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Research Article

Assessment of fruit damage caused by Small Kashmir Flying Squirrel (*Hylopetes fimbriatus*; Gray, 1837) in district Bagh, Azad Jammu and Kashmir, Pakistan

Nausheen Irshad[1]*, Anees Ahmad Sheikh[1], Siyab Maroof Khan[1], Majid Mahmood[1], Ali Muhammad[1], Ghulam Rasool[2], Muhammad Rafique Khan[1], Tariq Mahmood[3], Nasra Ashraf [4], Nadeem Munawar [3], Muhammad Altaf[5]

[1]Department of Zoology, University of Poonch, Rawalakot, Azad Jammu and Kashmir.
[2]Deputy Director, Wildlife, Punjab Wildlife and Parks Department
[3]Department of Zoology, Wildlife and Fisheries, PMAS Arid Agriculture University, Rawalpindi, Pakistan.
[4]Department of Zoology, The University of Azad Jammu and Kashmir, Muzaffarabad
[5]Institute of Forest Science, The University of Bahawalpur, Pakistan
*****Email: nausheen_irshad@yahoo.com

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Abstract

The Small Kashmir Flying Squirrel (*Hylopetes fimbriatus*) is a frugivorous rodent that consumes various fruits and causes economic loss to farmers and gardeners. The current study aimed at assessing the fruit damage caused by the flying squirrel in district Bagh, Azad Kashmir (from December 2020 to December 2021). The data was collected from the direct field observations by recording the number of affected trees (wild and planted) in an area of 300 km^2. In addition, fecal pellets (n=100) and stomach contents (n=32) of the species were collected from study sites to investigate the feeding habits of the species. The results of direct observations showed that the Small Kashmir Flying Squirrel consumed fifteen different plant species (cultivated and wild=). The seasonal data revealed that maximum fruits were damaged during summer (44.85 %), followed by winter (31.38%), fall (37.53%), and spring (83.21%), by the squirrel species. The stomach samples analyzed revealed that this rodent species consumed Pinus *wallichiana* (36%) in spring, *Pyrus pashia* (50%) in winter, *Juglans regia* (45%) in summer, and *Malus pumila* (57%) in fall. The fecal analysis also confirmed similar fruit consumption, as the presence of parts of different fruits was recovered. It is worth mentioning that a total of N = 193 squirrels were killed by the local community due to human-squirrel conflict, for fruit damage during one year. Despite of its protected status, "Near threatened", the species is being killed brutally and massively by the natives. The area needs to be further explored to estimate population dynamics and feeding habits of the species so that the management program can be implemented.

Keywords: Frugivore, harmful effects, assessed, feed, planted fruit

Introduction

Pakistan consists of 195 mammalian species, while Azad Jammu and Kashmir has 67 species by Robert, 1997). Rich diversity shows that the landscape is favorable for fauna (Rasheed & Faiz, 2024). The Small Kashmir Flying Squirrel (*Hyloppetes fimbriatus*) is also an important mammalian species. The Small Kashmir Flying Squirrel (*Hyloppetes fimbriatus*) is a rodent species belonging to the family Sciuridae (Thorington, 2005; Molur, 2008). There are about 38 to 45 species of flying squirrels grouped in 5 genera, found throughout the world (Thorington et al., 2002). In Pakistan, only two species are reported, which include the Giant flying squirrel (*Petaurista petaurista*) and Small Kashmir flying squirrel (*Hylopetes fimbritus*). The *Petaurista petauristais commonly known as the* Indian giant flying squirrel, while *Hylopetes fimbritus*is is commonly called the Small Kashmir Flying Squirrel (Roberts, 1997).

The Small Kashmir Flying Squirrel is mainly restricted to the Himalayan moist temperate forest, which has a mixture of deciduous and coniferous tree species, and northern drier regions. In winter, this species may descend into the tropical pine forest zone. It is found in Gilgit and Indus Kohistan regions between 2440-3350 m elevations, associated with coniferous and birch forests. It is widespread in drier forest zones that occur in southern Chitral, Dir, Swat, and Kohistan. Besides, it also occurs in Murree Hills, Hazara, Azad Kashmir, and dry blue Pine forest on the slope of Nanga Parbat (Corbet & Hill, 1992; Hoffman et al., 1993; Roberts, 1997). The Small Kashmir Flying Squirrel is characterized by front reddish-yellow incisors that are continuously growing, sharp teeth used to gnaw wood, break hard nuts, and bite predators (Single, 2001). It has a long, flattened tail that serves as a rudder during glides (Wirchow et al., 1999). These adaptations aid in the frugivore mode of diet as they feed upon fruits and seeds of both wild and cultivated trees. The preferred plants consumed by the species included *Janglius regia*, *Prunus armeniaca*, *Pinusw allichiana* and *Qurus incana* (Qamar et al., 2006). It also consumes cones, especially those of Silver fir (*Abies pindrow*) and Blue Pine, *Pinus wallichiana* (Vantassel et al. 2009).

