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Ear-marking of roe deer fawns (*Capreolus capreolus*): Results of long-term studies in Central Europe

Key words/Schlagworte: roe deer, earmarks, dispersal, mortality, population structure, monitoring, management, Europe, Rehkitze, Ohrmarken

1. Introduction

Over the past several decades, ungulates have expanded throughout Europe in both number and distribution (Apollonio et al. 2010). If left unchecked, such expansion can result in disease transmission, increased traffic collisions and negative impacts on forest regeneration (Reimoser & Gossow 1996; Gortázar et al. 2006; Putman et al. 2011). To prevent such problems, it is important to monitor wildlife populations and to build sustainable management plans that are supported by reliable population data.

One of the classic methods for monitoring wildlife populations is to mark animals with unique identifiers (Silvy et al. 2005). By individually identifying animals, researchers can study demographics, behavior, ecology and other aspects of wild animals (Silvy et al. 2005) that are helpful for constructing effective management plans. Ear marks are simple artificial tags commonly used for marking mammals like wild ungulates, livestock and bats (Silvy et al. 2005). This marking method has been applied in long-term monitoring programs of ungulates in Europe for over a century (Borrmann 2003). However, the benefits and limitations of monitoring ungulates with this method have rarely been described.

Ear marking has been a widely used method for investigating roe deer ecology. Roe deer can strongly influence forest regeneration (Reimoser & Gossow 1996) and are an important food resource for least concerned species like lynx (*Lynx lynx*) and wolves (*Canis lupus*; Breitenmoser & Breitenmoser-Würsten 2008; Wagner et al. 2012). It is also an economically important game species (Danilkin 1996). For example, hunting bags in Switzerland increased by 280 % from 14,916 animals in 1933 to 41,973 animals in 2013 (Federal Office for the Environment 2015).

Roe deer are well suited for large-scale, long-term monitoring because they are widespread. They live in almost all available biotopes in Central Europe, ranging from coastal areas to alpine habitats (Sempéré et al. 1996). Thus, roe deer are a suitable species for the study of the potential influences of climate change (Plard et al. 2014) and landscape changes (Müri 1999a; Senn & Kühn 2014) on animal populations. For example, barriers and forest fragmentation can lead to genetic divergence and changes in the genetic diversity and population structure of roe deer (Coulon et al. 2006; Hepenstrick

et al. 2012; Senn & Kühn 2014), which can be an indicator of such processes in other species with similar mobility. Given the high importance of roe deer, it is not surprising that roe deer is one of the best-researched wildlife species in Europe. Most of the fundamental research on the species was conducted in the 1970s and 1980s by Wagenknecht (1971); Ellenberg (1978); Strandgaard (1972); Kurt (1974); Reimoser (1986); Hespeler (1988); Staines & Ratcliffe (1987); Stubbe (1990); and others. Long term studies revealing life-history traits have been carried out in several places in Europe e.g. in France (Gaillard et al. 1993) and Sweden (Kjellander et al. 2004). From a management perspective, much research focused on the absolute abundance of roe deer rather than the understanding of the ungulate-habitat system (Morellet et al. 2007).
This investigation aims to address the benefits and limitations of wildlife monitoring using the ear-marking technique. We provide an overview of the marking activities (systematic studies) on roe deer in Europe since 1904, as well as a summary of the main results gained from observations of over 60,000 marked fawns. Furthermore, we compare three long-term marking projects in Lower Austria, Baden-Württemberg (Germany) and Switzerland that took place between 1980 and 1999. Finally, we show that ear-marking remains an essential tool for investigating life-history patterns of roe deer and to assist wildlife managers and researchers as a tool for management decisions.

2. Material and methods

2.1 Roe deer fawn-marking projects in Europe

We give an overview about roe deer fawn-marking projects in Europe based on an intensive literature search in the Swiss Wildlife Information Service SWIS and web of knowledge which covered grey literature (popular-published) and scientific references. We used marking, roe deer, fawn and Europe as keywords and selected for ear-marking projects. Firstly, we present general procedure, objectives of and main publications about marking projects of roe deer fawns in Europe since marking activities began in 1904. In the second step, we summarize the main results from marking projects involving over 60.000 marked roe deer fawns. This summary provides an overview of the key trends observed after over a century of ear-marking studies.

2.2 Comparison of three marking projects (1980–1999)

We compare detailed results from three marking projects for the same marking (1980–1989) and feedback period (1980–1999): Lower Austria (LA), Baden-Württemberg (Germany; BW) and Switzerland (CH; Figure 1). We used Chi-squared tests to estimate differences in the compared variables between the three projects. Differences between the study areas are shown and recommendations for management are given.
In Austria, the study area (about 10,000 km^2) within the province “Lower Austria” consists of a mixed landscape (arable land, grassland, 40 % forest) with elevations ranging between 200 and 1,500 meters. The province is characterized by mountainous regions in the west (mainly forest, grassland) and hilly countryside with plains in the east (mainly arable land, vineyards, small forests). The average annual temperature is 7.8°C in the west (700 m a.s.l.) and 9.9°C in the east (350 m a.s.l.); annual precipitation ranges from 500 mm in the east to 1,200 mm in the west. The average hunting bag for roe deer was approximately constant between 1980 and 1999, with about 67,172 animals shot per year (Statistics Austria 2015). Hunting periods (in the 1980s and 1990s): bucks June 1st to October 31st, does and fawns August 16th to December 31st.
In Baden-Württemberg (Germany), the study area (about 35,000 km^2) is characterized by an Atlantic climate with mild winters and cool summers. From west to east, the climate becomes increasingly continental, with severe winters and warm summers. The average annual temperature is approximate 8.0°C. Temperatures are higher in the Rhine and Neckar valleys (e. g., the average temperature in Mannheim at 96 m a.s.l. is 10.2°C) and lower at higher elevations (e. g., Swabian Alb, 698 m a.s.l., 6.5°C; Black Forest, 870 m a.s.l., 5.7°C). The landscape in Baden-Württemberg is 27 % arable land, 18 %

grassland, 17 % settlement and roads, and 38 % forest. The average hunting bag rate for roe deer was approximately constant between 1980 and 1999 with 145,457 animals shot per year (Wildforschungsstelle 2015). Hunting periods are separated by age and sex: buck (16th of May to 15th of October); one-year old female roe deer (16th of May to 31st of January), doe (1st of September to 31st of January), and fawns (previously from 1st September to 28th of February; since 1st October 1996, from 1st September to 31st of January).

In Switzerland, project activities were concentrated in three biogeographic regions: the Swiss Plateau, the Northern Prealps, and the Eastern Central Alps (Christen et al. 2018). These biogeographical classifications are based on the distribution patterns of flora and fauna and reflect numerous biotic and abiotic factors (Gonseth et al. 2001). Around half of the Swiss Plateau is given over to agricultural use and one-quarter to forests and woodland. Most of Switzerland's main towns and cities and industrial centres are concentrated on the Plateau. The climate is temperate, with average annual temperatures of 7.7°C and annual precipitation of 1,040 mm at 600 m a.s.l. In the Northern Prealps, montane and subalpine forests reach an upper limit at about 1,800 m. a.s.l. There, precipitation exceeds 1,571 mm at 1,000 m a.s.l. and the average temperature is 5.4°C. The Eastern Central Alps are characterized by high relief over short distances, with mountains reaching elevations of up to 4,000 m a.s.l. The forests in this region occur in belts around mountain ranges and tree line lies at around 2,300 m a.s.l. Precipitation is low, with an average of 600–900 mm at 1,000 m a.s.l., and temperatures show high daily and seasonal variations. The average hunting bag rate for roe deer was approximately constant between 1980 and 1999 with 40,896 animals per year (Federal Office for the Environment 2015). Hunting periods are separated by age and sex in the different cantons of Switzerland. Main data came from Lucerne with district hunting (buck: 1st of May to middle of December; does: 1st of September to middle of December; fawns: 1st of October to middle of December) and Grison with patent hunting (buck and doe: three weeks in September and a few days in November and December depending on the hunting success of the prior period).

