Mammal Research
https://doi.org/10.1007/s13364-018-0386-9

ORIGINAL PAPER

Use of track counts and camera traps to estimate the abundance of roe deer in North-Eastern Italy: are they effective methods?

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Received: 30 March 2018 / Accepted: 19 June 2018

Abstract

Population density of European roe deer *Capreolus capreolus* was estimated in six forest areas of North-Eastern Italy through the use of different methods. The most effective method to estimate a population density is always case-dependent and, thus, varies across study areas. Particularly, drive count and vantage point count estimates (i.e. counts by hunters) have been reported to be the most effective to assess deer densities in woodlands, but they require a high volunteer human presence, which limit their feasibility. Results of count by hunters were thus compared with estimates obtained through camera trapping and track counts. Surveys were all carried out between 2014 and 2015. The three-used method provided us with comparable density results, suggesting that they all may be applied in the study area. Track-count survey was shown to be—with equal effectiveness—the cheapest method to infer roe deer density in forest areas (i.e. near 28% cheaper than camera trapping). As to our study sites, we therefore suggest that the proposal of track-count method might provide wildlife managers with a cost-effective alternative to other count methods to estimate roe deer population density. However, it is noteworthy that track-count method may also lead to lower density estimates than the drive counts; an apparent difference in the accuracy between methods needs to be considered when choosing for a certain count method.

Keywords *Capreolus capreolus* · Drive counts · Vantage point counts · Camera trapping · Track counts · Economic costs

Introduction

One of the main challenges faced by wildlife managers is to select the best counting practice to reduce time, efforts and financial costs (Reynolds et al. 2011; Chavel et al. 2017; Ancillotto et al. 2018). Most animal counts are imperfect, because it is not possible to obtain the actual population size of a wild species (Daniels 2006). Therefore, methods should be adapted across species and habitat types to minimise count errors (Yoccoz et al. 2001). Among mammals, deer are increasing in abundance and distribution throughout the Western Palearctic, increasing conflicts with human activities and natural environments (Côté et al. 2004; Putman et al. 2011). Deer count is therefore necessary to help decision-making within both protected and non-protected areas, to manage conflicts between animals and human activities (Putman 1986; Horcajada-Sánchez et al. 2018), as well as to increase the productivity of ecotourism (Thulin et al. 2015; Pęksa and Ciach 2015).

The European roe deer *Capreolus capreolus capreolus* is a small European cervid (~ 30 kg in adult body mass: Andersen et al. 1998), depending on forest glades (Lovari et al. 2017). Roe deer counts are required where the roe deer needs to be preserved in some areas, e.g. where native endemic subspecies occur (Focardi et al. 2005; Ferretti et al. 2011), where a high ecotouristic pressure is exerted (Cetin and Sevik 2016; Mori et al. 2017), or where it represents.

Methods to count roe deer show different effectiveness in different areas (Acevedo et al. 2010) and include:

1. Drive count, mainly by hunters and volunteers, for about 10–15% of the study site to have a reliable inference

Communicated by: Dries Kuijper

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Published online: 27 June 2018

(Zaccaroni et al. 2017). It is considered to be the most effective method in wooded area, when a high number (60–120 people) of well-coordinated observers and beaters is available;

2. Vantage point counts (including distance-sampling: Ward et al. 2004), mostly effective at the lowest peak of vegetation cover (i.e. in winter) or in open areas (e.g. Zaccaroni et al. 2017). Density estimation is based on the distance between animals from the observation points and the number of observed individuals;
3. Pellet group count, which is based on the count of faecal pellet groups and it is reported to be the most reliable indirect method when a dense scrubwood is present or where the disappearance rate is the lowest, i.e. far from human settlements and cultivations (Aulak and Babińska-Werka 1990; Massei et al. 1998; Acevedo et al. 2010).

