri et al. 2019; Packer et al. 2019), the wolf *Canis lupus* is perceived by the public as the most dangerous predator in Europe (Dressel et al. 2015), especially by inhabitants of areas recently recolonised by the species (van Heel et al. 2017; Arbieu et al. 2019). It is particularly important in regions where the range and number of wolves has substantially increased in the last few decades (Chapron et al. 2014), and the development of their population in human-dominated landscapes (Nowak and Mysłajek 2016; Nowak et al. 2017; Reinhardt et al. 2019) creates new conservation challenges (Kuijper et al. 2019).

Wolf attacks on humans are extremely rare; in addition, historical descriptions of wolf attacks on people often fail to provide reliable information due to errors in recording, exaggerations and problems with translations (Linnell et al. 2002; Löe and Röskft 2004). Therefore, our understanding of aggressive wolf-human encounters is largely based on anecdotal data (Jenness 1985; Rajpurohit 1999; Türkmen et al. 2012; Behdarvand and Kaboli 2015; McNay and Mooney 2005; Khan 2017). The whole picture is additionally blurred by false claims of wolf attacks (Caniglia et al. 2016) and the presence of wolf $\times$ dog hybrids in the wild (Salvatori et al. 2020).

In this paper, we provide detailed descriptions of contemporary wolf attacks on five people in two different areas in Poland, analysis of the behaviour and origin of individuals causing the attacks and management actions undertaken by official bodies to solve these problems.

Material and methods

Study sites

Our study includes two areas located in separate parts of Poland (700-km distance between them) (Fig. 1). The country is inhabited by three large carnivore species, the wolf, brown bear (*Ursus arctos*) and Eurasian lynx (*Lynx lynx*), all of them strictly protected. However, only the wolf is widely distributed (Jędrzejewski et al. 2008; Nowak and Mysłajek 2016), while the lynx population is restricted to eastern Poland and the Carpathian Mountains, with a few individuals in Western Poland (Niedziałkowska et al. 2006), while the brown bear occurs permanently only in the Carpathian Mountains (Selva et al. 2011).

Case #1 took part in the central part of the Bieszczady Mountains, in the Cisna community, situated in the easternmost part of Polish Carpathian Mts, near the Polish-Ukrainian and Polish-Slovakian borders. The site is located at the western edge of the Bieszczady National Park (hereafter BNP), being a part of the Natura 2000 site Bieszczady PLC180001 protecting large carnivores habitats (N 49° 1'–49° 13', E 22° 7'–22° 51') (Diserens et al. 2017). More than 80% of the area

is covered with dense mountainous forests of mostly natural character. Forests outside the BNP are intensively logged by the National Forest Holding “State Forests”. The wolf occurs in the Bieszczady Mts. sympatrically with the Eurasian lynx and the brown bear, although wolves are the most numerous with the average density of 2.6–5.0 individuals/100 km² (Pirga and Polakiewicz 2020). The local ungulate community consists of three game species: red deer (*Cervus elaphus*) with density of 7.4 individuals/km², and wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*) with densities of 0.5 and 0.6 individuals/km², respectively (Borkowski 2019). There is also a reintroduced, free-living, fully protected but small population of European bison (*Bison bonasus*). There is only limited deliberate reduction of game ungulates in the BNP, but in adjacent areas, intensive hunting is conducted within hunting grounds managed by state forests or hunting clubs of the Polish Hunting Union (PHU). Commercial trophy hunt tickets for wild ungulates are also sold to hunters from abroad. The BNP, together with a buffer zone including the Cisna community (about 900 km²), is inhabited by four wolf packs (Pirga and Polakiewicz 2020). The area is sparsely populated, with an average human density of 14 inhabitants/km²; however, the Cisna community alone has only 6 people/km² and is the least populated community in Poland (Rogalińska et al. 2018). The main source of income of local people is farming and livestock breeding, following by forestry, sawmilling and woodwork. Over the last 10 years, however, there has been a substantial increase in tourism focused on natural resources, especially trophy hunting for game ungulates, wildlife watching and wildlife photography for which local communities provide accommodation, food and tourist guidance (Churski 2013).

