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USING PELLET GROUP COUNTS TO ESTIMATE THE POPULATION SIZE OF THE PERSIAN GAZELLE IN THE STEPPE AREA OF GOLESTAN NATIONAL PARK, IRAN

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Estimation of population abundance is a basic task in analyzing the dynamics of wildlife population. The information on population abundance is also crucial to scientific management of wildlife (Härkönen and Heikkilä, 1999). To estimate the population density, the accuracy of a method is an important consideration (Cairns and Telfer, 1980; Robel, 1960). One of the accepted and accurate methods to estimate ungulate population density is the pellet group count that has been used for at least 50 years (Neff, 1968). The use of pellet group count for the first time was reported by (Bennett *et al.,* 1940) on population size, movement and habitat use of the deer *Odocoileus* sp. in forest types. In later years, the method had also been used to estimate population trends and habitat use (Guillet *et al.,* 1995; Skarin, 2009; Skarin *et al.,* 2010). The followings are the general arguments for using the pellet count method at a landscape level study: 1) the technique is relatively simple and low in cost; 2) a strong correlation exists between estimates from the pellet group counts and other methods (Barnes, 2001; White and Fuller, 1992). Most authors, however, even when continuing to use pellet group count techniques, have stressed sources of inaccuracy, namely non-random use of a heterogeneous environment, differential mobility, non-regular defecation by the animals, differential observer search and differential dung decay rates in different habitats (Neff, 1968).

As a IUCN threatened species, the populations of the Persian gazelle (*Gazella subgutturosa subgutturosa*) have been declining within the country over the last few decades. Throughout their range, Persian gazelles are the victims of illegal hunting and habitat loss, and although still widely spread, their numbers are declining and their distribution is uneven. The Persian gazelle is legally protected across all countries it inhabit, except Iran, where, traditionally, ungulates are used for legal game hunting. Even elsewhere, where legal protection exists, the law is not necessarily enforced effectively. Consequently, the species remains mostly in protected areas, such as nature reserves, and may increasingly grow to rely on national parks and reserves for safe refuge (Kingswood and Blank, 1996).

The knowledge of gazelle population and their trends are central to any kind of conservation effort (Nowzari *et al.,* 2007). Therefore, there is a need for population studies that can evaluate the actual status of these cervids. In Golestan National Park (GNP), managing and monitoring gazelle populations have been based on drive counts method, which requires a large number of people, and a discrete, bounded area to be censused. The current population of Persian gazelle estimated by the Department of Environment at GNP is around 250 gazelles at Mirzabaiylou Plain, 27 gazelles at Solegerd and 9 gazelles at Lohondor. Drive counts are most valued in research studies for obtaining highly accurate estimates for comparison with estimates derived from other methods (Neff, 1968). Therefore, for obtaining more reliable data about gazelle numbers, we attempted the use of pellet group count for the first time to estimate population density and size of the Persian gazelles in Iran and the steppe area of GNP.

Study Area

Golestan National Park (GNP), with an area of 91,859 ha has been a protected area since 1957, and is one of the famous national parks in the Middle East because of its natural values, such as a verdant

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and virgin forest and species diversity of flora and fauna. It is located to the east of the Caspian Sea between longitude 55º43' to 56º17'E and latitude 37º16' to 37º31'N. Persian gazelles live in the steppe habitats of the GNP, scattered throughout the northern (Lohondor), south (Mirzabaylou) and eastern (Solegerd) parts of the region (Figure 1). The study was conducted in a small part of the GNP called the Mirzabaylou plain, the main habitat of the Persian gazelle in GNP, which is located between latitude 37º18' to 37º22'N and longitude 56º07' to 56º15'E, and covering an area of 2,374 ha. The elevations in our study area ranged from 1,100 to 1,300 m and the climate is characteristically arid to semi-arid. The annual average precipitation is 400 mm, while the annual average temperature varies between 11.5 to 17.5ºC, with the absolute minimum temperature at -25ºC and the reported maximum at 45ºC. The main plant cover included thick shrubs; evergreen and annual vegetation, which mostly belong to Iran-Tooranian elements. *Artemisia* spp. is the main endemic species of the local vegetation. The density of shrub growth forms ranged from sparse to dense thickets from Mirzabaylou plain and its surrounding areas right up to the southern parts of the park to the Dasht and Almeh valleys, including the surrounding mountains of Solegerd and northern parts of the park, up to Lohondor. These growths were associated with barberry shrubs, *Rosa* sp. and *Tamarix* sp. in some cases. Around the Almeh Valley, the density and variation of vegetation were higher. *Artemisia* spp., along with annual species and steppe communities provide good cover for the hills and valleys, giving an expanded scrubland landscape that is a suitable habitat for the wildlife species of the park, such as gazelles, wild sheep and goats. Among three gazelle habitats at GNP, Mirzabaylou plain was selected as the main habitat, because it had a variety of vegetation types (Table 1 and Figure 1) and the most dense population of Persian gazelles.

