FALLOW DEER AND WILD BOAR PELLET GROUP DISAPPEARANCE IN A MEDITERRANEAN AREA

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Abstract: Information about local population densities is essential to manage ungulates and is often obtained by pellet group counts. Estimating the rate of pellet group disappearance is critical for the reliability of this method. However, no studies have been performed on pellet group disappearance rates in Mediterranean climate, and no quantitative information is available on loss of pellet groups of wild boar (*Sus scrofa*) and fallow deer (*Dama dama*). We investigated disappearance rate of wild boar and fallow deer pellet groups in a coastal Mediterranean area and assessed the influence of possible correlates. Every season, 30 fresh pellet groups per species were deposited in each of 4 habitat types, and their disappearance rate was recorded the first week after placement and every 3 weeks thereafter. Pellet group loss varied more in relation to season than to habitat and followed a similar pattern in both ungulates. Pellet groups persisted longest in winter: at least 99% of fallow deer and 100% of wild boar pellet groups were still present 1 month after deposition, and 78% of pellet groups of both species had remained 3 months after deposition. Conversely, the disappearance rate increased dramatically in autumn, particularly for fallow deer: 88% of fallow deer and 5% of wild boar pellet groups disappeared 1 month after deposition. Dung beetles (*Geotrupes, Aphodius*) and rooting activity of wild boar influenced disappearance rate of pellet groups. In Mediterranean regions, pellet group counts should be performed during winter, and pellet groups should be counted in a 1-month period to optimize the reliability of the method.

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Key words: *Dama dama,* defecation rate, fallow deer, Mediterranean, *Sus scrofa,* wild boar.

Wild boar and fallow deer are presently found on 6 continents, with their distribution due to both natural occurrence and introduction (Chapman and Chapman 1980, Barrett and Spitz 1991). In most countries, both species can reach high densities and cause serious damage to crops and woodlands (Kay 1993, Bouldoire and Vassant 1994, Mayle et al. 1996). Hence, information about local population densities is essential for the management of these ungulates and is often estimated by pellet group counts.

Pellet group surveys have been widely used to assess ungulate numbers (e.g., Bailey and Putman 1981, Rowland et al. 1984, Aulak and Babinska-Werka 1990, Plumptree and Harris 1995), particularly in areas of low visibility and in large-scale studies. Assumptions necessary to interpret data from pellet group counts were discussed by Van Etten and Bennett (1965), Neff (1968), Baddeley (1985), Ratcliffe and Mayle (1992), and Massei and Genov (1998). The commonly used clearance-plot method is based on recording the fecal accumulation over a fixed amount of time in previously cleared plots and then dividing the count by the defecation rate of the species involved. Accounting for pellet group disappearance between consecutive site visits is critical for the reliability of this method.

Previous studies investigated the detectability of ungulate pellet groups in a variety of habitat types to provide correction factors for local disappearance rates (Wallmo et al. 1962, Wigley and Johnson 1981, Harestad and Bunnell 1987, Lehmkuhl et al. 1994). Because pellet group counts are time consuming and labor intensive, all these studies tried to optimize the time interval between consecutive visits. Specifically, these studies tried to define the time period when fecal accumulation was maximal and the pellet group disappearance was minimal. However, no studies have been performed on disappearance rates of pellet groups in Mediterranean regions, and no quantitative information on the decay rates of wild boar and fallow deer pellet groups are available. We investigated the disappearance rate of wild boar and fallow deer pellet groups in a Mediterranean coastal area and assessed the relative importance of habitat and season on pellet group loss.

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STUDY AREA

The study was conducted in the Maremma Natural Park, along the west coast in central Italy (42°39′N, 11°05′E). Altitude was 0–417 m and the climate was Mediterranean, with mean temperatures varying from 6°C in February to 23°C in July. Precipitation (500–750 mm/yr) was seasonal and mainly concentrated in spring and autumn.