Case #2 occurred at the north-western edge of the Noteć Forest (hereinafter NF), in Bagniewo and Trzebiecz Młyn villages located in the Drezdenko community. NF is the large lowland forest tract (ca. 1350 km²), north-west of Poznań (N 52° 39'–52° 53', E 15° 30'–16° 49'). The area is mainly covered with planted Scots pine *Pinus sylvestris* monocultures (Kusiak and Dymek-Kusiak 2002). There are several, although small, Natura 2000 sites protecting wolf habitats (Diserens et al. 2017). The whole forest is state owned, intensively harvested by the National Forest Holding “State Forests” and with a dense network of logging roads. After a long-term absence caused by their deliberate extermination (Nowak and Mysłajek 2017), wolves recolonised the area in 2008 (Nowak and Mysłajek 2016), and in 2018, the population reached six wolf packs (Nowak et al. unpublished). The wolf is the only large carnivore permanently inhabiting NF. The ungulate community consists of three native game species—the roe deer (0.4 indiv./km²), red deer (1.4 indiv./km²) and wild boar (1.0 indiv./km²) (Borkowski 2019), and introduced alien fallow deer *Dama dama*. Hunting is conducted within hunting grounds managed by state forests or hunting

Fig. 1 Locations of wolf attacks on people in Poland, 2018. Shaded areas denotes forests. (1) Bieszczady Mountains, (2) Noteć Forest

clubs of the Polish Hunting Union. The NF area is sparsely populated, with only lone settlements or small villages in the central part of the forest, while villages or towns are located on the edges, near larger lakes and on the banks of two big rivers. The NF serves as a recreation area in late spring, summer and early autumn. There are many camp sites, weekend cabins and hotels near the lakes and rivers, which cause an increasing human pressure on the forest during vegetation season. The human density in the Drezdenko community is 40 inhabitants/km², but most live in the Drezdenko town, outside of the NF. Bagniewo and Trzebiecz Młyn villages located about 1 km apart to each other comprise about 20 houses spread within woods and fields and adjacent to large meadows of the Noteć river valley. Their inhabitants mostly work in towns or bigger villages, have small fields and few livestock or are retired. Some residents are foresters or hunters.

Methods

Animal aggression towards humans is a result of both environmental and social factors. Therefore, to investigate causes of wolf aggressive behaviour, we aimed to gather information regarding animals causing attacks, and their relationship with

local wolf populations, as well as reactions of local citizens and actions undertaken by authorities. We applied the following methods:

Post mortem analysis and documentation Both wolves causing attacks on people were shot. After culling, a preliminary photo documentation was collected and tissue samples for genetic analysis were delivered to the laboratory at the Faculty of Biology at the University of Warsaw. Afterwards, the heads of wolves were taken to run tests for rabies in territorially relevant offices of the Veterinary Inspectorate and the rest of the bodies were stored in freezers. As results of tests were known, heads were returned to institutions performing necropsies. For the case #1 the necropsy was conducted at the County Veterinary Inspectorate in Sanok by a veterinarian specialised in internal diseases of wild animals (Kaczor 2018). For the case #2, the necropsy was done in a veterinary clinic in Bielsko-Biała (Całus 2018) by a veterinarian specialising in wild animals accompanied by two wildlife biologists (all co-authors of this paper—SN, IC, RWM). During both necropsies, comprehensive photo documentations were done. The age of wolves was estimated based on tooth wear (Gipson et al. 2000).

Genetic analyses We applied DNA analysis based on autosomal microsatellite loci and a fragment of mtDNA control region of both individuals causing attacks on people. To reveal their origin, we checked the relationships of both wolves with samples collected across the whole of Poland during studies on the wolf genetic structure in Central Europe (2011–2018), including samples from the forests where attacks occurred (Szewczyk et al. 2019). We also collected additional non-invasive (scats and hair) samples in areas neighbouring attacks on people (2018–2019), $n = 35$ for case #1 and $n = 26$ for case #2 (see [Supplementary Material](#) for further details).

Wolf tracking In case #1, we conducted wolf tracking in the Bieszczady Mts., including the Cisna community, the following autumn and winter season, as well as in autumn 2019. In case #2, 1 day after the first attack, we started and continued over the following months wolf tracking in the area surrounding the village. During tracking, the location of wolf tracks and other signs were recorded; we also assessed the number of individuals. All used field methods are described in Nowak and Mysłajek (2016) and Mysłajek et al. (2018).