Pellet Group Count

Two basic approaches to estimate the pellet group density are fecal standing crop (FSC) and fecal accumulation rate (FAR) (Campbell *et al.,* 2004; Hemami and Dolman, 2005). In the FSC method, the pellet group density was measured on the first visit to a plot, i.e. both old and fresh pellet groups were counted, and related to a known pellet group decay rate. In the FAR method, the pellet group accumulation over a fixed time period was measured in previously cleared plots (which should be short enough for decay not to significantly influence results), and there was no need to estimate the decay rate of the pellet groups. With both techniques, defecation rate was needed for calculation of the total animal abundance. Defecation and decay rates of ungulates are known to vary according to diet, their activity, rainfall, temperature and evaporation (Mayle and Peace, 1998; Mayle *et al.,* 1999; Murray *et al.,* 2005). Both techniques have been evaluated in the field but neither has proven to be more accurate or precise than the other, and most authors agree that the chosen technique and its success will depend on the species and the environment under consideration (Campbell *et al.,* 2004; Edge and Marcum, 1989; Hemami *et al.,* 2005; Smart *et al.,* 2004). In this study, density estimates were based on Fecal Accumulation Rate (FAR) technique as it has been successfully used in other geographical areas, including Finland (Härkönen and Heikkilä, 1999), Slovakia (Prokesova *et al.,* 2006), and China (Huapeng *et al.,* 1997).

In May 2010, the study area was divided into nine lines of 1-km intervals, with lengths of between 2 and 5 km. On these lines, we inspected 20 rectangular transects with 3-m width and 210-m length. Transects were distributed by stratified random design and the beginning and end of each transect were indicated by Global Positing System (GPS). At the same time, old pellets were cleared out

Table 1. Total number of transects and area of each vegetation type of gazelle habitat in the study site at Mirzabaylou in Golestan National Park

Vegetation type	Area (ha)	No. of Transects
I. *Artemisia herba-alba/ Eremopyrun bonaipartis/ Anabasis aphylla/ Aellenia* spp.	361.21	4
II. *Artemisia herba-alba/ Salsola rigida*	633.82	5
III. *Artemisia herba-alba/ Salsola vermiculata/stipa barbata/poa bulbosa*	86.36	3
IV. *Artemisia herba-alba/ Eurotia ceratoides /stipa barbata/poa bulbosa*	620.13	4
V. *Artemisia herba-alba/Aellenia* sp/*Annual forb*	672.76	4
Total	**2374.29**	**20**