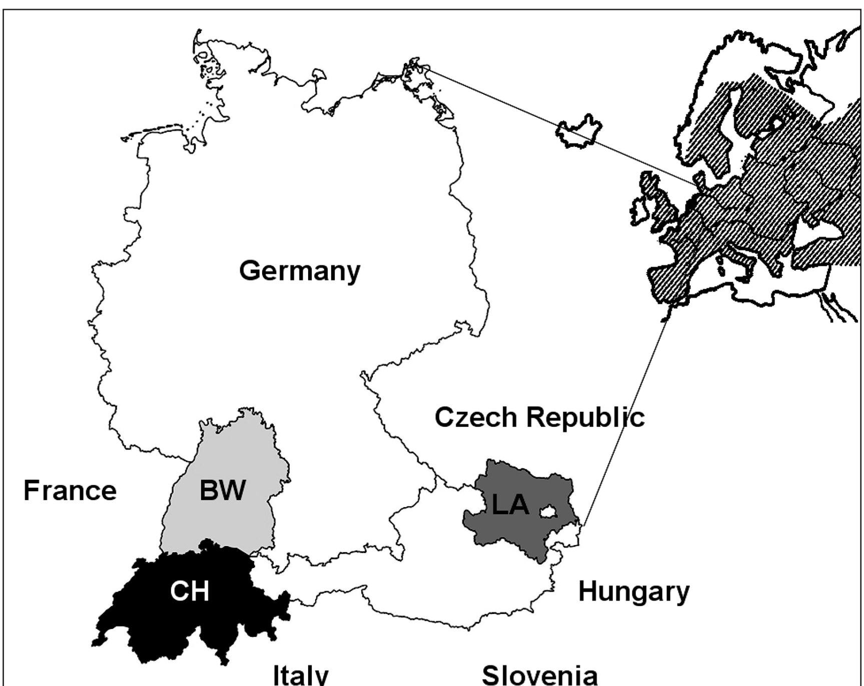

Fig. 1: Distribution of roe deer in Europe (adapted from Kurt 1974) and locations of the study areas in Lower Austria (LA), Baden-Württemberg (BW) and Switzerland (CH)

3. Results

3.1 Roe deer fawn-marking projects in Europe

3.1.1 Thoughts before marking

Roe deer have to be marked individually because they have no natural markers that can be used to identify individuals over time. Earmarking is an acceptable method for studying roe deer under natural conditions because it does not affect the animal's health and/or behavior (Delorme et al. 1988; Osgyan 2007). In the over 100 years that ear-marking has been in use, there have been no known cases of a marked fawn being rejected by its mother, nor any indication that marking increases the risk of predation (Elliger 2001; Osgyan 2007; Rehnus & Reimoser 2014). However, experience is necessary to apply the ear mark correctly, and thought should be given to the intended outcome of a project before beginning the marking process.

3.1.2 Monitoring and research purposes

The Danish teacher and ornithologist Hans Christian Cornelius Mortensen was the first to recognize the potential benefits of marking individuals. In 1899, he started to use aluminum rings to systematically mark starlings (*Sturnus vulgaris*) for his studies. After the successful establishment of this technique, Graf von Bernstorff, a German forest superintendent in Mecklenburg – West Pomerania, began developing marks that could be used on ungulates (Borrmann 2003). Based on his results and with the support of the German hunting association, the first roe deer ear-marking study in Central Europe was started in Germany in 1904 (Borrmann 2003). In the 1970s and 80s, a number of additional marking projects were started in Austria, Germany and Switzerland, some of which are still partly running today (Table 1). Roe deer fawns have been marked to study a range of questions about the species, including mortality, dispersal, fragmentation effects and age (Table 1).

3.1.3 General procedure

Ear marks are small plastic clips that are applied to the fawn's ears shortly after birth. In the first two to three weeks following birth, the fawns typically lay hidden (Kurt 1991), freezing rather than running if discovered (Danilkin 1996). The application of an ear mark is simple once a fawn is found. Pinchers are used to insert the marks in the ear and the whole marking process takes just a few seconds. Marks are individual because they are differently colored and imprinted with a nonrecurring number. To further ensure that each marked fawn is uniquely identifiable, a distinct number range is used each year and the marked side of the head (right ear vs. left ear) is systematically alternated.
Ear-marking allows for data collection at the beginning of a roe deer's life as well as at the end if the animal is shot or found dead. Two report forms are therefore used in a marking project, one that is filled out when the fawn is first marked, and one that is filled out when the animal is later found dead. The first form collects information about the date the marking occurred, the mark used, the sex, the approximate age, siblings, the vegetation around the marking location and the location coordinates. Similarly, the second report form collects data about when the individual was found, its mark, sex and weight, the nearby vegetation and the location and, if known, the cause of death.

3.1.4 The marking process

The timing of marking activities often depends on the timing of spring and on the local conditions. For instance, if winter is prolonged, births can be delayed by up to two weeks (Kurt 1991). In the Alps, the birth period depends on the elevation, with births occurring later at higher elevations (Rehnus & Reimoser 2014). These findings are in contrast to results found in the lowland area of Trois Fountaines, France, where timing of parturition was found to be constant over a period of 27 years, although the area has undergone substantial climatic changes during this time frame (Plard et al. 2014).
In general, the gravid does establish their birthing territories around the beginning of April. During this time, the does should be regularly

Table 1: Objectives of and main publications about marking projects of roe deer fawns in Europe since marking activities began in 1904