Camera trapping and analysis of photos and videos taken by local citizens We collected all available pictures and video footage of wolves before and after the attacks recorded by local people and tourists (1 video and 5 photos for case #1 and 5 videos and 16 photos for case #2). Additionally in case #2, a day after the initial attack, we installed three camera traps: at the front of the location of the attack, at the site indicated by inhabitants where wolves regularly visit and in the place which we defined during our tracking. After the wolf was shot, local people claimed that wolves still appeared close to buildings; therefore, we installed camera traps in three new locations shown by inhabitants. At the same time, we installed two camera traps in the nearby forest in places where we recorded signs of wolf presence. Altogether, we recorded 12 videos of wolves and dogs near houses and in the vicinity of both villages.

Interviews with local people In both areas, we personally or via phone interviewed people who observed wolves before the accidents or witnessed the behaviour of wolves during and after attacks. In case #1, the group included six people and in case #2, 10 people in total (see [Supplementary Material](#) for the list of interviewed people).

Analyses of wolf behaviour Wolf behaviour documented with pictures, videos and reported by witness was classified according to terminology described by the policy support statements of the Large Carnivore Initiative for Europe (LCIE 2019).

Documentation of the decision process Because the co-author of the paper (SN) was involved from the very beginning in

both cases as a wolf expert, we were able to document all stages of the decision process, and the exchange of information between local communities, regional and national authorities and other stakeholders involved. We also obtained copies of the decisions of the General Directorate for Environmental Protection (hereinafter GDEP), as well as documents issued by other authorities and institutions.

Results

Case #1

Within 2 weeks, attacks of a single wolf on three people occurred in two villages located 12 km apart in the Bieszczady Mts. (Fig. 1).

The first attack (June 12, 2018) took place about 10 p.m. on a private camping ground in Wetlina, a tourist village located in a narrow valley of the Wetlina river adjacent to large Carpathian forests. An adult woman coming back from a shower cabin to her tent heard an unusual sound and when looking back she noticed a wolf-like canid approaching her. Several seconds later the canid bit her in the calf. When she screamed, the canid started to run off. The alarmed owner of the camping came within few minutes and helped to chase away the animal. The bitten woman was taken to a hospital, and after necessary examination, anti-rabies vaccination and with wounds healing but without stitches, she came back to the camping site.

The second attack (June 26, 2018) took place about 7 p.m. The wolf bit an 8-year-old girl and 10-year-old boy playing outside in two different locations (several hundred meters apart) in Przysłop, a little village surrounded by forests. Their relatives quickly chased the wolf off. Both children had wounds on their legs, while the girl also had wounds on her buttock. They spent several hours in the hospital, got the necessary vaccinations and wound suturing and finally returned home.

In all these cases, no saliva samples from the wounds were taken for genetic analyses to identify the attacking animal.

Actions undertaken after attacks

After consultations with the wolf expert the General Director for Environmental Protection (GDEP, the national governmental agency responsible for wildlife management in Poland) issued on June 14, 2018, the decision for culling the wolf. However, despite it being observed in the adjacent villages, its presence was not reported to officers for the next 2 weeks, until the second attack occurred. One hour later, the wolf was shot in vicinity of the village by the local hunter having permission for its culling, from a distance of 6 m. Next day, an officer of the Bieszczady National Park (BNP) took

post mortem pictures, collected genetic samples and elaborated a preliminary report. After the cull, incidents with wolves attacking humans stopped abruptly in the area.

Post mortem analyses and characteristics of the wolf causing attacks

The shot wolf was a male. The officer of BNP and the veterinarian performing the necropsy assessed its age at 2–3 years, but later thorough examination of the skull and tooth, wear conducted by the authors (SN, RWM) revealed that the wolf was 13 months old. The animal was in a good shape, with a skin pattern typical for wolves and no signs of external parasites. All organs were of regular structure, without any evidences of diseases. The stomach was filled with the digested mass of leftovers, most probably eaten from garbage containers. The paws were regular and had the typical wolf black pads, without the fifth claws on the hind legs. The only anomaly was damaged, very short claws, unlike in other wild living wolves, but observed in dogs regularly walking on hard surfaces. Wounds and fractures, as well as broken canines, revealed during necropsy were caused by the shot from a short distance with a shotgun shell. The test for rabies was negative.