We recognized 4 types of habitat based on the vegetation communities described by Arrigoni et al. (1985): (1) maquis scrub, characterized by *Quercus ilex, Arbutus unedo,* and *Phyllirea latifolia*; (2) pinewood, dominated by *Pinus pinea*; (3) sand dunes with *Juniperus oxycedrus*; and (4) meadows dominated by grasses and sedges. Following Pigozzi (1991), we considered 4 seasons: winter (Dec–Feb), spring (Mar–May), summer (Jun–Sep), and autumn (Oct–Nov).

No wild boar hunting and very limited deer shooting were allowed in the area, and no large predators were present. In 1990, about 14.2 fallow deer/km^2 lived in the park (Rossi 1994), and in March 1993 the population of wild boar was estimated to be 12.8/km^2 (Massei et al. 1996).

METHODS

The study was conducted between January 1993 and January 1994. For each species, we placed 30 pellet groups in every habitat at the beginning of each season (n = 120 pellet groups/species). Within a habitat, we spaced pellet groups 7 m apart along a randomly chosen transect.

We collected fresh pellet groups of fallow deer in a 40-ha enclosure with a high density of deer; transects were cleared and visited every 2 days to ensure that feces were ≤48 hr old. Fresh pellets of wild boar were collected by daily visits to heavily used sites and were judged to be ≤2 days old. All pellets were refrigerated until placed at the experimental site. Mean values in this paper are reported ± standard errors.

In January 1993, an average of 64.2 ± 2.7 pellets/group was found (n = 81) for fallow deer; groups of 60 pellets each were therefore used in experiments. Wild boar feces (n = 49) were composed of a mean of 4.5 ± 0.2 pellets/group, but in contrast to deer, boar pellets belonging to a group often differed in size and shape; therefore, we used all pellet groups found in each group of wild boar.

We monitored pellet group disappearance 1 week after the beginning of the experiment and then every 3 weeks until ≥50% of the groups had disappeared from at least 2 habitats. For fallow deer, we counted the number of pellets per group at each visit, and groups were considered to have disappeared when the number of pellets per group was ≤5 (Freddy and Bowden 1983, Ratcliffe and Mayle 1992).

Pellet groups of wild boar were regarded as having disappeared when no visible sign remained. For fallow deer, the effects of habitat, season, and habitat × season interaction were tested on the number of pellets remaining in each group after 1 month and 3 months. Data were arcsine transformed to stabilize the variance and analyzed by a general linear model (GLM; Zar 1984). Because the location of pellet group was not replicated within habitat and season, we tested the main effects of season and habitat against their interaction mean square (MS), whereas we assessed the potential for a genuine interaction against the within-location variability (error MS).

We recorded the number of cases where pellet groups were partially or totally buried by coprofagous insects. Counting the number of pellet groups disturbed by insects was possible only for fallow deer because insects buried entire pellets. We could not count pellets for wild boar, because insects cut pellets into smaller pieces before burying them, and the effects of insects versus natural decay were thus not separable.

We tested effects of habitat and season on disappearance of pellet groups of fallow deer and wild boar by fitting a log-linear model (Sokal and Rohlf 1995) to the number of pellet groups that disappeared after 1 and 3 months. We derived correction factors for the number of pellet groups likely to remain in different habitats and seasons from the proportion of pellet groups missing after 1 and 3 months. We calculated the proportion of pellet groups missing after time t, and the asymmetrical 95% confidence limits (Stuart and Ord 1991), as follows:

$$p = (1 - n_i/n) \pm 1.96\sqrt{\{[p(1-p)/n] + (1.96)^2/4n^2\}},$$

where p = proportion missing, n_i = number of groups found, and n = number of groups de-

