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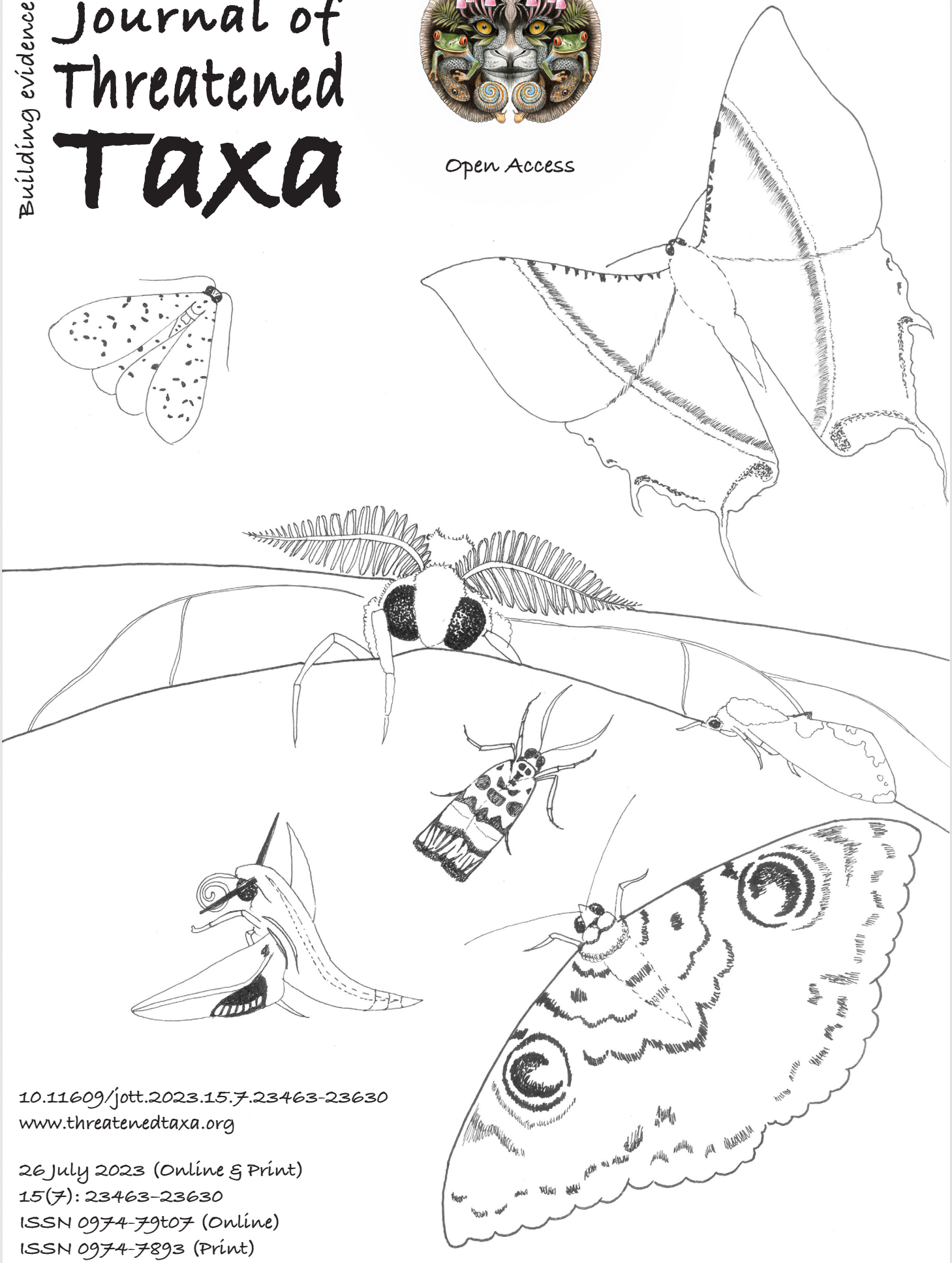

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Cover: Celebrating the unsung heroes—moths, our nocturnal pollinators. © Priyanka Iyer.