Country	Period	Number of marked fawns	Objectives							References
			Age determination	Body growth	Habitat use	Mobility	Morality	Population structure	Reproduction	
Austria I	1980–1999	4,026	X			X	X	X	X	Reimoser et al. 1999
						X	X			Reimoser & Zandl 1993
			X							Reimoser et al. 2004
Austria II	since 1997	580	X			X	X	X		Waldhäusl 2011
France	since 1975	N.A.		X		X	X	X	X	Gaillard et al. 1993
					X		X		X	Plard et al. 2014
Germany I	1904–1995	127	X							Eckstein 1910
		15,196	X	X		X		X		Bieger 1932
		12,340							X	Rieck 1955
			X							Rieck 1970
Germany II	1977–2007	205				X		X	X	Osgyan 1989
			X	X	X	X	X		X	Osgyan 2007
Germany III	since 1970	15,153				X	X	X	X	Neuhaus 1986
					X		X	X		Elliger 2001
				X		X	X	X	X	Bauch et al. 2014, 2016
Norway	1991–1994	231	X	X				X	X	Andersen & Linnell 1998
Sweden	1988–1999	43								Kjellander et al. 2004
Switzerland	since 1971	13,951		X	X	X	X		X	Blankenhorn 1978
				X		X	X	X		Stocker & Meier 1985
						X				Müri 1999a
									X	Müri 1999b
				X	X	X	X	X	X	Signer & Jenny 2006
						X	X	X	X	Rehnus & Reimoser 2014
						X				Fuchs et al. 2015; Fuchs 2015
				X						Nägeli & Rehnus 2018
United Kingdom					X			X	X	Gill et al. 1996

observed in order to identify the future birth site (Rehnus & Reimoser 2014). Later, when a fawn is found, the surrounding area should be carefully searched, as twin fawns rarely lie together (Kurt 1991). To determine the day of birth, the age of the fawn has to be estimated. For young fawns, the age can be determined to within a few days of the actual birth date; for older fawns, the age can be estimated with an inaccuracy of a few weeks. The size, color, coat pattern and behavior are considered reliable age characteristics (Table 2; but see Stamm et al. 2017). Although these factors only give an approximate birth date, this is sufficiently accurate for most purposes. The birth date can be established more precisely only by closely observing the doe before and after she gives birth (Stamm et al. 2017).

Ideally, fawns should be found within the first two weeks of birth, as the young animals freeze rather than try to escape (Kurt 1991), which makes ear-marking easier. The fawns should then be quickly marked by placing an individual identifier in the thick cartilage of the lower, inner region of the ear, where the mark is best protected.

Table 2: Age determination of fawns based on fur color and behavior (modified after Stocker 1984)

Weight	1–1.5 kg	1.5–2.5 kg	2–4 kg	3–6 kg
Fur color	Dark with many black hairs	Dark brown with few black hairs	Brown with few black hairs	Brown, no black hairs
	Very light flecks	Light flecks	Light flecks	Pale flecks
Behavior	Freezes when approached by humans		Flushes when approached by humans	
Age	1 week	2 weeks	3 weeks	4 weeks

3.1.5 Comparison of main results

Age determination

One of the first goals of initial ear-marking studies was to determine whether tooth wear is an accurate indicator of age. As roe deer are a key game animal in Central Europe, being able to quickly and easily estimate the age of a shot animal facilitates more informed management decisions.

Bieger (1932) compared the real ages of 75 ear-marked roe deer with ages estimated from tooth wear. The study showed that tooth wear was not homogeneous and therefore a poor indicator of age. Bieger (1935) then developed new guidelines for determining the age of roe deer based on additional indicators.

Rieck (1970) tested the reliability of age estimation using the jaws of roe deer identified as fawns with respect to their trophy development. The lower jaws of 250 roe deer between one and 13 years of age were used for this purpose. The variation of wear on the first and third molars was examined for each year of age and showed considerable scattering. Using this method, approximately 80 % of the teeth were aged correctly. Rieck (1970) concluded that this method is sufficient for deer management but its reliability must not be overestimated.

Reimoser et al. (2004) tested the accuracy of tooth wear in the lower jaw as an age determinant. The lower jaws of 126 marked roe deer (maximum age of eight years) were age-estimated by different groups of hunters with long experience in estimating age based on tooth wear. In total, 5,658 age estimations were carried out. Age was correctly estimated for 79 % of the yearlings, but accuracy declined with increasing age to 27 % for deer six years of age and older (Table 3). With a tolerance limit of ±1 year, the results improved to 98 % for yearlings and to 64 % for deer six years of age and older. If hunters were told the correct ages and then asked to repeat their estimations one year later, the estimations improved by approximately 10% (learning effect). Regional differences in age estimation accuracy were found.

Waldhäusl (2011) found in his Upper Austrian study that with the usual age estimation doctrine, 68 % of 104 lower jaws of marked roe deer (> 1 year old) were correctly age classified. After including the yearling class, the accuracy increased to 81 %.

Body growth

The documentation of body weights based on roe deer of known ages enables investigations regarding the status and condition of a target

Table 3: Accuracy of age estimation by means of tooth wear in the lower jaws of 126 marked roe deer (number of roe deer in %; adapted from REIMOSER *et al. 2004)*

Age determination by trophy evaluators	**True age of marked deer (years)**					
	1	**2**	**3**	**4**	**5**	**6+**
Correctly classified age	79	48	32	34	29	27
Incorrect within ±1 year	19	39	43	41	39	37
Incorrect more than ±1 year	2	13	25	25	32	36
Total	100	100	100	100	100	100

population. Two projects in Baden-Württemberg (Germany) and in Switzerland have investigated body growth over time (BAUCH et al. 2014; NÄGELI & REHNUS 2018). Both studies found that roe deer are fully grown by 19 months of age. This similarity can be explained by the close proximity of these regions and hence similar conditions (e.g. habitat and weather) during the growth phase of fawns. However, the accuracy of these estimated ages is strongly biased by the hunting season. The majority of animals were reported back during the hunting season; only a few animals were reported back between hunting seasons. For example, most animals were reported back during the hunting season in autumn in Switzerland. Gaps between hunting seasons were sparsely populated by reports of deer killed by road traffic. In contrast, in France HEWISON et al. (2011) found that roe deer are fully grown not before reaching an age of two for females and males gaining body mass until the age of three years.

Ear-marking projects have shown that the body weight of animals varies over the course of a year (BIEGER 1932). This can be explained by the defined annual cycle in both body weight and body fat reserves of adult deer (HOLAND 1992). Marking projects showed that the body weight of adult bucks is higher than that of females (BIEGER 1932; BAUCH et al. 2014; NÄGELI & REHNUS 2018). For instance, the weight (with head, without organs) of adult bucks in the Northern Alps of Switzerland was 18.5 ± 0.3 kg compared to 16.7 ± 0.4 kg for does (NÄGELI & REHNUS 2018).

Habitat

The long-term documentation of birthing habitats has enabled researchers to identify ‘typical’ birthplaces. This has made it easier to find fawns for marking and to save them from being killed when farmers mow their meadows. Although the detection probability varies among habitat types, records indicate that most fawns are marked in meadows. For instance, SIGNER & JENNY (2006) showed that 81 % of fawns were marked in meadows and fields, while only 19 % were found in forests. BLANKENHORN (1978) further observed that in years with earlier haymaking activities, the number of fawns found in forests increased.

It seems that the preferred bed-site locations of fawns in meadows are not random. 51–53 % of all recorded fawns were found in meadows with vegetation ranging from 20 to 50 cm in height; approximately a quarter of fawns were found in meadows with average vegetation heights less than 20 cm or greater than 50 cm (BLANKENHORN 1978; SIGNER & JENNY 2006). Although the overall availability of meadows with different vegetation heights is unknown, and we therefore cannot distinguish preference from necessity, it seems that vegetation heights over 20 cm are more commonly used (CHRISTEN et al. 2018). We assume that cover from above is more important than surrounding cover. For instance, fawns have been found in forests with canopy cover but no surrounding vegetation (BLANKENHORN 1978). Similarly, meadows with vegetation heights greater than 20 cm allow fawns to be covered from above. LINNELL et al. (1998) argue that canopy cover provides roe deer with visual and olfactory protection against predators, as well as assistance with thermoregulation. Cover protects against sun on sunny days and against cold on cold days.

