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Do urban red foxes attack people? An exploratory study and review of incidents in Britain

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Abstract: Human–wildlife interactions are believed to be increasing worldwide, and a number of studies have analyzed the risks posed by larger carnivores. However, people can also perceive smaller species of carnivores as threatening, particularly in urban areas. Red foxes (*Vulpes vulpes*) started to colonize British cities in the 1930s, and there is growing public concern about foxes biting people, particularly babies. These events are generally described in the press as attacks and generate intense media coverage and speculation that foxes view human infants as potential prey. Because foxes rely primarily on auditory cues for hunting, we conducted acoustic playback experiments in the gardens of 15 residential houses in northwest Bristol, United Kingdom, in December 2015 and 11 gardens from May to June 2016 to determine whether urban foxes were attracted to infant distress calls (cries). Foxes were not more likely to be attracted to infant cries or laughs than silence, although a minority of foxes cautiously approached and contacted the source of both types of infant vocalization. Their behavior appeared to be investigative rather than aggressive or predatory. Our review of the incidents reported in the British media showed that most people were bitten or scratched while sleeping, and adults were more likely to be bitten than children. The nature of the interactions and the wounds inflicted suggest that the foxes were using their mouth or forefeet to investigate an unusual object. Most incidents occurred inside people's homes, even though it is unusual for foxes to enter houses. The data suggested that incidents where people were bitten were chance events, possibly involving a particularly bold fox. To minimize the risk to the public, more quantitative data are required on the age, social status, and health of the foxes that enter houses and those that bite people.

Key words: canid attacks, dominance, human–wildlife interactions, infant vocalizations, investigative behavior, playback experiments, red fox, United Kingdom, urban carnivores, *Vulpes vulpes*

Human–wildlife interactions are complex, and our inability to control or predict wildlife behavior enhances human perceptions of risk (Armfield 2007, Johansson and Karlsson 2011), especially for potentially dangerous carnivores (Røskaft et al. 2003, Dickman 2010, Johansson and Karlsson 2011, Linnell and Alleau 2016). Physical contact with humans that results in injury or death evokes strong emotional reactions and intense media coverage (Dickman 2010), which often focuses on the consequences of predator attacks while ignoring the low probability of these attacks occurring (Bruskotter and Wilson 2014). The frequent use of inappropriate language in the media amplifies the public perceptions of risk (Alexander and Quinn 2011, Frank and Glikman 2019), spreads moral panic (i.e., the perception that something is threatening the well-being of society [Gröling 2016]), and causes people to overlook a species' aesthetic, ecological or economic benefits (Bruskotter and Wilson 2014). Published and online media therefore plays a critical role in shaping public opinions about incidents involving predators (Siemer et al. 2014, Bombieri et al. 2018*a*).

Recent studies have assessed the potential dangers posed by wild carnivores living in close proximity to people (Penteriani et al. 2016, 2017; Bombieri et al. 2018*b*). Canids are commonly associated with injury to people (Schmidt and Timm 2007), and even small species can be perceived as threatening (König 2008). While pet and feral dogs (*Canis lupus familiaris*) cause the vast majority of human injuries (Gilchrist et al. 2008), some are caused by 3 wild canids that associate with humans: coyotes (*C. latrans*), dingoes (*C. l. dingo*) and red foxes (foxes; *Vulpes vulpes*; Schmidt and Timm 2007, Cassidy and Mills 2012). Coyotes and din-

goes hunt medium-sized to large prey, whereas red foxes are specialist predators of small rodents (Slater et al. 2009), although they occasionally take prey weighing up to 5 kg (Baker and Harris 2003).

Coyotes occupy urban areas throughout their range (White and Gehrt 2009), and there are frequent reports of attacks on infants and small children as well as aggressive behavior toward adults (Timm and Baker 2007). Coyote interactions with humans may be defensive, investigative, or predatory (Schmidt and Timm 2007), although most are predatory (White and Gehrt 2009). Predatory injuries, such as extensive bites to the head and neck and victims being dragged away generally involve children, the majority of which are attacked while playing alone in their garden (Howell 1982, Carbyn 1989, White and Gehrt 2009, Alexander and Quinn 2011, Baker and Timm 2017, Bombieri et al. 2018*b*).

Most recent dingo attacks have occurred on Fraser Island, Australia, a popular tourist destination. A 9-year-old boy was killed by 2 dingoes in 2001 while playing with his brother (Burns and Howard 2003, Edgar et al. 2007), and 4,166 incidents were reported on the island between January 2001 and September 2013, 24% of which involved aggressive or dangerous behavior by dingoes (Allen et al. 2015). The general consensus is that feeding by humans habituated the Fraser Island dingoes (Allen et al. 2015), although this has been disputed (O'Neill et al. 2016).