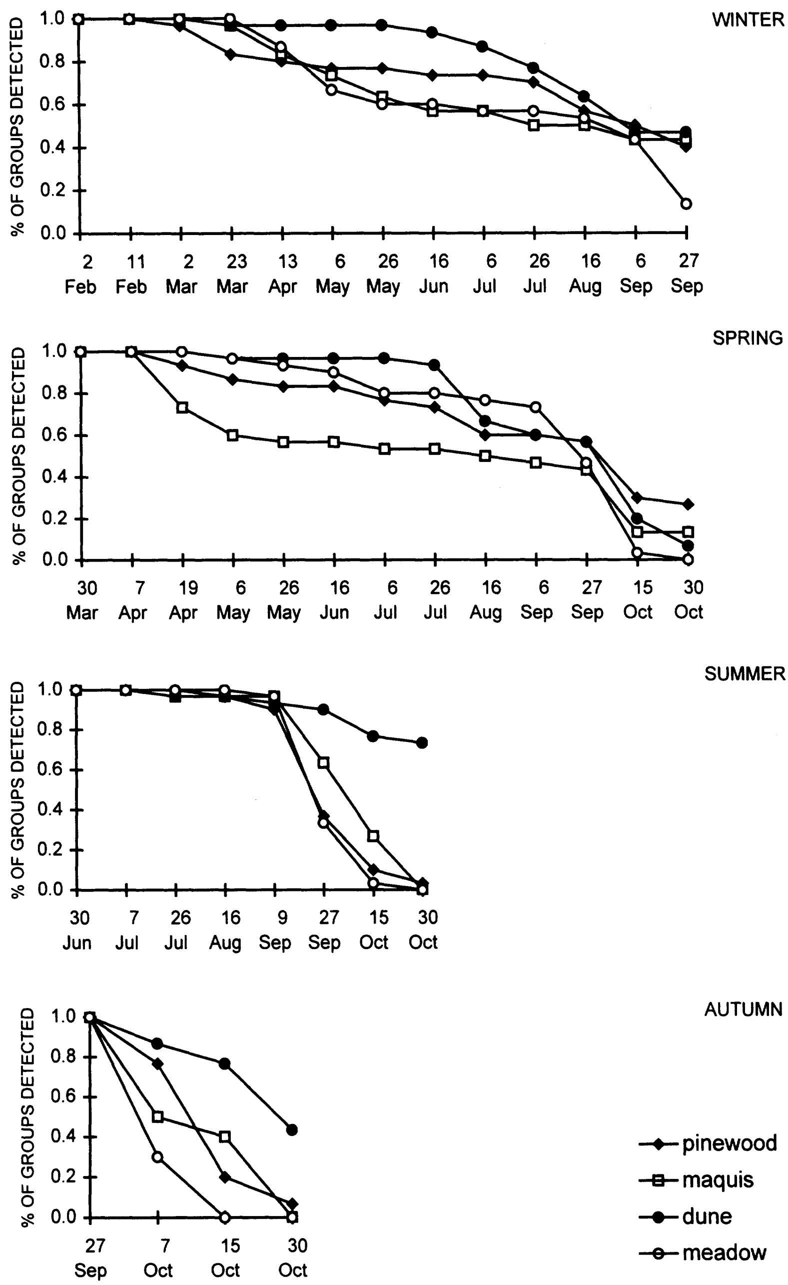

Fig. 1. Seasonal disappearance rate of fallow deer pellet groups expressed as the proportion of experimental pellet groups detected over time in 4 habitat types in Maremma Natural Park, Italy, 1993–94.

posited at the beginning of the experiment. We performed the statistical analyses with MINITAB (MINITAB, 1991). We used the EX program (Krebs 1989) to calculate pellet group persistence (mean length of time a pellet group will last in a particular habitat and season) and 95% confidence limits.

