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Temporal occurrence and species composition of birds on artificial feeding sites maintained for game mammals in the Dinaric Mountains, Slovenia

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Artificial feeding is a widely used management tool, but it often attracts nontarget species, including birds, to permanent feeding sites. This study used camera traps to monitor the presence of birds at selected sites used for bear management in Dinaric forest. A large number of bird species (35) were recorded, representing roughly half of all species breeding in the surrounding area. These species were grouped based on monthly and hourly presence, and corresponded to food groups, with most belonging to granivores or scavengers. Some species, such as Pigeons (*Columba* sp.), Raven (*Corvus corax*) and Buzzard (*Buteo buteo*), adapted their presence to the availability of food at the feeding sites, while others were not affected by this. Both Chaffinches (*Fringilla coelebs*) and Jays (*Garrulus glandarius*) frequented the feeding sites, but their temporal presence was influenced by their biology rather than by food availability. The Sparrowhawk (*Accipiter nisus*) also adapted its presence to food availability, and its presence was closely associated with that of the Jay. This study confirms the temporal differences in the use of feeding sites by birds and mammals, which is likely due to their different biology and past management. This can be used to make wildlife management more efficient and reduce the undesirable effects of artificial feeding.

1. Introduction

Human activities result in the provision of large quantities of food for wildlife, either unintentionally (Perkins *et al.* 2007, Plaza & Lambertucci 2017) or intentionally for various purposes (Robb *et al.* 2008). Some wildlife populations, such as northern populations of the Great Tit (*Parus major*) or vultures, rely heavily on artificial feeding (Orell 2008; Cortés-Avizanda *et al.* 2016), while others are affected in all aspects of their ecology, including reproduction, behaviour, demography and distribution (Robb *et al.* 2008).

Artificial feeding of wildlife, including birds,

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occurs in many forms. For example, bird feeders are common in urban areas worldwide (Robb *et al.* 2008). In some parts of the world, carrion feeding stations are a common practice for vulture conservation (Cortés-Avizanda *et al.* 2016). In addition to intentional feeding (*e.g.*, bird feeders), birds are offered artificial food in large quantities at feeding stations maintained (usually by hunters) for mammals for the purposes of hunting, monitoring, conflict prevention and/or wildlife watching. This type of feeding is a common practice in much of the world, has a long tradition and can be fairly intensive. For instance, in Slovenia, about 12.5 tonnes of corn per 100 km^2 are fed to wildlife annually by hunters (Krofel & Jerina 2016). This artificial feeding is usually intended for only a few species. In Europe, such species include ungulates (*i.e.*, Milner *et al.* 2014), mesopredators and Brown Bears (*Ursus arctos*) (Graf *et al.* 2018). However, numerous non-target species also visit these feeding sites, including several bird species (Fležar *et al.* 2019).

Most research on the effects of artificial feeding on birds has focused on bird feeders in urban areas (Jones & James Reynolds 2008; Robb *et al.* 2008). Although bird feeders are designed to provide sustenance during harsh conditions and to foster a connection between people and nature (Robb *et al.* 2008), unanticipated ecological and behavioural consequences can arise. For example, birds can colonise areas with feeders beyond their natural range (Robb *et al.* 2008) or at densities not seen in nature (Wilson 1994). Artificial feeding can also allow some non-native species to survive (Clergeau & Vergnes 2011) or even dominate over native species (Galbraith *et al.* 2017) in new areas. Furthermore, artificial feeding may also alter breeding through increased breeding success (Harrison *et al.* 2010) or increased nest predation rates (Selva *et al.* 2014; Oja 2017).

Although artificial feeding sites intended for hunting have been studied primarily from the perspective of ungulate game species (Wirsing & Murray 2007; Sorensen *et al.* 2014; Pedersen *et al.* 2014; Milner *et al.* 2014) and Brown and Black Bears (*U. americanus*) (Bowman *et al.* 2015; Selva *et al.* 2017; Graf *et al.* 2018; Candler *et al.* 2019; Fležar *et al.* 2019), effects on birds have received little attention. Previous studies have primarily focused on nest predation (Cooper & Ginnett 2000; Selva *et al.* 2014; Oja 2017) and breeding success (Pedersen *et al.* 2007). Most studies have noted the presence of birds among non-target species without further investigation (Lambert & Demaris 2001; Selva *et al.* 2014; Bowman *et al.* 2015; Fležar *et al.* 2019), and surprisingly, even basic information on bird use of these feeding sites is lacking.

The main objective of the present study was to investigate the temporal occurrence of birds at artificial feeding sites maintained by hunters for game mammals. The temporal availability of the food offered at these sites differs from that of natural food. In some cases, such as in Slovenia, artificial food may be available almost continuously (Fležar *et al.* 2019), which could potentially impact the seasonal and circadian activity of birds. Despite its potential effects, the topic has received limited attention, with no existing data on the influence of artificial feeding sites for game animals on the temporal occurrence of birds. The study aimed to (i) analyse the species composition of birds visiting feeding sites; (ii) examine the seasonal and circadian use of feeding sites by selected bird species, with an emphasis on the timing of occurrence and the overlap of different species at artificial feeders; and (iii) compare this use of the sites with that of better-studied game mammals (Candler *et al.* 2019).

2. Material and methods

2.1. Study area

The study area includes a large part of the Dinaric Mountains in southern and central Slovenia (Fig. 1). The region is the core habitat area for several large ungulate species, including Red Deer (*Cervus elaphus*) and Wild Boar (*Sus scrofa*) as well as large carnivores such as Brown Bear, Wolf (*Canis lupus*) and Lynx (*Lynx lynx*). The study area spans an altitude range from 300 to 1,796 m a.s.l. and is primarily covered by mixed forests dominated by Silver Fir (*Abies alba*) and Common Beech (*Fagus sylvatica*). This area is the most forested in Slovenia (over 80% covered by forest), with settlements located in Karst fields and a few river valleys. The area has a high vertebrate diversity, especially that of mammals

(Fležar *et al.* 2019). However, permanent water sources are scarce, especially at higher elevations, and open habitats are limited to the edges of the mountain massifs. As a result, breading bird density and diversity is relatively low, consisting mainly of forest specialists (Mihelič *et al*. 2019).

The practice of artificially feeding wildlife in the Dinaric Mountains is widespread and has a long tradition, with some feeding sites dating back to the late 19th century (Garshelis *et al*. 2017). The feeding sites are managed by local hunters and serve various purposes. As observed in other countries (Selva *et al*. 2014; Bowman *et al*. 2015; Oja 2017), the sites typically offer two main types of food: corn (or other grain) and carrion. While corn is widely available and often available year-round at many feeding sites, carrion is supplied more opportunistically and in smaller quantities (mostly offal from hunted game species and road carcasses of ungulates; see Mohorović *et al*. 2015 and Graf *et al*. 2018 for a detailed description).