Red foxes started to colonize British cities in the 1930s (Harris and Rayner 1986) and have a long history of living in close proximity with people. Although even very young infants are outside their normal prey size, incidents involving foxes biting children are generally described in the press as predatory (Cassidy and Mills 2012) and are invariably accompanied with the warning that it is necessary to start culling urban foxes before a child is killed (e.g., Crowden 2013). Currently, there is no formal policy of fox culling in British cities, although some householders employ private contractors to trap or shoot the foxes that visit their garden.

Most incidents involving children occur in houses. Why foxes enter houses is unclear: media reports often state that the foxes were foraging and/or attracted by the smell of food or odors associated with babies, such as milk or soiled diapers. However, red foxes have a poor sense of smell (Österholm 1964) and use auditory rather than olfactory cues for hunting (Österholm 1964, Isley and Gysel 1975, Červený et al. 2011). Therefore, if foxes are attracted to babies as potential prey, it is more likely that they would respond to vocal rather than olfactory cues. Hunters, for instance, mimic the distress calls of potential prey to lure foxes within shooting range (Morse and Balser 1961, Bucknell 2010).

Furthermore, there is considerable overlap in the fundamental frequencies and ranges of sensitivity of the infant distress calls of different species of mammals (Newman 2007, Belin et al. 2008, McComb et al. 2009, Lingle et al. 2012, Teichroeb et al. 2013), and mammals may investigate the distress calls made by infants of unrelated species (Lingle and Riede 2014). Domestic dogs, for instance, may whine, howl, or show other signs of distress when a human baby cries, sometimes referred to as emotional contagion (Yong and Ruffman 2014). This primitive form of empathy is more frequent in female dogs (Katayama et al. 2019), and it is possible that foxes could be attracted to crying babies for similar reasons.

Understanding animal behavior is central to assessing the potential risks posed by a species and improving management decisions (Blackwell et al. 2016, Tablado and Jenni 2017). However, despite the media interest, we know very little about the circumstance in which foxes enter houses and bite people, or the frequency of such events. Because foxes rely primarily on auditory cues for hunting, we used playback experiments in residential gardens in an urban area to determine whether foxes are attracted to infant vocalizations, particularly distress calls (i.e., "crying"), and reviewed published media reports to analyze the circumstances in which people are bitten by foxes.

Study area

We conducted acoustic playback experiments for 4 consecutive nights in the gardens of 15 residential houses in northwest Bristol, United Kingdom (UK) in December 2015 and 11 gardens from May to June 2016; 4 gardens were only used in December (Figure 1). This was the site of a 40-year intensive study on red fox ecol-

Figure 1. The location of the city of Bristol, United Kingdom, and the study area in the northwest of the city (*courtesy of Google Maps*).

Figure 2. A suburban garden typical of those used in the acoustic playback experiments, northwest Bristol, United Kingdom, December 2015 and May to June 2016.

ogy and behavior, so we had a long-term record of fox territorial boundaries (Dorning and Harris 2019*a*). Each house was located within the territory of a different social group of foxes, and trials were conducted concurrently at the 3 or 4 sites closest to each other to minimize the possibility that foxes were exposed to the same vocalizations on another night. However, foxes forage in neighboring territories (Dorning and Harris 2019*b*), so it is possible that some foxes were exposed to the treatments in different gardens. Each house had a rear garden with a lawn area ≥10 m^2 that was not surrounded by thick vegetation or large trees (Figure 2). Dried dog or other food was provided each night between 1700 and 2000 GMT/BST (Greenwich Mean Time/British Summer Time) for ≥10 days prior to the experiment to encourage visits by the foxes.

Methods

Selection of vocalizations

Infant laughing and comfort vocalizations have a similar sharp onset and fundamental frequency to distress cries (Kent and Murray 1982, Rothgänger 2003) and were used to determine whether foxes were responding to distress calls or any baby vocalization. From video recordings with high sound quality (https://www.youtube.com), we extracted infant distress and comfort vocalizations that lasted >30 seconds, involved a single infant <1 year old, and had minimal background noise. Typically, infant cries get louder and higher in pitch as the infant becomes more distressed (Lingle et al. 2012, Zeskind 2013). Infant laughs included comfort sounds such as babbling, goos, grunts, hics, laughing, raspberries, whooping, and yawns (Scheiner et al. 2002, Buder et al. 2013).