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COMMUNICATION

Tree cover and built-up area regulate the territory size in Eurasian Magpie *Pica pica* in Ladakh, India

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Abstract: Eurasian Magpie *Pica pica* is one of the well-studied corvids, but the majority of our understanding of this species is from Europe. In India, its distribution is restricted to some valleys of Ladakh such as the northwestern part of the Indus, Nubra, Zanskar, Drass, and Suru. The present study aimed at understanding the territorial behavior of this species in small urban settlements of Ladakh region. Twenty-five pairs were studied in March 2020–April 2021. Territories were outlined for each color-banded individual, and data on habitat variables (namely built-up, agriculture, and green cover) was extracted. Generalized linear mixed models were used to study the effect of the habitat structure on territory size. The territory size (Mean ± SD) was 0.042 ± 0.025 km^2, with tree cover comprising the highest proportion (24.36 ± 15.41 %) of area within territories. Built-up area was a feature of all territories, highlighting the affinity of magpies towards human presence. Presence of tree cover and built-up area significantly (~ <0.002) reduced territory size. High adaptability, foraging, and nesting opportunities, and protection from predators have been recognized as the reasons for magpies' affinity with human habitation. Foraging opportunities are minimal outside human settlements in this region, magpies' territories are largely shaped by the fulfilment of foraging requirements.

Keywords: Behavior, Corvid, foraging, Himalaya, territorial, territory sharing, urban settlements.

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Author contributions: IAK undertook field surveys, colour-banded the focal individuals of Eurasian Magpie, noted the behavioural data, took the images in the field and collected the literature for manuscript preparation. AK designed and planned the study including interpretation of data and manuscript writing. DB checked the manuscript and provided inputs for improvements. PR undertook the statistical analysis, prepared graphs and provided inputs for the interpretation of the statistical outcome.

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INTRODUCTION

Territory is an area defended by an organism or a group of organisms for mating, nesting, roosting, and foraging. During the breeding season, songbirds show territoriality in which the mated pairs defend the nest and feeding grounds until the young ones fledge (Alcock 2009). The size of the territory varies, depending on the habitat quality, structure, and the number of conspecific neighbors (Jones 2001; Flockhart et al. 2016; Skorupski et al. 2018). In urban areas, territory size differs in conspecific individuals depending on their ability to adapt to urban environments (Juarez et al. 2020). Territory size is crucial for breeding success which plays a major role for the survival and sustainability of species (Flockhart et al. 2016; Phillips et al. 2020). Hence, understanding of the territorial behavior is not only an interesting ecological inquiry but can also provide insights to manage landscapes, particularly urban ones, in a manner that can aid in the conservation of desired species.

The Eurasian Magpie *Pica pica* is a medium-sized corvid; an omnivorous bird with a range that includes Asia, Europe, and parts of northwestern Africa. Magpies often defend a vast, multi-purpose territory in which they nest, forage, and spend the majority of their time (Birkhead 1991). Eurasian Magpies are an urban adapter species, capable of invading towns while also maintaining a wild population in rural and natural habitats (Jokimäki 2017). Although it is one of the most studied species of corvids with majority of the research conducted in Europe. Studies on the bird in other continents are still scanty (Benmazouz et al. 2021). Magpies have a high level of fidelity to their home range, indicating that their dispersal lengths are quite small (Birkhead 1991).

Ladakh is characterized by large stretches of uninhabited land interspersed with small human settlements where magpies can be found. Magpies are known to be sedentary and usually do not migrate among these villages, and they act as isolated habitats rather than a gradient, with no individuals observed in between (Newton 2010). The study of bird territorial behavior in such isolated systems can help us understand how territorial individuals coexist in small habitats. Studies on magpies from these high-altitude regions of Ladakh are virtually absent (Khan et al. 2022).

In this study, we investigated the territorial behavior of Eurasian Magpies in the small, isolated urban settlements of Ladakh. Our preliminary findings revealed that the distribution of the species in Ladakh is patchy, with most populations confined to areas with human settlements. We assumed that human settlements might have an impact on the daily activities of magpies, either directly or indirectly. According to previous research, magpies are more attracted to man-made food scraps, which reduces magpie hunting and natural food consumption (Croci et al. 2008; Jokimaki et al. 2017; Salek et al. 2020). Based on this, we predicted that (1) magpie territory would be smaller near built-up areas due to increased food provisioning and (2) territory with a higher proportion of tree cover would be smaller in size because tree patches provide all essential food resources. We also predicted that (3) an open area with fewer tree patches would have lower food production and that the magpie's territory size would be larger in order to meet the food requirements.