The published literature from other regions shows that there is a seasonal variation in feeding patterns. The Small Kashmir Flying Squirrel uses floral buds and flowers during the spring season, fruits in the summer and autumn season, while buds and shoots in winter (Shafique et al., 2006). It also collects nuts and cached seeds in the fall and tree bark during winter (Stenseth et al., 2003). The feeding behavior of the species is diversified to corns, walnuts, seeds of Pinus cones various fruit trees. It is particularly fond of feeding on the corns of the evergreen Holly Oak (*Quercus ilex*)

and Walnut (*Juglans regia)* in the Swat region of Pakistan. (Zahler & Khan, 2003). It also feeds on the seeds of young fir cones, especially those of Silver fir (*Abies pindrow*) and immature cones of the Blue Pine (*Pinus wallichiana*). In the Murree Hills of Pakistan, its diet comprised young shoots and buds of Silver fir (*Abies pindrow),* and active feeding was also noted for the species (Abbasi et al., 2010).

The Small Kashmir Flying Squirrel was found responsible for the exploitation of forests as it damages the barks and trunks of various plants (Jackson, 1994). They discard the outer bark and eat the un-lignified tissue beneath, implying that it was a feeding activity (Kenward, 1983). This strategy enables the species to survive in an environment with restricted food resources. In addition, squirrel caused the damage of trees, flowers, lawns, and garden vehicles. It also dissimilated the structural insulation and electrical wires in homes, vehicles and power lines (Vantassel et al., 2009).

Some of the squirrel species store food while other species burry it throughout their habitat. These species also eat whatever is available for feeding includes insects, birds, mushrooms and animal's materials. In some cases, they live near the human populated areas from where they also take advantages of birdfeeders, orchards and gardens. They have ability to quickly adopt the variety of habitat and environmental conditions. So, they live in close contact with human being and damage orchards, crops, inhabit building, digging up lawn, shorting power lines, eating from birdfeeder and damage crops (Cornan et al., 1968).

In the world, nearly every country is experiencing through vertebrate pest damage, specifically from rodents (Stenseth et al., 2001). It becomes, sometime so drastic that results in scarcity of food and malnutrition (Hafeez, 2011). In this regard squirrel damage is more distressing. During 1998, in California, rodents and pests caused 944 million dollars loss annually out of which squirrels alone caused 8 to 12 million dollars loss in fruits and agricultural crops. Similarly, in Europe, the grey squirrels had a considerable impact on biodiversity and woodland ecosystems, and causing damage to both broad-leaved and conifer woodland. The economic cost of grey squirrel management and damaged to the forestry sector was estimated to be £6 million per year. This raised to an annual cost of £14 million per year to the British economy where costs to other sectors, such as construction, development and infrastructure were included (Gurnell & Pepper, 1993).Ground squirrels, was important pest species in north central and western North America, causing serious losses of tree seeds and emergent seedlings. A careful search of an area showing that it damaged seed hulls and caches. Ground squirrels inflicted serious damage to pastures,

rangelands, grain fields, vegetable gardens, and fruit or nut crops. Their burrows caused collapse of irrigation levees, increase erosion and result in damage to farm machinery (Marsh & Howard, 1990).

Although Pakistan has rich diversity of mammals (Ejaz & Rasheed. 2024; Batool et al., 2014), but, no scientific studies have yet been focused on studying the ecology and food habits of Small Kashmir Flying Squirrel, especially their impact on fruits. Therefore, the current study was designed to investigate the food habits, seasonal variation in the diet, and assessment of fruit damage inflicted by the Small Kashmir flying squirrel in the district Bagh, AJ&K.

Materials and Methods

Study Area

The current study was conducted in the district Bagh of AJ&K, which is located at 33^0 to 51^0N and 73^0 to 29^0E (Figure 1). The general elevation range is between 1500 to 2500m. The entire topography of the district comprises mountains because it lies in Lesser Himalayan zone. The slope of the area varies from northeast to southwest. The study district lies in "Pir-Panjal mountainous pathway. The climate of the district varies with altitude, and temperature generally remains between 2 °C to 40 °C (Altaf & Umair, 2022; Bashir & Saddam, 2024).