In natural areas, i.e. where it is impossible to determine the accuracy of counts, drive counts and vantage point counts are considered the most effective methods to assess roe deer density (Zaccaroni et al. 2017). Accordingly, they are thoroughly used to define roe deer selective culling calendars and programs in Italy. Despite this, they mainly rely on volunteers as beaters (often hunters), and thus they require a huge human effort, which may limit their feasibility in some areas (Acevedo et al. 2010). Conversely, pellet count requires a low human effort but is ineffective during the rainy season (i.e. autumn), when the combined effect of pellet disappearance rate, density of understory and presence of dung beetles is the highest, thus preventing the transect setup (Mandujano and Gallina 1995; Iborra and Lumaret 1997; Massei et al. 1998; Acevedo et al. 2010). Direct observations (e.g. with spotlight at night) and helicopter counts may be effective for deer species typical of open areas (e.g. Daniels 2006; Mysterud et al. 2007; Garel et al. 2010; Corlatti et al. 2016), but not for the woodland-dwelling roe deer.

In our work, we aimed to find a method to overcome these limits of these methods in wooded areas, reducing involved people and economic costs, but keeping the high effectiveness of vantage point counts (Zaccaroni et al. 2017). To assess roe deer density, we proposed the use of track count and camera trapping, which have been used for other deer species (Silveira et al. 2003; Mandujano 2005; Roberts et al. 2006), but the effectiveness of their application on roe deer is not available on scientific literature. To reach our objective, results by hunter counts performed through vantage point counts and drive counts were compared to data obtained through two indirect methods: camera trapping and track count. Given the presence of mud and clay soils in our study area, we predicted that both track count and camera trapping would produce effective results, comparable to those provided by the most used methods, i.e. vantage point counts and drive counts.

Materials and methods

Study area

Surveys were conducted from the beginning of December 2014 to the end of March 2015, in six forest game reserves of Friuli Venezia-Giulia region, NE Italy (Fig. 1; Table 1).

Site 1 (Moggio Udinese, province of Udine: 46.47° N–13.18° E, 800–1200 m a.s.l.) includes a mixed forest of conifers and deciduous trees (mainly *Pinus* spp., *Fraxinus* spp. and *Fagus sylvatica*). Human settlements are limited in the valley and the natural grasslands at high altitude are used for herding activities.

Site 2 (Vito d'Asio, province of Pordenone: 46.23° N–12.94° E, 700–1050 m a.s.l.) is mainly composed by deciduous forest (*Fraxinus* spp., *Fagus sylvatica* and *Corylus avellana*) and forest glades, with some mixed forest of *Pinus* spp.

Site 3 (Trasaghis, province of Udine: 46.28° N–13.07° E, 200–600 m a.s.l.) includes a riparian forest (*Populus* spp., *Salix viminalis*), which offers shelter to a wide animal community. Cultivations (most of all corn, wheat and soybean) occur in the Tagliamento riverbed or in its proximity.

Site 4 (Drenchia, province of Udine: 46.18° N–13.64° E, 400–600 m a.s.l.) and Site 5 (Stregna, province of Udine: 46.13° N–13.58° E, 600–900 m a.s.l.) show similar features, sharing the same habitat types and plant community (due to their proximity to each other), mostly composed by *Fagus sylvatica*, *Corylus avellana* and *Fraxinus* spp. The richness of water and the local soil fertility makes these territories particularly productive (especially in the valleys, cultivated with corn and permanent pastures), promoting the presence of a human settlement network, partially depressed by the local depopulation process.

Site 6 (Doberdò del Lago, province of Gorizia: 45.83° N–13.53° E, 30–160 m a.s.l.) is a calcareous plateau in karstland build up by some reliefs and wide depressions. This site is a human-dominated landscape, although a progressive abandonment of herding activities is ongoing, with cultivated areas remained only near human settlements. Scrubland, oakwoods (*Quercus* spp. with *Fraxinus* spp. and *Salix* spp.) also occurs as dominant vegetation.

