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Ecology of the Persian Squirrel, *Sciurus anomalus*, in Horsh Ehden Nature Reserve, Lebanon

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Abstract

The ecology of the Persian Squirrel, *Sciurus anomalus,* was studied in Horsh Ehden Nature Reserve, Lebanon. Trapping yielded very low trapping success (2 out of 572 trapping days), while camera trapping proved to be an efficient method to determine presence/absence of squirrels. The Persian Squirrel was found to feed on pine cones more than cedar cone. Association between feeding areas was established. Based on camera trapping, squirrels' activity began as early as 6:00 am and lasted until 18:00 pm. Peak activity was recorded between 9:00 am until 14:00 pm. An estimate of 1.04–1.82 squirrels per hectare was determined based on seed consumption and daily energy intake.

Key words

Persian Squirrel, *Sciurus anomalus,* Ecology, Horsh Ehden Nature Reserve, Lebanon.

Introduction

The Persian Squirrel, *Sciurus anomalus* Gueldenstaedt, 1785, is the only known species of family Sciuridae in the Middle East. This species is distributed from Greece through Turkey, Armenia, Georgia, Azerbaijan, Iran, Iraq, Palestine, Jordan, Lebanon and Syria in coniferous and temperate mixed forests (Harrison & Bates, 1991). This squirrel was reported from several localities in Lebanon (Lewis *et al*., 1967; Atallah, 1977; Tohmé & Tohmé, 1985). Here, its distribution is confined to cedar, oak or pine forests (Atallah, 1977).

Within its range of distribution, three subspecies of the Persian Squirrel were recognized; *Sciurus anomalus anomalus* Gueldenstaedt, 1785, distributed in the Caucasus, *Sciurus anomalus pallescens* Gray, 1867 in northern Iraq, and *Sciurus anomalus syriacus* Ehrenberg, 1829 in Syria, Lebanon, Jordan and Palestine. This is based on the coloration of specimens; *Sciurus anomalus syriacus* is described to have a dark dorsal pelage and generally dark tail and feet, *S. a. anomalus* to have a deep red tail and *S. a. pallescens* to possess a pale back and pale feet and a yellowish brown tail (Ellerman, 1948; Harrison & Bates, 1991; Amr *et al*., 2006). However, the validity of these subspecies is discussed controversially (Kryštufek & Vohralík, 2005, Grimmberger & Rudloff, 2009)

Very little is known concerning the biology and ecology of the Persian Squirrel within its range of distribution. Gavish (1993) gave some preliminary field observations on the behaviour and ecology at Mount Hermon. She provided brief descriptions of some aspects of activity, nest selection and feeding habits. From the Greek Island Lesvos, important studies focused on the threats and population dynamics and structure were published by Matsinos & Papadopoulou (2004). They found that

habitat loss and fragmentation are considered to be the most important factors responsible for population decline of the Persian Squirrel. Hecht-Markou (1994, 1999) studied the distribution, habitat, and the territorial behaviour of the Persian Squirrel, reporting that the territory is marked by urine and faeces and was renewed several times daily. Other studies gave some accounts on the ecology and distribution of the Persian Squirrel in Turkey (Özkan, 1999) and its morphology and karyology (Özkurt *et al*., 1999). Recently Amr *et al*. (2006) studied the ecology of this animal in Dibbin Nature Reserve, they examined freshly consumed acorn remains as a tool to identify the presence or absence of squirrels across the reserve, with notes on it conservation.

The main objectives of this study were to establish the association of the Persian Squirrel with forest types and its daily activity in Horsh Ehden Nature Reserve.

Materials and Methods

The study area

Horsh Ehden Nature Reserve (HENR) is situated on the upper north western slopes of Mount Lebanon, (34˚ 19' N and 36˚ 00' E) ranging in altitude from 1.200 m to 2.000 m. It covers 1.000 hectares of public land, the forested core of the protected reserve covers approximately 450 ha. Horsh Ehden forest is a unique assemblage of conifers, deciduous and evergreen broadleaf trees in an isolated phyto-climatic region with a highly varied topography. The reserve belongs to three altitudinal zones: the Supra-Mediterranean zone that extends over the lower parts of the slopes up to 1.500 m of altitude, the Mountainous Mediterranean zone that covers slopes between 1.500 and 1.900 m and the Oro-Mediterranean zone of vegetation which extends above 1.900 m. The annual rainfall average in HENR is 1,060 mm, and the mean annual temperature is 9.3 °C. The mean daily maximum temperature is 22.8 ºC in August, the mean minimum temperature in January is –3.4 ºC.