2.2. Selected feeding sites

As part of the Life DinAlp Bear project, 23 representative feeding sites were selected primarily to study the effect of artificial feeding on brown bears (Krofel *et al*. 2015). Corn was available year-round at all feeding sites, with smaller amounts (or none at all) in winter, but methods of delivery differed between some sites. Corn was either distributed in the afternoon using automatic dispensers or delivered manually during the day. In both cases, a few kilograms of corn were distributed to feeding sites daily. During the 2016–2017 study period, carrion was provided to the monitored feeding sites (Graf *et al*. 2018). Carrion in the form of hunting remains and road carcasses of ungulates were provided throughout the year, with a peak during the hunting season (fall). The selected study sites were located in small clearings within the forest, and were on average 2 km from the forest edge and 2.6 km

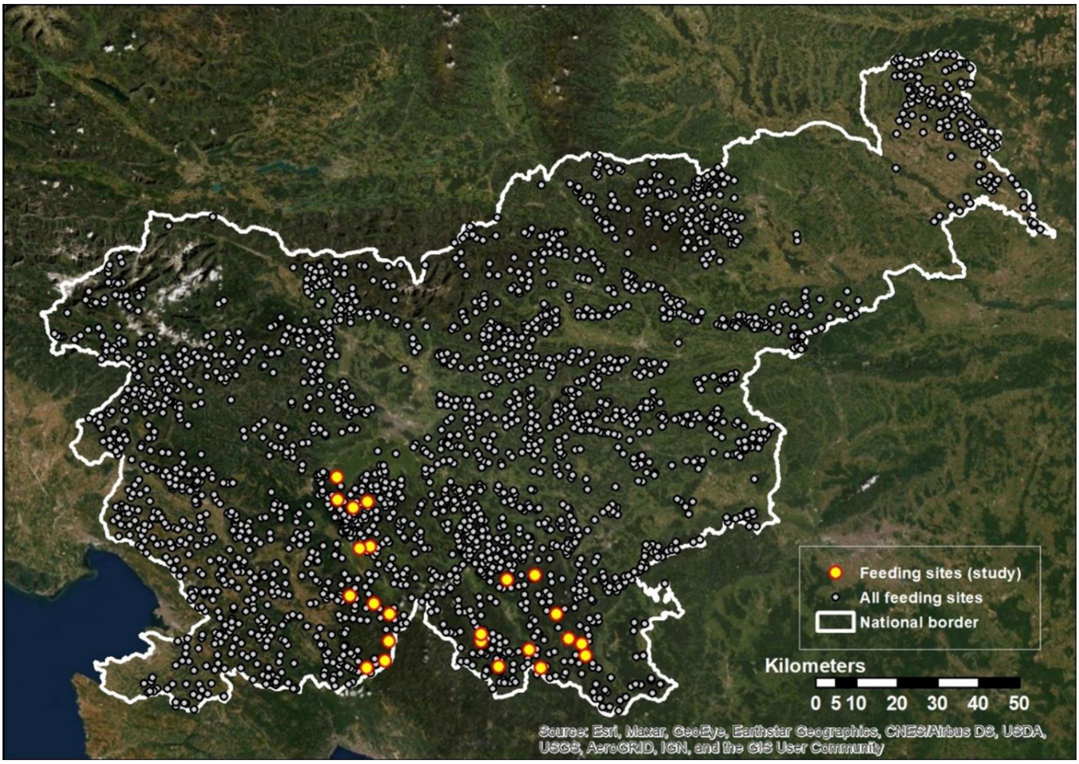

Fig. 1. Locations of artificial feeding sites for game mammals in Slovenia and those used in the study.

from the nearest settlement. The clearings varied in size, and vegetation was mowed and removed at least once a year, usually in summer, to ensure good visibility and prevent overgrowth.

2.3. Methods

The selected feeding sites were monitored 24 hours per day for 2 years with automatic photo/video cameras (UOVision IR PLUS BF HD UV 565). Camera traps were placed so that the feeder was in front of the camera and the view was not obstructed by woody vegetation. A 30-second video was recorded after each photo. The cameras were set so that the next possible photo could not be taken until a five-minute period had elapsed. If the camera took more than one photo within this five-minute interval, we analysed only the first photo and omitted the others (11.0% of photos). The cameras were checked approximately every two to three weeks. If a system malfunction occurred or the batteries were depleted between checks, the date and time were automatically reset to default settings. Unless they were corrected in the field, we considered these date settings to be incorrect. Periods with incorrect date settings were excluded from the temporal occurrence analysis (6.4% of photos). Temporal occurrence in this paper includes both seasonal occurrence expressed in monthly presence and circadian occurrence expressed in hourly presence. The study and feeding sites were set up for Brown Bears as the primary target species. At one feeding site, the feeder was only suitable for bears, and no food was available for other species. Therefore, we did not include the data collected at this feeding site in the study. Several feeding sites experienced problems with feeders, such as a malfunction of the automatic dispenser or damage to the feeder from Brown Bears or falling trees. Periods when cameras or feeders were not working resulted in gaps in our data set. When gaps extended over several months, the entire dataset for that year from that feeding site was excluded from temporal analyses. Only feeding sites with complete data sets (16 sites) were used for circadian and monthly presence analyses. Due to the inaccessibility and poor maintenance of feeding sites and cameras during the winter months (December–February), there were many gaps in the data. In addition, during this period, food is supplied at a lower frequency. For this reason, we did not include data gathered during the winter (4.5% of all photos). More detailed descriptions of camera settings, maintenance of feeding sites and cameras, data collection, photo review and species identification from photos can be found in Graf *et al*. (2018) and Fležar *et al*. (2019).

2.4. Bird species occurring at feeding sites

For the photo analysis, we focused on all identifiable bird species down to the size of tits (Paridae), including smallest species such as the Coal Tit (*Periparus ater*) and Marsh Tit (*Poecile palustris*). We did not separate individuals in the different photos, but considered each photo as a separate event, even if it may have captured the same individual. This approach was adopted based on previous studies that showed that temporal autocorrelation in camera trap data diminished after one minute (Kays & Parsons 2014, Kays *et al*. 2017, Kellner *et al.* 2022). Therefore, we grouped consecutive pictures taken five minutes (or greater) apart into sequences that were considered independent records. In this way we ensured that the capture events are more likely independent and the pseudo-replication impact is mitigated. We used the independent records of birds to model the temporal activity of birds and describe the relative degree of site use (*i.e.*, the amount of time birds spent at feeding sites). Given the similarities in feeding station characteristics, such as the use of camera traps over a long period of two years and the provision of the same food supplement (corn), we expected that, for a given species, the temporal activity pattern at feeding stations would be similar.