RESULTS

For the number of fallow deer pellets per group found 1 month after deposition, the habitat × season interaction was significant ($F_{9,464}$ = 8.14, $P < 0.001$) when tested against the error MS, but the interaction explained very little of the total variance (6.2%). Accordingly, we

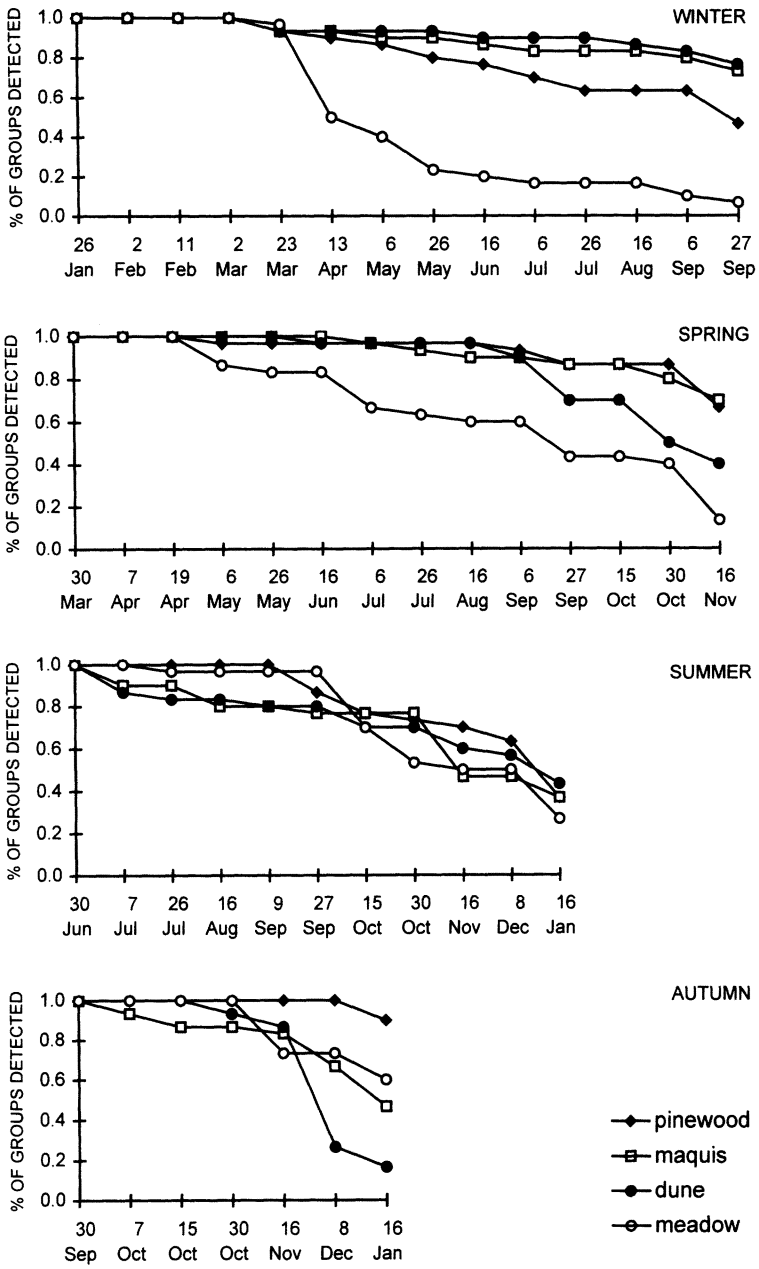

Fig. 2. Seasonal disappearance rate of wild boar pellet groups expressed as the proportion of experimental pellet groups detected over time in 4 habitat types in Maremma Natural Park, Italy, 1993–94.

tested the main effects against this interaction term. By far, the largest source of variability (50.6% of total variance) in the number of fallow deer pellets per group 1 month after deposition was due to season ($F_{3,9}$ = 25.21, $P <$ 0.001). Variation due to habitat (5.2% of total variance) was much less important ($F_{3,9}$ = 2.58, $P >$ 0.05). Similarly, season explained 14.7% of variance in number of fallow deer pellets per group recorded 3 months after deposition ($F_{3,9}$ = 11.64, $P <$ 0.001). Habitat ($F_{3,9}$ = 4.98, $P >$ 0.05) explained 5.3% of the total variance, whereas habitat × season ($F_{9,464}$ = 4.55, $P <$ 0.001) explained only 3.8% of the total variance.