The reserve encloses four forest communities: the Lebanese cedar, *Cedrus libani*, the cilician fir *Abies cilicica*, as well as *Pinus halepensis, Pinus brutia*, *Quercus calliprinus* and *Quercus infectoria*.

Methodology

1. Visual observations in trails. A total of ten trails representing different forest elements were studied. The total length of the trails was 6750 m, ranging between 200m and 1450 m (Table 1). Trails were walked on two intervals, starting at dawn after first light or three to four hours before sunset, stopping for 2 to 5 minutes every 100 m. All squirrel sightings, calls and the dominant habitat type during 322 hours of survey were recorded. When a squirrel was observed, the location was determined using GPS (Garmin 12 × l) and the type of tree was recorded.

Table 1. Summary description of studied trails.

Trail No.	Length (in meters)	Dominated trees
1	300	*Pinus halepensis* with 5% mixed *P. halepensis Quercus calliprinus*
2	500	*Pinus halepensis* with 20% mixed *P. halepensis Q. calliprinus*
3	1200	Mixed *P. halepensis* and *Q. calliprinus*
4	200	*Pinus halepensis*
5	300	*Q. calliprinos* and *Quercus infectoria* with 10% *Pinus brutia* and *Cedrus libani*
6	1000	*C. libani*
7	500	*C. libani* with 2% of broad leaf trees
8	1450	*Q. calliprinos* and *Q. infectoria* with 2% mixed *C. libani* and *Abies cilicica*
9	500	*C. libani* and *A. cilicica*
10	800	*Q. calliprinus* with 2% *P. halepensis* and *C. libani*

2. Consumed pine and cedar cones. In conifer forests, looking for consumed pine cones is the most efficient method to indicate the presence of squirrels (Amr *et al*., 2006). Cones collected when encountered along the trails were separated into three categories: freshly consumed, old (not freshly consumed but still maintain a fresh color) and very old (very dark in color) and counted.

3. Trapping. The trapping was carried out from the 7th of June till the 20th of July 2011, using 13 Tomahawk traps, with a total of 572 trapping days. During the first three weeks of the study, traps were set mainly under pine trees on the ground, parallel to the trail, squirrels' areas with remains of freshly consumed pine cones and/or, where visual individuals were observed. Traps were baited with sunflower seeds, corn, carrots and almond. Some of the bait was placed at the entrance of the trap to attract the squirrels. Traps were checked twice daily as recommended by Amr *et al*. (2006).

4. Camera traps. Fourteen digital Bushnell Trail Pro camera traps were set in different locations across the reserve, about 20 cm above the ground on tree trunks; they were triggered to take photos every two minutes over 24 hrs. Baits were placed on the ground, 3 m away from the camera trap. The bait was added every other day and the photos were downloaded once a week. The total number of photos for squirrels and the time of capture were recorded.

