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Population Explosion and Behavioural Changes of Opportunist Wild Avifauna at a Landfill at Gujranwala in Northeastern Punjab: A Baseline Deviation Study

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ABSTRACT

Urbanization and associated accumulation of solid waste at landfills is attracting large numbers of wild avifauna for food subsidies and transforming landfills into new habitats by changing the wild profile of native species. This study aims to establish the baseline situation of avian diversity and abundance on various land uses including the landfill at Gujranwala in northeastern Punjab, Pakistan, and understanding the impact of urban solid waste in changing bird behavior. Field observations in a variety of land uses (agriculture, forest, lake, urban and landfill) in summer 2018 using the point count method for bird census determined the baseline for 56 species (birds/10 min) indicating a significant change in native avian composition. PCA analysis showed four clusters based on the nature of habitat and species behavior. Agriculture land was found to be the highest (H'= 3.394) and landfill the lowest (H'= 1.414) in biodiversity. However, landfill site registered the most number of birds (>9000). Among twenty species recorded at the landfill, four species *viz.,* house crow, common myna, grey-throated martin and bank myna, recorded >95% of the total population of birds. Species evenness was the highest for lake site (E= 0.938) indicating the most balanced type of ecosystem. Sparrows were found only in urban areas. Two opportunist species (house crow and common myna) were found to be the most successful in exploiting available resources. Foraging of birds in layers with aggressive species feeding first and development of new learning mechanisms pointed to the change in bird behavior at the landfill. This work highlights the need for a new research field '*Landfill Ecology*' to study the impact of landfill on biota including avian, in a time when biodiversity loss is the hottest global issue.

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ZN conceived the study and collected the field data. ZN and KS designed the study and performed the statistical analysis. KS corrected and finalized the manuscript.

Key words
Avifauna, Baseline situation, Ecology, Landfill, Behavior, Pakistan

INTRODUCTION

The rapid human population growth and associated urbanization, is increasing the solid waste generation in the worlds' cities which is expected to rise to 2.2 billion tons per year by 2025 (Hoornweg and Bhada-Tata, 2012). The urban waste material that ends up in landfills contains a significant amount of food leftover (Parfitt *et al*., 2010). The wildlife (mammals, birds etc.) finds waste as the food subsidy, as it is easily accessible and predictably available in time and space, and this attraction is becoming an important ecological driver (Oro *et al*., 2013). The exploitation of abundant food supply by many opportunist avian species (e.g. gull, crow, stork) can cause the population explosion as compared to other species which are not able to exploit landfills as a food source (Belant *et al*., 1995; Gabrey, 1997; Tortosa *et al*., 2002). The migratory species can also shift their habitats by exploiting food from landfills disturbing the local avifauna species (Tortosa *et al*., 2002). The avian behavior may change in terms of landfill use, e.g. development of new learning mechanisms for better exploitation of food from landfills (Coulson *et al*., 1987; Sazima, 2007). The pathogen infection risk can also increase from birds to humans living in proximity of landfills (Plaza *et al*., 2019). Thus, the extensive use of landfills can change the ecology of birds at a local, regional and global level.

The use of landfills and the resulting impact on birds has been investigated in developed countries (Europe and North America) extensively during the last 60 years (Plaza, 2017) but there is a knowledge gap on the effect of waste on birds of South Asia in general and Pakistan in particular. With the increasing population the quantity of waste is bound to rise and the resulting number of landfill sites will also increase. The proper management and operation of landfills is not practiced in Pakistan thus exploitation of these landfills by birds in huge numbers has been observed in many areas. This study is designed to record the abundance and diversity of birds per 10 min observation time in all land uses of study area to establish

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present avifauna baseline in Gujranwala and find out how this baseline deviated on landfill in terms of population explosion and what is the dominant type of behavior of birds on the landfill?

MATERIALS AND METHODS

Study area

Gujranwala is an industrial city located in the northeast of Punjab province (Fig. 1) of Pakistan. It is the seventh most populous metropolitan (~5 million people; PBS, 2018). The climate of Gujranwala is hot semi–arid type according to the Köppen Climate Classification System (Köppen, 1936; Sarfaraz *et al*., 2014). Average annual rainfall is 581 mm with the highest occurring between July and August (Anjum *et al*., 2016).

The total land area of Gujranwala is 3,198 km^2. The prevailing land cover in the area can be divided into four main components: agriculture land (87.6%), built up or urbanized area (6.4%), forest of river bank and farmland plantation (4.4 %), and water bodies (1.6%) including lakes, ponds and canals (Land Cover Atlas, 2014). The study was conducted at four land use types (agriculture, urban, forest, lake) for comparison with the fifth type of land use of solid waste disposal site, the landfill of Bhakrywali area.

Field sites

Field work was carried out at selected locations in and around the city as shown in Fig. 1. The *forest site* is artificial plantation located along the bank of Upper Chenab canal about 10 km from the city center. The dominant tree species are shisham or Tahli (*Dalbergia sissoo*), keekar or babul (*Vachellia nilotica*), safeda, (*Eucalyptus camaldulensis*, jand (*Prosopis cineraria*), karir (*Capparis decidua*), jamun (*Syzygium cumini*), peepal (*Ficus religiosa*), neem (*Azadirachta indica*) and kanair (*Nerium oleander*).