Genetic analyses proved that the shot wolf had no detectable dog ancestry and belonged to the local (Carpathian) population ($q = 0.98$; see Fig. 2 and Suppl. Tab. S1). Relatedness analysis identified his two putative full siblings: a male sampled in March 2016, 3.4 km from and a female sampled in October 2019 7.5 km from the place where the problem wolf was shot, which indicate that the wolf originated from a local pack. Another two wolves sampled in the same area were not identified as first-order relatives of the problem wolf, but they also belonged to the same wolf pack (possibly half-siblings or cousins) (see [Supplementary Material](#) for further details).

Wolf presence in the area prior to attacks

According to studies conducted by Pirga and Polakiewicz (2020), the area is overlapped by the edges of territories of two wolf packs called Ruska and Sina. In 2018, the Ruska

pack consisted of 12–14 individuals, including several pups, while the Sina pack was estimated as 5–7 individuals. Interviewed local citizens reported that a lone wolf—most probably the same one who later attacked people—was observed in the vicinity of five villages (Cisna, Przysłop, Krzywe, Wetlina and Smerek), located a maximum of 13 km apart, at least 4 months before the attacks, from February 2018. The wolf was tolerant to houses and positively food conditioned as it regularly visited human settlements searching for food in backyards of bars and households during daylight, and allowed people to approach him to a distance of ca. 10 m before retreating slowly. He was not approaching humans by itself. Once was observed when grabbing and killing a small dog. Four days before the first attack, he was spotted and chased away at the camp ground—the place of the attack. Then, it was filmed with a smartphone when walking between houses and along a main road in daylight in Wetlina village. Before the second attack, it roamed among houses in search of food in Smerek and Przysłop villages and was photographed from a car on a public road there.

Case #2

Two attacks by a single wolf on people have occurred in two small villages located 1 km apart at the north-western edge of the Noteć Forest, W Poland (Fig. 1).

The first attack (on July 21, 2018) occurred about 10 p.m. in Trzebiecz Młyn—the settlement including three houses at the edge of the Noteć Forest. A barbeque party for about 100 people was organised in the garden of the farm house near which a young wolf had been provided with leftovers from a kitchen for the previous 4 months. Before it started, the wolf was sitting near the gate on a dirt road bordering the forest and watched people arranging tables and stoves, but later, it disappeared. During the barbeque after dusk two adult women, relatives of house owners and familiar with the wolf went outside of the fenced garden onto the dirt road. During their walk a wolf approached from behind and grabbed the leg of one of them. She caught the animal by its mouth to get the leg out, but the animal grabbed her hand instead. Her companion

Fig. 2 Results of Bayesian clustering analyses confirming that both animals involved in the attacks were wolves belonging to their respective local populations. Bar plot shows merged STRUCTURE results at $K = 4$ (most probable number of clusters as suggested by the

Evanno method—see Suppl. Fig. S1). Each bar represents a multilocus microsatellite genotype of a single individual. Exact values of individual assignments to clusters could be found in Suppl. Table S1

carried a glass bottle and hit the animal's head. After that, the animal retreated and the women escaped to the garden. The bitten woman stated that she recognised the wolf which over several months had regularly visited the feeding place in front of the gate. She had several wounds on her leg and hands. She was taken to a hospital, where she spent several hours, got the necessary vaccinations, some wounds were stitched, and finally she returned home. No saliva samples from wounds were taken for genetic analysis.

The second attack happened 6 days after (on July 27, 2018), ca. 9 p.m. in the Bagniewo village, 1 km from the first location. A retired woman was bitten on her leg by a single wolf in her garden, near the house. The wounds were not severe. The neighbour of the woman, who was in contact with one of the authors (SN) since the first attack, took a saliva sample from around the wound for the genetic analysis. The woman went to a hospital, got the necessary vaccinations, wounds were dressed, stitches were not needed, and she returned home a few hours later.