5. Density of squirrels in HENR. The squirrels' density was calculated as recommended by Gurnell *et al*. (2009).

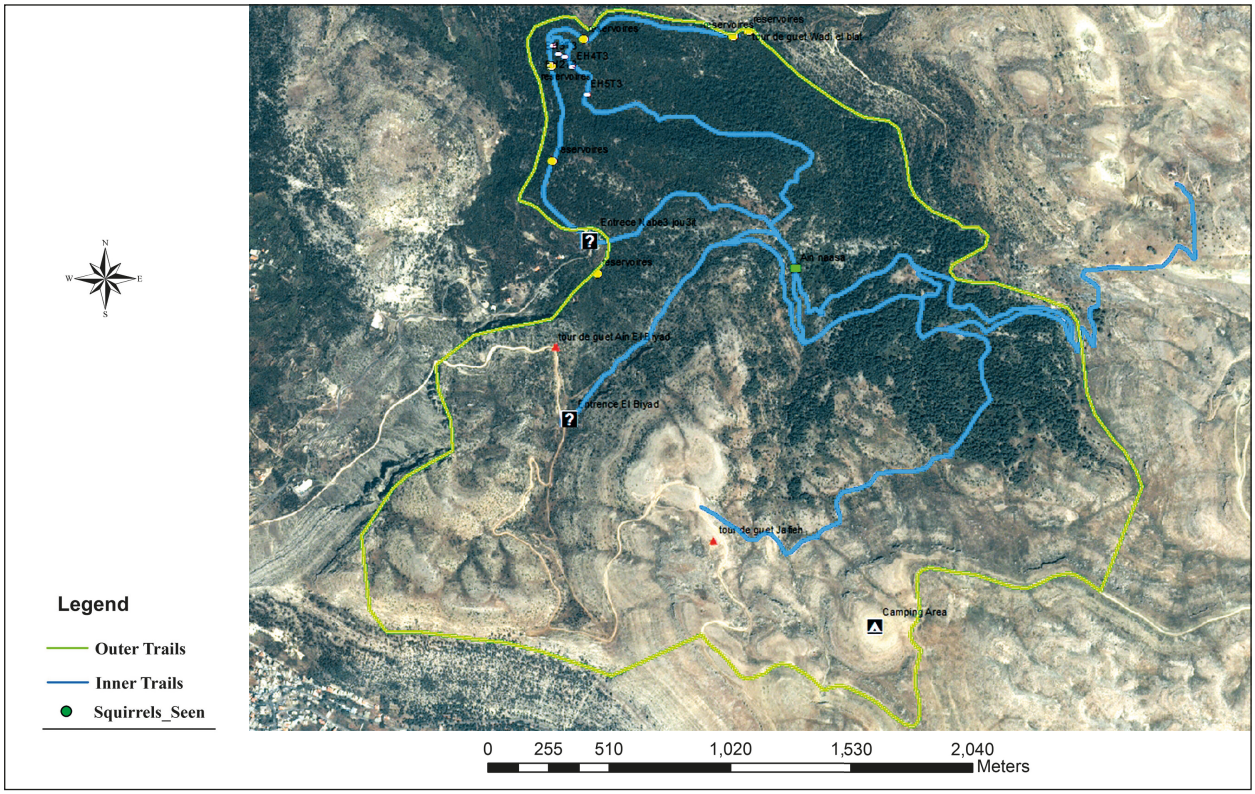

Fig. 1. Locations of visual observations of squirrels.

N Number of transects. If we consider only the transects where the pine cones were found.
L Average Length.
W Width.
A Total area sampled NxLxW.
D number of days when cones were collected.
C Total number of cone collected on all transects.
S (estimated) = Average number of seeds per cone.
E kj Average energy value per seed.
X kJ Total energy consumed = C × S × E.
Y kJ per day per hectare = X/D × 10.000/A. Since there are 10.000 m^2 in 1 hectare, the total amount of energy consumed per hectare per day.

Assuming that adult red squirrels consume between 700 and 400 kJ per day, the estimated density of squirrels for the 450 hectare woodland between the end of May and July = Y/700 to Y/400 = squirrels per hectare.

Results

1. Visual observations in trails

During the trails survey, 129 squirrels were spotted along the different trails (Fig. 1); with an average of 3.617 squirrels per visit. Most of the squirrels were sighted during early morning hours on pine trees, on the ground between pine trees, on oak trees, and near water. The number of observed squirrels per visit ranged between 0 to 12 individuals. Squirrels were observed either individually or in groups of up to 6 individuals.

Table 2. Locations where *Sciurus anomalus* was visually observed.

Location	No. of observed animals	% of observed animals
Oak trees	60	46.52
Pine trees	41	31.78
Cedar trees	22	17.05
Road sides	6	4.65
Total	**129**	**100**

2. Consumed pine and cedar cones

2.1. Pine cones. A total of 7225 consumed pine cones were collected during the survey (Fig. 2). Freshly eaten cones represented 55% of total cones, 24% were old and 21% were very old (Fig. 3). Most (82%) of the freshly consumed pine cones were found in a pine habitat, 13% in a mixed pine and oak habitat and 5% in the oak habitat (Fig. 4). The majority (67%) of old pine cones were collected from a pine habitat, 20% from the oak habitat and 13% from a mixed pine and oak habitat. Most (58%)