The lake site (area~ 1 km^2) is located in the east of the city near Ghaghark village about seven km from the city. Lake was formed due to soil excavation by the construction industry forming deep pits (depth~10 m) that later being filled by surface runoff from surrounding areas over the past 20 years or so. The land use of local area changed as a result of marshland type structure over the time attracting birds of various kinds and, currently, serves as a critical habitat for aquatic wildlife.

The urban site is located in the city, Chak Jagna (Fig. 1) encompssing built-up area with typical city characteristics such as houses, markets, roads, schools, parks, boosters for cell phones, heavy traffic and people (density~1,400/km^2; PBS, 2018). Vegetation is scarce with common tree species such as Jamun, Guava (*Psidium guajava), Toot* (*Morus alba),* Dharek (*Melia azedarach)* and few shrubby plants like Jasmine (*Jasminum officinale)*, Rose (*Rosa indica*). Many ornamental plants are also present in and around houses and parks.

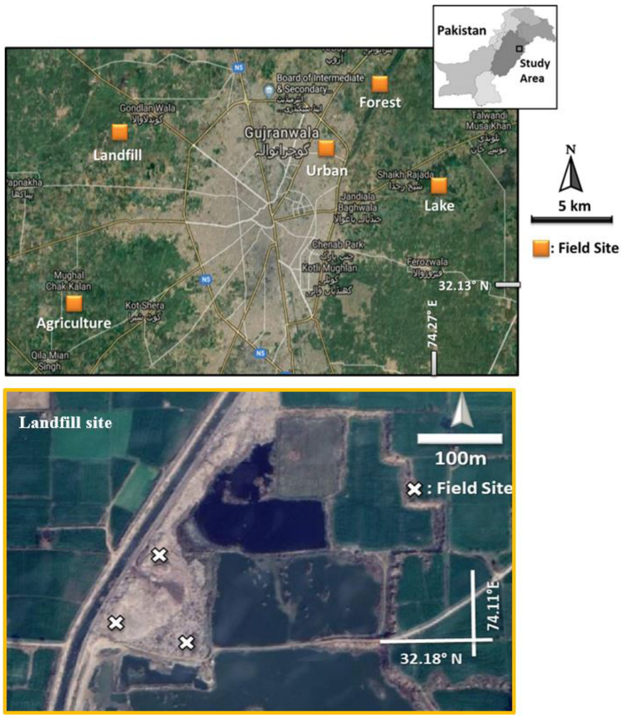

Fig. 1. Location map showing five selected field sites for avifauna data collection in Gujranwala area. The landfill site is a large depression in the ground and is being filled by solid urban waste. Locations marked 'X' shows sites points where field observations of avian species were taken.

The agriculture site is located about 12 km from the city center in the southwestern direction (Fig. 1). Agriculture is the dominant land use (area~88 %) with arable farming of major crops including wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), rice (*Oryza sativa*) etc. and pastures for livestock rearing (Land Cover Atlas, 2014).

The fifth site is the landfill for disposal of solid waste from the city and is the main focus of this study. The landfill site is located away from residential areas at about 8 km northwest of Gujranwala city center (Fig. 1). The area of landfill is about one km^2 and the pit is 18 to 20 m below the surface level. Over 100 vehicles are being used to take solid waste from various parts of the city to the landfill site (personal communication with field manager). Total amount of waste being dumped at the site is 21,379 tons/day (GWMC, 2018). Typically, the vehicles begin dumping waste transported from the city early in the morning and continue till dusk. A bulldozer is used to level the garbage surface whole the day during the dumping operation.

Field data were collected from June to July in 2018 which is the summer season with the highest temperatures ranging from 40°C to 45°C. Data were recorded three times a day: dawn (sunrise from 5:00 to 7:00 am), midday (noon time from 12:00 to 2:00 pm) and evening (before sunset from 5:00 to 7:00 pm); for three consecutive days at each of the four sites and for six days at landfill site (3 working and 3 non-working) to check whether there was any relation of number of birds with working and non-working days as working day is directly related to availability of fresh food to birds from the landfill.

Point count method was used for bird counting (Blondel *et al*., 1970). At each site the area was divided into three blocks (size of each block~ 1000 m^2) with equal distance from each other. Two counts of ten min were made in each block with a break of 10 min and this counting was repeated in all three blocks. In this way six observations were made in two hour time period. Because each observation was not independent of each other the mean value of all observations was calculated to find the number of birds per 10 min (Gabrey, 1997). All the species present in the area were recorded along with their number. Collins Field Guide of Birds (Arlott, 2014) was used to identify avian species. The landfill is new and a novel habitat that has its special characters like presence of plenty of food thus the behavior of birds was observed keenly at this site which was categorized into types based at the height above the landfill surface (e.g. sitting, flying, diving, foraging, and roosting).

Statistical analysis

Data were analyzed by using statistical tools SPSS, Minitab. Relative abundance of each species in the population was determined by the formula (Pi) Pi= Ni / N. The percentage of each species in population was also calculated as (Pi) Pi= Ni / N*100. Avian diversity index was calculated at each site by Shannon and Weaver diversity index (Shannon and Weaver, 1963). Species Richness (SR) (Margalef, 1951) and Species Evenness (E) was calculated (Pielou, 1966) to find out ecology of wild avifauna. The Principal Component Analysis (PCA) was carried out to understand the clusters and group behavior. Spatial distribution maps were developed using GIS software and Google Earth images.

RESULTS

Field data and observations of 56 species at five study sites are presented in Tables I-III and are discussed in the following subsections.

