Survival of juvenile European hares (*Lepus europaeus*) and the attempt to identify predators by trail cameras in areas of different population densities in Western Germany

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Abstract

Populations of European hares (*Lepus europaeus*) have declined dramatically throughout Europe. Predation of leverets has been suggested to have contributed to the population decline. We aimed to investigate the survival of young hares and the relative importance of predators as well as how their impact varies with habitat and landscape factors in three study sites in Germany in 2013, which differed in population size. Therefore, we searched for leverets by thermographic cameras and observed them by means of trail cameras. We found no differences in mean number of found leverets / 100 ha and in survival time between the study sites. Among the predictor variables vegetation type, vegetation height and distance to pathway only vegetation height had a significant effect on survival time. The mortality rates did not differ between the study sites in which leverets were found (75% vs. 89%). Causes of death could not be determined by trail cameras. Validity of our results was limited by small sample sizes and methods.

Keywords *Lepus europaeus* · Mortality · Survival · Predators · Trail camera

Introduction

The European hare (*Lepus europaeus* Pallas 1778) is widespread and probably one of the most important game species in Europe (Flux and Angermann 1990). But populations have declined dramatically since the 1960s in Europe (Flux and Angermann 1990; Smith et al. 2005). Also German records of hares shot suggest massive declines of populations (Strauss 2010; Anonymous 1968; Anonymous 1973; Anonymous 2010). Hence, the European hare has been classified as “threatened” on the Red List of Threatened Species in Germany (Haupt et al. 2009).

In general a reduction in population size can be due to a decreased natality or an increased mortality rate (Hackländer 2010). The European hare is still a symbol for high fertility (Hackländer et al. 2001) because it has normally three to five litters a year and the annual production of young per female amounts in most populations around 8-10 (Flux and Angermann 1990; Zörner 1996). Furthermore it has been shown that fecundity and fertility is not reduced in low-density areas (Hackländer et al. 2001). This focus on the factors, that may increase the mortality as reason for population declines. Especially the mortality of young hares is of high relevance for the population dynamics and varies mainly between 65-95% (Hackländer 2010; Voigt 2010; Zörner 1996). Leverets are precocial, the mother visits them only once or twice a day for nursing, the rest of the day they mainly remain motionless (Flux and Angermann 1990). This slight extent of maternal care could make the young vulnerable in some aspects. It is well known that diseases and climatic factors can have negative effects on juvenile hares in the early stages of their life due to high energetic costs of thermoregulation in cases of rainfall and low temperatures in spring (Hackländer et al. 2002a; Smith et al. 2005; Spittler 1976; Van Wieren et al. 2006). Further the intensification of agriculture can negatively affect population sizes (Smith et al. 2005; Zörner 1996). This can be due to (1) a reduction of habitat diversity and its effects on varied diet, milk quality of females and structures that provide shelter as well as (2) an increased mechanization and agro-chemical use (Hackländer et al. 2002b; Smith et al. 2005). Beside the factors of diseases, climate and agricultural intensification, predation has been suggested to contributed to the population decline (Hackländer 2010; Hoffmann 2003; Spittler 1972; Smith et al. 2005; Voigt 2009). The identity of predators and their relative importance must be known for an effective management and is of particular interest for hunters. However, despite the acknowledged importance of predation only few studies have investigated the factors that influence the effect of predation or determined the relative importance of predator species (Lang 2010). Furthermore, these studies mainly based on the analysis of stomach or fecal contents, thus their validity for the predation influence of species, which feed on carrion or which show kleptoparasitism remained uncertain (Voigt 2009; Zörner 1996).

In this study we aimed (1) to investigate the relative importance of predator species and how their influence varies with habitat and landscape factors in three hunting grounds in North

Rhine-Westphalia, Germany, which differed in population size. In this context we wanted to test the hypothesis of local hunters that corvids and raptors are important predators of young hares, as they were often observed in these areas. This hypothesis is supported by the facts that leverets have almost no inherent smell and the vegetation cover is low at time of the first litters in the year. Thus we suggest that their detection by optic-oriented predators such as birds is facilitated compared to olfactory-oriented mammalian predators. We wanted to test if trail cameras have potential for this purpose since they have already been used in many studies to identify nest predators of birds (Cutler and Swann 1999). In addition the applicability is supported by the fact that it has been shown that leverets move in most cases less than 30 m in their first weeks of life (Voigt 2010).