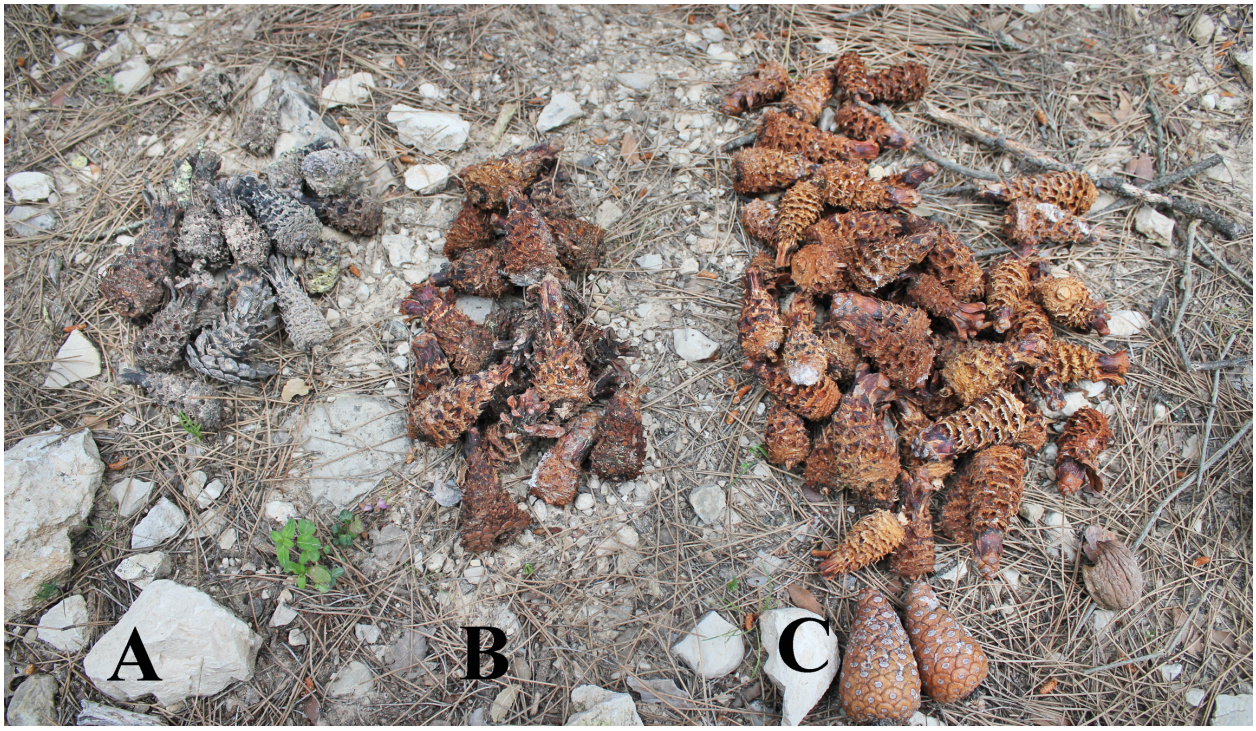

Fig. 2. Consumed Pine cones separated into three categories: **A**. Very old, **B**. Old. **C**. Fresh.

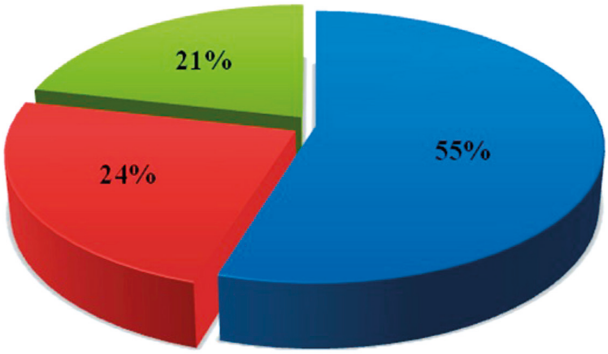

Fig. 3. Percentage of consumed pine cones according to their category. Freshly consumed cones (Blue), old (Red) and very old (Green).