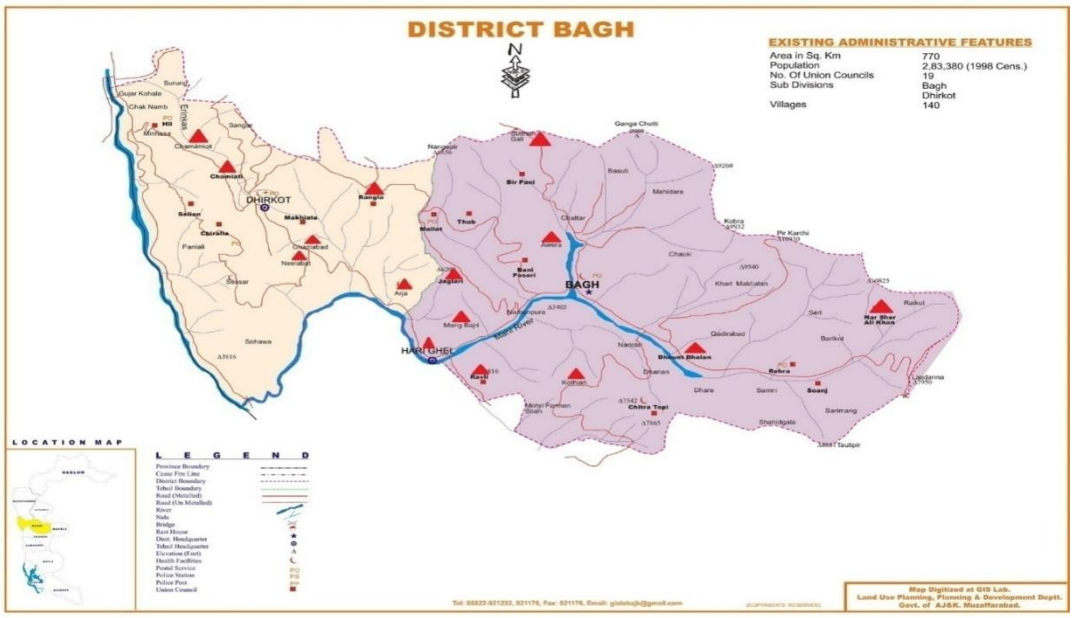

Figure 1. Map of study area; District Bagh of Azad Jammu & Kashmir (AJ&K)

Study Design

The study area (district Bagh) was divided into three main sites, Bagh, Dheerkot, and Harighal sites, respectively. These study sites were further divided into sampling sites (N = 16) for data collection.The study site-I(Bagh)was administratively divided into six further sub sites (Islam Nager, Sudhangali, Sariawara, Guglari, Kothian and Narhare Share Ali khan). The site-II (Dheerkot) was also divided into six sub sites (Neelabat, Chmankot, Ghaziabad, Chamayati, Rangala, and Jhala). The last site, Harigahal, was divided into four sub-sites (Mong-Bagri, Arja, Kaffalghar, and Ravli) (Fig. 1).

Each site was visited once in a season, and the field observations were made thoroughly to identify the feeding habitat and damage caused by the Small Kashmir Flying Squirrel. During field surveys, the damaged fruit trees were counted by the line transect method. The Global Positioning System (GPS; Garmin Trax Vista) was used to record the geographical coordinates of the locations and altitude of the sampling area. The damaged fruit plants, their fruits, and shells were collected and photographed using a digital camera. Each site was visited once a week to analyze the food habits and damage caused by the Small Kashmir Flying Squirrel. It covered all four seasons, namely, winter (December to February); spring (March to April); summer (May to September), and fall (October to November).

For data collection in the field, we used both direct as well as indirect methods.

a) Direct method

All sampling sites were directly visualized to record the number of plants damagedbysmall Kashmir Flying Squirrel. For this purpose, a transect of about 2 km2 was laid down at each site, covering a total area of 300 km2. The following formulae were used to calculate the damage percentage and relative damage percentage of trees (Abbasi et al., 2010).

$$\text{Damage percentage} = \frac{\text{Number of damaged plants}}{\text{Total number of plants}} \times 100$$

$$\text{Relative damaged percentage} = \frac{\text{Percentage damage of one Species}}{\text{Percentage damage of all species}} \times 100$$

Indirect Method

The food of the animal species was examined by analyzing 100 fecal pellets collected from all the study sites. The fecal samples were identified on the bases of their size and shape, were put into collecting polythene ziplock bags, labeled with place, time, date, and stored in the refrigerator until processing.