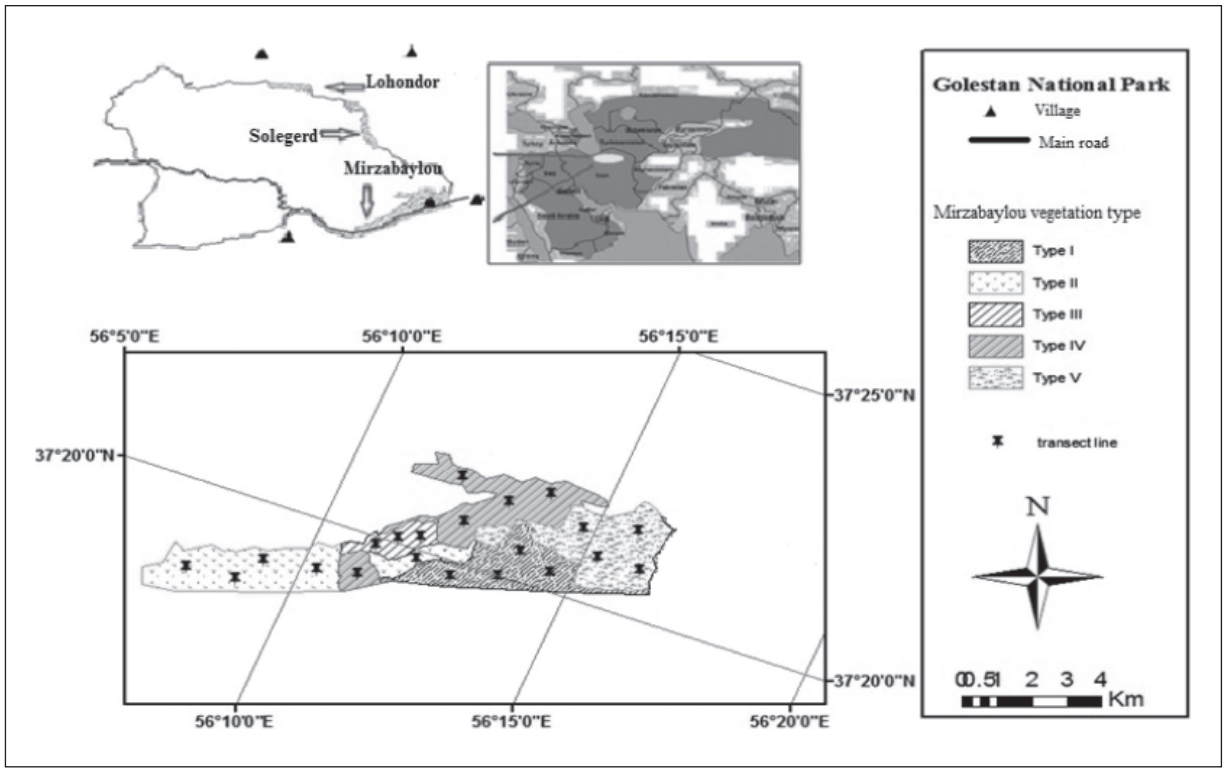

Fig. 1. Geographical location of three gazelle habitats (Mirzabaylou, Solegerd and Lohondor) at Golestan National Park and the location of sampling transects in Mirzabaylou plain as a study area (For more detail see Table 1).

on each transect while it was being established. The inspections were made by three observers, one of whom made the compass line, marked the midline of the transect and counted the pellet groups. The other two counted the pellet groups along a 1.5-m strip to the right and left of the mid-line. It was assumed that the number of missed pellet groups would be negligible using this procedure. An edge group was counted if half or more of the pellets were lying within the strip. Pellet groups are defined as fecal clusters containing five or more individual pellets (Hemami *et al.,* 2004). Pellet groups counted and pellets cleared were done at every two-month intervals due to the low decomposition rate of the pellet groups in arid areas (Hazeri *et al.,* 2009; Nowzari *et al.,* 2007). Lastly, all counted pellet groups were removed from the transects during each site visit. Therefore, accumulated pellet-groups within transects were counted and removed between 29th and 31th July; between 29th September and 1th October; between 28th and 30th November; between 28th February and 1th March; between 27th and 29th April. In winter, because of hard weather condition, we had to postpone data collection until one month later.

The population density of species was estimated using the following formula:

$$D\ [ind./km^2] = \left((D/A) \big/ (T \times F) \right)$$

where D is the number of pellet groups found on the transect, A is the size of the transect in km^2, T is the time (in days) of plot exposure and F is the defecation rate of the respective species (Olsson *et al.,* 1997). We calculated different gazelle population density values in order to investigate the effect of parameters (defecation rate and accumulation time) used in the results. The number of days during which the pellet groups had accumulated was set at 60 days, except in winter (90 days). The daily defecation rate of the Persian gazelle is unknown in the wild, so we utilized seven individual gazelles that were held captive in a 750-m^2 fenced enclosure in Eram Zoo at Tehran city of Iran. The counting of pellet groups lasted three days during summer/fall and each count was done in the early morning of each day.

Based on Paired t-test, there was no significant difference in defecation rate of Persian gazelle among three days of each month ($P > 0.05$), as well as there was no significant difference in defecation rate of Persian gazelle among different months ($P > 0.05$) (Table 2).

Daily defecation rate of 9.3 pellet groups/per gazelle/per day was obtained from the continuous observation of gazelles, which resulted in low defecation rates because of food and daily activity factors. In zoos, gazelles are mostly fed with fruits, such as apples, carrots, etc. as well as barley and

alfalfa. For more accuracy in estimating gazelle population size, we decided to use the average number of defecation per day and individual was set as 8.9 pellet groups/per day/per gazelle by (Abaturov *et al.,* 1995) for Grant gazelle. The mean density of pellet groups in 630 m^2 transects was compared between seasons using One-way ANOVA. It was found that pellet groups accumulated were significantly different among five seasons (F=2.70, P=0.035) (Figure 2).