We recorded pellets of fallow deer buried by coprofagous beetles in 92 of the 480 groups de-

Table 1. Proportion of pellet groups ($\bar{x}$ and 95% CI) of fallow deer that disappeared 1 month and 3 months after deposition in Maremma Natural Park, Italy, during 1993–94. Habitat means across seasons are omitted because seasonal values within habitat vary considerably, but the mean across habitats within seasons is shown because it is fairly constant.

Period	Habitat type									
	Pinewood		Maquis		Dune		Meadow		Mean	
Season	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
1 Month										
Winter	0.03	0.09	0.00		0.00		0.00		0.01	0.07
Spring	0.10	0.10	0.40	0.19	0.03	0.09	0.03	0.09	0.14	0.14
Summer	0.00		0.03	0.09	0.03	0.09	0.00		0.02	0.08
Autumn	0.93	0.11	1.00		0.57	0.19	1.00		0.88	0.13
3 Months										
Winter	0.23	0.16	0.27	0.17	0.03	0.09	0.33	0.09	0.22	0.16
Spring	0.20	0.16	0.47	0.19	0.03	0.09	0.20	0.16	0.23	0.16
Summer	0.63	0.18	0.37	0.18	0.10	0.10	0.67	0.18	0.44	0.19
Autumn	1.00		1.00		1.00		1.00		1.00	

posited: 63 cases (68.5%) occurred in autumn, of which 28 were in pinewood and 25 were in meadows. Rooting activity by wild boar also accelerated the disappearance of the number of pellets per group in 69 cases, of which 29 were in summer (n = 23 in maquis) and 22 were in autumn (n = 17 in maquis).

Disappearance of pellet groups of fallow deer (Fig. 1) and wild boar (Fig. 2) showed similar temporal patterns. For both species, irrespective of the season in which experimental pellet groups were put out, disappearance was generally low in winter, spring, and summer, and much faster in autumn. Apparent exceptions to this general trend appeared for fallow deer in winter (maquis, meadow) and for wild boar in winter and spring (meadow).

One week after deposition, none of the pellet groups of fallow deer had disappeared in winter, spring, and summer, but losses were recorded in autumn; therefore, 1-week data were analyzed only for autumn, and the disappearance of pellet groups varied with habitat (χ^2_3 = 10.44, $P < 0.023$). In contrast, number of pellet groups of fallow deer that had disappeared after 1 month varied with habitat (χ^2_3 = 10.54, $P <$ 0.027), season (χ^2_3 = 374.79, $P < 0.001$), and habitat × season (χ^2_3 = 18.52, $P < 0.020$). Number of pellet groups of fallow deer that had disappeared after 3 months also varied with habitat (χ^2_3 = 21.87, $P < 0.001$) and season (χ^2_3 = 265.43, $P < 0.001$), but not in relation to the habitat × season interaction (χ^2_9 = 12.96, $P >$ 0.10).

One week after deposition, no pellet groups of wild boar had disappeared in winter and spring, and losses in summer and autumn were too small to test for effect of habitat and season. Number of pellet groups of wild boar that had disappeared after 1 month varied with season (χ^2_3 = 13.22, $P < 0.005$) and habitat × season (χ^2_9 = 20.75, $P < 0.02$), but not in relation to

Table 2. Proportion of pellet groups ($\bar{x}$ and 95% CI) of wild boar that disappeared 1 month and 3 months after deposition in Maremma Natural Park, Italy, during 1993–94. Habitat means across seasons are omitted because seasonal values within habitat vary considerably, but the mean across habitats within seasons is shown because it is fairly constant.