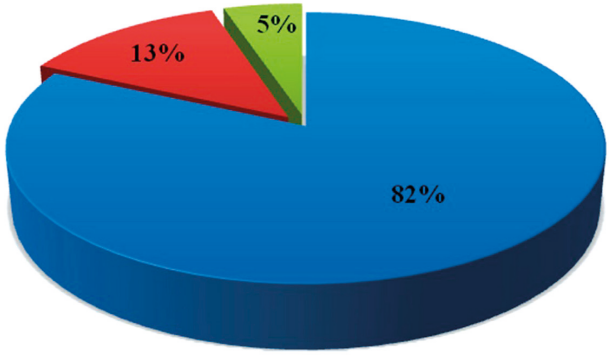

Fig. 4. Percentage of the freshly consumed pine cones collected according to habitat. Pine forest (Blue), mixed pine and oak forests (Red) and oak forests (Green).

Fig. 5. Consumed cedar cones.

of the very old consumed cones were collected from the pine habitat, 24% from the oak habitat and 18% from a mixed pine and oak habitat.

2.2. Cedar cones. In the cedar forests, a total of 68 consumed cedar cones were collected (Fig. 5), out of which 87% were freshly consumed, none was old and 13% were very old (Fig. 6). Cedar cones were mainly found in the cedar forest (74%), while 26% of these cones were found in the oak habitat with 2% of pine and cedar trees (Fig. 7).

3. Trapping

In spite of vigorous trapping effort with 572 trapping days, only 2 squirrels were trapped. The first one was trapped in the oak habitat (*Quercus calliprinos* and *Quercus infectoria* with 10% of pine *Pinus brutia* and cedar *Cedrus*

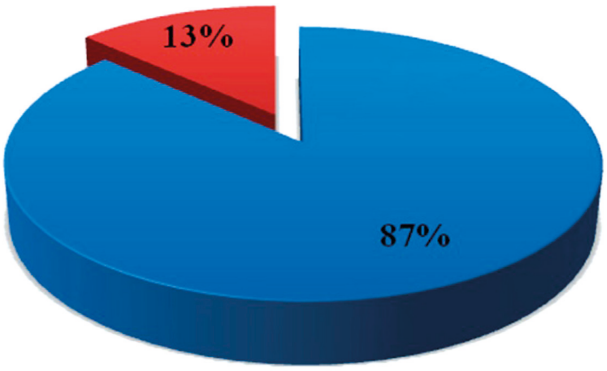

Fig. 6. Percentage of consumed cedar cones according to their category. Freshly consumed cones (Blue), and very old (Red).

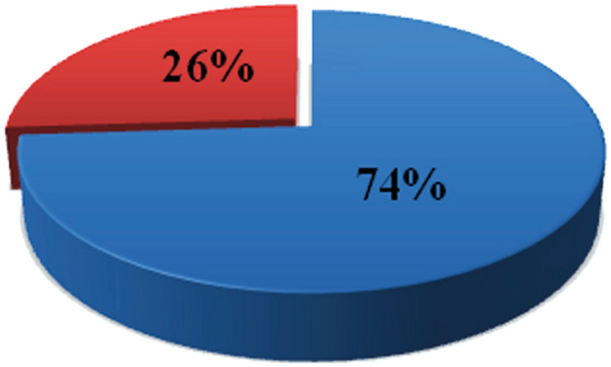

Fig. 7. Percentage of the freshly consumed cedar cones collected according to habitat. Cedar forest (Blue), and mixed cedar and oak forests (Red)

libani). The second was trapped in a habitat dominated with broad leaf trees with 2% mixed cedar, *Cedrus libani* and fir, *Abies cilicica*. Moreover, a Pine Marten (*Martes foina syriaca*) and a Mole Rat (*Spalax ehrenbergi*) were once trapped in a mixed vegetation habitat of pine and oak (*Quercus calliprinus*).

4. Camera traps

A total of 4128 photos were taken during a period of 44 days, however, only 63 (1.53%) were for squirrels (Fig. 8). The majority of photos were for birds, wild boars and small rodents. Table 3 shows the number of photos taken per habitat. Most (47.6%) number of photos were taken in pine forest while the least (3.2%) were in mixed pine and oak forests.

Table 3. Number and percentage of photos taken by camera traps according to habitat type.

Habitat type	Number of photos	%
Pine forest	30	47.6
Broad leaf trees	14	22.0
Oak forest	11	17.5
cedar forests	6	9.7
Mixed pine and oak forest	2	3.2
Total	63	100.0

5. Density of squirrels in HENR

The squirrels' density was calculated as recommended by Gurnell *et al*., 2009.