Table 3 shows the variables and results of the gazelle population study during different seasons at the GNP. The Persian gazelle population density estimated was significantly different among seasons (P<0.05), but no significant difference (P>0.05) was found between the estimate of population density by use of defecation rate in captive gazelle and literature (Abaturov *et al.,* 1995). Extrapolating these numbers to the 23 km^2 (2374.29 ha) sampled, we obtained an actual population of Persian gazelles in the study area. In GNP, the average population size of the Persian gazelles based on pellet group count (304 individuals) was close to the drive count method (250 individual was counted by Iranian Department of the Environment, 2012 unpublished). The estimates of the gazelle population density obtained using the pellet group counts varied partially. The number of days in the counting period can be standardized for between-years comparisons, and the use of permanent sampling area will minimize this type of error.

The Persian gazelle population density estimated in this study for the GNP is comparable to the values obtained using other techniques in other parts of their habitat, for example, in Sanliurfa (Turkey), the average population size and densities of the Goitered gazelles were estimated respectively at 242±184 and 2.302±1.59 ind/km^2 for July; 365±179 and 3.476±1.70 ind/km^2 for January; 319±111 and 3.039±1.059 ind/km^2 for June, and lastly, 317±243 and 3.019±2.31 for November (Cobanoglu, 2010).The differences among season's estimates in our study area were likely due to sampling errors or gathering of different amounts of

Table 2. The average defecation rate of Persian gazelle at different months of the year in the Eram Zoo

Month/gazelle number	Pellet groups counted during per day			Defecation rate (pellet groups/ per gazelle/per day)
	1st 24 hours	2nd 24 hours	3rd 24 hours	
August/(10 gazelles)	78	72	79	7.56
October/(7 gazelles)	78	75	72	10.71
December/(7 gazelles)	77	74	73	9.64
				Total defecation rate= 9.3

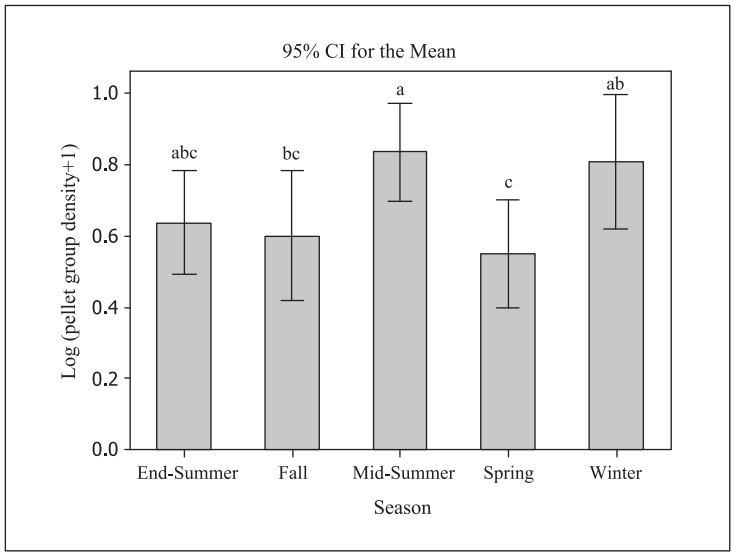

Fig. 2. Mean pellet group density accumulated in different seasons by pellet-group clearance transects in the gazelle habitat of the Golestan National Park (a, b, c indicate difference or similarity of the parameter across seasons by Fisher Test).

Table 3. Numbers of pellet group count in transect surveys and estimated density and population size of Persian gazelle at Golestan National Park

Transect surveys	Total pellet group	Accumulation time in day	Defecation rate	Population Density (animal/km^2)	Estimated population size (animal/study area)
Mid-summer	150	60	9.13	21.73	**500**
7.29.2010		60	8.9	22.32	**513**
Late-summer	89	60	9.13	12.89	**296**
9.29.2010		60	8.9	13.24	**304**
Fall	94	60	9.13	13.62	**313**
11.28.2010		60	8.9	13.98	**321**
Winter	161	90	9.13	15.5	**356**
2.28.2011		90	8.9	15.95	**366**
Spring	71	60	9.13	10.28	**236**
4.27.2011		60	8.9	10.56	**242**