Further (2) we want to investigate the abundance, frequency of survival and survival time of leverets of the first litters in the year. We hypothesised that abundance, frequency of survival and survival time of leverets is lower in low-density areas. In this context we were interested in the effect of habitat factors, such as vegetation type surrounding the whereabouts of leverets, vegetation height and distance to pathway on the survival time. We assumed that vegetation height and distance to pathway have positive effects on survival time because they provide shelter in terms of cover and distance to human activities (including domestic dogs as potential predator).

Materials and methods

Study sites

The study was conducted in the period from 25 March to 19 April 2013. This is the time of the first and second litter of European hare within one year. The surveys took place in three hunting grounds in North Rhine-Westphalia in Western Germany: Monheim, Heimerzheim-Vershoven and Hastenrath. These hunting grounds differed markedly in population size (Fig. 1), that was early estimated by spotlight counts. The agricultural use of the study sites Monheim and Heimerzheim-Vershoven was acquired by mapping in the field during the study period and the area proportions were calculated by Quantum GIS software (Version 1.7.4). For the district Hastenrath already existing data of the former year (2012) were resorted regarding the agricultural use.

Monheim

The 330 ha large study site Monheim (51° 6′ N, 6° 54′ E, elevation 40m above sea level) is characterized by its particular location between the city Monheim and the Rhine as a natural border. That implies a kind of habitat isolation and a flooding of a large part of the landscape at irregular intervals. This particular location makes the hunting ground also attractive for recreational activities. The landscape was composed of approximately 33% grassland, 23% woody plants (riparian forest and hedges) and arable land in form of 31% cereals (12% wheat *Triticum aestivum* , 10% barley *Hordeum vulgare* and 9% rye *Secale cereale*), 9% rape cultivation (*Brassica napus*), 1% fallow land and a disused quarry pond. The vegetation height was in average about 10 cm for cereals, from 15 to 40 cm for fallow land vegetation and from 10 to 25 cm for grassland. The mowing took place once a year in July. The mean field size was approximately 8 ha (Min 1.2 ha, Max 27.4 ha). The spring population density of hares estimated by spotlight counts was on average 105 hares / 100 ha for the years 2010 to 2012. The population size was stable in the last 3 years.

Heimerzheim-Vershoven

The 237 ha large hunting ground Heimerzheim-Vershoven (50°43'N, 6°54'E, elevation 130 m above sea level) is characterized by an intensively agricultural use and few woody plants. The agricultural use was composed of approximately 45% cereals cultivation (35% wheat *Triticum aestivum* and 10% barley *Hordeum vulgare*), 40% new ploughed field, 4% spinach (*Spinacia oleracea*), 3% turf, 5% grassland and 3% fallow land. The height of the vegetation varied during the study period from 5 to 10 cm for cereals, from 10 to 20 cm for spinach and around 10 cm for grass. The average field size was approximately 3.3 ha (Min 0.2 ha, Max 39 ha). The spring population density that was estimated yearly by spotlight counts was on average about 61 hares / 100 ha for the years 2010 to 2012. The population size was stable in the last 3 years.

Hastenrath

The area Hastenrath (51° 0′ N, 5° 58′ E, elevation 70m above sea level, total size 355 ha) is dominated by intensively used arable land. Main crops are wheat (*Triticum aestivum*, 35% of the study site), barley (*Hordeum vulgare*, 3%), sugar beet (*Beta* vulgaris, 23%), strawberrys (*Fragaria ananassa*, 6%), maize (*Zea mays*) and chicory (*Cichorium intybus*) respectively 5% of the study area. Grassland represents approximately 15% of the area, fallow land is rare. In addition a tree nursery is located in the study area. The field size was on average approximately 4.8 ha (Min 0.57 ha, Max 20.8 ha). The spring density of hares estimated by spotlight counts was on average 58 hares / 100 ha for the years 2010 to 2012. The population size decreased in the last years.