Audio files were downloaded and processed using Audacity (https://www.audacityteam.org/). One-hour sound files were created by cutting and pasting the cry or laugh bouts of a single infant: we included sounds of breathing at the beginning and end to reduce unnatural intervals. Background noises were removed, the amplitude was normalized to -1 dB, and the tracks were saved as MP3 files.

Experimental design

The experiments were undertaken between 1800 and 1900 GMT in December and between 1930 and 2030 BST in May and June; these time periods coincided with peak foraging activity (Dorning and Harris 2017). Tracks were played for 1 hour to maximize the opportunity for foxes moving around their territory (typically ≤20 ha in size) to hear and respond to the vocalizations. Infant vocalizations were played through a portable, waterproof outdoor speaker with a frequency response range of 100–20,000 Hz (Omaker M4 Portable Bluetooth 4.0 Speaker, Omaker, Dallas, Texas, USA). The speaker was encased in a wire mesh cage fixed to the ground with a tent peg, and a dog toy attached to the

Figure 3. Left: speaker encased in wire-mesh cage on a garden lawn with the toy in position. Right: closed-circuit television (CCTV) camera fixed to a 2-m wooden pole adjacent to the garden lawn, acoustic playback experiments, northwest Bristol, United Kingdom, December 2015 and May to June 2016.

cage with duct tape so that foxes could interact with the source of the sound (Figure 3). The toys were washed between sites with a scentless detergent to remove any potential scent cues.

A waterproof MP3 player placed inside the cage was attached to the speaker via an auxiliary cable (SanDisk Clip Sport, Western Digital Technologies Inc., Milpitas, California, USA). The speaker and MP3 player settings were set to maximum volume for all trials to reflect the amplitude of human baby vocalizations. Food was placed >1.5 m from the speaker 30 minutes before each trial. Sound tracks were then switched on and began with 30 minutes of silence to minimize disturbance effects. Foxes were unlikely to be influenced by human scent because of the high levels of human activity in the study area (average human density 30/ha). We recorded fox behavior using 2 closed-circuit television (CCTV) cameras fixed to 2-m wooden poles secured with buckets of gravel (Figure 3) and connected to a digital video recorder (Home Guard DIY CCTV kit, Storage Options, Castleford, UK). We used 2 video cameras because views from different angles facilitated interpretation of behavior (Padovani 2015). However, individual fox identification is difficult without high-quality color images (Dorning and Harris 2019*c*). While we were able to recognize most animals that visited a garden during each trial, this was difficult between gardens and seasons.

On the first night, no sounds were played and no behavior recorded to allow the foxes to habituate to the equipment. We did not use a longer habituation period because urban foxes experience daily changes in their environment. On the second night, the speakers and video equipment were turned on but no sounds broadcast, and any fox behavior recorded to provide a control to compare any behavioral changes during the treatments on nights 3 and 4. We flipped a coin to decide whether laugh or cry vocalizations were played on the third or fourth night, and tracks were only used once per season.

Behavior recording

We undertook a pilot study in November 2015; infant laughs and cries were played for 30 minutes on 2 consecutive nights in a garden not

Table 1. Summary of the models used during stepwise deletion, red fox (*Vulpes vulpes*) acoustic playback experiments, northwest Bristol, United Kingdom, December 2015 and May to June 2016.

Model number	Description of model
Model 1	Response variable and its relationship with treatment, wind speed, and rain
Model 2	Response variable and its relationship with treatment and wind speed
Model 3	Response variable and its relationship with treatment
Model 4	Response variable ~ 1

used in the main study. From this we selected the following response variables for the main study: (1) whether a fox visited the garden during the trial hour; (2) the number of seconds a fox remained in the garden; (3) the number of seconds a fox remained alert to the speaker; (4) whether a fox approached the speaker; and (5) whether a fox made contact with the cage containing the speaker or the toy. During the pilot study, foxes tilted their head from side to side when approaching the speaker. Because this is characteristic of a fox paying particular attention to the source of a sound (Červený et al. 2011), we used it to decide whether a fox was alert to, and approaching, the speaker rather than the food or moving elsewhere.

Although we recorded continuously throughout the night, we only analyzed fox behavior during the trial (control [i.e., when no sounds were played] and treatment) hours. For consistency, all the data were extracted from the videos by B. Bridge: data extraction was blind (i.e., she did not know whether the video was a control or treatment hour). Videos were reviewed at 16-speed using Windows Media Player 12 (Microsoft Corporation, Fort Collins, Colorado, USA), and when a fox entered the frame, the tape was replayed slowly and information from both cameras used to record the response variables. All timings were in seconds. In May and June, we excluded any cubs. If 2 foxes were present during the trial hour, their behavior was recorded separately. Since weather could have influenced both animal behavior and the distance over which sounds were transmitted (Wiley and Richards 1978, Cresswell and Harris 1988, Snoeks et al. 2015), we obtained wind and rainfall data, in standard categories (https://www.timeanddate.com/).