Actions undertaken after attacks

The day after the first attack (Sunday, July 22), the location was inspected by experts from Association for Nature "Wolf", who installed camera traps in various places for further monitoring. Two days later, the location was visited by the RDEP officers. As some local citizens reported the presence of three different wolves in the vicinity of the village, after consultation with the wolf expert, GDEP issued an immediate decision to kill three wolves. Two local hunters were assigned to this task. Early morning after the second attack the wolf was shot at the edge of the adjacent forest (several hundred meters away) by the designated local hunter. At once, pictures were taken and sent via MMS to the wolf expert for species confirmation, as well as to GDEP and RDEP. After the cull, incidents with wolves attacking humans stopped abruptly but local inhabitants reported wolf sightings in the area for several weeks. Further camera trapping revealed the presence of a large German shepherd dog freely roaming among houses, but no wolves.

Post mortem analyses and characteristics of the wolf causing attacks

The wolf who caused the attacks was a female. Her age, based on teeth wear, was estimated at 14 months. The wolf weighed 30.7 kg, her belly was unusually large, but the stomach weighed only 0.8 kg and was filled with remains of a roe deer and plant debris. Her appearance (including the large belly) was identical with the wolf recorded several days after the first attack on the camera trap installed at a gate of the farm house where the attack occurred.

Her coat had typical colouration for European wolves with no signs of sarcoptic mange, but with numerous ticks (*Ixodes* and *Siphonaptera*). The paws were typical for wolves with black pads and black long and sharp claws, and without the fifth claws on the hind legs. Under the skin, there was a thick layer of adipose tissue (from 2.6 cm in an axil area to 2.9 cm in a spine area). Skin muscles were firmly stuck with fat. All organs, except for the spleen, were of regular structure, without any evidence of disease, but were coated with fat tissue. The spleen was abnormal—instead of the regular organ, there were 12 splenic nodules with diameters between 5 and 33 mm (polysplenia), and no artery or splenic vein were found. Massive deposits of fatty tissue were also in the area of the bladder, the bulging part of the spine and the entire length of the white line. The small uterus and ovaries were also surrounded by adipose tissue. The size and pale colour of those organs as well as very small, almost undetectable nipples and small vulva revealed that the female had not yet been on heat or given birth. Teeth were very sharp, not worn, but with about 0.3 cm of tartar on premolars and molars. The only wounds and fractures were caused by the shot from the hunter's gun.

Genetic analyses confirmed that the shot canid was the wolf causing the second attack (100% match in all microsatellite loci between its tissue sample and the saliva sample taken from the wound of a second attacked woman). The female had no significant dog ancestry ($q_{\text{wolf}} = 0.96$) and belonged to the Central European population ($q = 0.77$) (Fig. 2; Suppl. Tab. S1). Relatedness analysis identified her two putative full siblings: a female sampled a day after the incident (July 22, 2018) 1.2 km away, and a second female sampled January 22, 2019, 5.8 km from the location where the wolf was shot. It clearly indicates that the shot female originated from the local pack (see [Supplementary Material](#) for further details).

Wolf presence in the area prior to attacks

As was revealed by our tracking and camera trapping, in the vicinity of both villages, there was an edge of the territory of a newly formed wolf pack accounting for 11 individuals including two breeders, one subadult and 8 young in 2018. The pup rearing area of this group was located 2–3 km from these settlements. In summer 2017, the same wolf pair had their first litter close to the camping grounds at the lake. These pups were discovered by local foresters and forest workers.

In summer 2018, inhabitants from both Bagniewo and Trzebiec Młyn villages reported that a young wolf appeared near their households at least in early March 2018. As time progressed, it was increasingly habituated and positively food conditioned and was not afraid of people, approaching them to a distance of less than 30 m and in some cases only several meters. It was also observed and filmed from cars moving on

the local public road linking both villages. The wolf foraged among houses, entered gardens and searched for leftovers and garbage. It killed at least one village dog taking it from a backyard. The owner of the house where the first attack occurred provided the wolf with leftovers from her kitchen for several months. Food was delivered to a ground hole under trees on a side of the dirt road at the front of the garden gate, where later the attack took place. The wolf regularly visited the food location on afternoons or evenings. When nothing was there, the wolf took to sitting 2–3 m from the gate and waited for leftovers.