MATERIALS AND METHODS

Study area

The research was carried out at two locations, namely Gramthang village of Suru Valley and Bursaika village of Wakha Valley in the district of Kargil (Image 2), Ladakh of India. About 8 km^2 area at each location was explored for study. Gramthang (34.467^{0}N, 76.084^{0}E) is situated about 12 km from Kargil. It is located at an average elevation of 2750 m and has river-fed well-vegetated lands with a high concentration of *Populus alba*, *P. ciliata*, *P. nigra*, *Prunus armeniaca*, *Salix alba*, *S. excelsa*, and *S. fragilis* plantations. Bursaika (34.366^{0}N, 76.383^{0}E) is 40 km from Kargil and is part of the Wakha Valley with an elevation of 3,450 m. The landscape consists of open, arable cropland, patchy shrublands, a moist meadow with perennial spring water, and *Salix* vegetation. The number of *Populus* trees plantation in Bursaika are substantially smaller than in Gramthang due to water constraints and harsh terrain. Instead, the vegetation is comprised of *Salix fragilis* and Sea buckthorn *Hippophae rhamnoides* shrubs, with fewer *P. alba*. The summer temperature in Gramthang ranges from 10°–25° C, while the winter temperature can reach -29° C at its coldest. Bursaika winters are colder, with temperatures dropping to -35° C during peak winters (Khan et al. 2022).

Behavioral observations and territory marking

Twenty-five breeding individuals were caught using bait traps. The method was adopted from a past study (Kautz & Seamans 1992) and color-banded for individual identification (Image 2). In 2019 and 2020, the same individuals were seen at the sites, indicating little to no migration. Territorial observations were made in the