Species richness, diversity index and evenness

The species richness and Shannon-Wiener Index of diversity (H') were calculated for all sites as given in Table I. Results showed that the agriculture site H'=3.394 and forest site H'=3.224 were richer in biodiversity as compared to all sites. The value of urban (H'=2.369) and lake Site (H'=2.856) showed a moderate value of diversity. The landfill site showed the lowest value of the index (H'=1.414). The species evenness value was observed to be the highest (E=0.938) at the lake site indicating a balanced type of ecosystem. The agriculture (E=0.908) and forest site (E=0.922) also showed better species evenness value pointing to a healthy ecosystem. The urban site, however, showed the lower value (E=0.820) but the landfill site showed the lowest value (E=0.472) in all study sites.

Diversity and abundance of species at study sites

Forest site

At the forest site a total of 1,085 birds of 33 species were recorded during the three days of field observations (Table II). Number of birds per 10 min observation ranged from 1 to 13. Number of species varied between 28 in the noon and 33 in the morning. The results showed that the house crow (*Corvus splendens*) and common myna (*Acridotheres tristis*), made 10% (*N*= 39) and 9% (*N*=35) of the total population of all birds in the morning time, respectively. The next abundant species were noted to be black kite (*Milvus migrans)* 6% (*N*=22) and red-vented bulbul (*Pycnonotus cafer)* making 6% (*N*=21) of the population. The jungle babbler (*Argya striata*) made 5% (*N*=18), Indian pond heron (*Ardeola grayii*) 5% (*N=18)*, grey-throated martin (*Riparia chinensis*) 5% (*N=20)* and house martin (*Delichon urbicum*) 5% (*N=18)* of the total population of birds. The 23 species made 49% of population but percentage of each species was 4% and below 4%. The composition of species was changed by the noon time. House crow and common myna recorded 10% (*N*=30) and 9% (*N*=28) of the population respectively, and Jungle babbler was the next abundant species contributing 6% (*N*=21) of the population. Red-vented bulbul made 5% (*N=16)*, striated babbler (*Argya earlei*) 5% (*N=16)*, House swift (*Apus nipalensis)* 5% (*N=16*), common babbler (*Argya caudate)* 5% (*N=17)* and Black kite made 5% (*N=17)* of population. The other 20 species made 50% of population but percentage of each species was below 4%. The evening time composition was also different from the morning and noon. House crow was the most dominant species making 10% (*N=36)* of the population of birds. Both house martins and grey-throated martins were found to be 9% (*N*=32 and *N*=25, respectively) of the population. Common myna recorded 8% (*N*=29) of population of birds.

Table I. Species richness, Shannon-Wiener index of diversity and species evenness at five study sites.

Name of site	Forest	Lake	Urban	Agriculture	Landfill
Species richness (SR)	33	21	18	42	20
Shannon-wiener index of diversity (H')	3.224	2.856	2.369	3.394	1.414
Species evenness (E)	0.922	0.938	0.820	0.908	0.472

Table II. Field data on the bird population at five locations of the study area.

Location	Observation time	Number of birds in three days	Number of species	Temperature (°C)	Latitude (°N)	Longitude (°E)
Forest site	Morning	387	33	28	32.180527	74.227362
	Noon	326	28	41		
	Evening	372	30	38		
Lake site	Morning	364	21	27	32.174784	74.270416
	Noon	270	21	39		
	Evening	345	21	37		
Urban site	Morning	287	16	26	32.187088	74.214409
	Noon	182	12	41		
	Evening	276	15	37		
Agriculture site	Morning	512	41	30	32.120124	74.054786
	Noon	289	26	39		
	Evening	487	41	35		
Landfill site	Morning	3321	20	34	32.187900	74.105267
	Noon	2471	17	42		
	Evening	3268	20	37		
	Sunday	625	19	38		

Table III. Percentage population of 20 avian species at the landfill site on working days.

Sr. no.	Common name of species	Scientific names	Population (%)	Sr no.	Common name of species	Scientific names	Population (%)
1	Asian koel	*Eudynamys scolopaceus*	0.1	11	Indian pond heron	*Ardeola grayii*	0.5
2	Bank myna	*Acridotheres ginginianus*	11.7	12	Pied kingfisher	*Ceryle rudis*	0.2
3	Black drongo		0.6	13	Sand martin	*Riparia riparia*	1.5
4	Barn swallow	*Hirundo rustica*	0.5	14	Red-vented bulbul	*Pycnonotus cafer*	0.5
5	Black kite	*Milvus migrans*	2	15	Red-wattled lapwing	*Vanellus indicus*	0.2
6	Eurasian collard dove	*Streptopelia decaocto*	0.1	16	Grey-throated martin	*Riparia paludicola*	23
7	Common myna	*Acridotheres tristis*	29.7	17	Striated babbler	*Argya earlei*	0.4
8	Green bee-eater	*Merops orientalis*	2	18	White-breasted water hen	*Amaurornis phoenicurus*	0.1
9	Greater caucal	*Centropus sinensis*	0.1	19	Wire-tailed swallow	*Hirundo smithii*	0.3
10	House crow	*Corvus splendens*	26	20	White-throated kingfisher	*Halcyon smyrnensis*	0.5

Red-vented bulbul made 6% (*N=18)* and Black kite (*N=18*) also made 6% of population of birds. The other 22 species made 48% of population of birds but contribution by each species was less than 5%.