Reference Slides

For the preparation of reference slides, ripened and unripened fruits were collected from each study site following William (1992) and Wards (1970) for establishing reference slides. The following steps were applied for the preparation of slides. For the preparation of reference slides, fruits and vegetative parts of cultivated and non-cultivated plants were collected from the study area and dried. Then these items were drenched in plant soaking solution (Distilled water, ethyl alcohol, and glycerin (1:1:1). for twelve hours. After being removed from the solution, the contents were washed with distilled water for 10 to 20 minutes. Then, Vertis homogenizers were used for the grinding of fruit plants with distilled water. The contents were put into a micro sieve in such a way that it remained filled and soaked within 1% sodium hypochlorite for cleaning the specimen. Sodium hypochlorite 5% Chlorax and 4 parts of distilled water (1:4) were used to keep the content soaked for 20-30 minutes. The Specimens were treated with an equal amount of dilute acetic acid for 15 to 30 minutes to neutralize the basic effect of sodium hypochlorite. For the removal of all residues, distilled water was dripped into a sieve. Then the contents were placed into hematoxylin stain for 10-15 minutes, washed with tap water. A drop of mounting medium (Canada balsam) was placed on a clean slide. The stained fruit plant material was mixed with this mounting medium. The material was equally placed over the slide with a wet camel brush, and ten to two drops of mounting medium were added to the stained contents of the fruit plants. The material is covered with a Glass cover and pressed tightly. Finally, the slides were labeled for identification and left at room temperature overnight for fixation of materials (Hayward & Rosentreter, 1994).

Stomach contents and fecal analysis technique

The stomach samples of the dead individuals were dissected immediately by cutting mid mid-ventral part. Each stomach was fixed in 10% formalin. The geographic location and date of collection of each sample were labeled. Then the sample was carried out to the laboratory, where the stomach content was removed and preserved in 10% formalin. The material was washed with tap water and placed in Petri plates and identified by microscopic examination and compared with the reference slides. In addition, fresh fecal pellets were collected from the different study areas and brought to the laboratory for analysis. To prevent the exposure of Hantaviruses the collected fecal pellets were put in 4% formaldehyde (formalin) in glass vial. For fecal sample analysis, total of one hundred and sixty freshly collected fecal pellets were socked in distilled water. Then these pellets were placed on micro sieve and washed with running tape water. The winter fecal pellets

were thinned then summer and therefore required more time for softening. Approximately 2ml of formalin solution were taken in glass vial to sock pellet. These pellets were heated at 45 ^{0} C to 48^{0} C for 24 hours. The warmer pellets were crushed with glass rod in glass vial. The pallets were squeezed quickly with eye dropper in glass vial to mix the sample through. The remaining fragments of different fruits in fecal content were put in several alcoholic concentrations. (70%, 60%, 40% and 30%) for ten minutes. To distinguish among different components these fecal contents were stained with light green stain dye. A clean glass slide was taken and a drop of mixture was placed in air to dry partially. A clean glass cover slip was placed over this material. Finally permanent mount were papered (Maser et al., 1986 Mclntire & Carel, 1989). From each of these fecal pallets five slide were prepared and examined through compound microscope of 60xlens. Every fragment under examination on each slide was up lowest possible taxonomic category. The photographs of different fragments present on each slide were taken through a camera fitted microscope. These photographs were identified through their comparison with reference slides of dominant local fruits. After identification, the total number of fragments for each fruit species was noted and present relative frequency was calculated by using following formula. The comparison among various seasons was also calculated.

$$\text{percent Relative frequency \%} = \frac{\text{Total number of fragments of a plant species}}{\text{Total number of fragments of all analyzed fruit species}} \times 100$$

Frequency occurrence was also calculated for different fruit plant species recovered from fecal pellets by following the formula.

$$\text{Frequency of occurrence} = \frac{\text{Number of fecal containing fragments of a fruit species}}{\text{Total number of fecal samples analyzed}} \times 100$$

The similarities among field visualized data, stomach contents analysis data, and fecal pellet analysis data of all seasons were calculated by using Spearman rank correlation in SPSS software (SPSS, 1996).

Results

The Small Kashmir Flying Squirrel is a small rodent that uses various seasonal fruits as food. The local people and farmers grow different types of fruit trees in four seasons. In summer, Walnut

(*Juglans regia*), Apricot (*Prunus armeniaca*), Pear (*Pyrus communis*), Plum (*Prunus domestica*), Peach (*Prunus persica*), Wild Peach (*Prunus persica var. nectarina*), Apple (*Malus pumila*), (*Ficuscarica*) are grown. Whereas in winter, Japanese Fruit (*Diopyross Kaki*), Apple (*Malus pumila*), Pomegranate (*Punica granatum*), Himalayan wild pear (*Prunus pardis and Pyrus pashia*), and Date-plum (*Diopyross lotus*) are grown. The seasonal fruits of fall are Walnut (*Juglans regia*), pear (*Pyrus communis*), Apple (*Malus pumila*), Pomegranate (*Punica granatum*), Wild Peach (*Prunus persica var. nectarina*), Himalayan wild pear (*Prunus pardis and Pyrus pashia*), and Date-plum (*Diopyross lotus*). Whereas Pine (*Pinus roxburghi*), Blue Pine (*Pinus wallichiana*), and Blue Jack Oak (*Quercus incana*) are evergreen plants.