The edge between forest and meadow is an important factor in the selection of a birthplace. In Switzerland, 60 % of all fawns found in meadows/fields were within 50 m of the forest edge; conversely, 56 % of all fawns found in forests were within 50 m of the next forest edge (Christen et al. 2018). Similar results were observed in a systematic survey of fawns in Baden-Württemberg. There, 15 % of fawns found outside forests and 30 % of fawns found within forests were within a 50 m buffer of the forest edge (Elliger 2001).

Dispersal

Documentation of marked roe deer provides information about location shifts of individuals between the marking location and the finding location; whatever happens in between remains unknown. However, ear-marking provides an overview of how individual animals use a spatial territory, especially if data is collected over several decades. Furthermore, ear-marking is better suited for multiple study purposes than expensive (Hebblewhite & Haydon 2010) and time-limited methods like telemetry (Millspaugh et al. 2012).

The use of marking data to explore mobility behavior indicates that the roe deer is a philopatric species that normally does not range far from its birthplace (Bieger 1932; Neuhaus 1986; Reimoser & Zandl 1993; Reimoser et al. 1999; Waldhäusl 2011; Bauch et al. 2014; Fuchs et al. 2015). For instance, Bieger (1932) showed that 65 % of marked individuals were found within three kilometers of their marking place. However, the average dispersal distance can vary strongly depending on the region, e. g. the Alps versus a flatland region (Fuchs et al. 2015).

The maximum dispersal distance documented within a marking project was 220 km (Mecklenburg-Western Pomeriana to Saxonia, Germany) by a five-year-old doe (Bieger 1932). For bucks, the record is 109 km (marked in Grison in 1998 and found in Zurich in 2003, Switzerland; Rehnus & Reimoser 2014). In general, roe deer do not go that far, but exceptions are possible (dispersal).

No significant sex differences were found in the mean dispersal distances (Bieger 1932; Reimoser & Zandl 1993; Müri 1999a; Signer & Jenny 2006; Fuchs 2015), which is in agreement with the results of other European studies using telemetry (Heurich 2013) or capture–mark–recapture methods (Gaillard et al. 2008). The absence of a between-sex difference in dispersal behavior is consistent with the low sexual size dimorphism, the mating tactic of resource defence, and the low level of polygyny exhibited by roe deer (Gaillard et al. 2008).

The average dispersal distance depends on the age of the animal (Bieger 1932; Neuhaus 1986; Reimoser & Zandl 1993; Osgyan 2007; Waldhäusl 2011; Bauch et al. 2014; Fuchs et al. 2015). In the first year, fawns stay with their mothers and move within the mother's home range (Linnell et al. 1998). After they are weaned, they need to look for their own territory (Heurich 2013). A study in Switzerland showed that more than 80 % of fawns were found within 1 km of their marking location, while only about 50 % of the sub-adult and adult animals were found within 1 km of their marking locations (Fuchs 2015).

Long-term data have the potential to show changes over time in the dispersal behavior of roe deer. For example, it enables researchers to investigate the potential influences of habitat fragmentation or barriers on roe deer populations (Müri 1999a; Fuchs 2015). Although Fuchs (2015) found no trend in the changes in dispersal distance over time, Müri (1999a) showed that the frequency of emigration and the dispersed distances decreased significantly over time. Potential reasons for these differences may be differences in the availability of data and the length of observation. For instance, data from 2537 animals (1971–2013) were available for the analysis by Fuchs (2015) compared the 700 animals (1971–1995) studied by Müri (1999a). Furthermore, Fuchs (2015) used data from across the Swiss Plateau and the Alps in Switzerland, whereas Müri (1999a) used data mainly from the Swiss Plateau. Finally, many new barriers were being constructed in the 1990s; the deer had probably adapted to the new barriers by the 2000s. Müri (1999a) also found a negative correlation between the barrier density and the migrated distance.

Mortality

The documentation of the cause of death of marked roe deer allows us to analyse how, where and when most animals were killed.

The feedback rates of marked roe deer (animals reported dead) were 15–38 % (max. of 38 %, i. e. 225 von 592, see Dietrich et al. 2018). The rest of the marked animals were not found dead, or were not reported back, or lost their earmarks. More than 50 % of the feedbacked marked animals in all projects were shot (Neuhaus 1986; Reimoser et al. 1999; Bauch et al. 2014; Rehnus & Reimoser 2014). The maximum number of shot animals was reached in Upper Austria, with 85 % for fawns and 86 % for sub-adults and adults (Waldhäusl 2011). Mortality rates due to collision with vehicles or mowing machines varied from 4 % in Upper Austria to 20 % in Lower Austria, and from 7 % in Upper Austria to 10 % in Switzerland, respectively (Reimoser et al. 1999; Waldhäusl 2011; Bauch et al. 2014; Rehnus & Reimoser 2014). Unfortunately, other categories of death (e. g., disease, predation) were defined differently or not given. However, it is important to interpret the mortality rates per category with caution, as animals that are shot or killed by road traffic are far more likely to be found and reported than those that die from disease or predation.

Population structure

Marking projects provide details about the target population like sex ratio and age structure (Figure 2). In the reviewed marking projects, the sex ratio of fawns at the time of marking was nearly balanced; however, the ratio of does to bucks increased over time (Bieger 1932; Reimoser et al. 1999; Osgyan 2007; Bauch et al. 2014; Rehnus & Reimoser 2014). This change can be explained by trophy-oriented hunting practices, which prize bucks over does due to their antlers (Osgyan 2007). Prime-age male are less likely to survive (Strandgaard 1972; Gaillard et al. 1993) and greater mortality among males could be related to sexual selection because of both larger size in males and polygyny (see Gaillard et al. 1993).

However, the sex ratio of fawns can vary from year to year. For instance, between 1904 and 1914, 52 to 65 % of marked fawns were bucks (Bieger 1932). Variations can be explained by population density, weather conditions and available resources, especially during rut (Ellenberg 1978, 1980; Müri 1999b).

The higher number of animals in young age classes that are reported back as compared to those in older age classes (Neuhaus 1986; Reimoser et al. 1999; Osgyan 2007; Rehnus & Reimoser 2014; Bauch et al. 2014) indi-