For species with greater than 10 records, we used hierarchical clustering analysis to group species with similar activity patterns (both seasonal and circadian, see below). To this end, we applied an unweighted pair-group clustering algorithm based on the arithmetic averages (UPGMA) to the dissimilarity matrix. This matrix was calculated based on the Kulczynski distance of the abundance data. The optimal number of clusters (*i.e.*, groups) was determined by applying the Kelley–Gardner–Sutcliffe penalty function (KGS) (Kelley *et al*. 1996). This analysis was performed using the "vegan" R package (Oksanen *et al*. 2017).

2.5. Seasonal and circadian occurrence of birds at feeding sites

For species with over 100 records, temporal activity for each species was estimated by pooling data across years and summing the number of independent records of a given species per hour and month. We then related the temporal data to relative solar time (Nouvellet *et al*. 2012) using the "SunTime" function in the "Overlap" R package (Meredith & Ridout 2020). We then compared temporal activity patterns between species statistically using the Watson-Wheeler test (Zar 1999) and graphically (Fig. 3). This test, a common approach to assess differences between two circular distributions (Frey *et al*. 2017; Massara *et al*. 2018), was performed using the "hms2rad" function implemented in the "astroFns" R package to convert species activity time from angular format (hh:mm:ss) to radians where 1 hour $=\pi/12$ (Harris 2012). By doing this, we created a vector of activity time for each species and used the Watson-Wheeler test to compare the mean time of day in which species were active.

2.6. Comparison of temporal occurrence between birds and mammals

We measured the daily activity overlap between mammal and bird species using the sum of individuals in five-minute intervals using the framework developed by Ridout and Linkie (2009), which fits a kernel density to temporal data. We then estimated the degree of overlap between the two density curves by calculating the coefficient of overlap (Dhat1), which is most appropriate when the sample size is small (at least 10 records/species) (Linkie & Ridout 2011; Frey *et al*. 2017). The value of Dhat varies between "0" (*i.e.*, no overlap) and "1" (*i.e.*, complete overlap) (Linkie & Ridout 2011). This analysis was performed using the "Overlap" R package (Ridout & Linkie 2009).

3. Results

3.1. Bird species occurring at feeding sites

We detected a total of 35 bird species at all sites (Table 1, Appendix 1). Of these species, eight were recorded with only one photo and five species were present in five or fewer photos. Only 14.8% of all photos (36,686) had a bird, representing 1.63% of all possible five-minute time intervals when camera traps were in

Table 1. Number of photographs on selected artificial feeding sites in Slovenia for eight species of birds with more than 100 photographs.

Species	No. of photos	Percentage of all possible 5 min intervals*
Jay, *Garrulus glandarius*	19,356	0.86%
Raven, *Corvus corax*	9,882	0.44%
Common Wood Pigeon, *Columba palumbus*	9,748	0.43%
Common Chaffinch, *Fringilla coelebs*	2,416	0.11%
Common Buzzard, *Buteo buteo*	1,537	0.07%
Common Blackbird, *Turdus merula*	1,237	0.05%
Stock Dove, *Columba oenas*	577	0.03%
Great Tit, *Parus major*	332	0.01%

* - a proxy for proportion of time with the species present at feeding sites

operation (serving as a proxy for the percentage of time with bird presence). Most photos with birds included only one species (87.8%), with a maximum of four species in a single photo (only 20 photos). The Jay (*Garrulus glandarius*) was the most common species at feeding sites and the top three species (including Raven, *Corvus corax,* and Wood Pigeon, *Columba palumbus*) accounted for 85.8% of all photos with birds. Among all species, eight were present in more than 100 photos (Table 1).

3.2. Temporal occurrence of birds at feeding sites

When comparing temporal patterns of occurrence, most species were divided into three clusters. The largest cluster included eight species, including Sparrowhawk (*Accipiter nisus*), with Sparrowhawk and Jay being the closest, followed by White-tailed Eagle (*Haliaeetus albicilla*) and Raven and Wood Pigeon and Stock Dove (*Columba oenas*) (Fig. 2).

Seven out of the eight species with more than 100 photographs were present throughout the study period from March to November (Fig. 3). The only exception was Stock Dove, which was present in only nine photographs after July and completely absent in October and November. Although most species were present throughout the studied period, there were marked differences in the frequency of their presence. For example, Jay, Wood Pigeon, Raven and Stock Dove had unimodal monthly distributions; Chaffinch (*Fringilla coelebs*) and Great Tit had bimodal distributions; and Blackbird (*Turdus merula*) and Buzzard (*Buteo buteo*) had multimodal monthly distributions. Each species had its peak or peaks in different months (Fig. 3). Four species (Jay, Wood Pigeon, Chaffinch, Great Tit) peaked in late summer, two (Raven and Buzzard) peaked in fall and only one peaked in May (Stock Dove) and April (Chaffinch).

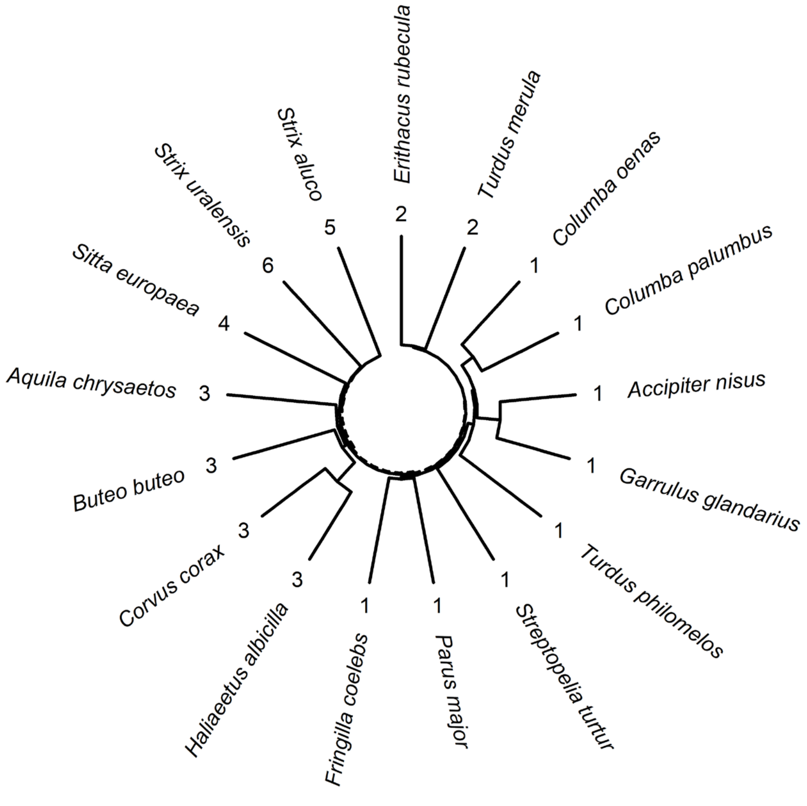

Fig. 2. Cluster dendrogram based on temporal distribution (circadian occurrence in hours per day, and seasonal presence in months per year) of bird species with more than 10 records. Species with a similar colour are similar in their temporal activity.