Reaction and actions of local citizens in both cases

Although both in case #1 and case #2, these wolves were frequently observed searching for food in the backyards of houses and other buildings for about 4 months before attacks, those incidents were not formally reported to any agencies responsible for wildlife management. In case #2, some of the interviewed local inhabitants, however, claimed that they had spoken informally with local foresters and police about the presence of strange wolves. Very rarely people attempted to scare away or discourage a wolf which appeared near their houses, more frequently they just filmed the animal with their smartphones and posted videos and photos on social media. Some of those materials were then published by the local online media or by local public television stations. In case #2, these materials were forwarded to wolf experts with request for advice only 2 days before the first attack. Experts recommended an immediate submission of formal information about the wolf to RDEP and the local community office for urgent intervention.

Discussion

The reconstruction of predator attacks on people is based on data with varying certainty, from statements delivered by victims and witnesses, through indirect signs of the predator's presence, like tracks or faeces, up to hard facts like results of genetic analysis and necropsy or videos and photos. While testimonies in legal procedures play an important role (Walton 2007), in standards of large carnivores monitoring, if these are not accompanied with photos or videos, they are treated as unconfirmed observations (C3 data category, Reinhardt et al. 2015). Victim and witness testimonies are affected by numerous psychological and environmental factors (Yuille and Cutshall 1989; Albright 2017), which should be taken under consideration when interpreting wolf attacks on humans. For example, in the case #2, an interviewed inhabitant claimed that he saw a big black wolf several times from his window, while our camera traps recorded a large black-backed dog roaming in the vicinity. This is why in such

cases the early introduction of camera traps to monitor the area visited by animals behaving strangely, collecting genetic samples, both from victims (wounds and clothing) and from predators (Caniglia et al. 2016) as well as conducting necropsy of dead animals is so important.

Without a doubt, the wolves which caused the attacks on humans in Poland were young individuals: 13–14 months old during attacks and 8–9 months old when they appeared in the vicinity of households. Both were offspring of local wolf packs. Although wolves usually keep their distance from human settlements (Kaartinen et al. 2005; Bassi et al. 2015; Carricondo-Sanchez et al. 2020), young or dispersing individuals are more likely to approach houses than territorial adults. Despite this, wild-living wolves usually do not show bold behaviour towards people and do not seek food among buildings during daylight (Karlsson et al. 2007; Kojola et al. 2016; Mancinelli et al. 2019). Such unusual behaviour might be connected with earlier regular contact with humans and being rewarded with food resulting in habituation and/or positive food conditioning (LCIE 2019). Both possibilities were considered when searching for explanation for wolf attacks on people in Poland.

In case #1, the young male wolf displayed the behaviour typical for positively food conditioned and habituated individuals, in searching for food he operated in a quite large area along a 13-km-long section of a local road in the Bieszczady Mts. He did not appear regularly in the same place and until the first attack did not approach people intentionally. We observed similar habits in a 10-month-old female wolf that was most likely taken from a denning area as a very young pup and kept for several months by people and freed. The young was found in late November in suburbs of a mid-sized town and moved to a rehabilitation centre. Because her origin was unclear and she was timid in the centre, she was radio-collared and released to a distant large forest tract together with an adult male wolf in early March. After releasing she moved immediately to a town located at the forest edge and lived there for weeks, foraging at night in backyards and waste containers but also killing some roe deer on green suburbs. Although she frequently walked during daylight and observed people from a distance, she retreated when approached too closely (on less than 30 m) by humans. Finally she was captured and returned to an enclosure (Nowak and Mysłajek, unpublished).