No foxes were captured or handled for this project. The study was observational and approved by the University of Bristol's Animal Welfare and Ethics Committee (UB/14/015).

Statistical analyses

We used generalized linear mixed models (GLMMs) in R (R Core Team 2015) to include random effects. Of the 5 response variables, approach to the speaker and contact with the speaker or toy occurred infrequently and were excluded from the analyses. Explanatory terms were site, season, treatment, rainfall, and wind. Since it was possible that individual foxes were tested in both seasons and multiple times, site and season were both included as random effects to mitigate possible effects of pseudoreplication. This was because, while tracks were not used at the same site in both seasons, we were not always able to identify individual foxes and could not be sure that a fox was not exposed to the same tracks on another territory.

The data were over-dispersed and zero-inflated, so we used a hurdle model, package *glmmADMB* (Fournier et al. 2012, Skaug et al. 2018) to determine whether treatment affected the likelihood that a fox entered the garden, and then analyzed the positive counts to determine whether the fox stayed in the garden for longer or was alert to the speaker for longer (O'Hara and Kotze 2010). We used Akaike's information criterion (AIC) to determine whether the models were a good fit. Stepwise deletion using likelihood ratio tests was used to determine which models explained the most variation in the data for both parts of the hurdle models separately. Sample sizes were 26 sites in the presence model and 16 sites in the alertness model. The models are summarized (Table 1); the process was repeated for each of the 3 response variables. Effect sizes for the different treatment groups were calculated using Cohen's *d*.

Review of media reports

We entered the search terms "UK fox attacks," "UK fox attacks on babies," and "Do foxes attack people UK" into Google to identify local and national published media (i.e., we did

Table 2. Summary of the data collected in all 15 gardens in December 2015 and 11 gardens from May to June 2016, red fox (*Vulpes vulpes*) acoustic playback experiments, northwest Bristol, United Kingdom.

	Control trials	Cry trials	Laugh trials
Total number of trials	26	26	26
Number of times foxes were present	3	6	7
Mean number of seconds foxes were present	25.6	69.1	75.0
Mean number of seconds foxes were alert to the speaker	1.6	5.3	21.9
Number of times a fox approached the speaker	0	3	2
Number of times foxes made contact with the speaker	0	1	1

Table 3. Effect sizes with 95% confidence intervals (CI) for each treatment, calculated using Cohen's *d*, red fox (*Vulpes vulpes*) acoustic playback experiments, northwest Bristol, United Kingdom, December 2015 and May to June 2016.

Response variable	Effect size of cry treatment	Lower 95% CI	Upper 95% CI	Effect size of laugh treatment	Lower 95% CI	Upper 95% CI
Presence	0.269	-0.125	0.657	0.340	0.059	0.733
Number of seconds present	0.051	-0.752	0.850	0.072	-0.672	0.811
Number of seconds alert to speaker	-0.119	-0.992	0.769	0.421	-0.437	1.242

not include social media) reports of spontaneous or non-provoked events where foxes bit or scratched people in the UK in the decade 2010 to 2019. We excluded incidents where people were bitten after interacting with a fox, such as when trying to catch it or drive it from their house, because the behavior of the fox could be interpreted as defensive. Similarly, we excluded food-associated incidents, such as when people were trying to feed a fox or carrying bags of food. Media reports of incidents were generally sensationalized and often provided conflicting details, so we collated data from several accounts of each incident to establish the locality, age, and sex of the person involved, where on their body they were bitten or scratched, and the circumstances of the incident.

Results

Data collection

Data collection is summarized for control, cry, and laugh trials (Table 2). Foxes were not in the garden immediately prior to the onset of any trial and were generally alone, although 2 foxes were present at 1 site in winter during the cry treatment, and 2 foxes were present at another site in summer during both treatments.

Wind speed was a gentle breeze (i.e., 12.9–19.3 kph) for 65% of trials and did not exceed a moderate breeze (i.e., 20.9–29.0 kph) in May or June or a fresh breeze (i.e., 30.6–38.6 kph) in December. Of the 13 trials with rainfall, it was light (<1 mm) for 12 trials and heavy (<4 mm) for 1 trial in December: the 2 categories were combined for the analyses. Rainfall did not affect whether foxes were present, but they stayed for 1.3 seconds longer on average than on dry nights ($P = 0.042$, df = 1 when the control trials were excluded). Treatments had either no or small effects on the response variables (Table 3).