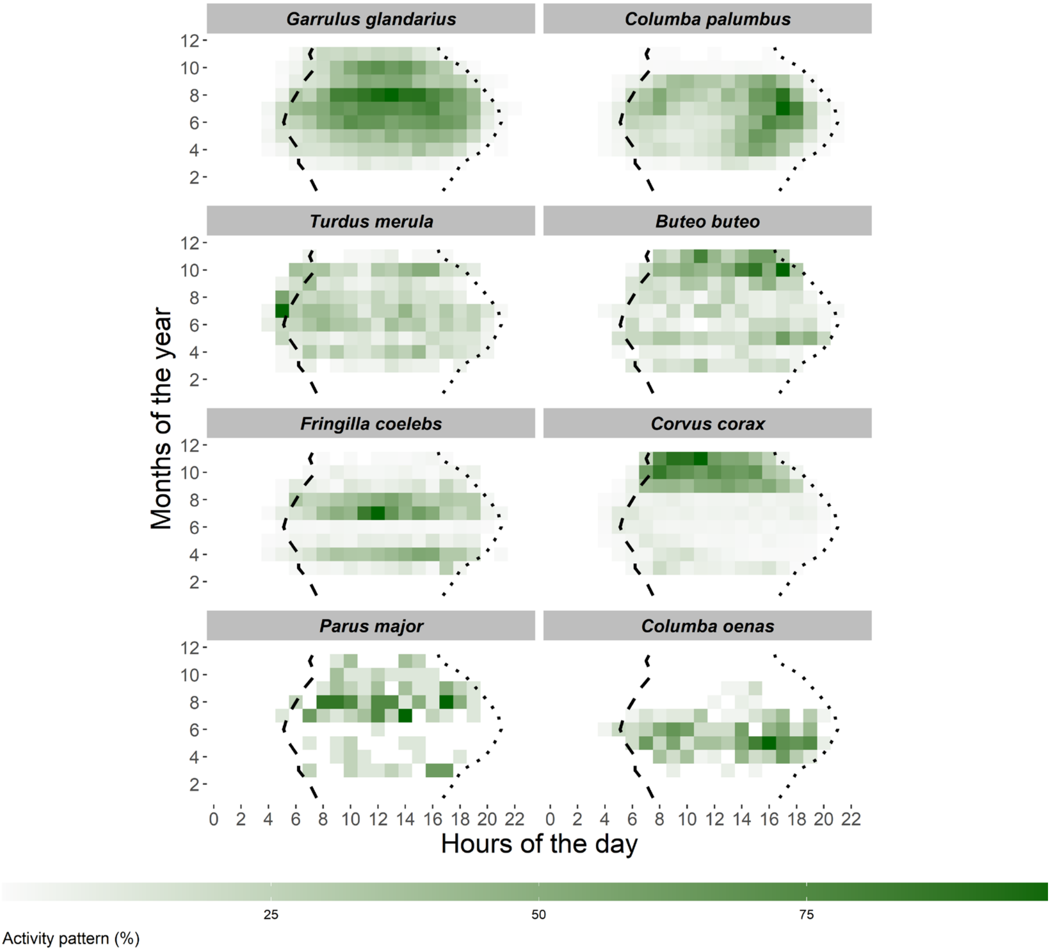

Fig. 3. Temporal distribution of selected species according to detected monthly and hourly occurrence at artificial feeding sites in Slovenia. The activity pattern is a scaled index between 0 and 100%. It was calculated by dividing the number of independent records in a given hour by the maximum number of independent records in an hour for a given species. Lines indicate an average monthly sunrise (dashed line) and sunset (dotted line).

Although all selected species were present throughout the day, the Watson–Wheeler test for differences in activity distributions showed significant differences ($p=0.001$ at $df=2$) in the temporal activity patterns for all species comparisons: Ravens and Blackbirds were more often present in the morning; Chaffinches and Jays in the middle of the day; and Wood Pigeons, Stock Doves and Buzzards in the afternoon (Fig. 3).

3.3. Temporal occurrence of birds and comparison with mammals

The highest percentage of birds was photographed in September (Fig. 4). The overall distribution of the monthly presence of birds and mammals was similar, but the correlation was not significant (Spearman's $r=0.53$, $df=8$; $p=0.1475$). Birds peaked in fall while mammals were more abundant in summer (Fig. 4). The only month in which there were more birds than mammals was October, and both groups had similar presence in September.

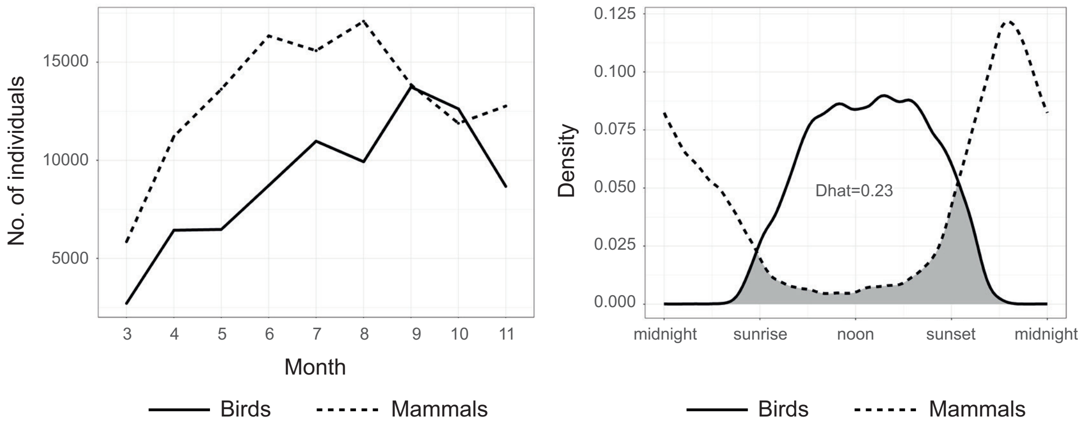

Fig. 4. Monthly and hourly (adjusted to sun time) distribution of mammals (dashed line) and birds (solid line) captured with camera traps in Slovenia between March and November.

Birds were photographed exclusively during the day (Fig. 4), with the exception of a few photos of owls taken at night. Most birds were photographed in the afternoon, with a peak between 2 and 3 pm (9.3% of photos). The occurrence of birds at feeding sites had an "inverted" hourly distribution compared to mammals (Spearman's r=–0.75, df=22; p<0.001). They were almost completely absent at night when most mammals were present, but abundant during the day when mammals were rare. The shift occurred just before sunrise in the morning and just after sunset in the evening (Fig. 4).