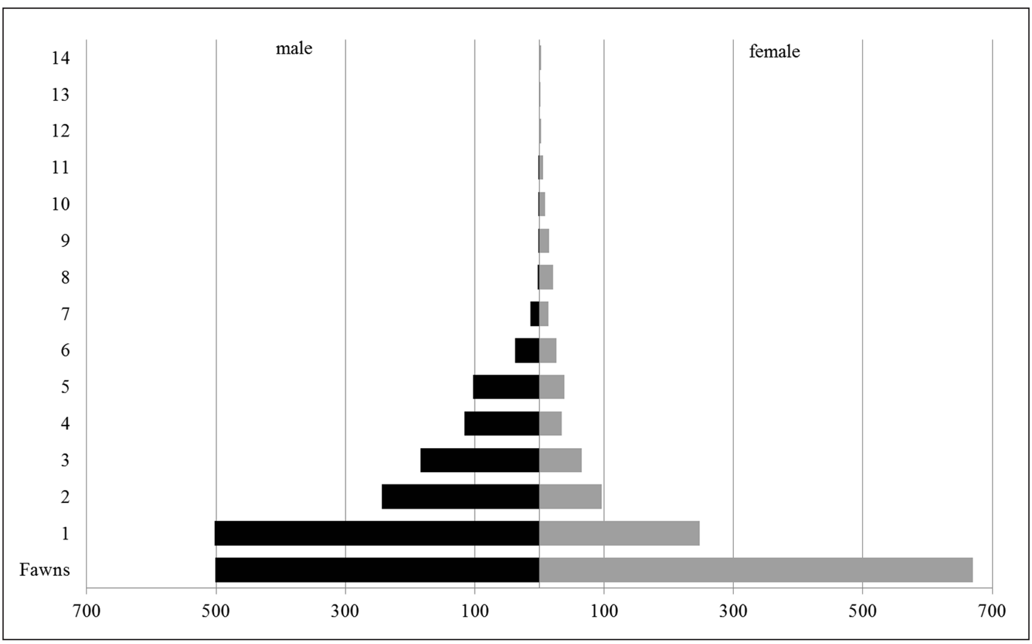

Fig. 2: Age structure of found marked roe deer in Baden-Württemberg in Germany (1970–2014; adapted from Bauch et al. 2014) separated for bucks (N = 1,707) and does (N = 1,252)

cates an unbalanced age structure in the investigated populations. For the Swiss Plateau, Kurt (1991) estimated that 35 % of fawns survive until November; in Sweden, Jarnemo et al. (2004) showed that the overall majority of fawns was 42 % and that predation rate was highest during the first week of life and declined thereafter almost linearly. The majority of fawns (85 %) are killed before 30 days of age, and 98 % of fawns before 40 days of age. The 'real' mortality rate is higher than that presented here, as the detection rate for fawns that die from predation, hypothermia, starvation or disease shortly after birth is probably quite low (Kurt 1991). The oldest documented age of free-ranging, ear-marked roe deer was 20.5 years for a doe (Osgyan 2007), and 17 years for a buck (Bieger 1932). Free-ranging roe deer older than 10 years are rare, but obviously extreme exceptions are possible.

Reproduction

A breeding season of six months (March to August) was observed during marking project activities in Central Europe. The earliest recorded birth date was before March 22 in Austria (Reimoser et al. 1999); the latest was August 11 in Germany (Bauch et al. 2014). The highest birth location was documented at 2231 m a.s.l. in Switzerland (Rehnus, unpublished).

The majority of fawns were born in May and June, and the total amount of fawns born in this period ranged from 96 % in Germany (Rieck 1955) to over 99 % in Switzerland (Rehnus & Reimoser 2014). Although local differences were noted, births typically occurred between the end of May and the beginning of June. Rieck (1955) noted that birthing times are increasingly displaced toward summer with increasing latitude and elevation. In Middle Franconia (Germany), 61 % of fawns were found and marked in May and 37 % in June. In Carinthia (Austria), 71 % were found and marked in June and 5 % in May (Rieck 1955). A similar but elevation-related pattern was found in Switzerland: the average birth date up to 500 m a.s.l. on the Swiss Plateau was May 24, in the Prealps between 501 and 1,500 m a.s.l. it was May 30, and in the Alps over 1,500 m a.s.l. it was June 7. The local shift of birth times is in line with the results of Linnel et al. (1998), who showed a south to north gradient in the birth times of roe deer in Europe. For instance, most fawns are born in April in southern Spain and in mid-July in southern Sweden. Linnel et al. (1998) suggest that this timing is linked to the quality of available vegetation, which is important for lactating does. In France, Gaillard et al. (1993) found synchronisation of births, with all births taking place in a period less than 30 days, with a mean birth date of 15th of May. This supports the hypothesis that roe deer are constrained at both ends of the fawning season by the short time window between the fawning season and the rutting season, as well as by the need to match optimal climate conditions and forage quality to face late gestation and lactation (Gaillard et al. 1993; Raganella-Pelliccioni et al. 2007). Together, these factors result in a relatively stable and synchronous birth season. Janermo et al. (2004) showed that fawns that are born either very early or very late in the season have a higher predation risk.

In general, breeding activity in does begins after 14 month of age (Sempéré et al. 1996). Multiples births by roe deer are common. For instance, of the 11,081 birth cases analyzed in Switzerland between 1971 and 2011, 41% were twin births, 2% were triplets and in five cases, four fawns were observed (Rehnus & Reimoser 2014). However, it is difficult to determine how many of the fawns found in a meadow belong to a single doe, and to know if all of a doe's fawns have been found. For instance, some field personnel are happy to find one fawn; if a second is found, the searchers may assume that all have been found. However, a lot of participants search systematically to save fawns from being mown to death by mowing machines.

3.2 Comparison of three marking projects (1980–1999)

3.2.1 Marking activities (1980–1989)

In LA, 4,026 roe deer (51.4 % male, 48.6 % female) were marked between 1980 and 1989. In the same period, 5,513 deer were marked in BW (38.5 % male, 37.0 % female, 24.5 % unknown) and 1,823 in CH (45.0 % male, 45.0 % female, 10.0 % unknown).

The earliest seasonal marking date occurred on March 22 in LA, April 5 in BW and April 26 in

Table 4: Distribution of marking activities from March to August in Lower Austria (LA), Baden-Württemberg (BW) and Switzerland (CH) between 1980 and 1989 (χ^2 = 760.6, df = 18, p < 0.001)

Marking date	Lower Austria		Baden-Württemberg		Switzerland	
	N	%	N	%	N	%
March	1	0.03	0	0	0	0
April	8	0.2	29	0.5	1	0.1
01.–10. May	52	1.3	160	2.9	24	1.3
11.–20. May	332	8.3	928	16.8	120	6.6
21.–31. May	1,349	33.5	2,136	38.7	383	21.0
01.–10. June	1,493	37.1	1,532	27.8	693	38.0
11.–20. June	604	15.0	600	10.9	471	25.8
21.–30. June	144	3.6	98	1.8	94	5.2
July	38	1.0	27	0.5	37	2.0
August	4	0.1	3	0.1	0	0.0
Total	4,026	100.0	5,513	100.0	1,823	100.0

CH. The latest marking occurred on August 24 in LA, August 18 in BW, and July 19 in CH. 98.7% (LA), 98.8% (BW) and 97.9% (CH) of fawn were marked in May and June. 70.6% (LA), 66.5% (BW) and 59.0% (CH) were marked between May 21 and June 10 (Table 4).

3.2.2 Feedback (1980–1999)

Feedback rate

In LA, 634 marked animals were reported dead for the feedback period 1980–1999, which translates to a feedback rate of 15.7%. In BW, 1,347 animals were reported (feedback rate 24.4%), and in CH 295 animals were reported (16.1%).

Age

More than half of the marked animals in all three study areas were recovered within the first two years after marking. Before completing their first year of life, 34.7% of the marked fawns were found in LA, 42.8% in BW, and 40.0% in CH (Table 5). Only 4.9% (LA), 4.4% (BW) and 4.1% (CH) of the recovered deer were six years old or older (Table 5). Within the older age class (≥ six years), does (74.0% in LA, 58.0% in BW, 83.5% in CH) are more strongly represented than bucks (26.0% in LA, 42% in BW, 16.5% in CH). Only a small number of animals reached an age greater than 10 years: 0.3% in LA, 0.6% in BW, and 0.7% in CH (Table 5). In LA, the oldest recovered roe deer doe was 13 years old and the oldest buck nine years; in BW, the oldest doe was 12 years and the oldest buck 10 years, and in CH the oldest recovered doe was 11 years old and the oldest buck eight years.