Lake site

At the lake site, 979 birds of 21 species were observed during the three days of field data collection. The number of birds per 10 min observation ranged between 1 and 16. A total of 21 species were present in the morning, noon and evening time without any variation. The six species i.e. common moorhen (*Gallinula chloropus*) (*N*=51) 14%, house crow 8% (*N=29)*, purple swamp hen (*Porphyrio porphyrio)* 8% (*N*=28) common house martin 8% (*N=28),* Common myna 7% (*N=24)* and Indian pond heron 7% (*N=26)* made 52% of population. The other 15 species made 48% of population but percentage of each species was below 6%. The noon time composition was different from morning. The five species i.e. common moorhen 16% (*N=43)*, house crow 9% (*N=24)* purple swamp hen 9% (*N=24)*, common house martin 7% (*N=20)* and common myna 7% (*N=19)* made 48% of population of birds. The other 16 species made 52% of population but percentage of each species was below 6%. In the evening time, six species i.e. common moorhen 14% (*N*=49) common house martin 11% (*N=39)*, house crow 8 % (*N=28)*, Indian pond heron 8 % (*N=24),* grey -throated martin 7% (*N*=25) and common myna 7% (*N*=21) made 55% of population of birds. The other 15 species made 45% of population but percentage of each species was below 6%.

Urban site

In the urban area, 745 birds of 18 species were recorded in the three days of field work (Table II). The number of birds per 10 min observation ranged between 1 and 23. There was a minor variation in the number of species with the time of day. The four species i.e. house sparrow 23% (*N*= 65) house crow 16% (*N*=47), common myna 15% (*N=42)* and black kites 8% (*N*= 17) made 62% of the population of birds. The other 12 species contributed to 28% of population but percentage of each species was less than 8%. At noon time the species composition was different from morning. The house sparrow (*Passer domesticus)* (*N*=49) made 27% of bird population while house crow (*N*= 35) and common myna (*N*= 33) made 19% and 18 % respectively of all birds' population. Rock pigeon (*Columba livia) 9%* (*N*=17) and black kite (*N*= 17) each made 9 % of population. In the evening six species i.e. house sparrow 21% (*N*=49), house crow 15% (*N*=41) common myna 14% (*N*=38) rock pigeon 9% (*N*=24), common house martin 8% (*N*=21) and black kite 7% (*N*=20) made 74% of the population. The other 11 species made 24% of population but percentage of each species was below 6%.

Agriculture site

At the agriculture site, 1288 birds of 42 species were recorded in three days observation period during morning, noon and evening time (Table II). The number of birds during 10 min observation time ranged from 1 to 14. The variation in number of species by the time of the day was almost nonexistent. The three species i.e. house crow 7% (*N=38)*, common myna 7% (*N=35)* and Red-wattled lapwing *(Vanellus indicus)* 6% *(N=29)* made 20% of population of birds. The other 39 species contributed 80% of the population, each species contributing from 1% to 5%. The variation in number of species from morning (41) to noon (26) was the highest at agriculture site from all other sites (Table II). Many species were absent in the noon in the fields. The House crow (*N=28)* made 10% of the population while common myna (*N=22)* and Red-wattled lapwing (*N=25)* respectively made 8% and 9 % of the bird population. Grey-throated martin made 7 % (*N=19)* of population. Common house martin (*N=18)*, Sand martin (*Riparia riparia*) (*N=17)*, Striated babbler (*N=17)* made 6 % of bird population. All other bird species made less than 5 % of the population of birds. The evening composition showed that Common house martin (*N=37)* and Sand martin (*N=33)* made 8% and 7 % of population, respectively. House crow (*N=34)* made 7% of total population while common myna *(N=30)* comprised 6% of the population. The other 37 species made 72% of population.

Landfill site

Landfill site data were collected for 3 working days and 3 non-working days (i.e. Sundays). The 9060 birds of 20 species were observed to be congregated at the landfill during the 3 working days (Table II). Mean number of birds ranged from 1 to 341 per 10 min observation, the highest among all sites. The variation in number of species with time of the day was minor. The four species i.e. common myna 29% (*N=974)* house crow 27% (*N=887)*, Grey-throated martin 23% (*N=755)* and bank myna 12% (*N=392)* contributed significantly by making 91% of the population of birds. Black kite made 1.6% (*N=56)* and green bee- eaters (*Merops orientalis*) (*N=66)* made 2.1% of population. The other 14 species made only 6% of total population of birds collectively. The composition of species was different for noon with common myna (*N=802)* contributing to 32% of population of birds. House crow (*N=615)* was the second most dominant species and made 25% of the population. Grey-throated martin made 22 % (*N=553)* and Bank myna made 12% (*N*=308) of the population. Black kite made 2% (*N=40)* and green bee-eaters (*N=35)* also made 2 % of population. The other 11 species made 5% of population but percentage of each species was 1% and below 1%. In the evening 5 species i.e. Common myna 28% (*N=915)*, House crow 26% (*N=847)*, Bank myna 11% (*N=360)* Grey-throated martin 25% (*N=807),* Sand martin 3% (*N=71)* made 93% of the population. The other 15 species made 7% of population but percentage of each species was 2% and below 2%. It was found that on an average 625 birds of 19 species were present at the landfill site on any non-working day when waste was not being dumped.