Presence of foxes

Rainfall ($P = 0.273$, df = 1), wind speed ($P = 0.723$, df = 3), and treatment group ($P = 0.819$, df = 2) had no effect on whether foxes were present at sites during the trial hour (Figure 4). Rainfall influenced the length of time foxes were present across all treatments ($P = 0.013$, df = 1), but there was no effect of wind speed ($P = 0.431$, df = 2) or treatment group ($P = 0.734$, df = 2).

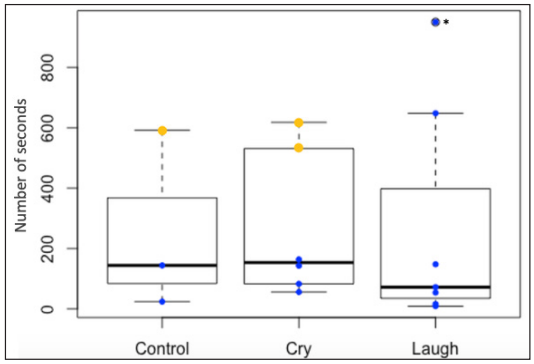

Figure 4. Boxplots of the time (seconds) red foxes (*Vulpes vulpes*) were present during each trial across all acoustic playback experimental sites, northwest Bristol, United Kingdom, December 2015 and May to June 2016. There were no differences between the 3 groups. The boxes indicate the median and the upper and lower quartiles of the data; the whiskers extend 1.5 times the interquartile distance. Asterisks indicate outliers, the yellow circles nights with rain and the blue circles nights with no rain.

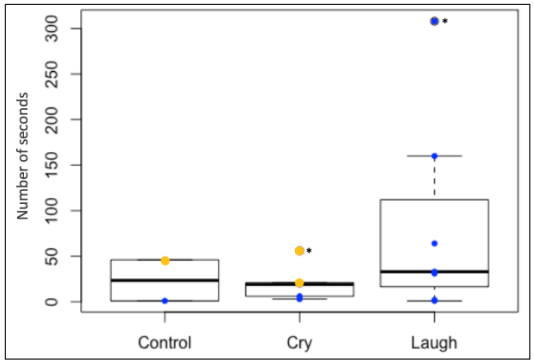

Figure 5. Boxplots of the time (seconds) red foxes (*Vulpes vulpes*) remained alert to the speaker during each trial across all acoustic playback experimental sites, northwest Bristol, United Kingdom, December 2015 and May to June 2016. There was no difference between the 3 groups. The boxes show the median and the upper and lower quartiles; the whiskers extend 1.5 times the interquartile distance. Asterisks indicate outliers, the yellow circles nights with rain and the blue circles nights with no rain.

Alertness to the speaker

Of the 3 control trials where foxes were present, a fox was alert to the speaker on 1 occasion, for 46 seconds. Foxes were alert to the speaker on 5 of 6 of the cry trials for which they were present, although only for 3 seconds on 1 occasion. Foxes were alert to the speaker on 6 of 7 of the laugh trials, although only for 2 seconds on 1 occasion. On average foxes were alert to the speaker for 6% of the time they were present during the control trials, 8% during the cry trials, and 29% during the laugh trials, although this included an outlier of 308 seconds; excluding this, foxes were alert for 23% of the time they were present during laugh trials (Figure 5). Rainfall ($P = 0.647$, df = 1), wind speed ($P = 0.866$, df = 2), and treatment group ($P = 0.603$, df = 2) had no effect on how long foxes were alert to the speaker during the trial hours.

Rainfall influenced whether foxes became alert to the speaker ($P = 0.032$, df = 1), whereas wind speed ($P = 0.691$, df = 3) and treatment group ($P = 0.188$, df = 2) did not. Foxes were 4 times more likely to become alert to the speaker during trials with rain (coefficient -4.382), but rainfall did not affect the amount of time foxes were alert to the speaker. When the control trials were excluded, rainfall did not affect the likelihood that foxes became alert to the speaker ($P = 0.438$, df = 1).

Approaching and contacting the speaker

Foxes approached the speaker 3 of 6 times during the cry trials and 2 of 7 times during the laugh trials; they did not approach the speaker during any of the control trials. A single fox made contact with the speaker on 2 occasions, once during the cry trials and once during the laugh trials in the same garden. No fox contacted the toy during the trails, but some did so at other times.