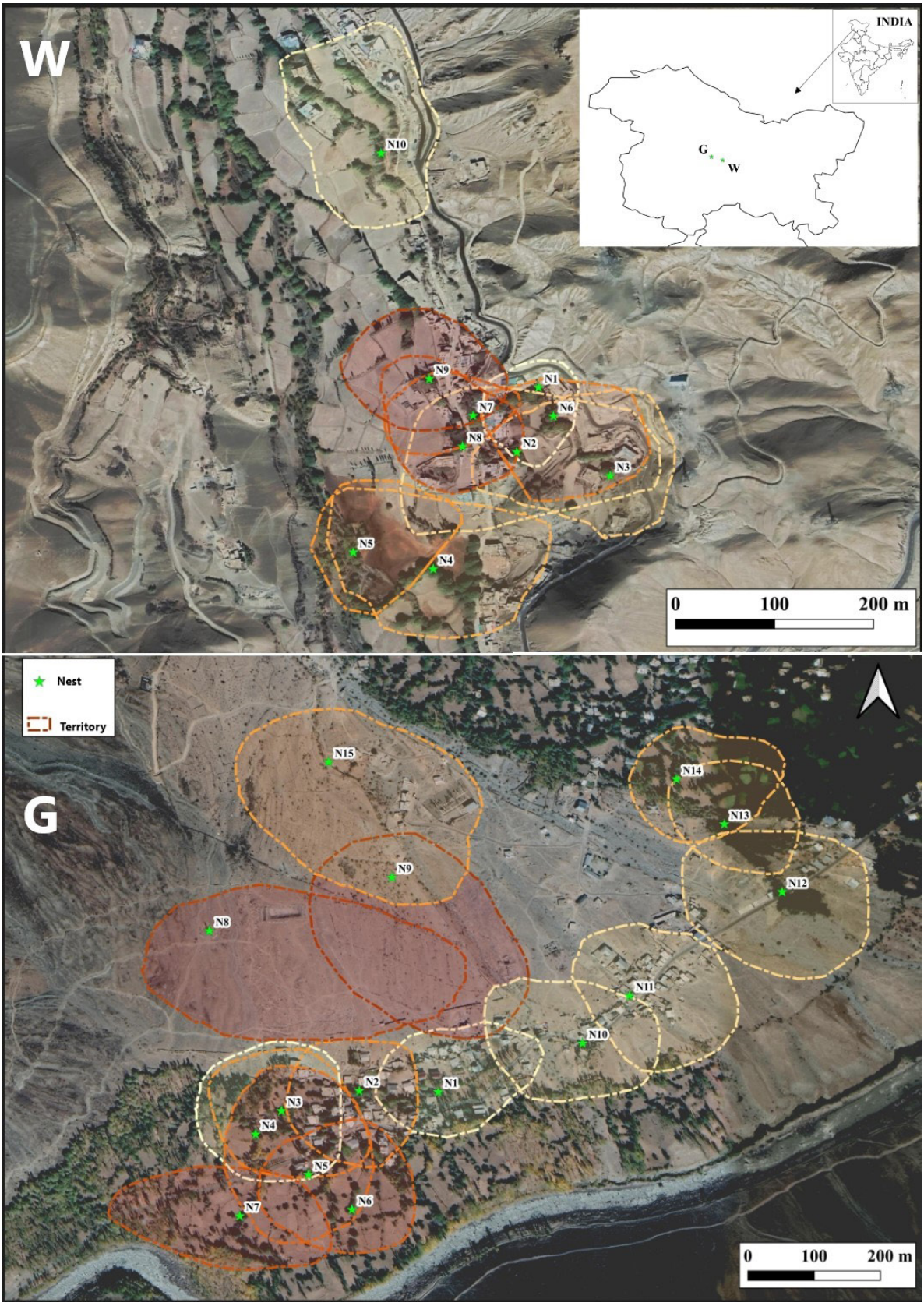

Image 1. Satellite imagery of Bursaika village in Wakha (above) and Gramthang village (G, below). The territories of individuals (assigned with a number) are marked with nest locations (N) and dotted boundaries. A gradient of color is used to differentiate territories. Small box in top right shows the location of two sites in India.

Image 2. The colour-banded tagged Eurasian Magpie *Pica pica* during nest/ territory vigilance: A—Colour banding of an adult individual | B—Adult individual released after banding | C—Colour-banded nestling | D—Another colour-banded nestling. © Iqbal Ali Khan.

months of March and April when the birds were nesting. Observations were carried out in 2020 and 2021 at sites Bursaika and Gramthang, respectively. Behavioral observations were made with field binoculars or with the naked eyes, depending on the situation. Nesting locations of territory owners were also discovered prior to egg laying by simply looking for birds carrying nest material. This was relatively easy in the early part of the season before the trees went into leaf in the summer (May–June). Since magpies are diurnal, each focal individual was tracked from a safe distance (about 10–30 m) for almost the whole day from early morning emergence time (0600–0630 h) to late roosting time (1830–1900 h). The locations visited by magpies for foraging, roosting, water drinking, and playing (Image 3, 4) were all tracked and marked using GPS (Garmin Etrex 30) shortly after the bird left the spot.

Variable extractions

Territorial variables included territory size, number of foraging points & the amount of tree cover, cultivated area, built-up area, and miscellaneous area (shrubland,

Image 3. A pair of Eurasian Magpie *Pica pica.* The male is seen here producing territorial calls. © Iqbal Ali Khan.

Image 4. The nesting female defending the nest. © Iqbal Ali Khan.

rock terrain, river stream, and grassy meadow) within the territory were extracted using polygons in Google Earth Pro software (version 7.3.6.9345). We determined the total area of the territory by connecting all the GPS points used by the focal pair of magpies during the breeding season, plotting all the points in the Google Earth satellite imagery and tracing out the total territory of the magpie by connecting all the points and forming a polygon. Other variables within the territory, such as tree patches, cultivated area, built-up area, and other miscellaneous areas were also traced using polygons. Multiple polygons were traced in one territory, and then all the polygons were combined to identify the different variable areas. Field notes and Google satellite images were used to cross-check all the sites and areas, and a high-resolution territories map was created. We studied the influence of neighbors by extracting the proportion of their territory which overlapped with the territory of other individuals.

Data analysis

The analysis was carried out using R version 4.2.2. As the territory size was not normally distributed (Shapiro-Wilk normality test, $p = 0.01$), and individuals were selected from two different sites, we used Generalized Linear Mixed Models (GLMM) to study the influence of the proportion of different land cover type on the territory size using the package lmerTest (Kuznetsova et al. 2017). Based on a correlation matrix, we removed the highly correlated ($r > |0.4|$) variables and selected 4 variables for the analysis – tree, agricultural, built-up cover, and neighbor presence. Their proportions were used, rather than the absolute area. The response variable was territory size in m^2, but the results are

presented in km^2 for clarity. Sites (Gramthang & Bursaika) were taken as the random effects. We ran multiple models using different families and selected the best model based on AIC values. Regression plots were created using model results with the help of package effects (Fox & Weisberg 2019).