4. Discussion

4.1. Bird species occurring at feeding sites

The present study reports the highest number of bird species (35) reported to date at a wild game feeding site. To date, most studies have reported fewer than 10 taxa (Lambert & Demaris 2001; Bowman *et al.* 2015; Selva *et al.* 2017; Candler *et al.* 2019; Fležar *et al.* 2019), but this may be due in part to the grouping of species into passerine birds (Lambert & Demaris 2001), unknown birds (Bowman *et al.* 2015) or small and medium-sized birds (Fležar *et al.* 2019). Other possible reasons for the greater species diversity of birds in our study compared to other studies include shorter monitoring periods in other studies (Lambert & Demaris 2001; Bowman *et al.* 2015; Fležar *et al.* 2019), specific baits (Candler *et al.* 2019) and a focus on a specific group, such as potential nest predators (Selva *et al.* 2014). We detected about half of all breeding species in surrounding Karst upland forests (Mihelič *et al.* 2019; Fležar *et al.* 2019). It is possible that some species were overlooked in the study because they are too small to trigger cameras (Randler & Kalb 2018), but this seems unlikely for two reasons: 1) Most smaller species that breed in the surrounding forests and were not detected at feeding sites are either insectivorous or foraging specialists (Mihelič *et al.* 2019) and would only be accidental at feeding sites; 2) Only a few species found in surrounding forests are smaller than Coal, Blue and Marsh Tits (*e.g.*, Goldcrest, *Regulus regulus*) and most avoid open areas such as clearings. On the other hand, a few abundant species breeding in the vicinity were expected but not recorded in the study, such as several finch species (*e.g.*, Goldfinch, *C. carduelis,* or Hawfinch, *C. coccothraustes*) and two remaining tit species (Crested Tit, *Lophophanus cristatus,* and Willow Tit, *Poecile montanus*). Also, more species could have been observed during the migration and winter periods, such as the abundant Marsh Harrier (*Circus aeruginosus*), which often feeds on carrion and hunts rodents (Orta *et al.* 2020), or Starling (*Sturnus vulgaris*), which feeds on corn and visits feeders (Cabe 2020).

Although we divided birds into groups based on their temporal occurrence at the feeding sites, the groups actually represent the types of food the birds ate. Most detected species were either granivores (7 species) or scavengers (4 species) and were grouped as such. There were a few exceptions, the most important of which was the Sparrowhawk, which was grouped with granivorous species, indicating a predatory response to the temporal presence of its prey (Botts *et al.* 2020). Out of five species not included in the two biggest clusters, two formed a separate group. These two were probably not attracted to either type of food offered (corn and carrion) or to potential prey attracted to the food (mice, birds). Both feed on seeds and grains and likely eat some of the available corn, but the majority of their diet consists of invertebrates (Collar 2020; Collar & Christie 2020). Both species likely only take advantage of forest clearings that result from maintained feeding sites and do not adjust their presence to the availability of offered food.

4.2. Seasonal and circadian occurrence

The availability of certain types of food at feeding sites changes over time, and the temporal activity of birds reflects these changes for some, but not all, species. Automatic feeders generally dispensed corn in the late afternoon or evening, while sites supplied by hand were visited by managers during the day. Wood Pigeons and Stock Doves, which are primarily grain feeders and frequently feed on corn (Billerman *et al.* 2020), peaked in the afternoon when corn was most available. Ravens and Buzzards also likely responded to carrion availability, peaking during the period of highest human hunting activity from September to November, confirming the importance of human-provided carrion for Ravens (Legagneux *et al.* 2014). On the other hand, the availability of artificial food does not appear to strongly influence the temporal presence of Chaffinches and Jays, although both frequently feed on grains (Clement 2020; Madge *et al.* 2020). Chaffinches, for example, peaked in the middle of the day and in April and late summer, most likely due to migration and dispersal (Clement 2020). In addition, seeds are only an important food for Chaffinches outside of the breeding season (Clement 2020), which at least partly explains their lower presence in May and June, when they feed mainly on invertebrates. It is less clear why they peak in the middle of the day, since most of their food is available in the afternoon. One possible explanation is competitive niche displacement (Carother & Jaksić 1984) in combination with predator pressure. Chaffinches occurred when few other species were present, so they avoided possible predators and larger and more competitive granivores that feed on the ground (*e.g.*, pigeons). Although Jays are also granivores, they peaked at midday rather than in the afternoon like pigeons. One explanation for the observed difference could be a feeding adaptation. The Jay's ability to feed along branches allows it to feed on corn high up on artificial feeders that is inaccessible to most mammals. Although the quantities are small, corn is thus available to jays for most of the day. In fact, they were often observed feeding on corn directly from feeders. In addition, Jays occur in smaller groups (Madge *et al.* 2020; present study), each of which requires a smaller amount of food than a group of pigeons.

Artificial food also indirectly influences bird activity and food choice through the presence of other species. At the studied feeding sites, this is true for predators such as Sparrowhawks and owls. Constantly available corn attracts small rodents and several small to medium-sized bird species (Fležar *et al.* 2019). While owls attracted to rodents did not change their temporal presence (both rodents and owls are active at night), the Sparrowhawk synchronised its presence at feeding sites with its prey of small and medium-sized birds (Meyburg *et al.* 2020). It probably also hunts smaller species in the granivore group, especially smaller males, but its main prey at feeding sites appears to be Jays, with which it was most closely associated in the cluster analyses. Of the 31 analysed records of Sparrowhawks in our data, four photos/film clips show successful capture and another seven show a close pursuit. The Jay was the most common bird species at feeding sites, but is also at the upper size limit of Sparrowhawk prey (Meyburg *et al.* 2020), suggesting a shift in prey size preference due to prey availability and accessibility. Aside from the high presence of Jays at feeding sites, the habitat and position of prey may also be favourable for the Sparrowhawk. It prefers to hunt in clearings (Meyburg *et al.* 2020), which are not unlike typical managed feeding sites. In addition, most of the food is scattered on the ground in the middle of the clearing, allowing the Sparrowhawk to surprise its prey from above. Overall, feeding sites appear to be a highly concentrated food source for raptors as well.

Although there are a number of similarities between the selected feeding sites, there are some differences that are worth exploring. The biggest difference between feeding sites is in the method of distributing corn. Corn is distributed manually at a few feeding sites. This means that there may be slight variations in the time of distribution, and that there is also the increased presence of people on the site. Also, the presence of some species can influence the temporal distribution of other species (Carother & Jaksić 1984), as was also discussed with respect to Chaffinches. Thus, different feeding sites offer the opportunity to study a possible niche shift.