Review of media reports

We identified 23 cases of foxes biting or scratching people in the decade 2010 to 2019 (Table 4); we only located reports of incidents in mainland Britain. Of the 6 incidents involving infants in their own home, 4 of the children were ≥2 years old, and there were equal numbers of boys and girls. We did not include incidents where foxes investigated but did not scratch or bite the child. For instance, in September 2013, a mother in Clapham, London, UK found a fox licking the face of her 6-year-old daughter while she was asleep. Eight adults (7 women, 1 man, age range 22–77) also were bitten in their own homes, and 9 people (7 men, 1 woman, and 1 boy, age range 3–83) were bitten or scratched outside their homes. Of these, 3 men had fallen asleep while drunk (in 1 case, the fox bit/pulled at the man's trousers but he

Table 4. Summary of the media reports of incidents where red foxes (*Vulpes vulpes*) bit or scratched humans spontaneously in the United Kingdom, 2010 to 2019.

Date	Locality	Habitat	Details of incident
Children bitten inside their home			
June 2010	Hackney, London	Urban	9-month-old twin girls repeatedly bitten on arms and face while sleeping
October 2011	Hackney, London	Urban	5-year-old boy bitten on ear while sleeping
February 2013	Bromley, London	Urban	4-week-old boy bitten on face while sleeping and dragged out of cot by the hand; a finger had to be reattached
November 2014	New Addington, London	Urban	2-year-old boy bitten on heel while sleeping
February 2018	Plymouth, Devon	Urban	7-month-old girl bitten on foot and hand while playing in a bouncer
August 2018	Orpington, London	Urban	3-year-old girl bitten on hand and arm while sleeping
Adults bitten inside their home			
June 2010	Fulham, London	Urban	33-year-old woman bitten on same foot on 2 separate nights several days apart while sleeping
September 2010	Fulham, London	Urban	46-year-old woman bitten on ear while sleeping
June 2011	Stockwell, London	Urban	24-year-old man bitten on eyelid while sleeping in attic bedroom
September 2016	Wallington, Surrey	Urban	33-year-old woman bitten on hand while sitting in living room
July 2017	Richmond, London	Urban	71-year-old woman bitten on finger and arm while sleeping
June 2018	Clapham, London	Urban	22-year-old woman bitten on arm while sleeping
July 2018	Little Chesterford, Essex	Rural	77-year-old woman bitten on finger and foot while reading a newspaper in her lounge
October 2019	Willesden, London	Urban	53-year-old woman bitten on lip and ear while sleeping
People bitten or scratched outside their home			
October 2010	Inveresk, East Lothian	Rural	37-year-old drunken man bitten on nose and fingers while sleeping in cemetery
April 2011	Steeple Langford, Wiltshire	Rural	26-year-old fisherman bitten on face while sleeping in tent
September 2012	London	Urban	83-year-old man bitten on hand while sleeping in garden
November 2012	Uckfield, East Sussex	Rural	41-year-old fisherman bitten on face while sleeping in tent
January 2013	Chislehurst, Kent	Urban	3-year-old boy bitten on foot while playing on sledge in garden
March 2016	Sidcup, Kent	Rural	28-year-old fisherman scratched on face while sleeping in tent
March 2016	South Woodford, London	Urban	35-year-old drunken man sleeping at bus stop woke to find fox tugging at his trousers
January 2017	Storrington, West Sussex	Rural	24-year-old drunken man sleeping on park bench bitten on ear
June 2017	Eltham, London	Urban	Woman walking to work bitten on ankle but fox did not penetrate her trousers

was not bitten himself), 3 men were sleeping in their tent while night-fishing (2 were bitten, 1 was scratched), and the other 2 were bitten in their garden. Eighteen incidents (78%) involved people who were sleeping; 17 incidents (74%) were in urban habitats; 6 incidents (26%) were in rural areas (i.e., 3 adult men sleeping while fishing, 2 men who were sleeping while drunk, and a woman reading in her lounge). In 15 cases (65%), the person was bitten in 1 place, generally only once, whereas in 8 cases (35%) the person was bitten in >1 place. When people were bitten once, published photographs of the bite wounds generally showed canine puncture marks with relatively little associated bruising, whereas the wounds were more extensive on people who were bitten more than once.

Discussion

Responses of foxes to infant vocalizations

Foxes quickly and deliberately run toward the sounds of potential prey (Österholm 1964), whereas only a minority of the foxes we recorded approached the source of the infant vocalizations and those that did so approached cautiously, exhibiting no stalking or hunting behavior. A fox that contacted the speaker when both cry and laugh vocalizations were broadcast used its forefeet to investigate the speaker after paying attention to the source of the sound for a few seconds. None of the foxes bit the equipment during the trial hours, but some did so when no vocalizations were being played. The pawing or biting responses we observed were typical canid investigative behavior (Bradshaw 2011, Moretti et al. 2015, Marshall-Pescini et al. 2017).