Sex ratio

The sex ratio of marked individuals varied strongly according to the age class.

Newborn fawns: In all three projects, the sex ratio of the fawns at the time of marking was nearly balanced: 51.4% (LA), 51.0% (BW), and 50.7% (CH) of births were buck fawns. Interestingly, the sex ratio (% buck fawns marked) varied over the 10-year marking period by up to 25.0% in LA, 6.8% in BW and 14.5% in CH.

Recovered roe deer: Of all the deer recovered, 58.0% (LA), 51.0% (BW) and 56.9% (CH) were males (Table 5). Within the one- to five-year-old class, 58.8% to 72.7% of bucks in LA, 68.1% to 78.6% of bucks in BW and 53.3% to 72.9% of bucks in CH were recovered. Less than 50% of the recovered fawns were male in LA (46.3%) and BW (41.5%), but not in CH (53.4%). Less than 50% of the recovered roe deer older than five years were male in LA (0.0–38.5%) and CH (0.0–50.0), but not in BW (0.0–71.4%; Table 5).

Table 5: Sex ratio of marked animals and characteristics of feedbacks in Lower Austria, Baden-Württemberg and Switzerland between 1980 and 1999. Distribution of shot roe deer over age classes were different between the three projects ($\chi^2 = 100.3$, $df = 20$, $p < 0.001$), while other causes were not.

Lower Austria	marked: 4,026	**Age of roe deer**											
	reported: 634	**K**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Total**
Sex ratio of marked animals	buck %	51.4											51.4
Feedback	roe deer %	34.7	20.6	12.5	9.6	10.8	6.9	2.1	1.4	0.5	0.6	0.3	100.0
Sex ratio of recovered animals	buck %	46.3	67.4	65.8	70.5	58.8	72.7	38.5	22.2	0.0	25.0	0.0	58.0
Cause of death:	roe deer %												
Shot (N = 324)		18.8	23.2	10.8	12.1	16.8	11.1	3.1	2.2	0.6	0.9	0.4	100.0
Traffic (N = 129)		32.0	27.3	21.1	8.6	6.3	2.3	0.8	0.8	0.8	0.0	0.0	100.0
Mowed (N = 59)		96.6	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Unknown/other (N = 122)		50.0	14.8	14.0	9.0	4.9	4.1	1.6	0.8	0.8	0.0	0.0	100.0
Baden-Württemberg	marked: 5,513												
	reported: 1,347												
Sex ratio of marked animals	buck %	51.0											51.0
Feedback	roe deer %	42.8	24.7	10.9	7.2	5.5	4.5	2.1	0.5	0.7	0.4	0.6	100.0
Sex ratio of recovered animals	buck %	41.9	68.1	73.9	73.6	78.6	74.1	66.7	71.4	0.0	0.0	11.1	51.0
Cause of death:	roe deer %												
Shot (N = 905)		34.8	28.1	11.7	8.0	7.2	5.7	2.6	0.8	0.3	0.3	0.5	100.0
Traffic (N = 121)		34.3	29.7	15.1	8.1	3.5	2.3	1.7	0.0	2.9	1.2	1.2	100.0
Mowed (N = 177)		98.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Unknown/other (N = 144)		55.0	18.4	8.9	7.6	1.9	3.8	0.6	0.0	0.6	0.0	3.2	100.0
Switzerland	marked: 1,823												
	reported: 295												
Sex ratio of marked animals	buck %	50.0	–	–	–	–	–	–	–	–	–	–	50.0
Feedback	roe deer %	40.0	25.4	16.3	8.1	4.4	1.7	0.7	1.0	1.0	0.7	0.7	100.0
Sex ratio of recovered animals	buck %	53.4	53.3	72.9	70.8	61.5	60.0	50.0	0.0	33.3	0.0	0.0	41.4
Cause of death:	roe deer %												
Shot (N = 180)		27.2	33.9	18.3	10.6	4.4	1.7	0.6	0.6	1.7	0.0	1.1	100.0
Traffic (N = 51)		41.2	21.6	23.5	5.9	3.9	2.0	0.0	2.0	0.0	0.0	0.0	100.0
Mowed (N = 27)		96.2	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Unknown/other (N = 37)		75.0	4.7	4.7	3.1	4.7	1.6	1.6	1.6	0.0	3.1	0.0	100.0

Mortality

Marking activities enable the analysis of causes of death per age class. In all three projects, most of the recovered marked deer were hunted: 51.0 % in LA, 66.1 % in BW 60.8 % in CH. Collisions with motor vehicles killed 20.3% in LA, 13.0 % in BW and 17.6 % in CH, and mowing machines were responsible for the deaths of 9.3 % in LA, 10.0 % in BW and 8.8 % in CH.

Seasonal distribution of deer-vehicle collisions
There is a much more irregular distribution in the number of marked deer killed by road traffic over the course of a year, and depends on age class and sex (Table 6).

Season: Of all the marked deer killed by road traffic, most were found in spring (33.0 %) in LA, in summer (32.4 %) in BW and in winter in CH (33.3 %, Table 6).

Age: For recovered fawns killed by road traffic, the following seasonal distribution arises with respect to age in the three projects: There are few road kills in spring when fawns are least active, a peak in autumn when they are preparing to move into their winter home-range, and a decline in winter following the hunting season (Table 6). In all three regions, the deer-traffic mortality rates of yearlings and two-year-old roe deer were highest in spring (Table 6).

Sex: Peak mortalities occur in spring for roe bucks one-year-old and older in all three regions (Table 6). Fewer bucks were killed by traffic in summer in LA (17.0 %) as compared to BW (31.4 %) and CH (29.2 %). For female roe deer one-year-old and older, the differences between the three study areas and the seasons were less distinctive (Table 6).

Dispersal behavior
In both LA and BW, the dispersal distance (linear distance) of the roe deer from the marking site to the culling or recovery site exceeded 1 km in about 20 % of the cases, and in CH 44 %. In only up to about 2 % of the cases were deer recovered more than 20 km from the marking site (Table 7). In LA, the maximum distance covered by a doe was 64 km; the longest distance travelled by a buck was 43 km. In BW, the maximum distance was 50 km for a doe and 30 km for a buck, and in CH the farthest distance covered was 28 km by a doe and 22 km by a buck.

Table 6: Seasonal distribution (months) of marked roe deer (%) that died due to collisions with vehicles in Lower Austria (LA), Baden-Württemberg (BW) and Switzerland (CH).