Period	Habitat type									
	Pinewood		Maquis		Dune		Meadow		Mean	
Season	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
1 Month										
Winter	0.00		0.00		0.00		0.00		0.00	
Spring	0.03	0.09	0.00		0.00		0.00		0.01	0.07
Summer	0.00		0.07	0.11	0.17	0.15	0.03	0.03	0.07	0.15
Autumn	0.00		0.13	0.13	0.07	0.11	0.00		0.05	0.10
3 Months										
Winter	0.13	0.13	0.10	0.12	0.07	0.11	0.57	0.19	0.22	0.16
Spring	0.03	0.09	0.03	0.09	0.03	0.09	0.27	0.17	0.09	0.16
Summer	0.13	0.13	0.23	0.16	0.20	0.16	0.03	0.09	0.15	0.14
Autumn	0.10	0.12	0.50	0.19	0.80	0.16	0.37	0.18	0.44	0.19

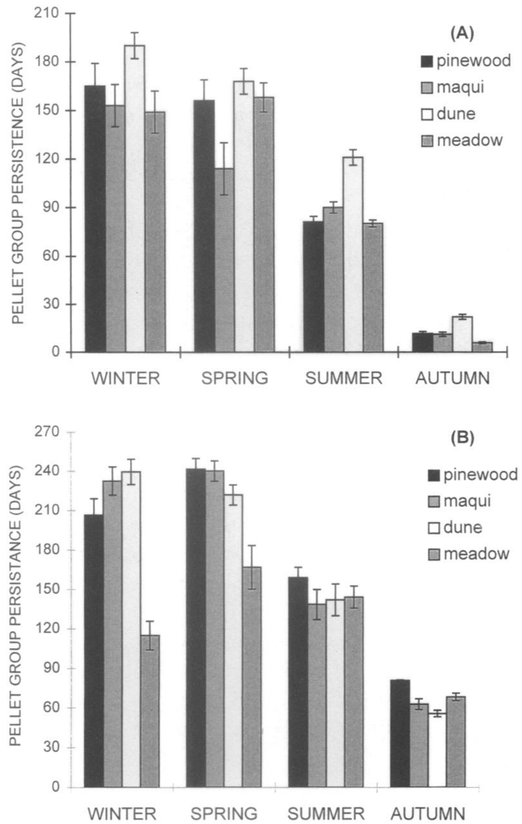

Fig. 3. Mean persistence of pellet groups of fallow deer (A) and wild boar (B) in Maremma Natural Park, Italy, 1993–94. Bars indicate 95% confidence intervals.

habitat ($\chi^2_3 = 6.41$, $P > 0.12$). Number of pellet groups of wild boar that disappeared after 3 months varied with season ($\chi^2_3 = 13.02$, $P < 0.005$), but not with habitat ($\chi^2_3 = 7.66$, $P < 0.11$), or habitat × season ($\chi^2_9 = 7.53$, $P > 0.10$).

Correction factors for the proportion of pellet groups of fallow deer likely to have disappeared after 1 and 3 months (Table 1) varied between zero and 100% and were higher in autumn and in the maquis. For wild boar, the correction factors (Table 2) varied between zero and 17% for 1-month-old pellet groups and between 3 and 57% for 3-month-old pellet groups. Pellet groups 1 month old had highest values in summer and in dune habitat, and 3-month-old pellet groups had highest values in autumn and meadow habitat. One and 3-month-old pellet groups of fallow deer disappeared more quickly than those of wild boar (1-month: $\chi^2_{15} = 76.80$, $P < 0.01$; 3-month: $\chi^2_{15} = 50.20$, $P < 0.01$).

Mean persistence of pellet groups of fallow deer (Fig. 3A) declined between winter and autumn. Within each season, pellet groups in the dunes consistently showed the longest persistence. Mean persistence of pellet groups of wild boar (Fig. 3B) showed a similar seasonal pattern to fallow deer, but not consistently among habitat types. The lowest persistence of pellet groups was recorded in autumn, with mean values of 12.7 ± 23.4 days for fallow deer and 62.0 ± 6.5 days for wild boar. For fallow deer, the highest persistence was recorded in winter, with a mean value of 164.3 ± 9.2 days; for wild boar the highest persistence was recorded in spring, with a mean value of 217.5 ± 17.6 days.