DISCUSSION

Distribution pattern of species at all study sites

Spatial distribution pattern of avian species is shown in maps along with diversity and abundance in Figure 2(g – h). All the study sites were unique in types of species and their abundance but distribution pattern of selected species with most distinct characteristics will be discussed here. The forest site for example showed its characteristics of sustaining population of species adapted to tree canopies. The dominant species at the forest site was house crow (Fig. 2c). The number of House crow per 10 min was more or less equal at all study sites except landfill but it was leading all other avian species in the forest. Goodwin and Gillmor (1976) and Roberts (1992) established that it was an opportunist species, present in all types of habitats but made nests only on trees as its nests were present on many trees in the forest. It is also very aggressive to other bird species (Lamba, 1976; Britton, 1980) and this aggressive behavior may expel other birds from the area which may be the reason for its dominance in the forest. A special feature of the forest site was the presence of colorful avian species e.g. alexandrine parakeet (*Psittacula eupatria)*, rose ringed parakeet (*Psittacula krameri)*, Indian golden oriole (*Oriolus kundoo)* which were absent from all other habitats. Forest provides the most suitable place to these birds for hiding from predators and also provide food (Newell and Rodewald, 2011). House sparrow was totally absent from the forest site. The lake site was dominated by birds related to the aquatic environment. Common moorhen was the most dominant species at lake site (Fig. 2f) but absent from all other sites including landfill. Rais *et al*. (2010) and Altaf *et al*. (2013) have also reported its presence on various wetlands of Pakistan. Some of the aquatic birds are threatened (e.g. Marbled teal (*Marmaronetta angustirostris*)) in Punjab (Rais *et al*., 2010) and in this critical situation, the aquatic birds may be finding a place of survival away from human disturbance and their population is maintained for the time being in the area. House sparrow was totally absent from the lake site.

The agriculture site was different from all other sites in sustaining a huge diversity of bird species. The House crow was the dominant species at this site as well followed by Red-wattled lapwing, a bird well adapted to agricultural lands. The urban site showed its own characteristics by sustaining huge population of birds adapted to urban settlements. House sparrow that was absent from all other study sites including landfill was found to be present abundantly here (Fig. 2e). The habitat of this bird species is strongly associated with urban structures and human habituation as it can find many places for nesting in urban structures and also find many feeding opportunities here (Robinson *et al*., 2005; Shaw *et al*.,2008). Thus it can justify the presence in huge numbers at this site. Its flocks were recorded at the agriculture site in the morning and evening flying to an unknown destination but they did not stay in agriculture fields (data in this study). Sparrow was also absent from the forest site. Maan and Chaudhry (2001) reported the presence of house sparrow in Changa Manga plantation but not in the Chichwatni and Kamalia plantation in Pakistan. This means that sparrow can be present or absent in forests at a time depending on geographic location and other factors. Sparrow was also absent from landfill site. Plaza and Lambertucci (2017) reported their presence at different landfills in the world. At Bhakrywali landfill sparrow was absent. The reason behind its absence may be presence of landfill site at place far away from the urban area as they don't move very far away from urban settlements.

The landfill site showed a unique character from all sites by registering the highest population of birds (9060) (Fig. 2g) in three working days. This is the baseline situation of landfill site which differs significantly from other sampling sites. Such large congregation of birds at landfill sites have also been reported from other parts of the world during the last 50 years. For example, Pomeroy (1975) reported large abundance and foraging of many avian species on landfills of Kampala, Uganda. Similarly, on landfills of Tampa Bay and Virginia, about 90,000 and 112,693 birds of different species were respectively reported at any moment of time of the year (Patton, 1988). The abundance of birds on landfills depends upon various factors including nature of food subsidy (Bertellotti *et al*., 2001), shelter (Burger, 2001) and breeding season (Pons and Migot, 1995; Tortosa *et al*., 2002). Many threatened species like vultures are also found to be present on landfills (Houston *et al*., 2007) taking advantage of food source. The cause of presence of huge number of birds at the landfill site is most probably the food subsidy but requires further investigation.