Direct field visualization to observe damage inflicted by the Small Kashmir flying squirrel

During the winter season, a total of N = 8958 fruit plants were sampled, out of which 3242 (38%) were found damaged by the Small Kashmir Flying Squirrel. The highest relative frequency was recorded for *Malus Pumila* (25.5%), followed by *Pyrus pashia* (22.39%), and least for *Diospyrus lotus* (9.9%). During the spring season, small Kashmir Flying Squirrel was observed to feed upon three wild trees (*Pinus wallichiana, Pinus roxburghii, and Quercus inncana*). During this season, a total of N =14,163 non-cultivated trees were sampled, out of which 11,996 (85%) were found damaged by the small Kashmir flying squirrel. The highest relative frequency was recorded for *Pinus wallichiana* (34.3%) followed by *Pinus roxiburghii* (33.4%) and *Quercus incana* (32.19%). During the summer season, a total of N=11929 trees were sampled, and 1697 (14.2%) were found damaged. Among those, the highest relative frequency of damage was recorded for *Juglans regia* (25.5%), followed by *Prunus persica* (16.37%), *Prunus armeniaca* (15.46%), and least for *Prunus domestica* (13.77%). In the fall season, a total of N = 15172 trees were sampled, and 4699 (30%) were found damaged by the small Kashmir Flying Squirrel. The highest relative damage was noted for *Malus pumila* (19.62%), followed by *Punica granatum* (13.4%), and least for *Diospyrus kaki* (7.8%) (Table 1).

Stomach Content Analysis

For the stomach content analysis, a total of thirty-two dead animals were collected (eight in each season) dissected, and processed to check their diet composition. The stomach content analysis of winter showed that the species consumed *Malus pumila* (53.83%), *Pyrus pashia* (19.16%), *Diospyrus kaki* (15.51%). *Punica granatum* (9.12%), *Diospyrus lotus* (2.37%). Whereas *Pinus wallichiana* (36.81 %), *Pinus roxburghii* (30.71 %) and *Quercus incana* (27.65%) were found

damaged during spring. During summer the species feed on six fruits, these fruits were *Juglansregia*, (44.84 %), *Prunus persica* (25.05%) *prunus armeniaca* (11.03%), *Pyrus communis* (5.25%), *Prunus persica var. nectrina* (12.47%) and *prunus domestica* (4.43%). The stomach content analysis of fall revealed that the specie feed upon *Malus pumila* (22.57%), *Punica granatum* (17.93%), *Diospyrus kaki* (15.18%), *Prunus persica* (12.65%),), *Pyrus communis* (9.07%), *Juglan regia* (7.80%) and lowest for *Diospyros lotus* (3.79%) (Table 2).

Fecal Sample Analysis

The fecal pellets of the Small Kashmir flying squirrel (n=100) were collected and identified based on morphological properties (cylindrical shape), two extremities, and one slightly tapered. The large size of fecal pellet 1.02 ± 0.53 cm and the small 0.92± 0.53 cm were found. The width was recorded between 0.42 ± 0.21cm to 0.53 ± 0.27cm. The highest average weight was recorded in Summer, 1.35 ± 0.51g, and spring, 0.78 ± 0.47g

Figure 2. Damage fruits in study area (A), *Prunus persica avar. nectarine* (B) *Punica granatum* (C, D) *Pyrus communis*

Figure 3. Damage fruits in study area (A), *Prunus armeniaca* (B), *Prunus domestics* (C) *Juglans regia,* (D) *Prunus persica var. nectarine*

Seasonal variation in diet by fecal analysis

The fecal pellets analysis of samples collected in winters showed the highest percent relative frequency for *Pyrus pashia* (28.57%), followed by *Punica granatum* (25.89%), *Malus pumila* (22.32%), *Diospyros kaki* (16.96%) and minimum for *Diospyros lotus* (6.26%).The fecal pallets of spring season showed, the highest percentage for *Pinus wallichiana* (43.52 %) followed by *Pinus roxburghii* (36.47%) and *Quercus incana* (20.00%). Whereas in summer six fruits were traced out from feces of squirrel species. The highest Percent relative frequency was recorded for *Juglansregia* (33.39%) followed by *Prunus armeniaca* (20.65%), *Prunus persica* (18.47%), *Pyrus*

communis (11.95%), *Pyrus communis varnectrina* (9.78%) and *Prunus domestica* (5.76%). The fecal analysis of fall revealed that the species feed upon *Malus pumila* (21.48 %), *Pyrus communis* (17.35%), *Pyrus pashia* (15.7%), *Punica granatum* (13.22%) *Diospyros kaki* (10.56%)), *Prunus persica var. nectrine* (9.09%), *Juglan regia* (7.43%) and lowest for *Diospyros lotus* (5.17%) (Table 3)