4.3. Comparison of temporal presence between mammals and birds

The apparent difference in the circadian occurrence of birds and mammals at feeding sites is due to differences in biology and probably also to differences in management between the two groups. Most birds feed during the day, which is clearly reflected in their circadian distribution at feeding sites, where all birds except owls were observed during the day. In contrast, most mammals were detected at night, a pattern also observed at Black Bear bait sites (Candler *et al.* 2019). Most mammals detected at feeding sites are game species, and while some are naturally nocturnal, many became nocturnal due to long-term human disturbance and hunting (Russo *et al.* 1997; Marchand *et al.* 2014; Hertel *et al.* 2016). In the Slovenian Dinarics, most game species are hunted at feeding sites, making these sites areas of higher “predation risk” in the “landscape of fear” (Laundré *et al.* 2010) and possibly even exacerbating nocturnal behaviour at feeding sites. The difference in the circadian occurrence of mammals and birds provides an opportunity to reduce the amount of food at feeding sites, reduce costs and reduce impacts to birds (non-target species) while maintaining all of the desired effects of artificial feeding on game mammals (target species). Although birds were detected on approximately 30% fewer photographs than mammals at feeding sites and their biomass is an order of magnitude lower, birds still occur often and likely consume a significant portion of the available food. Most feeding sites are designed for mammals, not birds. Therefore, if the majority of the food is to reach the desired species, it should be available just after sunset when bird presence is decreasing and mammals can be present in notable numbers.

Although there are some similarities between birds and mammals in terms of monthly occurrence, there are also some important differences. One of the possible reasons for the earlier decline in mammals in autumn could be the hunting season, which begins in September for many game species in Slovenia (Adamič & Jerina 2010). Almost all mammal species detected at feeding sites are game species. The decline of game species at feeding sites during the hunting season has also been documented in other studies (*e.g.*, Candler *et al.* 2019). On the other hand, of the birds recorded, only the Jay and the Hooded Crow (*Corvus cornix*) (only one record in the study) are hunted in Slovenia, and although the Jay was the most frequently recorded species, hunting interest in this species is low (up to 4000 individuals culled in the country, compared to more than 40,000 Roe Deer, *C. caprelous*). The avoidance of feeders by game species because of hunting is likely since preliminary results in mammal temporal distribution suggest that at least some species (*e.g.*, Wild Boar) are less often observed during the day in the hunting season than outside of it. In addition, in years with a good beech mast, a huge quantity of preferred natural food is available for many game species. Beech masting affects the presence of birds at feeders (Chamberlain *et al.* 2007), but the effect at feeding sites appears to be less pronounced for birds than for game mammals. The peak of bird occurrence in early October also coincides with the peak migration period for many species at feeding sites, *e.g.*, Wood Pigeon, Blackbird, Chaffinch and Buzzard (Billerman *et al.* 2020).

4.4. Conclusions

The study offers valuable insights into the temporal occurrence of birds in natural systems and the impact of artificial food on this phenomenon. For some bird species, artificial food constitutes a significant food source, causing them to adjust their temporal occurrence to the availability of this food, either directly or through an increase in the presence of the prey. For other species the influence is less direct, since they can be attracted to the food offered but their presence is also shaped by the presence of other species. The role of different types of feeding methods is worth studying, particularly for the species demonstrating greater temporal adaptation to artificial feeding. However, for some bird species, feeding sites simply provide a suitable habitat. The study raises several questions. A more in-depth investigation of bird-mammal interactions and avoidance behaviours is necessary, particularly during sunrise and sunset when the overlap is greatest. Additionally, exploring the relationship between the temporal availability of food and bird-mammal relations by manipulating the time of food availability would also be a noteworthy area of study.

Lintujen lajikoostumus ja ajallinen esiintyminen riistanisäkkäille tarkoitetuilla ruokintapaikoilla Dinaarisilla vuorilla Sloveniassa

Lisäruokinta on laajalti käytetty riistanhoitomenetelmä. Se kuitenkin houkuttelee ruokintapaikoille usein muitakin kuin kohdelajeja, esimerkiksi lintuja. Tässä tutkimuksessa seurasimme karhuille suunnattuja ruokintapaikkoja ja niillä vierailevia lintuja Dinaaristen Alppien metsissä. Tarkkailuun käytettiin kameroita. Ruokintapaikoilla havaittiin 35 eri lintulajia, mikä edustaa noin puolta lähialueen pesimälajeista. Ryhmittelimme lajit niiden ajallisen esiintymisen perusteella, mutta ryhmät vastasivat myös lajien ruokavaliota suurimman osa kuuluessa siemen- tai raadonsyöjiin. Joidenkin lajien, kuten kyyhken (*Columba* spp.), korppien (*Corvux corax*) ja hiirihaukkojen (*Buteo buteo*) läsnäolo riippui ravinnon saatavuudesta ruokintapaikoilla. Toisiin lajeihin tämä ei vaikuttanut. Sekä peipot (*Fringilla coelebs*) että närhet (*Garrulus glandarius*) kävivät usein ruokintapaikoilla, mutta niiden ajalliseen läsnäoloon vaikuttivat lajien biologia, ei ravinnon saatavuus. Myös varpushaukat (*Accipiter nisus*) sopeuttivat läsnäoloaan ravinnon saatavuuteen, minkä lisäksi niiden läsnäolo liittyi närhien esiintymiseen. Tutkimuksemme osoittaa, että ruokintapaikkojen käyttö on linnuilla ja nisäkkäillä erilaista, mikä todennäköisesti johtuu niiden erilaisesta biologiasta. Tutkimuksen tietoa voidaan hyödyntää esimerkiksi riistanhoidossa, ja lisäksi se auttaa vähentämään lisäruokinnan ei-toivottuja vaikutuksia.

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References

Adamič M., Jerina K. 2010: Ungulate management in Europe in the XXI. Century: Slovenia. — In Apollonio M., Andersen R., Putman R. (eds): European ungulates and their management in the 21st Century: 507–526. Cambridge, UK; New York: Cambridge University Press.

Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T.S. (eds). 2020: Birds of the World. — Cornell Lab of Ornithology. https://doi.org/10.2173/bow.ferduc.01

Botts R. T., Eppert A. A., Weigman T. J., Rodriguez A., Blankenship S. R., Asselin E. M., Garley W. M., Wagner A. P., Ullrich S. E., Allen G. R., Mooring M. S. 2020: Circadian activity patterns of mammalian predators and prey in Costa Rica. — Journal of Mammalogy 101(5): 1313–1331.

Bowman B., Belant J. L., Beyer D. E. Jr, Martel D. 2015: Characterizing nontarget species use at bait sites for white-tailed deer. — Human-Wildlife Interactions 9(1): 110–118.

Cabe, P. R. (2020). European Starling (*Sturnus vulgaris*), version 1.0. — In Billerman S. M. (ed.). Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.eursta.01

Candler E. M., Severud W. J., Bump J. K. 2019: Who takes the bait? Nontarget species use of bear hunter bait sites. — Human-Wildlife Interactions 13(1): 98–110.

Carothers J. H., Jaksić F. M. 1984: Time as a Niche Difference: The Role of Interference Competition. — Oikos 42(3): 403–406.