We found no evidence that foxes were attracted to infant distress calls. It is also likely that many more foxes were exposed to the sounds than we recorded, since there were several foxes (excluding cubs) on each territory, and most, if not all, would have heard the sounds played on 1 or both treatment nights; we were only able to record the number of foxes that visited the monitored gardens during each trial hour. However, playback experiments are notoriously difficult (Deecke 2006). Our study was exploratory, and much larger samples would be needed to discount the possibility that a small proportion of a fox population may respond to infant distress calls.

Future studies should also consider the following: (1) the responses we recorded may have been stronger or different if pauses had been added to the tracks to reduce habituation; (2) foxes also use visual cues to help locate the source of a sound (Österholm 1964), so it may have been better to have hidden the speaker (Fischer et al. 2013); we did not do so because we wanted to observe the foxes' responses to and interactions with the source of the sound; (3) using interactive playback experiments may produce more powerful and authentic responses (King 2015); (4) including a positive control such as rabbit distress calls and a negative control such as white noise would enhance future analyses; and (5) multiple signals (auditory, olfactory, and visual) may have produced a stronger response once the foxes arrived in the garden (Rosenthal 2010), although this would not have affected the frequency of visits by foxes.

Media reports of foxes biting people

Analyzing the circumstances in which foxes bite or scratch humans spontaneously was complicated because we had to derive information from media reports, which were sensationalized and sometimes provided conflicting information. While we found several accounts of each event, suggesting that we located most of the events reported in the published media, there were undoubtedly other cases that were not reported. However, it is clear that situations where foxes bite people are rare compared to those involving coyotes and dingoes.

One possible explanation for the low number of incidents is that the foxes involved are particularly bold individuals. Boldness-shyness and investigation-avoidance are key factors that influence differences in individual behavior (Réale et al. 2007). Boldness is associated with increased investigation and reduced neophobia (Wilson et al. 1994). A comparison of bold and investigative behavior in urban and rural coyotes suggested that boldness is associated with living in urban areas, that the behavior emerged over several decades, and that it has led to an increased risk of predation on pets or attacks on humans (Breck et al. 2019). However, boldness in canids is characteristic of subordinates in both rural and urban habitats

(Padovani 2015, Dorning and Harris 2017). Low levels of fox culling in British cities has led to larger social groups (Harris and Smith 1987) consisting of a dominant pair and a number of subordinates (Baker et al. 1998). Subordinate foxes are bolder than dominants (Padovani 2015), and the number of bold foxes in British cities appears to be a reflection of social group size rather than an adaptation to living in urban areas (Harris 2020).

An animal's health status also affects its levels of boldness and neophobia. Britain is currently free of rabies and sylvatic plague, both of which can induce bold and/or aggressive behavior in foxes, but there is growing evidence that *Toxoplasma gondii* infection is associated with bold behavior in a variety of species of mammals, including humans (Webster et al. 2013, Johnson et al. 2018). While 20% of 549 UK foxes tested positive for *T. gondii* (Hamilton et al. 2005), we know very little about how this parasite influences fox behavior.

An unusual feature of incidents involving foxes biting people in Britain is that most of those we identified (14/23, 61%) occurred within residential homes, unlike most other incidents involving carnivores biting or attacking people in urban areas (Bombieri et al. 2018*b*). In Britain, urban foxes typically live and breed in residential gardens, and a high proportion of their food is provided by local residents (Dorning and Harris 2017). There are countless media reports of foxes entering and denning in factories, offices, residential houses, and shops; they have even been recorded on the upper floors of tall buildings and in the London underground railway. In the vast majority of these situations, they do not interact with humans, reinforcing the impression that their behavior is investigative rather than aggressive or foraging.

While the media has focused on foxes biting sleeping babies, with 1 incident in particular covered for an extended period (Cassidy and Mills 2012), only 7 (30%) of the 23 cases we identified involved children ≤5 years old. The other 16 (70%) cases were adults ranging from 22–83 years old. Since children ≤5 years old only constitute around 7% of the UK population (GOV. UK 2020), this may suggest that infants are more likely to be bitten than people aged ≥18 (79% of the UK population). However, this may simply be an artifact of the small sample size, especially since there is greater media coverage of events involving children, so more data are needed to establish whether young children really are at greater risk. Similarly, while most of the adults bitten in their own homes were female, and most of those bitten outside their homes were male, more data are needed to determine whether this is also an artifact of sample size.