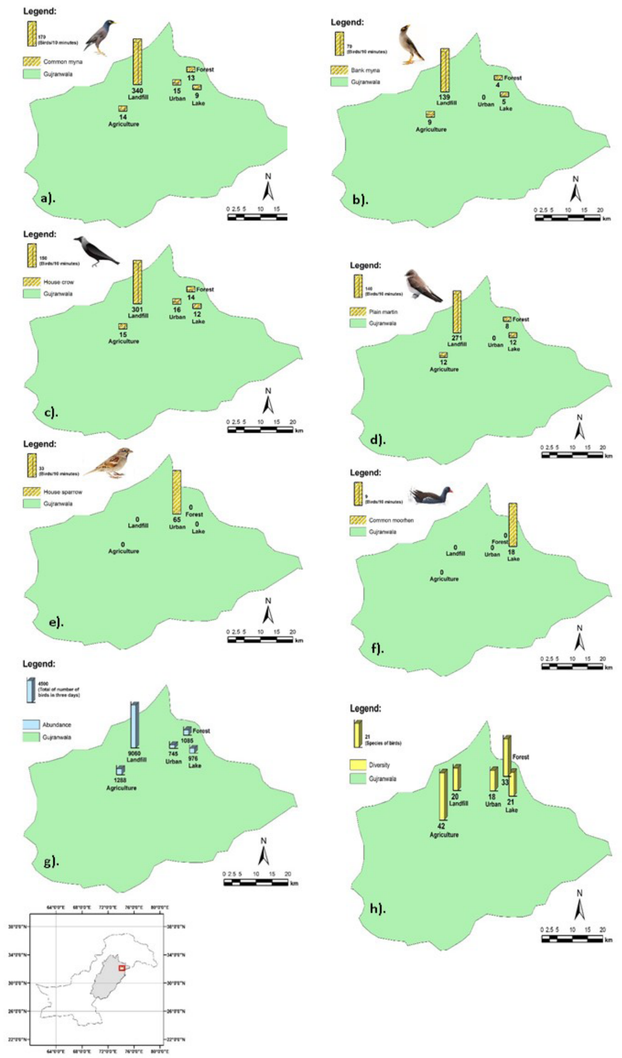

Fig. 2. Maps showing spatial distribution of selected wildlife avifauna based on field data (birds per 10 min) from the agriculture, landfill, urban, forest and lake sites. Abundance (Figure-g is the total number of birds) and diversity (Figure-h is the number of species) were also determined in this study.

The dominant species at the landfill was common myna (Fig. 2a). The common myna was observed foraging on the landfill while flying and sitting at different places. The second dominant species was the house crow (Fig. 2c). The presence of house crow on landfills has already been well documented around the world (Plaza and Lambertucci, 2017). The third most abundant species at the landfill site was Grey-throated martin (Fig. 2d). They are insectivorous birds (Arena *et al*., 2011) and were present in huge numbers where active dumping took place at the landfill especially in the evening time. At the landfill a huge mass of house flies blanketed the site in July that attracted the grey-throated martin at the landfill. The fourth abundant species at landfill site was bank myna (Fig. 2b). Plaza and Lambertucci (2017) reported 58 avian species that dominate the landfills around the globe. In this study presence of many of the species has already been established on landfills (Plaza and Lambertucci, 2017) but the presence of common myna, bank myna, grey-throated martin and green bee-eater in huge abundance is a new observation and has not been reported elsewhere.

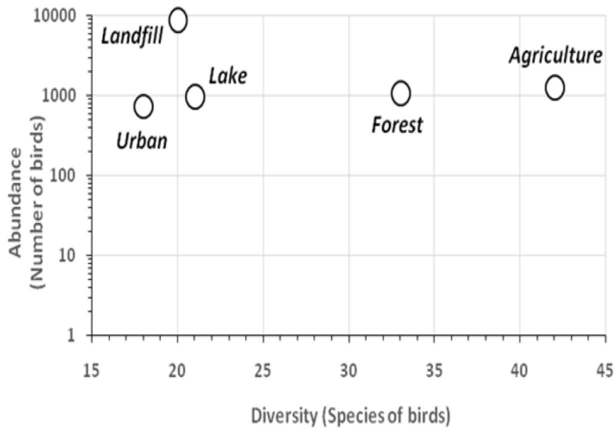

Fig. 3. Avian diversity and abundance at five study sites.

Diversity versus abundance at five sites

A large variation in the species diversity was observed at all study sites (Fig. 2h) and (Fig. 3). The abundance of birds at three natural sites i.e. agriculture, lake and forest was not significantly different but abundance of birds at the landfill was phenominal. Bird diversity at the agriculture site was highest and at urban site the lowest. The diversity at the agriculture site was nearly double than that at the urban site. Vaccaro *et al*. (2019) compared the diversity of birds in protected natural areas, planted areas, agricultural lands and urbanized areas concluding that after forests and protected areas the agricultural lands supported the most avian species. The low bird diversity at the landfill has also been observed in many other regions of the world. For example, large abundance of only five gull species has been reported on the landfills of Europe and North America (Harris, 1970; Vidal *et al*., 1998; Ramos *et al*., 2009). In Brazil, Novaes and Cintra (2015) reported abundance of only two species, i.e., Black vulture (*Coragyps atratus*) and Turkey vulture (*Cathartes aura*), on landfills. The situation can be different at other locations, however, as Belant *et al*. (1995) and Gabrey (1997) recorded presence of up to 42 species on the landfills in Ohio, USA. The diversity at landfills can be huge or small depending upon geographic area (Plaza and Lambertucci, 2017), accessibility to landfills (Duhem *et al*., 2005; Weiser and Powell, 2010), seasonality (Horton *et al*., 1983; Belant *et al*., 1993; Baxter *et al*., 2003), life stage of birds (Elliott *et al*., 2006; Turrin *et al*., 2015) and gender (Monaghan, 1980).

Time dependent variation in population

Birds were most active (foraging, flying etc.) in the morning at all sites than in the evening time and least active at noon (Fig. 4). This variation in the bird activity with time of the day fluctuated at five sites. At the lake site all 21 species were active at all times of the day. The urban and forest site also did not show significant variation which can be explained in the absence of huge fluctuation in environmental condition of forest, lake and even urban in the morning, noon and evening.