Counts by hunters: drive counts and vantage point counts

The accuracy and precision of wildlife counts cannot be assessed as the real number describing the population size is unknown (see Daniels 2006). Selective culling programs of deer population should be carried out on the basis of local counts, and direct counts by hunters are considered the most reliable estimates of deer population size (Daniels 2006; Mysterud et al. 2007; Zaccaroni et al. 2017). Roe deer are

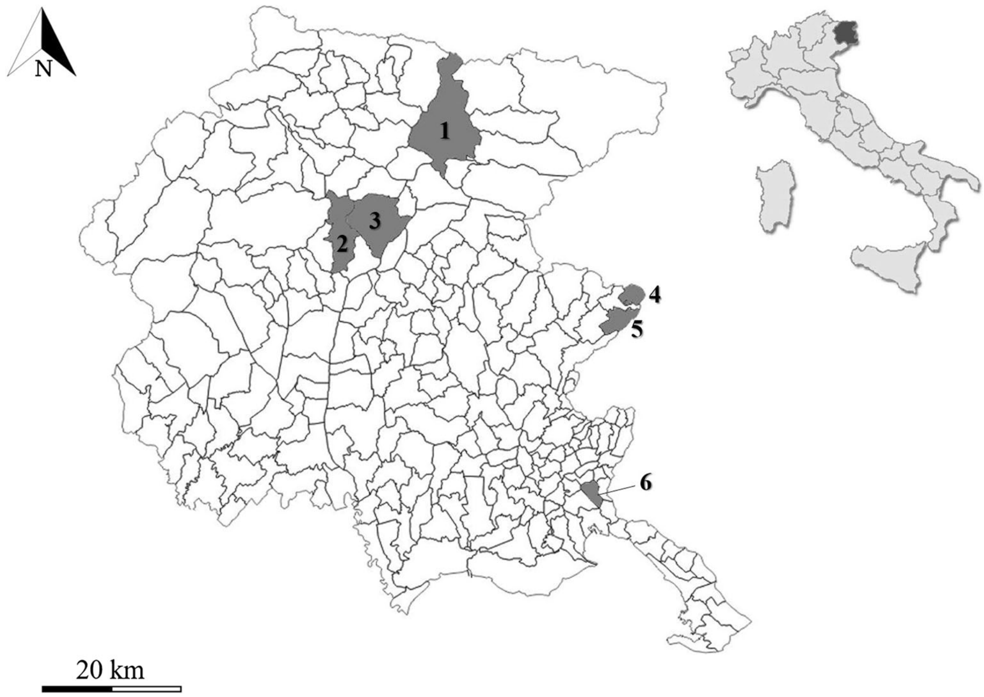

Fig. 1 Location of the study sites. (1) Moggio Udinese; (2) Vito d'Asio; (3) Trasaghis; (4) Drenchia; (5) Stregna; (6) Doberdò del Lago

widespread both in forests and in plain, open areas in Friuli Venezia-Giulia. Counts are usually carried out through vantage point counts together with drive counts, involving about 60–80% of local hunters (Table 2). Drive counts are finalized to an estimation of at least 15% of each management unit (game reserve), coordinated by the Regional Plan of Wildlife Management (RPWM). In our study sites, counts covered randomly selected areas of 25–40 ha and were carried out between March and April (with at least two repetitions), when the roe deer shows solitary and territorial habits (Andersen et al. 1998), thus being distributed more homogeneously and randomly on the territory (Zaccaroni et al. 2017). Vantage point counts are carried out following Zaccaroni et al. (2017) as an additional method to drive counts only in open areas. Counts involved at least 10–20 beaters per sampled area and 20–30 vantage point observers separated each other 10–20 m, depending on their local availability.

Camera trapping

The roe deer is not individual recognizable, thus we used the method described by Rowcliffe et al. (2008). The use of camera traps, with the method developed by Rowcliffe et al. (2008) takes into account the contact between animals and cameras, eliminates the requirement for individual recognition of animals and offers an important tool for estimate densities. It depends basically on the animal speed and on the characteristics of the camera trap (i.e. distance and angle of animal detection).