RESULTS

Descriptions of territories

We collected territorial data of 25 breeding pairs of Eurasian Magpies and observations showed that the magpie territory is almost circular in shape, with the nest being located close to the center. The breeding territory size of magpies varies from a minimum of 0.0094 km^2 to a maximum of 0.1049 km^2 (mean: 0.0415 ± 0.0248 km^2, n = 25) for all territories in the two sites. Magpie territories overlapped heavily, seen at both study sites, and magpies actively defended only the close proximity of the nesting tree (~ <20 m radius). Juveniles and non-breeding individuals (floaters) were occasionally spotted foraging in groups inside breeding territories of nesting pairs. Tree cover composed the highest amount of territory cover (mean proportion of territory for all individuals: 24.36 ± 15.41 %), followed by agricultural land (22.32 ± 15.51 %), and built-up areas (14.12 ± 9.73 %). All magpie territories in both sites feature human presence (mean proportion of territory for all individuals: 36.4 ± 19.13 %), either in the form of agricultural land or built-up areas, or both. Magpie territories in Bursaika were smaller (mean: 0.0212 ± 0.0084 km^2) and showed greater overlapping, with seven of the 10 individuals sharing more than 75 % of their territories (mean territory shared: 73.3 ± 30.5 %). The distance between nests at this site was also smaller, with an average distance of 81 m to the nearest nest. On the other hand, territories at Gramthang were larger (0.055 ± 0.0219 km^2) and with relatively lower territory sharing (55.6 ± 28.5 %). The average distance to the nearest nest was also larger at this site (134 m). The majority of the nests were located on *Populus* (9.22 ± 1.64 m; n = 9) and willow trees (6.62 ± 0.74 m; n = 8), followed by apricot (6.75 ± 0.95 m; n = 4), mulberry (8.5 ± 0.7 m; n = 2), and sea-buckthorn shrub (3.00 m; n = 1). Only one of the 25 nests was found on an artificial structure, an electric tower (in Gramthang). Nearly all nests (except a single nest on sea-buckthorn shrub), were constructed at a height >5 m.

Effect of habitat variables on territory size

We found that both increased built-up area and tree cover proportions within the territory had a significantly strong negative effect on the territory size of magpies, meaning that magpie territories are smaller near urban areas and greater tree cover (Figure 1). This is likely due to the high availability of resources near trees and urban areas, removing the need to defend large territories. Agriculture area had no significant effect, indicating limited feeding opportunities in agricultural fields during the study period. The presence of neighbors is also found to not have any significant effect, which is in-line with previous studies which have shown magpies to share feeding grounds. Table 1 summarizes the GLMM results describing the individual contributions of habitat variables in predicting territory size.

DISCUSSION

The current study describes the territorial behavior of Eurasian Magpies, and how territory size varies with habitat variables in the sparse urban settlements of the Himalayas. Characteristics of magpie territories, including choice of nesting sites, territory size, and territory sharing behavior, are largely similar to those observed in previous studies from other parts of the world. Previous studies have found magpie territory sizes to be 5 ha on average (Moller 1982; Birkhead 1991), but the mean can range anywhere from 1 ha–7.5 ha (Reese & Kadlec 1985; Dhindsa & Boag 1991). The mean territory size in our sites also lies within the expected range, with a mean of 4.15 ha. Although, only part of the territory close to the nest (~ within a 20 m radius of the nest) is actively defended by the breeding pair, other individuals entering this space aggressively pushed away. Magpie territories appear to be less rigidly defined, as both breeders and non-breeders can be found in the same spaces on subsequent visits. During breeding seasons, magpies were frequently seen chasing each other and calling from prominent perches with aggressive wing-fluttering. Although magpies are primarily territorial during breeding seasons, they are known to flock for 'ceremonial gatherings' (Baeyens 1979), roosting (Moller 1985), and feeding (Vogrin 1998). Magpies in our sites shared territories primary for feeding, gathering to feed at a few selected points where food waste was dumped. Magpies are likely to feed together, even during the breeding season, most probably owing to the limited food resources in this landscape, largely restricted to these small urban