DISCUSSION

Seasonal variation in disappearance rate of pellet groups occurs in both tropical (Anderson and Coe 1974, Jachmann and Bell 1984, Plumptree and Harris 1995) and temperate climate (Wallmo et al. 1962, Wigley and Johnson 1981, Mitchell et al 1985). Factors affecting pellet group disappearance include temperature, moisture, rain, frequency of freeze–thaw cycles, composition of pellet group, presence of coprofagous insects, and foraging for insects by birds (Neff 1968, Jachman and Bell 1984, Harestad and Bunnell 1987).

Our study showed that season explained most of the changes in disappearance of fallow deer pellets per group and of number of fallow deer and wild boar pellet groups. Habitat was significant only for fallow deer pellet groups. Differential disappearance rates among habitats were apparent in winter and spring, and pellet groups in dune habitat showed the lowest disappearance rate. We suggest seasonal factors such as temperature and rain are probably more important than habitat-related factors such as cover (e.g., closed pinewood and maquis vs. open meadows and dune). The rapid disappearance of pellet groups in autumn could be partly explained by rain. Although total annual precipitation in 1993 did not differ from previous years, 80% of the 1993 precipitation occurred between September and December (Massei 1995).

We could not separate effects of rain from those of dung beetles, whose influence on pellet groups was maximal in autumn. The role of beetles in affecting pellet loss is predominant in Mediterranean climates (Merritt and Anderson 1977, Lumaret et al. 1992), and dung beetle species are most abundant in late summer and autumn (Heijerman 1990). Dung beetle activity is strongly related to onset of rain and the rates of dung removed by beetles can be very high (Anderson and Coe 1974, Jachmann and Bell 1984). In autumn, we recorded beetles arriving on some pellets <1 hr after deposition.

Rain also influences the rooting activity of wild boar (Bowman and McDonough 1991, Hone 1995) and has been indicated as another factor accelerating disappearance of fallow deer pellets. In 1993, density of wild boar in the study area was very high (Massei et al. 1997), so their influence on pellet loss could have been unusually high in our study.

The mean persistence of pellet groups found in our study was within the range reported in temperate climates. For instance, Mitchell et al. (1985) indicated most pellet groups of roe deer (*Capreolus capreolus*) disappear within 3–5 months in invertebrate-rich areas with mild climate (southern England), and last for ≥1 year in colder climates (northwest Scotland). In Poland, Aulak and Babinska-Werka (1990) found pellet groups of roe deer persisted between 7 and 166 days; the minimum value was due to activity of dung beetles.

The fact that pellet groups of wild boar lasted longer than those of fallow deer could be explained by a possible difference in both fiber content and texture of pellets. According to Lehmkuhl et al. (1994), pellets with high fiber content would likely be more resistant to decomposition from physical and biological processes. Wild boar are monogastric, and their pellets contain partly undigested food parts. In contrast, fallow deer are ruminants, and their pellets are composed of finely digested particles. The size of the pellets may also be important in determining their disappearance rate. Dung processing by beetles possibly required more effort for wild boar pellets than for those of fallow deer. We observed dung beetles burying intact pellets of fallow deer, whereas wild boar pellets had to be broken into pieces before being transported underground.

MANAGEMENT IMPLICATIONS

In Mediterranean regions, winter is the period in which the disappearance rate of pellet groups is minimal. Hence, to minimize biases, winter is the period when pellet counts for both wild boar and fallow deer should be performed. The pellet group loss after 1 month was nil for wild boar and only 1 ± 0.03% for fallow deer. After 3 months (i.e., end of winter), loss is 22 ± 0.08% for both species. Nevertheless, relative to counts of accumulated pellet groups in the wild, our correction factors are maximal because they are all based on pellet groups deposited on day zero and recorded, for instance, on day 30.