Following Rowcliffe et al. (2008), camera traps were randomly placed along and in the immediate of transects, complying with the method parameters. The Rowcliffe formula provides an estimation of animal density in the study area:

$$D = \frac{y}{t} * \frac{\pi}{vr(2+0)}$$

Table 1 Habitat composition of the study sites. Snowfalls are reported as a percentage on the total annual precipitations (www.regione.fvg.it)

Study site	Size (ha)	% of wildlife reserve	% human settlements	Annual precipitations (mm)	Snowfall (%)
Site 1	11,021.00	22.3	6.2	2000–2200	8–10
Site 2	4.84	7.0	3.5	2000–2400	10–11
Site 3	5.65	23.8	8.3	2000–2400	2–3
Site 4	1223.00	0.0	17.1	3000–3500	9–11
Site 5	1921.00	0.0	17.1	3000–3500	9–11
Site 6	670.00	32.3	21.3	1200–1400	4–6

Table 2 Number of volunteers involved in drive counts and vantage point counts of roe deer in each study site during our survey period

Site	Drive counts	Vantage point counts
Site 1	94	55
Site 2	43	25
Site 3	79	45
Site 4	22	20
Site 5	30	18
Site 6	14	14

where y is the numbers of detection during time t in which camera traps worked, v is the animal speed and r and θ are the parameters of camera trap (radius r and angle θ of camera-trap sight).

Before the field-placement of camera traps, each reserve was analysed through satellite maps to select the best sites to cover the entire area. We used 24 Boskon-guard camera traps ($r = 0.0125$ km and $\theta = 1.35$ rad), kept active between 1st of December 2014 and 31st of March 2015 and controlled once every 15 days. We did not use any attractive substance to avoid the violation of the random sample. Each photo including a roe deer was considered as a single score.

The animal speed (v) of the Rowcliffe formula was calculated in two ways: speed 1 was detected from literature data (Pépin et al. 2004; Coulon et al. 2008), whereas speed 2 was calculated through the body mass scaling rules (BMSR) described by Carbone et al. (2005). For the calculation of speed 2 through BMSR, we calculated firstly the daily traveled distance M rising the value of roe deer body mass, obtained from an average winter weight of the target species in our study sites (19.75 kg, $n = 50$: Romani 2016), to the exponent 0.26. We involved a wide range of species from different biomes and we used that scaling exponent for the Cetartiodactyla order following Keeping (2014). Following Coulon et al. (2008), we assumed 11 h of activity per day. To obtain daily-travelled distance of roe deer (M), speed data from literature were multiplied for the activity hours per day (Table 1). We use the mean density obtained using speed 1 and speed 2 (Table 1) in our analyses.

Track count

Surveys were conducted on a set of plots, selected from each game reserve according to the stratified random systematic sample. Four transects for each game reserve have been randomly placed. We avoided to use existing animal paths or trails, since this will lead to an overestimation and therefore unrepresentative evidence of animal density, as the possibility of sighting animal tracks would increase. It is also important that the direction of transect lines do not be parallel to physical or biological structures (e.g. fences, roads, rivers, ecological corridors), potentially affecting animal distribution and creating density gradients (Keeping 2014).

Roe deer footprints (Fig. 2) can be easily distinguished from those of other ungulates present in the study area (i.e. the wild boar *Sus scrofa* and the red deer *Cervus elaphus*), according to their size and shape. Between December and March, no young roe deer (i.e. < 6 months, as the births are given in May/June) occur. All detected footprints belonged to adult individuals (i.e. 3–5 cm in roe deer). Footprints showing intermediate sizes could be distinguished from that of wild boar (even of a young) considering the distal part of the hoofs (more pointed in roe deer with respect to wild boar) and dew claws which are wide on the side of the hoofs in wild boar and aligned in deer species (Fig. 2). Considering the variations of footprint size and shape depending on different gaits and substrates, field-operators were experienced trackers and perfectly knew the study site and the study species to be tracked.

This method requires the track count of known age and the estimation of the daily animal movement (Stephens et al. 2006; Keeping 2014; Keeping and Pelletier 2014). Formozov (1932) found a relationship between the number of tracks and the density of an animal species in a particular area (Keeping and Pelletier 2014).

Density is calculated through the Formozov-Malyshev-Pereleshin (FMP) formula (Formozov 1932):

$$D = \frac{\pi}{2} \frac{x}{SM}$$

where D is the density of the target species, x is the number of the intercepted tracks, S is the transect length and M is the daily-travelled distance by the target species (i.e. 2.31 km).