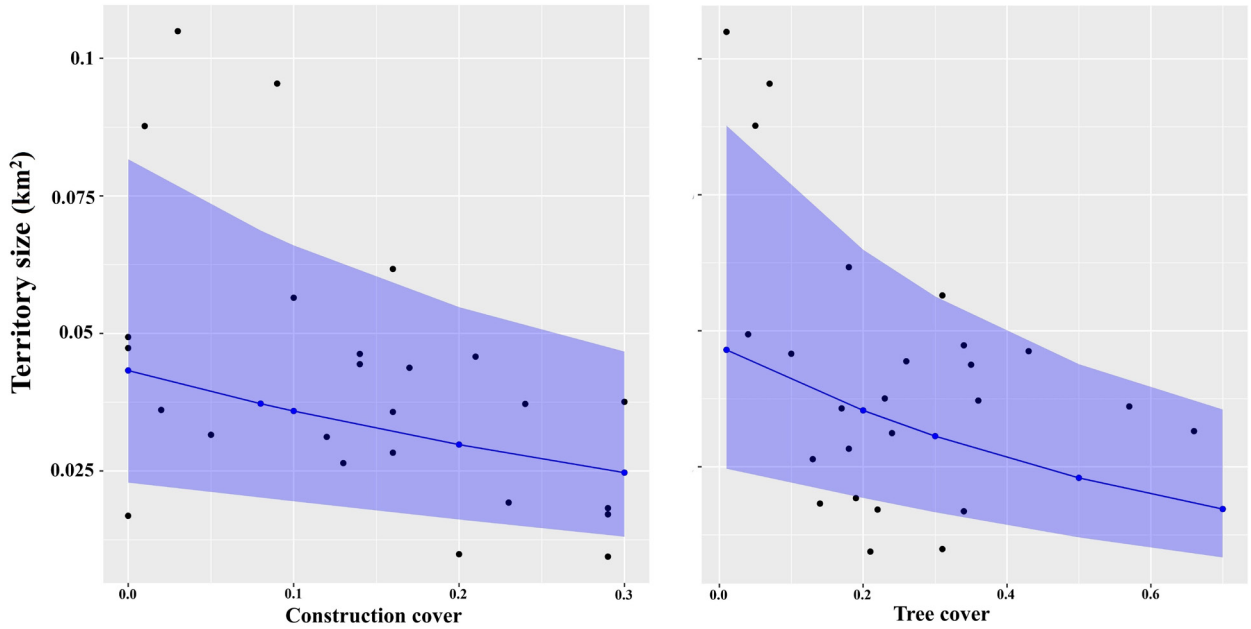

Figure 1. Linear response of territory size to construction and tree cover as obtained from results of generalized linear mixed model (GLMM).

settlements. This claim is further strengthened by the fact that magpies formed smaller territories and stayed closer to neighbors at the site, i.e., Wakha, pointing to the need for magpies to stay close to human habitation, even at the cost of sharing feeding spaces. Magpies have previously been observed to form feeding flocks when the resources are localized and clumped (Eden 1987).

Although magpies are widely known to be able to nest on artificial structures (Birkhead 1991; Takeishi 1994), they prefer to nest on trees, and only choose artificial nesting sites in case the tree density is low (Nakahara 2015). Additionally, in human habitations magpies construct their nests at greater heights (usually over 5 m), primarily to avoid human disturbance and predation (Antonov 2002, 2003; Salek 2020). Both *Populus* and willow trees, which were majorly used for nesting in the region, are tall trees providing suitable nesting sites for magpies (growing up to ~30 m) and have previously been shown to be preferred tree species for nesting of magpies (Antonov 2002). Moreover, large artificial structures are absent in the sparse urban settlements of this region, limiting opportunities for nesting on artificial structures. Therefore, all (except one) nests were constructed on trees. The sole nest constructed on an electric tower was away from housing, with no trees in close proximity.

Trees are not only an absolute necessity for nesting in these sites, but they may also be provisioning important food resources, like insects, butterfly/moth larvae at these sites. The other primary food source in magpie territories was human-dumped waste sites, as explained earlier. Urban adapter species are known to form smaller territories near human habitation due to high availability of resources in close proximity, such as waste dump (Juarez et al. 2020). Hence, in line with our predictions, we found the presence of both tree cover and built-up area to have a significant negative effect on territory size (Table 1). Additionally, due to the localization of resources to these small sites, magpies are willing to share feeding sites even during the breeding season. Therefore, in these sites the presence of neighboring magpies does not significantly affect territory size, indicating that the major driver of territory size in these isolated urban settlements is resource availability, rather than interspecific interactions. Tatner (1982) previously found no association between magpie

Table 1. Summary of GLMM results with values of coefficients, standard errors (SE) and p-value for the selected variables.

Variables	Coefficient	SE	P value
Intercept estimate	11.15	0.33	<0.001
Tree cover	- 1.44	0.41	<0.001
Built-up	- 1.87	0.62	0.002
Agriculture	- 0.41	0.36	0.26
Neighbor	-0.05	0.19	0.79

density and breeding success in urban areas, as long as the territory is resourceful. Magpies have previously been shown to prefer urban areas with suitable nesting sites and trees from different parts of the world (Wang et al. 2008; Salek et al. 2020), and we add to the existing knowledge from the isolated urban settlements of the Himalaya, for the first time.

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