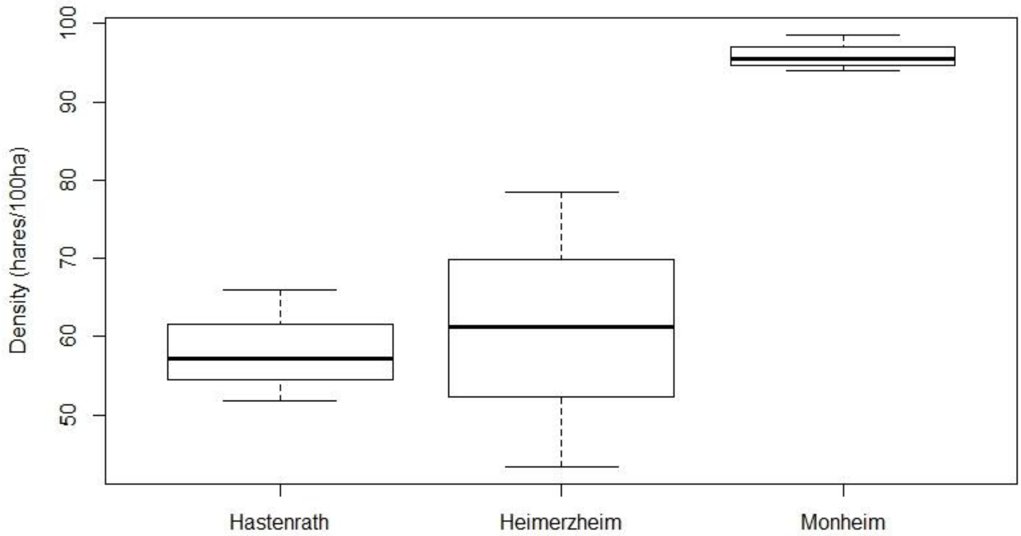

Fig. 1 Boxplots of spring hare densities for different study sites of the years 2010- 2012 estimated by spotlight counts

Abundance, survival frequency and survival time of leverets

We searched for juvenile hares by means of a thermo-graphic video camera (FLIR T335, FLIR, USA) with a 15° infrared lens. Because warming of soil and vegetation hampered the detection of leverets the searches only took place during the night and started at earliest one hour after sunset. The areas were searched out of a car during drive in walking speed. Mainly the existing road network was used, only in exceptional cases we cut across country. The driven routes were noticed on a map. Suspicious objects were observed and if possible identified by binoculars (8x56, Zeiss, Germany or 8x56 Habicht, Swarovski, Austria) in spotlight. We took pictures of each leveret and measured the body length in the given position of the hares by putting a measuring tape next to them without touching the hare. In addition we estimated the age based on the body length and notice the location on a map. Also the distance between the where about of the leveret and the nearest pathway (in meters), the vegetation height (in cm) as well as the vegetation type surrounding the locality of leverets (e.g. fallow land, woody plants, cereals, spinach, new ploughed field or grassland) were recorded. The searched area was calculated as product of the driving route in meters and the detection range in meters. We assumed a detection range of 130 m in cases of unobstructed view since this was the maximum distance of a detected leveret during our test phase. In cases of limited view (e.g. due to hedges) the detection range was correspondingly reduced. In most cases we tried to rediscover the already found leverets within 48 hours by thermal camera. If a leveret was not found within a radius of approximately 130 m around its former position by thermo graphic camera we assumed its dead. We calculated the survival time of each leveret in days as sum of the estimated age (at the time of first finding) and the period from the date of first finding until the assumed dead and in case of survival until the end of the study period, respectively. Subsequently we calculated the means for the hunting grounds. Furthermore we calculated the frequencies of survived and as dead assumed leverets for each hunting ground.

Monitoring of leverets by trail cameras

The surveillance of the leverets was carried out by use of trail cameras (Spypoint IR-7, GG Telecom, Canada), equipped with infrared spotlights. The cameras were placed on a metal stick at a height of approximately 0.8 m and a distance of 8 m from the leveret. The motion triggered system recorded 90 seconds lasting videos with a delay time of one minute between two consecutive videos. We chose a high image quality (640 x 480 pixels) for the videos. Six 1.5-volt-AA batteries were used to power the camera systems. The videos were stored on 4 GB SD memory cards. The leverets were revisited once a day to check their location, to reset the camera position and to replace the SD memory cards. We analysed the collected videos regarding the trigger causes, detect ability of the leveret (yes/no) and presence of predators, whereas if possible the species were determined.