We used the CyberTracker software to collect georeferenced data of track counts on the field, which is user-friendly and not time-consuming. We collected data through the use of a smartphone and downloaded them on a PC afterwards. We use the mean density obtained using speed 1 (i.e. 0.083 km/h) and speed 2 (i.e. 0.210 km/h) in our analyses.

Data analysis

We estimated the effectiveness of camera trapping and track-count density estimates, by comparing them with results of counts by hunters in 2014–2015 through Pearson's correlation test, calculated by using the Student's t distribution with n-2 degrees of freedom (where n is the sample size). A further similar test was conducted to compare camera trapping and track-count results. Tests were carried out using R 3.3.2 (R Core Team 2013). Then, we calculated the total cost of camera trapping and track-count survey methods. Costs included materials (camera traps, softwares) and human effort, including the time needed to organize counts and to place camera traps, time to control camera traps and time spent in the field at a

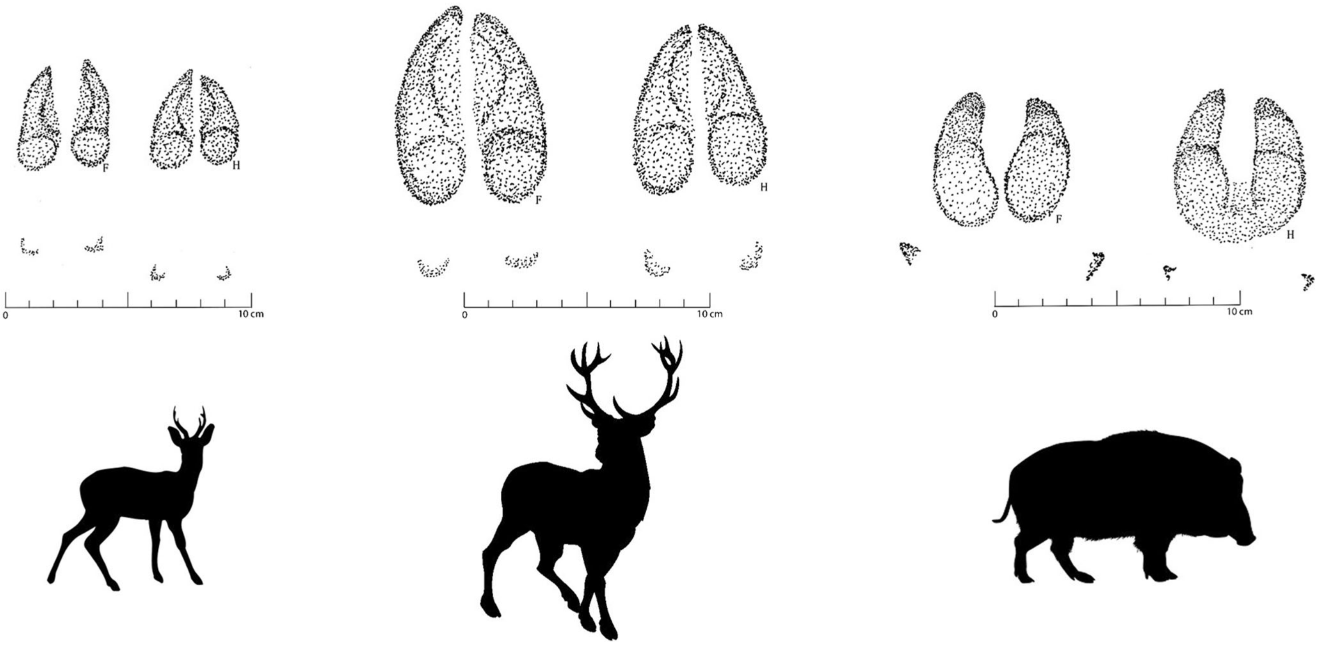

Fig. 2 Ichnotypes of roe deer, red deer and wild boar footprints; F = front, H = hind. Drawn by the first author (TR)

standard rate of 10.00 €/h. Total costs were calculated by multiplying costs per visit by the minimum number of visits needed to assess roe deer densities.

Results

Results of counts conducted by hunters (drive counts + vantage point counts) for our survey are shown in Table 3. Previous records (2012–2013 and 2013–2014) showed that density of roe deer has been similar in all the surveyed sites (Table 3).