Statistical Analysis

The co-relation between the damage caused by Small Kashmir flying squirrel directly through field visualizations, stomach contents analysis and fecal analysis has been found out. In spring season, data of direct visualizations showed a non-significant positive correlation with stomach content analysis data (r= 0.889, p= 0.093) and a highly strong positive correlation (r= 0.093, p= 0.28) with fecal sample analysis data. During summer, the field data showed a moderate positive correlation with stomach content data (r= 0.623, p= 0.173) and a highly significant positive strong correlation (r= 0.989, p= 0.001) with fecal sample analysis. The fall`s season data indicate no significant positive correlation with stomach material analysis (r= 0.412, p= 0.198) and a very highly significant positive correlation with fecal analysis data (r= 0.875, p= 0.000)

Kill record of the small Kashmir flying squirrel

The small Kashmir Flying Squirrel, a frugivorous rodent, caused substantial economic loss to orchard owners. Hence, local residents killed the species wherever encountered (Figure 4). A total of 193 reported kills and 61 dead bodies were recovered during one year. Moreover, it was found that people used different methods to kill squirrel species, including shooting with guns/ pellet bow, and explosive materials (Table 4).

Table 1. Direct field visualization to observe damage inflicted by the Small Kashmir flying squirrel of the year 2019--2020

Sr. no	Season	Tree species	Total trees	Damaged trees	Percentage	Relative percentage
1	**Winter**	*Diospyros lotus*	1597	275	17.26%	9.90%
2		*Malus Pumila*	2757	1222	44.32%	25.50%
3		*Pyrus pashia*	2290	889	38.82%	22.39%
4		*Diospyros kaki*	1043	326	31.25%	18%
5		*Punica granatum*	1271	530	41.69%	24%
		Total	**8958**	**3242**	173.34	
1	**Spring**	*Pinus wallichiana*	4650	4050	87.80%	34.30%
2		*Pinus roxburghii*	4663	3960	85.34%	33.40%
3		*Quercus incana*	4850	3986	82.20%	32.19%

		Total	**14163**	**11996**	255.34	
1	**Summer**	*Juglans regia*	2394	1586	66.23%	25.50%
2		*Prunus armeniaca*	2187	888	40.06%	15.46%
3		*Prunus persica var nectarina*	2182	806	36.93%	14.20%
4		*Prunus persica*	1228	521	42.42%	16.37%
5		*Prunus domestica*	1995	712	35.68%	13.77%
6		*Pyrus communis*	1943	734	37.77%	14.50%
		Total	**11929**	**1697**	259.09	
1	**Fall**	*Juglans regia*	2340	645	27.56%	11.28%
2		*Diospyros kaki*	1359	399	29.35%	12.01%
3		*Malus pumila*	2126	1019	47.93%	19.62%
4		*Pyrus communis*	2116	636	30.05%	12.30%
5		*Punica granatum*	1357	447	32.94%	13.40%
6		*Prunus persicavar nectarina*	2139	661	30.90%	12.62%
7		*Pyrus pasha*	2419	641	26.49%	10.84%
8		*Diospyros lotus*	1316	251	19.07%	7.80%
		Total	**15172**	**4699**	244.29	

Figure 4. (A, B) Small Kashmir Flying Squirrels killed by local community in study area

Table 2: Seasonal variation in stomach contents of the small Kashmir Flying Squirrel in the study area.

Season	Common name of the fruit	Scientific name: Stomach content	No. of particles	Relative frequency
Winter	Apple	*Mallus pumila*	295	53.83%
	Wild Himalayan pear	*Pyrus pashia*	105	19.16%
	Oriental persimmon	*Diospyros kaki*	85	15.51%
	Wild Pomegranate	*Punica granatum*	50	9.12%
	Date-plum,	*Diospyrus lotus*	13	2.37%
		Total	**548**	**100%**
Spring	Blue pine (kail)	*Pinus wallichiana*	398	36.81%
	Chir pine	*Pinus roxburghii*	332	30.71%
	Bluejack oak	*Quercus incana*	299	27.65%
		Total	**1081**	**100%**
Summer	common walnut	*Juglans regia*	435	44.84%
	Peach	*Prunus persica*	243	25.05%
	Apricot	*Prunus armeniaca*	107	11.03%
	Common Pear	*Pyrus communis*	51	5.25%
	Plum	*Prunus domestics*	43	4.43%
	Peach variety	*Prunus persica var. nectarine*	121	12.47%
		Total	**970**	**100%**
Fall	Peach	*Prunus persica*	60	12.65%
	Wild Pomegranate	*Punica granatum*	85	17.93%
	Apple	*Malus pumila*	107	22.57%
	Common Pear	*Pyrus communis*	43	9.07%
	Oriental persimmon	*Diospyros kaki*	72	15.18%
	common walnut	*Juglan regia*	37	7.80%
	Date-plum,	*Diospyros lotus*	18	3.79%
	Peach variety	*Prunus persica* var. nectrina	52	10.90%
		Total	**474**	**100%**