Statistical analysis

All statistical analyses were conducted in RStudio (Version 0.97.551, R Development Core Team, 2013). Normality of data was visualized graphically and determined statistically through Shapiro-Wilk tests. Homogeneity of variances was tested by Levene tests. We compared the mean number of found leverets per hundred hectares between the study sites by means of a Kruskal-Wallis test, because data were not normally distributed. To compare the frequency of as dead assumed and survived leverets within the hunting grounds exact binominal tests were used. An exact Fisher test was used to compare the frequency of as dead assumed and survived leverets between the hunting grounds. In cases of uncertain survival status data were excluded. The variable survival time was skewed to the right. Therefore, this variable was log transformed, which resulted in normal distribution (Shapiro-Wilk test, $P > 0.05$). To compare the mean survival time between the study sites Heimerzheim and Monheim a two sample t-test was used. An Analysis of Variance (ANOVA Type I) was used to test effects of hunting ground, vegetation height, distance to pathway and vegetation type on survival time. Data are presented as medians and $P < 0.05$ was considered significant.

Results

Abundance, survival frequency and survival time of leverets

We searched an area of 1113 ha, 1359 ha and 960 ha in total in the hunting grounds Monheim, Heimerzheim-Vershoven and Hastenrath, respectively. In the study site Monheim we found 18 leverets during 8 searches (Table 1). About 89% (16 of 18) of the found leverets were assumed as dead during the study period, this frequency was significant ($P < 0.01$). In Heimerzheim five searches were conducted and we found six leverets. Three of six were assumed as dead during the study period. Two further cases remained uncertain because we searched for the leverets without the thermal camera and they could not be found around their former position. Thus these two cases were excluded in the analysis of survival time and frequency. Only one leveret (25%) survived definitely until the end of the study period in Heimerzheim, this frequency was not significant ($P = 0.63$). In the hunting ground Hastenrath 3 searches were conducted and no leverets were found. We found no differences in medians of found leverets per hundred hectare between the study sites Monheim, Heimerzheim and Hastenrath (Medians: 1.36 vs. 0.37 vs. 0.00 leverets/100 ha respectively, Chi-squared = 4.05, df = 2, $P = 0.13$, Fig.2). Further the frequency of as dead assumed leverets did not differ significantly between the two hunting grounds Monheim and Heimerzheim (89% vs. 75%, $P = 0.47$). Moreover, the mean survival time did not differ significantly between the hunting grounds Monheim and Heimerzheim (Medians: 8.5 days vs. 6.5 days, respectively; $t = -1.78$, df = 6.01, $P = 0.13$, Fig. 3). In addition the ANOVA (Adjusted R-squared = 0.25) revealed no significant effect of hunting ground on survival time (df = 1, $F = 2.59$, $P = 0.13$). Also the predictor variables vegetation type (df = 4, $F = 1.09$, $P = 0.40$) and distance to pathway (df = 1, $F = 1.95$, $P = 0.18$) had no significant effects on survival time. Only the vegetation height had a significant positive effect on survival time (df = 1, $F = 5.07$, $P < 0.05$).

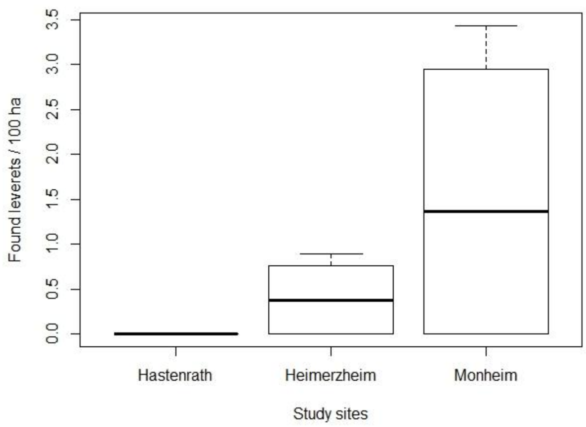

Fig. 2 Boxplots of found leverets per hundred hectares by thermographic search for different study sites