Density of roe deer measured through camera-trapping and track-count methods showed comparable results with that of counts by hunters (camera trapping: $r = 0.94$, df = 4, $p = 0.004$, $n = 6$; track count: $r = 0.85$, df = 4, $p = 0.003$, $n = 6$: Fig. 3). Accordingly, results of the density estimate through camera-trapping and track-count methods were highly correlated ($r = 0.94$, df = 4, $p = 0.004$, $n = 6$).

Track-count survey was 28% cheaper than camera trapping (Table 4), even if corrected for the number of necessary surveys.

Discussion

Our work suggests that both camera-trapping and track-count survey are as effective as counts by hunters to assess roe deer density in forested areas of North-Eastern Italy, thus fulfilling our prediction. Accordingly, results of analysed count methods were significantly correlated, therefore suggesting a comparable effectiveness. We are aware of the snags related to a small sample size, so we cannot rule out that our correlation tests may have provided results biased by a low amount of data (Soper et al. 1917); despite this, high significant correlation tests suggest that assessed methods could be actually as effective as counts by hunters.

Camera-trapping and track-count methods require a low human effort (i.e. two field-operators), with track count being ~ 28% cheaper than camera trapping. Our cost analysis did not take into account the fact that plastic camera traps could be reused for several surveys, partially reducing the costs of this type of survey, therefore making the methods comparable in terms of required budget. By contrast, if on one side track count cannot be used where soil is too hard/dry or rocky, camera traps requires suitable places to be set, which may be challenging in open areas or in the surroundings of human settlements. Some authors have criticized the method proposed by Rowcliffe et al. (2008), considering it unreliable (Foster and Hamsen 2012; Parsons et al. 2017), thus supporting the use of camera traps only to assess densities of

Table 3 Density of roe deer (on 100 ha) assessed through counts by hunters in our survey year (2014–2015) and in previous periods

Site	2012–2013	2013–2014	2014–2015 (our survey)
Site 1	2.47	3.40	3.58
Site 2	5.78	6.50	6.50
Site 3	5.24	5.13	5.06
Site 4	8.67	8.99	6.54
Site 5	16.66	17.70	18.22
Site 6	20.90	21.34	20.44

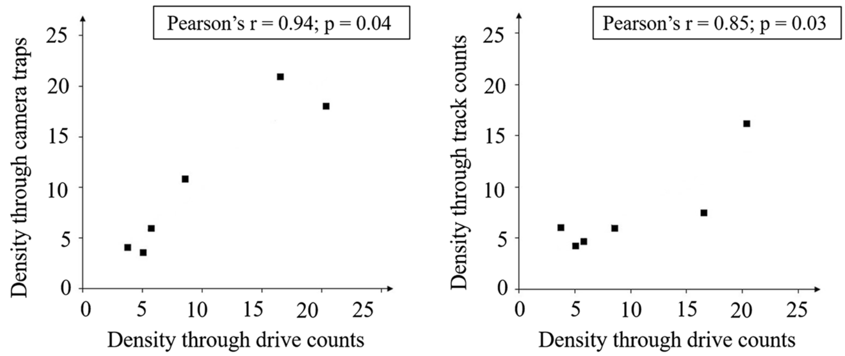

Fig. 3 Relationship between density estimation through drive counts and camera trapping (left), and counts by hunters and track counts (right)

individually recognizable species (e.g. Tobler and Powell 2013; Anile et al. 2014; Villafañe-Trujillo et al. 2018). The track-count method seems to be reliable, particularly when carried out on sandy, muddy or humid terrains (Stephens et al. 2006; Keeping 2014; Keeping and Pelletier 2014), as those of our study sites. Conversely, track-count method may also lead to lower density estimates than hunter counts (see Fig. 3); apparent differences in the accuracy between methods should be considered when choosing for a certain count method. The persistence of ungulate tracks on the ground depends on habitat features, as well as on weather, which may in turn change across study sites; deer spatial behaviour (e.g. home range and foraging movements, which may vary across sites) also affects track deposition rate (e.g. D'Eon 2001; Breed et al. 2012). Tracks of roe deer may be easily detected in all our study sites and only recent tracks were counted by specialized trackers. Conversely, because of the small sample size, we pooled data from different study areas, to compare counting methods; therefore, we cannot rule out that our results may have been influenced by the local confounding factors (i.e. habitat, weather and deer mobility).