Taking wolf pups from the natural environment and keeping by a private person is illegal in Poland. Nonetheless, in recent years at least one or two such incidents per year have been recorded, some of them for profit but others to rescue an “abandoned or sick” young. As growing wolf pups often become a nuisance for illegal keepers, they release already habituated young back to nature (Nowak and Mysłajek 2019). Such an incident was also reported by a local inhabitant of Wetlina, the location of the first attack in the Bieszczady Mts.,

but as people are afraid to report neighbours, we are unable to confirm it. However, it may be a very probable explanation of the appearance of an already habituated and food-conditioned young wolf originating from a local pack near houses in late winter. The second explanation could be positive food conditioning caused by feeding at baiting places for large carnivores set by locals to rent to wildlife photographers and watchers. Numerous such baiting places are regularly supplemented with remains of domestic and wild animals, with some of them being in close proximity to villages in the Bieszczady Mts. (Pirga and Polakiewicz 2020). These sites are frequently attended by wolves and bears, including females and their young. There are also unprotected compost heaps of leftovers in the backyards of restaurants, guesthouses and camp grounds found in tourist villages in this region. Wolves are observed to feed on them regularly. Therefore positive food conditioning as well as associating humans with food delivery is a very likely reason for appearing of young wolves in the vicinity of human settlements in the Bieszczady Mts. As a result, although the whole Polish Carpathians and almost all the Polish lowlands are inhabited by wolves (Nowak et al. 2017; Szewczyk et al. 2019), conflicts with large carnivores (wolves and bears), are much more frequent in the Bieszczady Mts. than in other parts of Carpathians and the rest of Poland (Domańska et al. 2018).

As in case #2, several wolf pups were observed by forest workers in summer 2017 near the camping grounds at the lakes, a few kilometres from the location of the attacks; it is very likely that tourists or local inhabitants intentionally provided food for these young or they fed occasionally on leftovers from waste bins. However, the more important factor which might have provoked and enhanced the food conditioning in this young wolf female was the abnormality of her spleen (polysplenia) which prevented this organ from acting properly. In highly aerobic mammal species, e.g. seals, hunting dogs or racing horses, the spleen acts as a blood reservoir (Barcroft and Pole 1927; Barcroft and Stephens 1927). Sympathetic-mediated splenic contraction during intensive exercise reversibly enhances convective O_2 transport by increasing circulating haematocrit, blood volume and O_2 -carrying capacity but also augments diffusive O_2 transport in the lung (Dane et al. 2006). These mechanisms allow the animal to achieve supra-high exercise capacities. Splenectomy impairs these mechanisms and negatively impacts the fitness of animals that depend on a high O_2 delivery for survival (Wagner et al. 1995). Wolves are wild ancestors of dogs (Frantz et al. 2016). Their survival, territory maintenance and hunting success depend on the ability to mobilise the body to large physical exertion during hunts, intraspecific strife and long-distance movement within their large territories (Mech and Boitani 2003). The importance of the spleen must be at least the same in wolves as in hunting dogs. Thus, the significant abnormality of the spleen that impaired both the

collection of blood and contraction of the spleen during exercise, very likely negatively influenced fitness of the wolf. It satisfactorily explains the reason for staying close to the homesite of the pack, while the rest of the growing young in late winter started to follow the parental pack. The regular presence of leftovers delivered for several months near a household in vicinity of the wolf home site combined with the lack of actions by people to deter the wolf, developed and strengthened the positive food conditioning, habituation and then in consequence the bold behaviour in this young female. Her obesity revealed by necropsy also suggests that her fitness was poor and she had inhibited movement, which resulted in her gaining weight from early on in her life. On the day of the first attack she probably expected some leftovers in the feeding site but when nothing was there, she became pushy and impudent towards the women coming out of the garden. Similar behaviour was observed by Mech (2017) in a free-ranging male wolf that was food-conditioned on the Ellsmere Island. The presence of remains of roe deer in the female wolf stomach, a dead roe deer found close to houses during our field survey and observations of other wolves in vicinity may suggest that her pack mates were visiting and delivering her prey but irregularly. We recorded such behaviour in wolf parental pairs where young were heavily infected with sarcoptic mange and could not follow the rest of the pack.