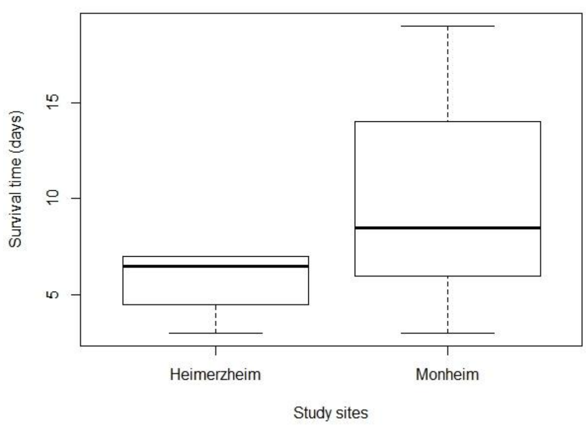

Fig. 3 Survival time of found leverets for the study sites Monheim (n=18) and Heimerzheim (n=4)

Table 1 Number of found, as dead assumed and survived leverets as well as cases of uncertain survival status and median of survival time (days) and median of found leverets per 100 hectare are shown for the three hunting grounds.

	Monheim	Heimerzheim	Hastenrath
No. found leverets	18	6	0
No. as dead assumed leverets	16	3	-
No. survived leverets	2	1	-
Cases of uncertain status	0	2	-
Median of survival time	8.5	6.5	-
Median of found leverets/100 ha	1.4	0.4	0.0

Monitoring of leverets by trail cameras

We monitored three leverets in the hunting ground Heimerzheim and two in Monheim. In total 703 videos were recorded. Most of the recordings were triggered by adult hares, human activities (e.g. recreational as well as agricultural vehicles) and unknown effects (Table 2, Figure 4 and 5 in the Appendix). The cameras recorded no discrete predation event or other cause of death. One of the observed leverets in Heimerzheim survived until the end of the study period. The survival status of the two other observed leverets in this study site remained uncertain like described above. The observation of one of these leverets was not possible because the leveret moved too much and left the camera field of view. The two observed leverets in the study site Monheim were assumed as dead, whereas the trail cameras did not record their causes of death. Only four videos recorded potential predators in Monheim: in two independent cases domestic dogs (*Canis familiaris*) were seen and two consecutive videos recorded a beech marten (*Martes foina*). The beech marten could be excluded as cause of death because we assume the leverets dead already two days before. Also one dog could be excluded as possible predator because the leveret was still alive after recording this event. The other dog could not be excluded as possible predator as well as other animals, which could not be identified in the videos. Also a death caused by a horse hoof could not be excluded since equestrians rode close to the leverets assumed locality. Thus the de facto causes of death of all observed and as dead assumed leverets remain uncertain.

Table 2 Total numbers of video triggers classified by categories for the study sites Monheim and Heimerzheim. The relative frequencies of trigger categories are given in the parentheses.

Trigger category	Monheim	Heimerzheim
Adult Hare	85 (50.3%)	35 (6.6%)
Unknown	39 (23.0%)	408 (76.4%)
Human	29 (17.2%)	84 (15.7%)
Unidentifiable animal	8 (4.7%)	4 (0.7%)
Leveret	4 (2.4%)	3 (0.6%)
Domestic dog (*Canis familiaris*)	2 (1.2%)	0 (0.0%)
Beech marten (*Martes foina*)	2 (1.2%)	0 (0.0%)
Total	169 (100%)	534 (100%)

Discussion

The application of trail cameras was not suitable for the purpose to monitor juvenile hares and to identify the relative importance of their predators. Also Cutler and Swann (1990) referred to limitations of data collection with remote photography equipment. In our study the causes of unsuitability was due to a combination of camera features on the one hand and the behaviour and characteristic of the leverets on the other hand. Because of the leverets movement we chose a camera distance of approximately eight meters to the leveret to observe an appropriate surrounding area. The small body size and the camouflage fur colour of the leverets rendered the detection of the leverets on the video recordings impossible in this distance, especially during day time. This could be one reason for the high number of unknown triggers because the leveret could leave the field of view without our awareness. Furthermore the detection by night was aggravated by the low image quality (brightness of image) of the videos that reduced the field of view enormously. Thus the field of view was too small compared to the movement behaviour of the leverets. Both, day and night recordings did not allow a gapless observation of leverets activities. This is indicated by the high number of unknown triggers as well as by the low number of videos triggered by the leverets itself. Furthermore we assume that the trigger velocity was too low to record fast predator species like raptors. This was indicated by the fact, that recreationist (walking in normal walking speed) and adult hares were recorded at the first time when located in the field of views centre. In addition the weather impaired the image quality, especially due to fog in the early morning hours and contributed to the high number of unknown triggers. Further we assume wind caused a great number of videos with unknown trigger, especially in the study site Heimerzheim. The high number of human triggered videos in Heimerzheim could be explained by the locality of a camera closed to a farm. In this case the driveway to the farm was directly in the camera viewing direction. Thus numerous videos were triggered by agricultural vehicles that drove to the farm and back. Recreationists were rarely recorded compared to the study site Monheim. Videos that recorded unidentifiable animal species were in most cases assumed to be triggered by adult hares but this could not be confirmed with certainty. Taken together, this method caused huge effort, did not come up with our expectations and provided no evaluable results regarding our study purpose and hypothesis.