pellet groups and indicated that the gazelles utilized their habitat all year round, even during periods of forage shortage in winter (Figure 2). Also, gathering of different amounts of pellet groups in each season can be related to variations in the gazelle defecation rate or levels of activities in different periods of the year. As some data suggest, factors that increase mean defecation rates include age, sex, and food quality (Rogers, 1987; Rollins *et al.,* 1984); high moisture content in the forage, high intake rates, rapid changes from native range forage to concentrates, and high percentages of fawns in the population (Connolly, 1981; Neff, 1968). Thus, the large variability in the daily defecation output can limit the use of pellet group counts for accurate censuses of ungulates. Despite all these limitations, pellet group count is a reliable method for determining ungulate population density, if each local population can be calibrated separately in order to use defecation rates that correspond to the food resources (Jordan *et al.,* 1993; Wallmo *et al.,* 1962). In our study area, we did not know the defecation rate of gazelles in the wild, thus, the number of daily defecations used (8.9 and 9.3 daily defecations) was obtained from the literature (Abaturov *et al.,* 1995) and zoo studies. Defecation rates are higher in wild ungulate in comparison with domesticated individuals (Rogers, 1987; Rollins *et al.,* 1984). Therefore, it would be necessary to conduct experiments to determine this variation, for example, by monitoring individuals in their natural habitat, to allow for a more accurate estimation of the gazelle population density.

In study area, population was estimated by clearance pellet group (FAR), which is more costly to install and monitor than that of standing crop (FSC), but has the advantage of allowing researchers to determine exactly the pellet group accumulation time (Freddy and Bowden, 1983) at different seasons. Pellet groups are frequently counted in a circular or rectangular plot (Neff, 1968), although both methods may, however, include considerable sources of error. Härkönen and Heikkilä (1999) reported that despite the strip counting being time-consuming, it evidently gave the moose population number closer to the actual ones, whereas the densities derived from circular samplings were overestimates. Hence, the strip sample was chosen in the study area, although there could be an overestimation of the gazelle number in the pellet group count despite the fact that the observations were made by three experienced observers. On the other hand, one possible source of error is that the observer may include more pellet groups lying on the border lines of the transect strip (Franzman *et al.,* 1976), and thus, there is a likely risk of overestimating the gazelle numbers by the pellet group count method in the study area.

Nevertheless, ungulate population estimates obtained with the pellet group count method have shown moderate to high agreement with estimates obtained by other methods, or even with known population sizes (Freddy and Bowden, 1983; Huapeng *et al.,* 1997; Neff, 1968; Robinette *et al.,* 1977) and dissensions are usually associated with errors in estimating time of deposition or defecation rate. Generally, the suitability of a given method to estimate the density of wildlife population depends mainly upon two factors, the accuracy and the simplicity. It is usually easier to use indirect method in practice, for ungulates. However, the accuracy of the indirect method would be a key consideration.

Huapeng *et al.* (1997) reported in comparison to other methods, such as line transect and track count, the estimation and precision of population density using the pellet group count method was the closest to the actual value. The gazelle densities obtained in the present study were partly higher than those estimated by the drive count method. This difference could be due to some gazelles escaping when they were counted by people. Gazelle population density estimated from pellet survey is based on a longer time period than the drive count, when the estimate is made during a relatively short period of time. Gazelles escaping when they are counted, however, may affect the accuracy of ground surveys. In this respect, we believe that the pellet surveys may provide results sufficiently reliable for management purposes. Pellet group counts can be combined with ground surveys (Forbes and Theberge, 1993) to obtain more comparative information. Ground surveys have, however, many sources of error that are difficult to quantify (Timmermann, 1993). If the density estimates are considered to be uncertain, between-year trends can be used to improve the situation.

The development of a density estimation method, which can be standardized for use in the steppe areas, is an important management tool that would serve to evaluate the conservation status of the gazelles in other areas. The population density of this species can be used as a reference for decision making, especially as current population numbers are unknown exactly and gazelles are affected by hunting and habitat destruction. Finally, it is suggested that the pellet group counts can be useful in monitoring the density of gazelles, and likely other cervid species as well. We strongly suggest replicating our study in other arid areas in order to test this sampling method. An important requirement is the comparison of this method under different levels of Persian gazelle abundance. However, considerable attention should be paid to the sampling procedure and parameters used in the calculations because they may have significant effects on the results. For example the problems involved in calculating exact population density values should be taken into account, and it would obviously be better to compare only between-year trends.

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