- Woodland type: pine Woodland size: 450 ha (core area of HENR).
- The six transects where the pine cones were found had an average length of 555 m and width of 2 m.
- The total area sampled: $A = 6 \times 555 \times 2 = 6.660$ m^2. Cones were collected every other day (13 collections during 26 days).
- Total number of cones collected on all 6 transects from all 13 collections C = 1.560.
- Average number of seeds per cone S = 45 (estimated).
- Average energy value per seed E = 0.18 kJ
- Total energy consumed $T = 1560 \times 45 \times 0.18 = 12.636$ kJ.
- Since there are 10,000 m^2 in 1 hectare, the total amount of energy consumed per hectare per day $Y = 12.636/26 \times 10.000/6.660 = 729.73$ kJ per day per hectare.

Fig. 8. Photo for the Persian Squirrel, *Sciurus anomalus,* taken by camera trap.

Assuming that adult Persian squirrel consumes between 700 and 400 kJ per day, the estimated density of squirrels for the 450 hectare woodland between the end of May and July = 729.73/700 to 729.73/400 = 1.04–1.82 squirrels per hectare. Assuming the reserve area at 450 ha; the total number of squirrels in Horch Ehden Nature Reserve ranges between 468 and 819 squirrels.

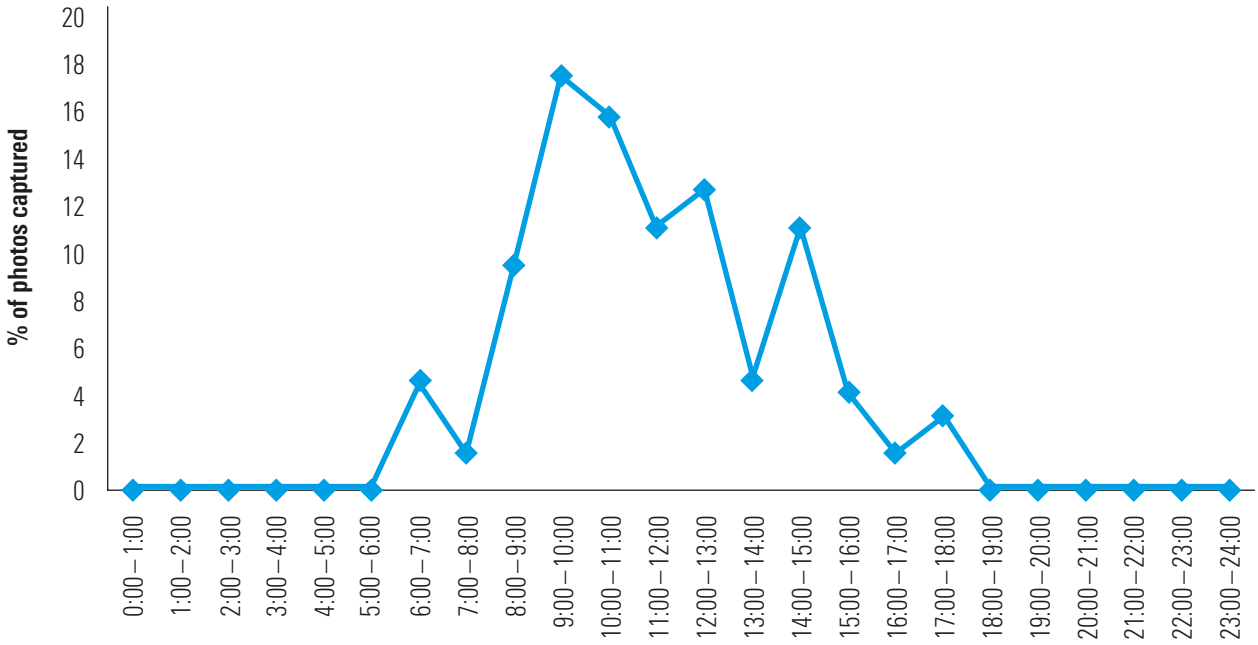

Fig. 9. Percentage of photos of squirrels taken per time of capture.

6. Activity pattern of the Persian Squirrels based on camera trapping

Photos captured by camera traps were used to analyze daily activity pattern for the Persian squirrel. Daily activity of squirrels in the study area is shown in Fig. 9. Activity started as early as 6:00 am and lasted until 18:00 pm. Peak activity was recorded between 9:00 am until 14:00 pm.