Table 3. Occurrence of fragments of different fruits obtained from fecal pellet analysis in different seasons of the year 2019—2020

Season	S. Name	Number of slides	Total No. fragments	Percent Relative Frequency	Frequency of occurrence	Percentage
Winter	*Malus pumila*	55	25	22.32%	10	45.45%
	Diospyros kaki	55	19	16.96%	7.16	34.54%
	Punica granatum	55	29	25.89%	10.94	52.72%
	Pyrus pashia	55	32	28.57%	12.07	58.18%
	Diospyros lotus	55	7	6.26%	2.64	12.70%
Total	**42%**	**265**	**112**	**100.00%**	**43**	**42%**
Spring	*Pinus wallichiana*	55	37	43.52%	21	67.27%
	Pinusr oxburghii	55	31	36.47%	17	56.36%
	Quercus incana	55	17	20.00%	12	30.90%
Total		**165**	**85**	**85%**	**50**	**51.51%**
Summer	*Juglansregia*	55	31	33.39%	9.2	56.36%
	Prunus persica	55	17	18.47%	4.45	30.90%
	Prunus armeniaca	55	19	20.65%	8.25	34.54%
	Pyrus communis	55	11	11.95%	5	20%
	Prunus persica var. nectarina	55	9	9.78%	3.15	16.36%
	Prunus Domestica	55	5	5.76%	2.21	9.09%
Total		**330**	**92**	**100%**	**32.26**	**27.87**
Fall	*Juglans regia*	55	9	7.43%	4.56	16.36%
	Diospyros kaki	55	13	10.56%	11.05	23.63%
	Punica granatum	55	16	13.22%	10.45	29.09%
	Malus pumila	55	26	21.48%	11.4	47.27%
	Pyrus communis	55	21	17.35%	15.65	38.18%
	Prunus persica var. nectarina	55	11	9.09%	9.93	20%
	Pyrus pashia	55	19	15.70%	12.35	34.54%
	Diospyros lotus	55	7	5.17%	2	12.72%
	Total	**440**	**122**	**100.00%**	**76.43**	**27.72**

Discusion

The small Kashmir Flying Squirrel is a pest responsible for fruit damage. It has been observed generally to be 'granivore-frugivore', which means to eat fruits to pick up deeply embedded seeds primarily as food. Whereas the published literature supported its folivorous nature (Nakagawa et al., 2007; Dinets, 2011). Shafique et al. (2006) as well as Zahler & Khan (2003) also reported needles of conifers as the primary food source. Robert (1997) stated that the squirrel species feed on immature cones of Pinus trees. During the current investigation, both cultivated (73%) and wild fruits (27%) were found damaged in the study area. This is following Shafique et al., (2006), who reported damage to planted trees (*Prunus armeniaca* (17) (Fig. 3), *Prunus persica* (08*), Pyrus pashia* (22) and non-domesticated plants (*Pinus wallichiana (*445*)* and *Quercus incana* (26) in the Himalayan moist temperate forests of northern Pakistan

The Small Kashmir flying squirrel was observed to use diverse food like corns, nuts, seeds of the Pinus cone, and many different fruiting plants and other starch-rich food items. In Swat Kohistan, this species is particularly fond of acorns of the evergreen Holly Oak (*Quercus ilex*) as well as Walnut (*Jangluns regia)*. It also feed on the seeds of young fir cones, especially those of Silver fir (*Abiespindrow*) and immature cones of the Blue Pine (*Pinus wallichiana*). In the Murree Hills, it took young shoots and buds of Silver fir (*Abiespindrow)* as sound was heard while actively feeding at night on such trees (Abbasi et al., 2010). The feeding pattern of the Small Kashmir Flying Squirrel was found to vary for different fruits trees. In general, it makes a neat hole on shell (walnut) and seed coat surface (apricot, plum *Prunus persica var. nectarine* Peach varity) to extract the inner kernel (Fig. 2A, 2B, 2C and 2D). Whereas in case of peach it breaks apart the seed into two components and feed upon inner food stuff. For seed distraction it damages the soft flash of fruits by sharp teeth. It used the pomegranate flabby crust to pick up the grains. The species also made hole on the broad surface, sometime made single hole whereas in some cases holes were visible on both side. In case of Pear both fruit flash and seed were damaged during early and lateral stage of ripening (Fig 3 A). Similarly, it utilized the seeds of apple (Fig 3 B). The species also feed upon soft parts of fruits