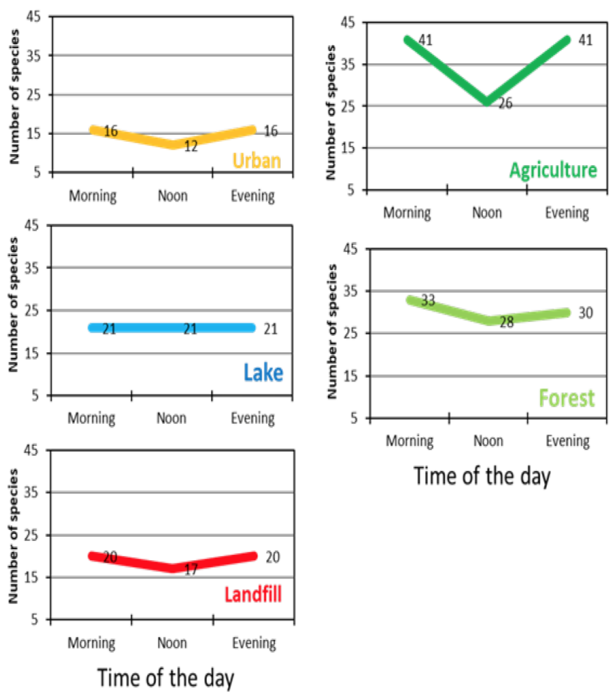

Fig. 4. Variation in number of active species with time of day (Morning, Noon and Evening) at the five observation sites in the study area.

The agriculture site showed the greatest variation to this trend as only 26 species ware active at noon. This low ratio can be explained in terms of intense heat in the fields at noon. To avoid this heat birds remain hidden in canopies in the noon. The landfill showed its own character different from all study sites as 90% of species and 82 % of the population were active in the noon time. It was novel behavior of birds as landfill was present in environmental conditions which were very similar to the agricultural site. The temperature was around 40 °C and no shade of tree or human made structure was present that could provide birds protection from heat. In the same situation at agricultural site 56% of population and only 60% of species present but here 90% of species and 82% of population was present. The reason behind this may be continuous availability of food which attracted these birds to the landfill even in the extreme weather conditions at noon. Gabrey (1997) found that maximum bird species were active all the day long at landfills. Burger (2001) also reported that gulls and kites were active at the landfill site from dawn to dusk and even forage at night in the moonlight. The night time dumping of waste on landfills did not reduce nocturnal foraging of gulls (Burger, 2001) which are diurnal birds.

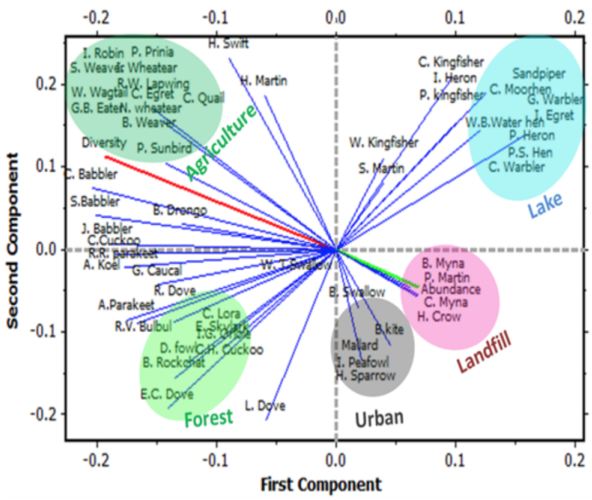

Fig. 5. PCA plot showing the clustering of different avian species at various observation sites.

Group behavior and habitat association

The principal component analysis (PCA) shows the results for the first two components of the 58 variables (Fig. 5). These variables were 56 bird species and two variables of diversity and abundance. Direction and the closeness of a line to another indicates how the species may be grouped. The nature of habitat seems to be the most determining factor in terms of how species associates with each other in abundance and diversity. A cluster of water birds is formed among four distinct clusters. Lake environment has large positive loadings on component 1 (in the horizontal direction), thus this component determines water body related species habitat hence variables are correlated. The agriculture site and forest site make clusters close to the variable of diversity of birds showing these sites are rich in biodiversity.

There is a gradual transition between forest and agriculture related bird species pointing to some similarities in the nature of habitat. At urban site a group of birds was found consisting of only a few species present on urban site only. The most unusual behavior was not ed at the landfill site. The four species i.e. house crow, common myna, bank myna and grey-throated martin are strongly correlated with variable of abundance hence plotted in a tight group. These four species can be categoried as opportunist in nature in terms of benefiting from food subsidies. Common myna and house crow are successful in all types of habitats and their number is likely to rise with time.

Equal abundance of two opportunist species at all study sites

It was found that common myna and house crow were the most abundant in a more or less equal ratio at all sites (Fig. 2a) and (Fig. 2c). The house crow was dominant at two sites viz., forest and agriculture. The common myna was the most dominant species at the landfill site. At urban site they were present in equal ratio after House sparrow. This work finds that these two opportunist species are most successful in all types of habitats and suggests that they in future may successfully compete with other avian species for food and other natural resources.

Baseline situation

Baseline situation documents the current number and type of wild avian species in the area (Fig. 6). It provides a reference point to establish a basis for comparison and assess any changes due to anthropogenic activities or natural causes. The four selected sites (agriculture, lake, forest and urban) represent about 99% of the land use that are compared with avian species present at the landfill site (<1% land use). The baseline of 56 avian species is shown in Figure 6 with abundance (average number of birds per 10 min). The deviation from the baseline is most likely due to the anthropogenic activities resulting in production of ample amount of food left over at the landfill. The 14 out of 56 species particularly benefit from urban waste material consumption and their number is far above the baseline. This is a sign of impact of urban solid waste's improper disposal on environment directly and avifauna indirectly, hence a set of opportunist species are rising in numbers. It can affect natural balance of wild avifauna and may have long-term consequences in the form of creating environment most suitable for a few generalist species and driving others towards scarcity.