Discussion

Over hundreds of years, the Middle East witnessed an excessive forest fragmentation and extensive wood cutting particularly in Jordan, Syria and Lebanon (Amr *et al.*, 2006). In Lebanon, the forests have been historically exploited; therefore, their extent has dramatically declined. Persian squirrels, as many other animals relying on these habitats, are now considered rare species in Lebanon (Lewis *et al.*, 1967; Tohmé *et al.*, 1996).

The presence of the squirrel was established at Horsh Ehden Nature Reserve by sightings, camera traps, freshly consumed cones and calls within the forests. Most sightings were in the pine forest of the reserve, probably due to the availability of fresh cones for feeding. These findings were similar to those reported in Jordan (Amr *et al.*, 2006) and in the Island of Lesvos in Greece (Mastinos & Papadopoulou, 2004) where the abundance of squirrels was due to the availability of food resources

Fresh remains of consumed pine cones represent an excellent indicator of the presence or absence of squirrels (Amr *et al.*, 2006). The consumed cones can be used to measure habitat use and spatial distribution of squirrels (Amr *et al.*, 2006; Gurnell *et al.*, 2009). Red squirrels generally leave prominent evidence of their feeding in the form of consumed or clipped pine or cedar cones (Merrick *et al.*, 2011). Therefore results obtained based on visual observations are confirmed by finding freshly consumed pine cones within the same localities in the reserve. Freshly consumed cones were clustered in pine dominated habitats, where mixed old, very old and freshly consumed cones were observed. Freshly consumed cedar cones were found repeatedly confirming the presence of squirrels in the cedar forests. Therefore the distribution of the Persian Squirrel in Horch Ehden Nature Reserve covers a large area of the reserve. However, the large number of pine cones compared to the relatively low number of cedar cones suggests that squirrels rely more on pine cone as a main food source. Finding consumed pine cones in oak forests suggests that cones were brought to the oak forests where the animal is living. Food preference may vary according to its availability. For instance, the Red Squirrel, *Sciurus vulgaris*, in England preferred Norway spruce and lodge pole pine when Sitka spruce was also producing seeds (Lurz & Garson, 1998). Pine cone preference could be referred to its digestibility as suggested by Smith & Follmer (1972) and Lurz *et al.* (1998). Also, Smith & Follmer (1972) stated that the annual feeding activity of gray and fox squirrels shifts during fall and winter, where as they feed on hard-shelled nuts of hickory and walnut in the fall and spring, while they feed on acorns in winter. During our study, we did not observe squirrels feeding on oak acorns. Perhaps they do feed on them, but their remains were not visible due to

their small size. Persian Squirrels in Mount Hermon were found to feed on oak acorns (Gavish, 1993). Squirrels live in both tree holes of pine and oak trees, and move within the forest in search of food. Individuals living in oak trees were found to bring pine and cedar acorns.

Efficiency of trapping method to determine presence/absence is controversial. In the present study, only 2 squirrels were caught during 572 trapping days. Similar results were recorded by Amr *et al*., (2006) in Dibbeen Nature Reserve, Jordan. On the other hand, several studies indicated that red squirrels were frequently and easily trapped in ground placed traps, mostly in coniferous habitats (Lurz *et al*., 2000; Trizio *et al*., 2005; Wauter *et al*., 2005 & 2007; Boon *et al*., 2008; Descamps *et al*., 2008; Pelech *et al*., 2010; Romeo *et al*., 2010; Zong *et al*., 2010).). The negative results in the pine habitat might be explained by bait shyness (Amr *et al*., 2006). In addition squirrels prefer dense habitat where they can move between trees without descending to the ground (Summers & Proctor, 1999); and with the abundance of food they might neglect the bait placed to attract them towards the trap and stay on the trees.

Although squirrels were abundant in HENR low trapping efficiency was due to several disturbances which perturbed the trapping process throughout the reserve. First, despite the fact that the traps were covered and hidden, they were sometimes discovered and displaced by curious visitors. Second, the activity of wild boars was very noticeable at the upper part of the reserve and at the cedar forest of the lower part of the reserve; traps were found empty closed and pushed from their original places with wild boars tracks surrounding them. Therefore traps were set on the branches of the trees when possible in order to avoid such disturbances. But none of the squirrels was caught in these traps. However, the bait on tree traps was frequently eaten and mice droppings were usually found in the empty trap.