When foxes bite people, they typically focus on small, easily accessible structures, such as the fingers of people bitten on the hand, the heel when bitten on the foot, or the ears, eyelids, lips, or nose of people bitten on the face. With children, the injuries were generally on the arms, feet, or hands, whereas for adults they were mostly on the face or hands. This may reflect differences in sleeping practices: the recommendation for babies is to have a sleep bag or the bedding tucked in below shoulder height (The Lullaby Trust 2020), so that both the arms and feet are accessible to a fox, whereas the bedding for adults tends to be bulkier and pulled further up their body, so that their feet, and sometimes their hands, are more likely to be covered. A sleeping fisherman who received extensive facial injuries was scratched, not bitten. The number of incidents involving sleeping fisherman was unexpected. While there is nothing to suggest that the behavior of the foxes was predatory, it may be that foxes are attracted to recreational fishing sites as a source of supplementary food, as observed with dingoes on Fraser Island (Déaux et al. 2018). Also, while the media focus has been on urban foxes biting people, similar incidents occurred in rural areas, albeit less frequently.

Media photographs of the bite wounds inflicted on people who were only bitten once typically show canine punctures with little imprint from other teeth and limited associated bruising. This suggests that the bite wounds were not aggressive. Bite wounds inflicted when a fox is defending itself usually cause extensive bruising and tissue damage (S. Harris, unpublished data). Individuals bitten more than once tend to have more extensive bruising and tissue damage, but the bite wounds were still focused on the extremities, also suggesting that the behavior of the fox was not aggressive or predatory. In contrast, >70% of injuries to children attacked by domestic dogs involve

the face, head, and neck; injuries to adults are more often defensive wounds to the extremities incurred when protecting their head and face (Overall and Love 2001, Tsokos et al. 2007).

Red foxes have long, narrow jaws to enable them to catch fast-moving prey (Slater et al. 2009). Since they do not have the bite force of larger canids (Damasceno et al. 2013, Behrendorff et al. 2018), foxes adopt a grab-and-shake mode of killing prey larger than voles and mice. Violent shaking of larger prey probably serves to enhance the size of wounds and hence blood loss and tissue damage. There was no evidence of similar behavior when foxes bit people.

More incidents involving coyotes and dingoes occur when breeding and pup-rearing, possibly reflecting seasonal changes in behavior (Baker and Timm 2017, Appleby et al. 2018, Bombieri et al. 2018*b*). With so few incidents involving foxes, it is hard to determine whether there is a seasonal pattern. However, 11 of the 14 incidents involving people in their homes occurred between June and October, whereas most of the situations where people were bitten outside their homes happened in the winter months. This suggests that there is no obvious association with periods of greater food demand and/or aggression in foxes, and the higher number of incidents in people's homes during the warmer months simply reflects easier, probably opportunistic access through open doors or windows.

Our experiments and the review of media reports both suggested that fox encounters with both infants and adults are rare chance events, possibly involving bolder foxes, and that the behavior of the foxes is investigative rather than aggressive or predatory. Thus, during our field studies, most of the foxes did not investigate or pay attention to the speaker any more when infant vocalizations were broadcast than during control trials. They did not arrive more often or remain in the garden for longer, nor did they remain alert to the speaker for longer, and often began eating the food that was provided soon after encountering the sounds.

The cases reported by the media suggested that the foxes were investigating unfamiliar objects. Fox bites were generally on the extremities, especially fingers or the parts of the face that are most easily reached, and the bites typically did not cause extensive damage. The nature of the injuries suggested that the fox usually quickly released its grip. The high proportion of adults rather than infants who were bitten suggested that the behavior was not predatory. Lastly, most of the individuals who were bitten were asleep and did not exhibit typical response behavior when approached by a fox.

Management implications

Instances of foxes biting people in Britain generate a great deal of media interest and misinformation. Our experiments were the first to explore how wild foxes react to potential stimuli from babies. The chance nature and rarity of events makes it difficult to identify management solutions that will reduce the number of incidents where people are bitten by foxes. One unresolved question is why some foxes enter houses, since this is itself unusual. Much of the evidence suggests that this is also usually investigative rather than foraging behavior. Whether particular foxes are more likely to enter houses requires further study: while subordinate canids are typically bolder, disease may also influence fox behavior. Future research should focus on the age, social status, and health of foxes that enter houses, and those that interact spontaneously with people. The biggest challenge is to address the moral panic spread by the British media whenever a child is bitten by a fox.

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