	N	Spring (AMJ)	Summer (JAS)	Autumn (OND)	Winter (JFM)	χ^2 p-value
Total						
LA	129	33.0	22.0	30.0	15.0	
BW	173	28.3	32.4	20.2	19.1	< 0.001
CH	143	17.6	27.5	21.6	33.3	
Age (♂+ ♀)						
Fawns, LA	42	0.0	30.0	41.0	30.0	
Fawns, BW	59	10.2	33.9	30.5	25.4	0.059
Fawns, CH	53	0.0	26.4	45.3	28.3	
Yearlings, LA	35	57.0	5.0	33.0	5.0	
Yearlings, BW	51	37.3	31.4	13.7	17.6	0.019
Yearlings, CH	45	40.0	28.9	20.0	11.1	
Two years +, LA	52	48.0	28.0	16.0	8.0	
Two years +, BW	62	38.7	32.3	16.1	12.9	0.193
Two years +, CH	45	35.6	20.0	17.8	26.7	
Sex (1 year +)						
Bucks, LA	57	60.0	17.0	20.0	3.0	
Bucks, BW	70	47.1	31.4	10.0	11.4	0.128
Bucks, CH	48	41.7	29.2	14.6	14.6	
Does, LA	30	38.0	19.0	31.0	13.0	
Does, BW	41	24.4	29.3	24.4	22.0	0.699
Does, CH	39	33.3	17.9	23.1	25.6	

Table 7: Distribution of marked roe deer dispersal distances reported in Lower Austria, Baden-Württemberg and Switzerland between 1980 and 1999 ($\chi^2 = 138.9$, $df = 14$, $p < 0.001$)

Distance (km)	Lower Austria		Baden-Württemberg		Switzerland	
	N	%	N	%	N	%
< 0.5	410	64.7	901	66.9	111	37.6
0.5–1.0	98	15.5	189	14.0	53	17.9
1.1–5.0	89	14.0	199	14.8	88	29.7
5.1–10.0	12	1.9	35	2.6	30	10.0
10.1–20.0	11	1.8	18	1.3	7	2.5
20.1–40.0	11	1.7	4	0.3	6	2.2
40.1–60.0	1	0.2	1	0.1	0	0.0
> 60	1	0.2	0	0.0	0	0.0
Total	634	100.0	1,347	100.0	295	100.0

Synthesis

Although the three ear-marking activities had similar aims, the specific methodical approach differed in detail. The experiences gained from these differences help to optimize on-going and future marking projects.

The results obtained after marking 11,362 animals show a well-synchronized peak in birth in May and June, as well as a wide range of births between March and August. The synchrony is in line with previous studies, although the range of birth dates is much greater than expected from previous studies of roe deer (Gaillard et al. 1993). However, a significant number of fawns were marked later in CH compared to in LA or BW, which is due to the later occurrence of births at higher elevations (Rehnus & Reimoser 2014). Estimations of sex ratios at marking varied according to the marking rules at each site. Although it was obligatory to determine the sex of animals marked in LA, it wasn't in the other two projects. Thus, the change in sex ratio over time can't be calculated for roe deer populations in BW and CH.

A general disadvantage of ear-marking is the low feedback rate, which is around 16–21 % over several decades (Bauch et al. 2014; Rehnus & Reimoser 2014; Reimoser et al. 1999). Ear marks can easily fall out, especially if they are not applied at the base of the ear. Marks may degrade over time due to UV radiation, and marks are sometimes found near fences, indicating that deer can rub off poorly applied marks. High fawn mortality and emigration can also lead to lower feedback rates (Kurt 1991; Gaillard et al. 1993; Jarnemo et al. 2004), as can a lack of knowledge about where to report a finding (Rehnus & Reimoser 2014). In addition, Bieger (1932) found that deer marked at the beginning of a study have lower feedback rates than those marked after field personnel have gained experience with the process. However, involving local people in the marking process can increase feedback by improving people's awareness of the effort, as was shown for BW. The low rate of feedback is primarily due to unseen mortality (dead animals that were not found, especially fawns) and poor reporting of found animals by hunters due to low motivation or a lack of information.

The majority of animals recovered were found within two years of being marked; only a few animals reached an age of ten years or more before being recovered. The mortality rates are high among young animals; it is estimated that only 35 % of fawns on the Swiss Plateau survive until the November after being marked (Kurt 1991).

Higher differences in fawn sex ratios at marking can be found between projects in different years depending on animal density, weather conditions and available resources, especially during the rutting season. The sex ratio of recovered roe deer is influenced by the hunting practices in the study regions, which may, for example, prize males over females on account of the antlers. Furthermore, females are less showy than the males because does live hidden with their offspring (Kurt 1991) what can lead to different hunting success, which could explain the different sex ratios of recovered animals. Results from the three projects support the observation that the life span of does is higher than that of bucks (Strandgaard 1972), and give insights into the turnover of roe deer populations at each study site.

The mortality patterns are similar between the three study sites (Table 5). The high death rate due to mowing machines is primarily because the fawning season overlaps with peak hay-making activities. The seasonal distribution of deer-vehicle collisions is correlated with the particular seasonal activity patterns of roe deer (Reimoser 1986), but there are significant differences between the three study areas concerning total numbers and yearlings (Table 6). Differences may be caused by the migration of roe deer inhabiting mountainous areas to lower elevations, or by differences in the densities of road networks, vehicle frequencies or roe deer densities (intraspecific competition for territories). For example, high snow depths in Switzerland lead to the migration of animals to areas with lower snow depths. To reduce deer-vehicle collisions, some regions in LA now concentrate hunting of one-year-old animals close to roads that are known to be collision hot spots. Traffic regulation (warning signs, etc.), light reflectors and wildlife corridors ("green bridges") can also help to prevent collisions.

These observations of migration behaviour support the hypothesis that roe deer maintain a high fidelity to their birthplaces (Linnel et al. 1998). However, estimated distances represent the minimum beeline distance between the marking place and the found place. The true distance of migration can be up one-third more depending on the habitats between the marking and the found place (Fuchs et al. 2015). In CH, nearly half of the deer were found at more than a kilometer's distance from the marking site. However, Switzerland is characterized by large topographic variations, with deep valleys and high mountains. Roe deer migrate seasonally to lower elevations in winter depending on snow depth, and follow the upward shift of fresh shoots in spring (Danilkin 1996; Heurich 2013). Therefore, animals marked in the mountains are likely to walk greater distances than animals from the lowlands. For Switzerland, this implies different management strategies and larger management units than are needed in BW and LA.

3.3 Conclusions for management

Marking projects are attractive for a variety of monitoring and research purposes. They can be conducted at low cost over several decades at landscape and regional scales. Volunteers with experience in handling wildlife can easily mark roe deer fawns, and new volunteers can easily be trained. Using this simple method, high numbers of animals can be studied, allowing insights into the biological plasticity of roe deer in different habitats. However, project leaders should be motivated and willing to educate active and non-active volunteers to participate in long-term marking efforts. Hunting organizations in particular are good sources of volunteers, but raising awareness about marking efforts among hunting communities depends on whether hunting is organized in districts or is based on the purchase of licenses. In either case, we recommend regular publications in journals for hunters and participation in the regional meetings of hunting associations. A web-based application that volunteers can use to find "their" animals will increase people's willingness to participate.

Marking activities can be combined with rescue campaigns to prevent fawns from being mowed to death in the birth period. Good communication between farmers and volunteers is essential (Rehnus & Reimoser 2014). For example, farmers should announce their intention to mow well in advance so that volunteers, especially hunting organizations, can organize and systematically search for fawns. Alternatively, volunteers or game wardens can help farmers install temporary scaring devices made of plastic sacks to prevent deaths (Jarnemo 2002).