Chamberlain D.E., Gosler A. G., Glue D. E. 2007: Effects of the winter beechmast crop on bird occurrence in British gardens. — Bird Study 54(1): 120–126.

Clement P. 2020: Common chaffinch *Fringilla coelebs*. — In Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T. S. (eds.): Birds of the World. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurcoo.01

Clergeau P., Vergnes A. 2011: Bird feeders may sustain feral Rose-ringed parakeets *Psittacula krameri* in temperate Europe. — Wildlife Biology 17 (3): 248–252. https://doi.org/10.2981/09-092

Collar N. 2020: European Robin *Erithacus rubecula*. — In Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T. S. (eds.): Birds of the World. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurrob1.01

Collar N., Christie D. 2020: Eurasian Blackbird *Turdus merula*. — In Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T. S. (eds.): Birds of the World. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurbla.01

Cooper S. M., Ginnett T. F. 2000: Potential Effects of Supplemental Feeding of Deer on Nest Predation. — Wildlife Society Bulletin 28(3): 660–666.

Cortés-Avizanda A., Blanco G., DeVault T. L., Markandya A., Virani M. Z., Brandt J., Donázar J. A. 2016: Supplementary feeding and endangered avian scavengers: benefits, caveats, and controversies. — Frontiers in Ecology and the Environment. 14(4): 191–199. https://doi.org/10.1002/fee.1257

Fležar U., Costa B., Bordjan D., Jerina K., Krofel M. 2019: Free food for everyone: artificial feeding of brown bears provides food for many non-target species. — European Journal of Wildlife Research 65(1): 1. https://doi.org/10.1007/s10344-018-1237-3

Frey S., Fisher J. T., Burton A.C, Volpe J. P. 2017: Investigating animal activity patterns and temporal niche partitioning using camera-trap data: challenges and opportunities. — Remote Sensing in Ecology and Conservation 3(3): 123–132. https://doi.org/10.1002/rse2.60

Galbraith J. A., Jones D. N., Beggs J. R., Parry K., Stanley M. C. 2017: Urban Bird Feeders Dominated by a Few Species and Individuals. — Frontiers in Ecology and Evolution 5: 81. https://doi.org/10.3389/fevo.2017.00081

Garshelis D. L., Baruch-Mordo S., Bryant A., Gunther K. A., Jerina K. 2017: Is diversionary feeding an effective tool for reducing human–bear conflicts? Case studies from North America and Europe. — Ursus 28(1): 31–55. https://doi.org/10.2192/URSU-D-16-00019.1

Graf P. M., Bordjan D., Fležar U., Jerina K. 2018: Feeding site use and food type preference of brown bears in Slovenia. — Ljubljana, prepared within the LIFE DINALP BEAR Project (LIFE13 NAT/SI/0005).

Harris A. 2012: astroFns: Astronomy: time and position functions, misc. utilities. R package version 4.1-0.

Harrison T. J. E., Smith J. A., Martin G. R., Chamberlain D. E., Bearhop S., Robb G. N., Reynolds S. J. 2010: Does food supplementation really enhance productivity of breeding birds? — Oecologia. 164(2): 311–320. https://doi.org/10.1007/s00442-010-1645-x

Hertel A. G., Zedrosser A., Mysterud A., Støen O. - G., Steyaert S. M. J. G., Swenson J. E. 2016: Temporal effects of hunting on foraging behavior of an apex predator: Do bears forego foraging when risk is high? — Oecologia 182(4): 1019–1029. https://doi.org/10.1007/s00442-016-3729-8

Jones D. N., James Reynolds S. 2008: Feeding birds in our towns and cities: a global research opportunity. — Journal of Avian Biology 39(3): 265–271. https://doi.org/10.1111/j.0908-8857.2008.04271.x

Kays R., Parsons A. W. 2014: Mammals in and around suburban yards, and the attraction of chicken coops. — Urban Ecosystems 17: 691–705

Kays R., Parsons A. W., Baker M. C., Kalies E. L., Forrester T., Costello R., Rota C. T., Millspaugh J. J., McShea W. J. 2017: Does hunting or hiking affect wildlife communities in protected areas? — Journal of Applied Ecology 54: 242–252. https://doi.org/10.1111/1365-2664.12700

Kelley L. A., Gardner S. P., Sutcliffe M. J. 1996: An automated approach for clustering an ensemble of NMR-derived protein structures into conformationally related subfamilies. — Protein Engineering, Design and Selection 9(11): 1063–1065. https://doi.org/10.1093/protein/9.11.1063

Kellner K. F., Parsons A. W., Kays R., Millspaugh J. J., Rota C. T. 2022: A Two-Species Occupancy Model with a Continuous-Time Detection Process Reveals Spatial and Temporal Interactions. — Journal of Agricultural, Biological and Environmental Statistics 27: 321–338

Krofel M., Jerina K. 2016: Mind the cat: Conservation management of a protected dominant scavenger indirectly affects an endangered apex predator. — Biological Conservation 197: 40–46. https://doi.org/10.1016/j.biocon.2016.02.019

Krofel M., Mohorović M., Jerina K. 2015: The plan for establishing the feeding of bears with carrion at selected feedlots and monitoring the effectiveness of feeding – in Slovene. — Ljubljana: University of Ljubljana.

Lambert B. C. Jr., Demaris S. 2001: Use of Supplemental Feed for Ungulates by Non-Target Species. — The

Southwestern Naturalist 46(1): 118–121.

Laundré J. W., Hernández L., Ripple W. J. 2010: The Landscape of Fear: Ecological Implications of Being Afraid. — Open Journal of Ecology 3: 1–7.

Legagneux P., Suffice P., Messier J. - S., Lelievre F., Tremblay J. A., Maisonneuve C., Saint-Louis R., Bêty J. 2014: High Risk of Lead Contamination for Scavengers in an Area with High Moose Hunting Success. — PLoS ONE 9(11): e111546. https://doi.org/10.1371/journal.pone.0111546

Linkie M., Ridout M. S. 2011: Assessing tiger-prey interactions in Sumatran rainforests: Tiger-prey temporal interactions. — Journal of Zoology 284(3): 224–229. https://doi.org/10.1111/j.1469-7998.2011.00801.x

Madge S., del Hoyo J., Christie D., Collar N., Kirwan G. M. 2020: Eurasian Jay *Garrulus glandarius*. — In Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T. S. (eds.): Birds of the World. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurjay1.01

Marchand P., Garel M., Bourgoin G., Dubray D., Maillard D., Loison A. 2014: Impacts of tourism and hunting on a large herbivore's spatio-temporal behavior in and around a French protected area. — Biological Conservation 177: 1–11. https://doi.org/10.1016/j.biocon.2014.05.022

Massara R. L., Paschoal A. M. de O., Bailey L. L., Doherty P. F., Barreto M. de F., Chiarello A. G. 2018: Effect of humans and pumas on the temporal activity of ocelots in protected areas of Atlantic Forest. — Mammalian Biology 92: 86–93. https://doi.org/10.1016/j.mambio.2018.04.009

Meredith M., Ridout M. 2020: Package 'overlap', version 0.3.3. Accessed at https://cran.pau.edu.tr/web/packages/overlap/overlap.pdf

Meyburg B. - U., Marks J. S., Garcia E. 2020: Eurasian Sparrowhawk *Accipiter nisus*. — In Billerman S. M., Keeney B. K., Rodewald P. G., Schulenberg T. S. (eds.): Birds of the World. Cornell Lab of Ornithology. https://doi.org/10.2173/bow.eurspa1.01

Mihelič T., Kmecl P., Denac K., Koce U., Vrezec A., Denac D. (eds.). 2019: Atlas of Slovenian birds. Breeding bird survey 2002-2017 – in Slovene with English summary. — DOPPS, Ljubljana.