The abundance of found leverets per hundred hectares did not differ between the study sites which differ in population size. This result is contrary to our assumption. One reason could be that the likelihood of leveret detection was not the same for all study sites. It is well known that human disturbance due to recreationists can alter game behavior and distribution (Knight and Cole 1995). The comparatively high number of videos triggered by humans in Heimerzheim was affected by the locality closed to a farm. The recorded videos of our study and our personal impressions suggested that the de facto number of recreationist to be highest in Monheim. Thus it is conceivable that hares rather avoided the proximity of pathways due to disturbance and preferred to give birth also rather in a higher distance to trails in Monheim compared to hunting grounds with lower human disturbance like Heimerzheim and Hastenrath. Otherwise the mean distance to pathway did not differ significantly between the two hunting grounds Monheim (Mean: 31.39 m ± SE 6.64 m) and Heimerzheim (Mean: 26.25 m ± SE 8 m). However we searched only the edges of fields with a detection range of maximum 130 m. Thus we did not search in the center of larger fields. It is also known that leverets partly prefer whereabouts like hedges, where they are hardly detectable by thermographic camera (Voigt 2010). Whereas Monheim had numerous hedges compared to Heimerzheim and Hastenrath we hypothesize that the likelihood to detect a leveret was lower in the hunting ground Monheim. However, the number of found leverets is only an indicator of fecundity or survival time to which we should not attach too much importance.

The mortality frequencies of 89% in Monheim and 75% in Heimerzheim were quite high but comply with the known mortality frequency of 65-95% in other studies (Voigt 2010; Zörner 1996). In contrast to our hypothesis the survival frequencies did not differ significantly between the hunting grounds. This could be due to the small sample sizes, especially in the hunting ground Heimerzheim (n=4).

The fact that we found no differences in survival time between the two hunting grounds Monheim and Heimerzheim could be also explained by the small sample size of our study. Thus the statistical power of our model was quite low. This could be also the reason why we did not find any impact of the predictor variables vegetation type and distance to pathway on survival time. However, Fernex (2010) showed that dummy-leverets located at field edges were found within a significant shorter time period compared to dummies located in field centers. Further, Fernex (2010) found that the detection likelihood of a dummy-leveret by a predator decreased with an increasing height of vegetation. Our results revealed also that vegetation height had a positive effect on survival time. Furthermore it is known that the survival of leverets depends on the place of birth and their whereabouts after birth combined with the landscape structure (Fernex 2010; Voigt 2010).

Taken together, our study revealed only little meaningful results due to unsuitable methods and small sample sizes. Therefore we suggest to repeat this study with more convenient trail cameras and dummy-leverets to investigate the impact of predation.