Marking data provide information about roe deer that would otherwise be impossible to obtain, like pedigree of marked fawns and age-dependent antler growth (Dietrich et al. 2016, 2017). If the same person marks fawns in a certain area systematically year after year, it is possible to develop a good understanding of typical birthing places and times, which can be particularly useful for reducing deaths due to mowing. Furthermore, knowledge about the movements of roe deer can be useful for hunting and land-use planning (e. g., agriculture and forestry, traffic, landscape-connectivity projects, tourism management).

Through a central organization of marking activities and data collection, it is possible to determine the movements of roe deer over time and to ensure high-quality, standardized data. The results presented in this paper show that roe deer may migrate between different hunting areas, which calls for a cooperative management. On the other hand, each hunting territory is designed differently and has a specific context (e. g., habitat composition, human disturbance, barriers/ fragmentation), so management approaches must be tailored to the specific location. Local knowledge about the target population can help determine the management strategy.

The data from fawn-marking projects give exact information about age if a marked animal is reported when found dead. This is an important detail because the mortality risks and their causes depend on the animal's age. This knowledge can be used in age-dependent management. For example, if the feedback rate is low, an increased number of animals could be culled to compensate for natural mortality. Furthermore, knowledge about the age structure and sex ratio in a population is essential for sustainable wildlife management. Marked animals can be monitored to identify sex ratio and mortality, as well as changes in these variables over time. Such marking activities should be done with the same intensity in large connected areas to recognize regional differences and to avoid misinterpreting the data.

In some projects fawns were marked to know the age of the caught roe deer in a later catch and then making visual markings (e. g. Stubbe & Stubbe 1985; Stubbe et al. 1987; Stubbe et al. 1995).

Perhaps most importantly, marking projects need defined and realistic goals, and proper documentation and analysis of data. Large amounts of data can be collected during marking projects, but the data must be of high quality to be useful. At a minimum, we recommend a basic documentation of individual- and habitat-specific parameters at the birth and death locations, and measurements should be done in the same way to ensure comparability (e. g., weights of recovered animals should be measured using the same method). The study area for marking activities should be spatially defined and should include large connected areas to study changes in different habitats. With regard to ongoing marking efforts, project managers should compare protocols and work together to ensure that future data are comparable over time at different sites, both in terms of quality and focus. This would enable more fact-based management policies.

In summary, ear-marking of roe deer is still a very useful tool for hunters, wildlife managers and biologists, in addition to the new and more costly techniques for individual deer monitoring (GPS, FLIR, DNA, etc.) that cannot substitute the simple marking method for each research question. We particularly recommend using marking techniques to address questions related to the deer's phenology, such as reactions to climate change, including body mass changes, changes in distribution and adaptation rates.

4. Abstract

In this study, the benefits and limitations of marking fawns with ear tags for the monitoring of roe deer populations were investigated. Information from more than 60,000 fawns marked in Central Europe since 1904 was available for this purpose. First, a comparison was made of the main results of various marking projects carried out between 1904 and 2016 in Europe. Subsequently, three marking projects were compared in more detail, which were carried out during the same period (1990–1999) in Austria, Germany and Switzerland. The objectives of the marking actions were mainly related to the identification of birth sites and birth times, the mobility and dispersal of animals, population structure and causes of death as well as the verification of the age determination of tooth wear. The first roe-deer fawns were born in March, the last ones in August; over 95 % of fawns were born in the months of May and June. The distance from the marking place of the deer to the place of death was in over 80 %

of the cases less than 5 km (as the crow flies), but some deer roamed very far (doe maximum 220 km, buck max 109 km). Roe deer older than 10 years are rare, but exceptions are possible (doe max 20.5 years, buck max 17 years). The feedback rates of marked roe deer (animals reported dead) were 15–33 %. In all projects more than 50 % of the roe deer reported back were shot by hunters (max 85 %), 4–20 % killed by vehicle collisions, about 7–10 % killed by mowing machines. The marking of fawns with ear tags is a practical and inexpensive method to observe roe deer populations long-term and large-scale, but also to study scientifically. The large number of marked animals from different regions provides a good insight into the adaptability of the deer. The ecology of roe deer can differ greatly from one region to another. There are better insights into the dynamic and behavior of the deer population, which enables regionally adapted management. At the same time, well-constructed fawn-marking projects can be used to detect long-term behavioral changes in roe deer in the event of external effects such as climate change and habitat fragmentation. Success factors for the planning and support of marking campaigns were compiled.

Zusammenfassung

Ohrmarkierung von Rehkitzen (*Capreolus capreolus*): Ergebnisse von Langzeitstudien in Mitteleuropa.

In dieser Studie wurden Vorteile und Grenzen der Markierung von Rehkitzen mit Ohrmarken für das Monitoring von Rehpopulationen untersucht. Informationen von über 60.000 seit 1904 in Mitteleuropa markierten Rehkitzen standen hierfür zu Verfügung. Zuerst erfolgt ein Vergleich der Hauptergebnisse verschiedener Markierungsprojekte, die zwischen 1904 und 2016 in Mitteleuropa durchgeführt wurden. Anschließend werden drei Markierungsprojekte detaillierter verglichen, die im selben Zeitraum (1990–1999) in Österreich, Deutschland und der Schweiz durchgeführt wurden. Die Ziele der Markierungsaktionen bezogen sich vor allem auf die Feststellung von Setzstandorten und Setzzeiten, Raumnutzung und Abwanderung der Tiere, Populationsstruktur und Todesursachen sowie auf die Verifizierung der Altersbestimmung an der Zahnabnutzung. Erste Kitze wurden bereits im März geboren, letzte im August; über 95 % der Kitze wurden in den Monaten Mai und Juni geboren. Die Abwanderungsdistanz der Rehe von Markierungs- bis zum Todesort lag in über 80 % der Fälle unter 5 km (Luftlinie), einzelne Rehe wanderten jedoch sehr weit (Rehgeiß max. 220 km, Rehbock max. 109 km). Rehe älter als 10 Jahre sind selten, aber Ausnahmen sind möglich (Geiß max. 20,5 Jahre, Bock max. 17 Jahre). Die Rückmelderaten der markierten Rehe lagen bei 15–33 %. In allen Projekten wurden mehr als 50 % der rückgemeldeten Rehe erlegt (max. 85 %), 4–20 % Verkehrsfallwild, etwa 7–10 % durch Mähmaschine getötet. Die Markierung von Rehkitzen mit Ohrenmarken ist eine praktische und kostengünstige Methode, um Rehpopulationen langfristig und großräumig zu beobachten, aber auch wissenschaftlich zu untersuchen. Die große Anzahl der markierten Tiere aus unterschiedlichen Regionen ermöglicht einen guten Einblick in die Anpassungsfähigkeit des Rehs. Verhalten und Ökologie der Rehe können sich regional stark unterscheiden. Es ergeben sich bessere Einblicke in die Dynamik und die Verhaltensmuster der Rehpopulation, die ein regional angepasstes Management ermöglichen. Gleichzeitig können gut aufgebaute Rehkitz-Markierungsprojekte verwendet werden, um längerfristige Verhaltensänderungen von Rehen bei externen Effekten wie Klimawandel und Lebensraumfragmentierung frühzeitig zu erkennen. Erfolgsfaktoren für die Planung und Betreuung von Markierungsaktionen wurden zusammengestellt.

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