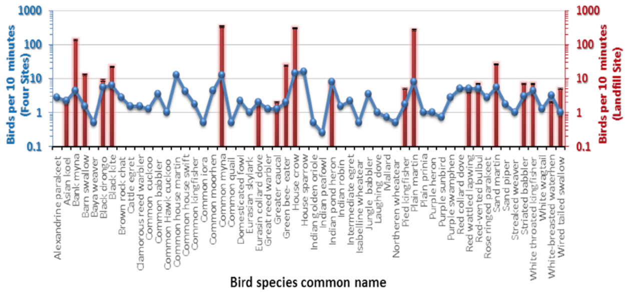

Fig. 6. Graph showing baseline situation of 56 wildlife avifauna species of the Gujranwala area with error bars from the four selected sites (~99% land use) as the number of birds observed per 10 min. The Landfill site histograms show the number of birds in contrast to the local baseline situation.

Behavior of avian species at the landfill site

Some interesting behavior of birds was noted on the landfill site discussed as the average number of birds was found to be 3,050 on a working day but on the non-working day (Sunday) only 625 birds were present at the landfill (Fig. 7). On Sundays, there is no arrival of food subsidy as vehicles carrying waste do not dispose of waste material at the site. The lack of fresh food on non-working days might have taught birds not to come at the landfill hence only a fewer number of birds were present as compared to working days. Monaghan *et al*. (1986) and Coulson *et al*. (1987) also reported a change in behavior in gulls that were present in large numbers on landfills during the weekdays but lesser numbers on Sundays. They found that continuous availability of food with a break of a day has switched on a learning mechanism in gulls making them able to recognize days of the week and distinguish Sundays from working days. The birds at the landfill of study area might also have switched on a similar learning mechanism however further research is required to explain this behavior.

A special type of foraging behavior was also observed at the landfill site. A layered structure in foraging behavior was observed with house crow, common myna and bank myna which were found to be sitting on the waste surface and feeding directly on the freshly arrived material close to the dumping vehicles (Fig. 7). House martin and grey-throated martin remained flying above landfill surface (~10 m high) and eating insects and flies. Black kites soared above the landfill (> 10 m high) often nose diving at the surface picking some waste or rodents making a separate layer. Green bee-eaters remain flying at a relatively high altitude and never come to the landfill surface for food items. This complex layered structure on a small area (and space) showed that bird species have adapted to and modified their behavior for the best exploitation of landfill as a food source. Burger and Gochfeld (1983) and Annorbah and Holbech (2012) also reported that birds modified their behavior to get maximum benefit of food from landfills.

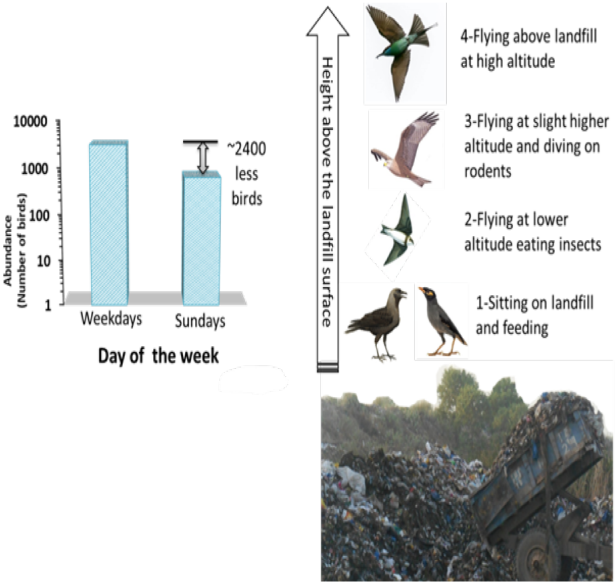

Fig. 7. Comparison of number of birds on the days of week and hierarchy in feeding behavior at the landfill site.

CONCLUSION

Landfill is found to have a significant impact on wild avifauna distribution pattern in the study area. A baseline situation in habitats such as forest and agriculture land registered higher avian diversity (~2 times) as compared to built-up areas (urban and landfill) pointing to the fact that the land use change from natural to anthropogenic reduces the diversity. House sparrow numbers dominated in urban areas however, none was found at all other habitats. The forest area has its unique character due to the presence of canopies for hiding and food from fruit trees, the colorful avian species (parakeets and orioles) were found only here and were absent from all other habitats.

Field observations indicated the congregation of a set of opportunist species, which is a sign of imbalance of species composition in the prevailing environment. These opportunist species with aggressive behavior have dominated most existing habitat types and now they are shifting towards a new manmade artificial habitat, the landfill, as shown by rise in numbers (>9000 individuals). Landfill area registered the highest population of four opportunist avian species *viz.*, common myna, house crow, bank myna and grey-throated martin creating an imbalance of native species composition. A hierarchy in feeding behavior is also observed at landfill as a layered structure with most aggressive species feeding first at freshly arrived waste and other flying above diving on the waste surface. Higher number of birds on weekdays than the weekend indicated the development of new learning mechanism. Poor management of anthropogenic waste products, especially food subsidies, is providing opportunities to wildlife to forage and take shelter, and a shift in behavior for better survival. Human population growth and urban solid waste production is creating an artificial habitat attracting wild avifauna for food subsidies with dominance of selected few species. As landfill has a huge impact in changing local avifauna profile is changing the behavior of birds, there should be a new field of landfill ecology to manage all these changes.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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