Counts of pellet groups accumulated in the wild will include groups exposed to decay for shorter periods. Hence, our correction factors will slightly overestimate number of pellet groups initially produced. Accordingly, the best period to optimize the reliability of the pellet count is 1 month, and the period should occur in winter. To minimize effects of rain and insects, this period ideally should coincide with the coldest and possibly driest month of the year.

In areas where density of ungulates is lower than recorded in our study, a longer period between clearance and counting may be needed to allow most plots or transects to have at least 1 pellet group. If pellet group counts are to be used in Mediterranean regions to determine habitat use by wild boar and fallow deer, great caution should be exercised on data collected in autumn, because this is the season when pellet loss is greatest. In areas with low ungulate density (i.e., low deposition rate of pellet groups), use of autumn habitat should not be determined by pellet counts. In this case, one might find no pellet groups in many plots, and it would be impossible to know if no deposition occurred or pellet groups had disappeared. However, the high disappearance rate in autumn indicates that if autumn pellets are collected for diet analysis, there is a high probability that they would be <1 month old.

However, our study was based on only 1 year and 1 study site; thus, more sites and consecutive years would be necessary to establish whether our quantitative estimates are general. Nevertheless, our explanations for the disappearance rate of pellet groups agree with similar studies, and we suggest our results should be used when the pellet count method is applied in Mediterranean regions.

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EFFECTIVENESS OF WILDLIFE WARNING REFLECTORS IN REDUCING DEER–VEHICLE COLLISIONS: A BEHAVIORAL STUDY

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Abstract: Various reflector systems have been in use for a number of years to reduce deer–vehicle collisions, but their effectiveness on a long-term basis is still in question. We examined habituation of deer to repeatedly occurring light reflections from WEGU reflectors by studying the behavioral responses of fallow deer (*Dama dama*). Our experimental design eliminated factors normally associated with light reflections from reflectors (vehicle noise, light), and deer were exposed to light reflections at predetermined time intervals. The distribution of the behaviors flight, alarm, movement of head, and no reaction varied among nights. Despite this variability, however, fallow deer exhibited increasing indifference to reflections, which was explained by a habituation to the stimulus. Our results are expected to be valid for other species of deer and other types of reflectors. Habituation of deer and technical limitations of the reflectors, such as limited angle and low light intensity of the reflection, mean that reflectors are not reliable as a method to reduce the number of deer–vehicle accidents on a long-term basis.

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During the last 2 decades, the effectiveness of different kinds of wildlife warning reflectors has been widely tested, but very different conclusions have been reached (Olbrich 1984, Désiré and Recorbet 1985, Schafer and Penland 1985, Zacks 1985). A precondition for reflectors to be effective on a long-term basis is that deer do not cease to respond to the stimulus.

Most previously used methods are based on the assumption that light reflections lead to a change in deer behavior, causing a decrease in the number of deer–vehicle collisions. In the present study, we tested the behavioral response of free-roaming fallow deer to light reflections from WEGU wildlife warning reflectors (Walter Dräbing KG, Kassel, Germany). The present experiment differs from previous studies by eliminating unmeasured factors, such as vehicle noise and light, to test the hypothesis that deer habituate to light reflections from WEGU reflectors.

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STUDY AREA

The study was conducted in the 5,600-ha forest of Gribskov (56°00′N, 12°20′E), located in northern Zealand, Denmark. Forest vegetation consisted of mixed hardwoods, especially beech (*Fagus sylvatica*) and oak (*Quercus robur*), with interspersed patches of conifers, mainly spruce (*Picea* spp.). The 2 most common deer species in the forest were roe deer (*Capreolus capreolus*) and fallow deer, but sika (*Cervus nippon*)