On the other hand, camera trapping became an important tool in conservation and ecology in the last 20 years (Rowcliffe & Carbone, 2008). Camera traps proved to be effective to confirm the presence of squirrels in the different habitats of the study area. The effectiveness of camera traps was reported by several authors. It was used to establish simple species inventories (Silveira *et al*., 2003; Abi Said & Amr, 2012), discovery of new species (Rovero *et al*., 2008), determine abundance estimation (Karanth, 1995), conservation assessments (Kinnaird *et al*., 2003), and population dynamics (Karanth *et al*., 2006). It is equally efficient at collecting data by day and night and provides the opportunity to collect additional information on species distribution and habitat use (Silveira *et al*., 2003).

The percentage of photos of squirrels taken per time of capture can reveal the activity pattern of the species. Apparently squirrels are diurnal animals since their photos were taken between six o'clock in the morning and they were more active 3 to 4 hours after sunrise. Similar results were reported by Lurz *et. al*. (2005) and Summers & Proctor (1999). The majority of photos of squirrels captured by camera traps (46%) were in pine habitats which is probably due to the abundance of food. Similar results were reported by Summers & Proctor (1999) and Lurz *et al*. (2000) whom noticed that squirrels track the availability of conifer seeds, and they were found in high numbers in habitats where nutritional needs are available and abundant.

Finally, the density of squirrels in Horch Ehden Nature Reserve ranges between 1.04 to1.82 squirrels per hectare. Lurz *et al*. (2005) reported very low densities of 0.02 – 0.2 squirrels/ha in boreal forests in Scandinavia and large conifer forests in northern England and Scotland and densities of 2 individuals/ha between May and July in Britain; whereas Gurnell *et al*. (2007) reported a density of 0.73 to 0.72 squirrels/ha on unbaited transects, and a density of 1.73 to1.82 squirrels/ ha on baited transects in a study across Britain, Parker & Nilon (2008) noted a density of gray squirrels 22.75/ha in the spring to 51.5 gray squirrels/ha in the fall in Lafayette Park, Washington, DC, while Greene *et al*. (2009) reported densities of 15.7 and 3.9 squirrels/ha squirrels in colonies were highest for two sagebrush and a density of 2.6 squirrels/ha in low shrub in the Columbian Basin, Oregon. Therefore the density of squirrels is acceptable in HENR and tends to be on the high level since it ranges between the highest density of squirrels reported by Gurnell *et al*. (2007) and the highest density reported by Greene *et al*. (2009).

In addition, the rate of squirrel abundance in the pine habitat was 20 times higher than the rate of abundance in the mixed habitat dominated with oak. Despite the fact that squirrels are usually frequent in broadleaved and mixed woodlands (Lurz, 1995) since the mixtures of tree species provide a more reliable year-to-year seed food supply than do single-species forests because of differences in mast intervals, seed size, and timing of seed dispersal (Lurz *et al*., 2005). Year-to-year fluctuations can be large and vary with weather and the availability of tree seeds, in monoculture plantation forest (Wauters & Lens, 1995). This difference is probably due to food availability as the nuts season in mixed habitat dominated with oak did not start.

Therefore to conserve squirrels it is vital to protect its habitat. Consequently suitable habitats should be declared protected areas; and this could be brought about through awareness among locals that nature and biodiversity must be conserved for their own sake, not because they have present utilitarian value. Arguments for conserving nature must be spiritual and aesthetic, motivated by feelings, and based on scientific knowledge.

Public educational efforts will always be important in conservation (Wilshusen *et al*., 2002; Abi-Said, 2006). Citizens must be convinced to accept restraints on their freedom of action when it serves the common good using moral argument based on the intrinsic right of nature to exist. Therefore, humans do not have the right to eradicate other species; and to accept that regional and local communities have the right to enjoy the aesthetic qualities of nature now and in the future (Wilshusen *et al*., 2002). Governments have to establish enforcement

mechanisms in implicit or explicit recognition of the underlying conflict of interest. They can claim forest lands as national property because they serve national and international interests (Wilshusen *et al*., 2002). Finally, continuous protection of Horch Ehden Nature Reserve is crucial in order to conserve one of the few remaining habitats where squirrels thrive in Lebanon.

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