Acknowledgements

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Appendix

Fig. 4 Triggers of videos recorded by trail cameras in the study site Monheim

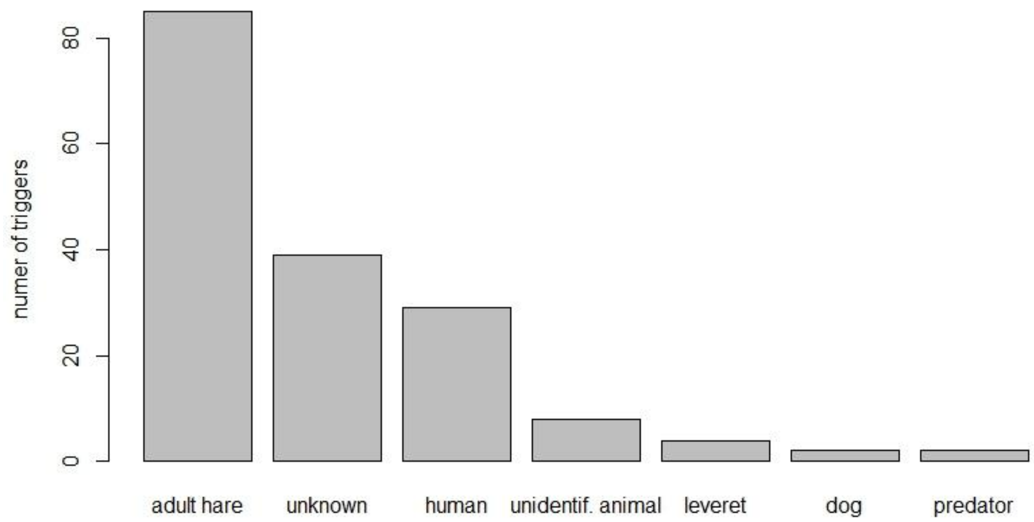

Fig. 5 Triggers of videos recorded by trail cameras in the study site Heimerzheim

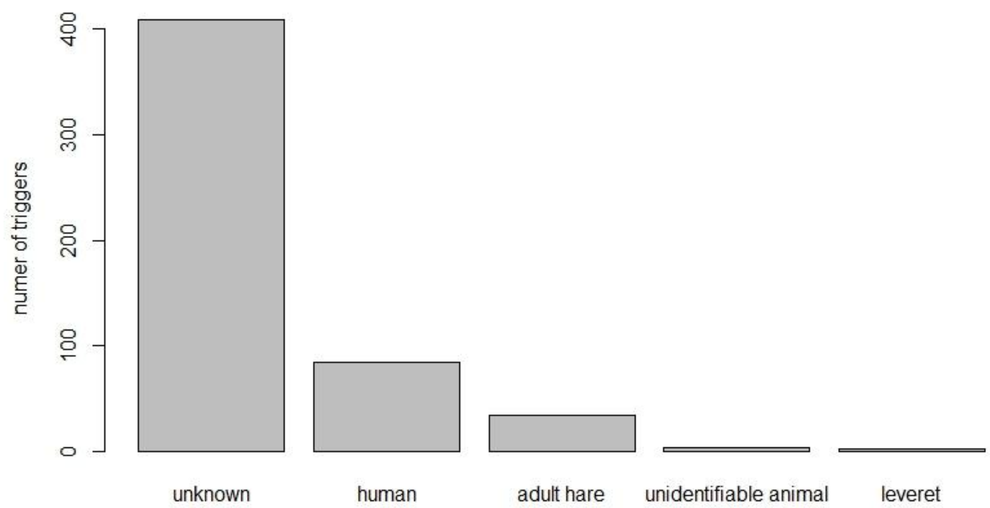

Table 3 Found leverets, their survival time, distance to pathway, vegetation height and vegetation type surrounding the locality of found leverets for all study sites

ID	Study site	Vegetation type	Survival time (days)	Vegetation height (cm)	Distance to pathway (m)
Heim1	Heimerzheim	new ploughed field	6	1	10
Heim2	Heimerzheim	new ploughed field	7	1	15
Heim3	Heimerzheim	cereals	NA	10	10
Heim4	Heimerzheim	spinach	3	15	40
Heim5	Heimerzheim	spinach	NA	15	40
Heim6	Heimerzheim	spinach	7	15	40
Mon 1	Monheim	woody plants	4	120	15
Mon 2	Monheim	fallow land	19	20	25
Mon 3	Monheim	fallow land	19	15	25
Mon 4	Monheim	cereals	8	5	50
Mon 5	Monheim	cereals	5	5	50
Mon 6	Monheim	grass land	16	25	25
Mon 7	Monheim	grass land	11	25	15
Mon 8	Monheim	grass land	15	25	15
Mon 9	Monheim	grass land	3	15	10
Mon 10	Monheim	grass land	3	15	10
Mon 11	Monheim	grass land	9	15	20
Mon 12	Monheim	grass land	9	15	20
Mon 13	Monheim	grass land	9	15	20
Mon 14	Monheim	woody plants	14	200	5
Mon 15	Monheim	woody plants	6	5	45
Mon 16	Monheim	fallow land	8	15	100
Mon 17	Monheim	fallow land	8	15	100
Mon 18	Monheim	grass land	8	25	15

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