In a modern human-dominated landscapes of Europe where wolf populations are increasing (Chapron et al. 2014), some may expect numerous examples of strongly habituated, food conditioned or even bold wolves that appear near human settlements and cause problems or attack people. However, outside of fake news in media, there are few well documented reports on such behaviour (Linnell and Albeau 2016). The most recent and comprehensive survey includes 12 documented cases between 2004 and 2017 in Germany (Reinhardt et al. 2020), however more of these were connected with the presence of sick individuals near households and wolves attempting to mate or fighting with dogs in the presence of humans. In the remaining four cases where three offspring of the same pack (called the Munster pack) were involved and in the fourth where a yearling male wolf originating from the Lower Silesian forest in Poland was involved, wolves exhibited a prolonged high tolerance to humans and cars, diurnal activity and positive conditioning. In case of the wolf from the Lower Silesian forest our camera trap recorded him several months before, in January 2016, as a heavily obese offspring of the local pack. That would prove that this young was provisioned with food by humans. There were some information on feeding by people also wolves from the Munster pack in their early life but impossible to confirm. Reinhardt et al. (2020) concluded that based on the current knowledge on factors leading to the development of such behaviour in wolves, their strong habituation and positive conditioning was caused by people behaving wrongly.

Similarly increasing habituation was observed in eastern Switzerland, where wolves from the Calanda pack were regularly observed approaching and staying close to humans, and part of those close-up observations were related to bait sites used for red fox hunting (Huber et al. 2016).

Linnell et al. (2002) categorised wolves attacking humans as (1) rabid wolves, (2) predatory wolves and (3) defensive attacks. As the negative tests for rabies as well as the observer interviews revealed the Polish cases do not fit into the first and third category. Furthermore, these attacks are also hard to clearly qualify as predatory, as all were mild, focused on legs and buttocks and caused by immature individuals. It is hard to state if these wolves would have escalated the aggressive behaviour causing more serious or even lethal attacks, like those described by Linnell and Allean (2016) or once maturing they would have switched to be more suspicious and timid (Kojola et al. 2016). For sure, the young female was disabled because of polysplenia and somehow forced to artificial feeding to survive. The reason for the young male food conditioning and habituation is uncertain, but if he was a young individual raised by humans, on maturing, his aggressiveness could have developed similarly to some tame wolves in enclosures or dogs. Also in a free-ranging wolf prolonged food conditioning could lead to increase of aggressiveness as was observed by Mech (2017) on Ellsmere Island. Reports from Alaska and Canada revealed that habituation contributed to the majority of wolf aggression towards people (McNay 2002).

In both Polish cases, the aggressive incidents were preceded by several months of interactions between inhabitants and wolves. In the German cases (Reinhardt et al. 2020) wolves had not expressed aggressiveness towards people which suggests that immediate reaction and introducing mitigation measures such as warning and education of inhabitants, removal of possible food attractants, stopping intentional feeding, introducing aversive conditioning such as deterring with dogs or rubber bullets and at the end removal of the most bold individuals, may eliminate any threat for local inhabitants and enable them to avoid attacks.

Detailed rigorous analyses of factors which led to every conflict situation would help to develop good practices for various human activities conducted in areas inhabited by wolves, such as forestry, farming, tourism, recreation, hunting, wildlife watching and photography. Without doubt proper management of waste from households, food markets, restaurants and camp grounds and livestock breeding farms, as well as a ban on baiting for hunting or photographic purposes, should be treated as an important solution for mitigation of conflicts between wolves and humans, especially in areas densely populated like Central and Western Europe (Morehouse and Boyce 2017; Newsome and Van Eeden 2017; Plaza and Lambertucci 2017). In a longer timescale,

also the education of wide public on rules of co-existence with large carnivores including science-based knowledge on wolf ecology would be very important, explaining the differences between natural and unnatural behaviour, the proper reaction in cases of unintentional or deliberate actions leading to wolf habituation, as well as guidance on how to behave in close encounters with wolves (Nowak and Mysłajek 2019; Reinhardt et al. 2020).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10344-020-01455-1>.

Acknowledgements We thank Antoni Kasprzak, Wojciech Ostapowicz, Hanna Witerek, Marek Witerek, Monika Zamojska and Honza Zamojski for their help in the field work. We also thank the General Directorate for Environmental Protection, Regional Directorate for Environmental Protection in Rzeszów, Regional Directorate for Environmental Protection in Gorzów Wielkopolski, Bieszczady National Park (Bartosz Pirga), Provincial Veterinary Inspection in Zielona Góra, County Veterinary Inspection in Sanok and Karwin State Forest Division for co-operation and providing us with documents, pictures, results of rabies tests and wolf necropsy. We are grateful to Dr. Chris Young for the English corrections. We applied the “first-last-author-emphasis” norm for the sequence of authors.

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