Usually, roe deer thrive in heterogeneous habitats (including forest glades: Morellet et al. 2011; Lovari et al. 2017), with access to a wide range of resources and conditions, including food and refuge. The high roe deer density in the Mediterranean region (site 6) and the one density in Alpine bioregion (site 1) may be justified if we consider the different climatic conditions. Furthermore, site 6 is composed by different ecotonal landscapes (scrubland, woodland and pastures), which are important for roe deer foraging and refuging (Cagnacci et al. 2011; Lovari et al. 2017); mild annual temperatures and occasional snowfalls result in low mortality due to snow cover and low winter temperatures. The lowest densities observed in site 1, on the one hand is due to the presence of long-lasting snow cover and low winter temperatures, which may increase the mortality rate.

Ecological monitoring, including population density estimates, represents a vital component of any conservation and management project (Kremen et al. 1994); this is particularly important both for species of conservation concern and for species interacting with human activities (i.e. crop raiders, problematic species: cf. Laurenzi et al. 2016). Adaptive management plans emphasize the importance of monitoring programs, which should be carried out with reliable methods (Elzinga et al. 2001). In times of economic crisis, it is mandatory to find the most effective method to monitor animal populations which would require the lowest amount of costs (Cagnacci et al. 2012), but which may vary across different

Table 4 Estimated total costs of camera-trap and track-count sampling to assess density of roe deer in six game reserves of NE Italy

Survey method	Item	Description	Single cost	Total cost at the end of survey
Camera trap	Field equipment	24 camera-trap model Scout Guard Camera SG-560V (including batteries and SD cards)	150.00€	3360.00€
		Human effort (808 h, 2 operators)	10.00€	8080.00€
	Transportation	4800 km	0.30€	1440.00€
	Total camera-trapping survey method			12,880.00€
Track count	Field equipment	CyberTracker Greenware software programming for data collection (16 h)	10.00€	160.00€
		1 Smartphone for data collection on the field	30.00€	30.00€
		Human effort (768 h, 2 operators)	10.00€	7680.00€
		4 forensic rulers	6.00€	24.00€
	Transportation	4800 km	0.30€	1440.00€
	Total track-count survey method			9334.00€

study areas. Our study sites were unsuitable for pellet counts, given the wide occurrences of open areas, ecotourism and human settlements, which may limit the effectiveness of this method (Massei et al. 1998; Ferretti et al. 2011).

Until last decades, indirect detection of animal species including tracks and camera traps were only considered to support other field techniques which involved the direct contact with individual animals (e.g. capture-mark-recapture methods) or were only used to determine the presence/absence of species (O'Connell et al. 2010). Thriving in a worldwide economic crisis, the use of methods and techniques which have a limited economic impact on the institutions or organizations focusing on wildlife conservation and management must be encouraged (Cagnacci et al. 2012). Indeed, the most effective method to estimate a population density and its accuracy are always dependent on the study area, and they should be evaluated time by time. As to our study site, we suggest that both camera-trapping and track-count methods described in our work may provide reliable and easily applicable alternatives to counts by hunters or to the use of relative abundance indices to estimate roe deer population density.

Acknowledgements We would like to thank the Friuli Venezia-Giulia Region for sharing their data, Cristina Comuzzo and hunters from the SIPS (Società Italiana Pro-Segugio- www.enci.it) project for their support with camera trapping and Yannick Fanin for his support in Doberdò del Lago Reserve. We thank CyberTracker Conservation for the software. Part of this research was carried out within the project named "L'interazione tra gli ungulati, attività cinofilia, caccia con l'uso dei cani da seguita e grandi e meso carnivori" funded by the Società Italiana Pro-Segugio- www.enci.it.

Author contributions TR, CG and SF conceived the idea and collected all the data; EM helped in the paper organization and wrote part of it based on the data collected by other authors. Two anonymous reviewers kindly improved the first version of our manuscript with their comments.

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