(Japanese fruit and Himalayan wild pear) during ripening process as their teeth signs were observed on flash of fruits. Ana et al. (2017) also reported the signs of squirrel teeth on soft fruits. Squirrel gnawed the external crust of cones to pick the seed of *Pinus roxburghii, Pinus wallichiana* due to flabby nature of cones. Whereas in case of *Quercus incana* the species utilized outer hard coat for the feeding purpose (Fig 4A, 4B). Moller (1986) confirmed the member of the family Sciuridae feed on pine seed endosperm extracted from cones. He also accounted that the squirrels ate about one-third of the cone covering before the cones' maturation by gnawing. Moreover, Zahaler and Khan (1996) also reported the partial or complete deterioration of the pine needle by squirrels during a field survey by observing their tooth marks on needles and cones

The highest percentage of damage was noted for *Juglans regia,* although it is protected by an outer shell. The Squirrel species has an adaptation of drilling small, quadrilateral holes to extract the entire kernel out of its hard nut shell (sharp incisors). It makes holes on either side of the walnut from which they can extract the entire kernel, performing what would be a difficult feat for a human being, even armed with a suitable spiked tool, considering the small size of the hole. The observation is under Robert (1997), who noticed such holes on either side of the shell of *Juglans regia* (Fig. 1. A).

The small Kashmir flying squirrel was found to damage different fruits during field surveys, although fruiting plants are a vital source of income for local farmers and have commercial value. *Juglans regia* in particular has added importance as it reduces blood pressure and contains an antioxidant that keeps the immune system healthy (Turner & Lisa, 2014). *Prunus armeniaca* and *Prunus persica* are used to extract cooking oils. *Malus pumila* is the most common edible fruit. Among wild fruits, the seeds of *Pinus roxburghii* are the source of oil extraction. Globally, approximately 29 species of Pinus produce seeds, which have been used as a food item at least by indigenous tribal cultures (Mirov and Hasbrouck, 1976). Traditionally and locally, the cones of *Pinus roxburghii* have also been used as firecrackers during many festivals. Cones can also be used as a fire starter in fireplaces or crushed and molded into pre-sto log shapes (Thomas and Schumann, 1992).

The occurrence of Small Kashmir Flying Squirrel (*Hylopetes fimbriatus*) is reported in northern hilly areas of Pakistan between 2400 m and -3800 m (Zahler, 1996; Zahler & Khan, 2003). However, the maximum elevation of the existence of the species was noted to be 720 m -2400 m in the current study (Hornskov & Foggin, 2007) (1356 m to 1981 m). Corbet & Hill (1992) described that the small Kashmir flying squirrel is distributed in the Himalayan moist temperate

forest between elevations of 1350m to 3050m. Although it is found to be active only during night (Roberts, 1997; Qamar et al., 2006) and reported to conceal itself under conifers during daytime. But this tree-dwelling mammal was often visualized/identified in the field (by dull pinkish buff color mixed with black hair and a long bushy tail) on trees and buildings in late evening. It is equipped with strong forelimbs with hard claws for climbing on the walls of buildings. It can also glide with the help of a membrane between the fore and hind limbs. It makes a nest in tall trees of *Pinus wallichina* and *Quercus incana*. The nests are also reported to be present on high rock cliffs (Zahler, 1996; Zahler & Khan, 2003). It lives in tree hollows and rock crevices (Molur et al, 2005; Rauf et al., 2019).

The published literature on the Small Kashmir Flying Squirrel (*Hylopetes fimbriatus*) is confined to limited ecological data on population estimation and distribution in Pakistan. In Ghomat Game Reserve, the population of Small Kashmir Flying Squirrel was estimated based on indirect evidence through dropping, walnuts showing quadrilateral holes, conifer shoots bitten, and bark of *Butulautilis* (Qamar et al., 2006). In Gilgit, extensive surveys were conducted to check the occurrence of the species, and six individuals captured were later released (Zahler, 1996; Zahler & Khan, 2003). Globally, the population of the Small Kashmir flying squirrel has been reduced by up to 50% in the last 50 years (Koli, 2016). It is also considered “Vulnerable” in Pakistan (Sheikh and Moular, 2003. Despite of protective status, it is noted to be killed massively by indigenous people due to its feeding habits. In rural areas, people generally used a shotgun and small-caliber rifle (Stephen and Hyganstrom, 2009) to kill it. Dagnall et al. (1998) also reported a wide range of control and eradication tactics, including shooting and poisoning. Koli (2016) also mentioned killing by humans as a major threat to the squirrel species, along with habitat destruction. This presents challenges of human-small Kashmir flying squirrel conflict arises due to deleterious effects on fruits, as it also feeds upon fruit trees. Consequently, 160 entities of this mammal were killed by local people as a pre-emptive strategy against its feeding habits. However, squirrels not only use the forest to live and eat, but also play a vital role in sustaining and expanding plant communities and ecosystems. Therefore, this vital mammal species must be conserved to keep an environmental balance.

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