Milner J. M., Van Beest F. M., Schmidt K. T., Brook R. K., Storaas T. 2014: To feed or not to feed? Evidence of the intended and unintended effects of feeding wild ungulates: Effects of Feeding Ungulates. — The Journal of Wildlife Management 78(8): 1322–1334. https://doi.org/10.1002/jwmg.798

Mohorović M., Krofel M., Jonozovič M., Stergar M., Hafner M., Pokorny B., Jerina K. 2015: Spatial and temporal availability of carrion from wild ungulates as food source for bears in Slovenia. — Report, Ljubljana, University of Ljubljana, Slovenian forest service and Erico.

Nouvellet P., Rasmussen G. S. A., Macdonald D. W., Courchamp F. 2012: Noisy clocks and silent sunrises: measurement methods of daily activity pattern: Measurement of activity pattern. — Journal of Zoology 286(3): 179–184. https://doi.org/10.1111/j.1469-7998.2011.00864.x

Oja R. 2017: Consequences of supplementary feeding of wild boar – concern for ground-nesting birds and endoparasite infection. — Doctoral theses, Tartu Estonia: Department of Zoology, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu.

Oksanen J., Blanchet G., Friendly M., Kindt R., Legendre P., McGlinn D, ..., Wagner H. 2017: vegan: Community Ecology Package. R Package Version 2.4-4.

Orell M. 2008: Population fluctuations and survival of Great Tits *Parus major* dependent on food supplied by man in winter. — Ibis. 131(1): 112–127. https://doi.org/10.1111/j.1474-919X.1989.tb02750.x

Orta, J., Boesman P. F. D., Marks J. S., Garcia E. F. J., Kirwan G. M. 2020. Eurasian Marsh-Harrier (*Circus aeruginosus*), version 1.0. — In del Hoyo, J., Elliott A., Sargatal J., Christie D. A., de Juana E. (eds.) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.wemhar1.01

Pedersen S., Mathisen K. M., Gorini L., Andreassen H. P., Røskaft E., Skarpe C. 2014: Small mammal responses to moose supplementary winter feeding. — European Journal of Wildlife Research 60(3): 527–534. https://doi.org/10.1007/s10344-014-0816-1

Pedersen S., Nilsen E. B., Andreassen H. P. 2007: Moose winter browsing affects the breeding success of great tits. — Ecoscience 14(4): 499–506. https://doi.org/10.2980/1195-6860(2007)14[499:MWBATB]2.0.CO;2

Perkins A. J., Anderson G., Wilson J. D. 2007: Seed food preferences of granivorous farmland passerines. — Bird Study 54(1): 46–53. https://doi.org/10.1080/00063650709461455

Plaza P. I., Lambertucci S. A. 2017: How are garbage dumps impacting vertebrate demography, health, and conservation? — Global Ecology and Conservation 12: 9–20. https://doi.org/10.1016/j.gecco.2017.08.002

Randler C., Kalb N. 2018: Distance and size matters: A comparison of six wildlife camera traps and their usefulness for wild birds. — Ecology and Evolution 8(14): 7151–7163. https://doi.org/10.1002/ece3.4240

Ridout M. S., Linkie M. 2009: Estimating overlap of daily activity patterns from camera trap data. — Journal of Agricultural, Biological and Environmental Statistics 14(3): 322–337. https://doi.org/10.1198/jabes.2009.08038

Robb G. N., McDonald R. A., Chamberlain D. E., Bearhop S. 2008: Food for thought: supplementary feeding as a driver of ecological change in avian populations. — Frontiers in Ecology and the Environment 6(9): 476–484. https://doi.org/10.1890/060152

Russo L., Massei G., Genov P. V. 1997: Daily home range and activity of wild boar in a Mediterranean area free from hunting. — Ethology Ecology & Evolution 9(3): 287–294. https://doi.org/10.1080/08927014.1997.9522888

Selva N., Berezowska-Cnota T., Elguero-Claramunt I. 2014: Unforeseen Effects of Supplementary Feeding: Ungulate Baiting Sites as Hotspots for Ground-Nest Predation — PLoS ONE 9(3): e90740. https://doi.org/10.1371/journal.pone.0090740

Selva N., Teitelbaum C. S., Sergiel A., Zwijacz-Kozica T., Zięba F., Bojarska K., Mueller T. 2017: Supplementary ungulate feeding affects movement behavior of brown bears. — Basic and Applied Ecology 24: 68–76. https://doi.org/10.1016/j.baae.2017.09.007

Sorensen A., van Beest F. M., Brook R. K. 2014: Impacts of wildlife baiting and supplemental feeding on infectious disease transmission risk: A synthesis of knowledge. — Preventive Veterinary Medicine 113(4): 356–363. https://doi.org/10.1016/j.prevetmed.2013.11.010

Wilson W. H. Jr. 1994: The Distribution of Wintering Birds in Central Maine: The Interactive Effects of Landscape and Bird Feeders. — Journal of Field Ornithology 65(4): 512–519.

Wirsing A. J., Murray D. L. 2007: Food supplementation experiments revisited: verifying that supplemental food is used by its intended recipients. — Canadian Journal of Zoology 85(6): 679–685. https://doi.org/10.1139/Z07-048

Zar J. H. 1999: Biostatistical analysis Section 27.5. 4th edition. — Prentice Hall International, Upper Saddle River, NJ.

Appendix

Appendix 1. Recorded species and the number of photographs per species and the number of photographs with only one individual of a species taken on artificial feeding sites in the Dinaric Mountains of Slovenia in 2016 and 2017.

Species	No. of photos	No. of photos with just one individual
Garrulus glandarius	19356	12783
Corvus corax	9882	3446
Columba palumbus	9748	4415
Fringilla coelebs	2416	1197
Buteo buteo	1537	1423
Turdus merula	1237	1050
Columba oenas	577	333
Parus major	332	254
Erithacus rubecula	58	52
Sitta europaea	31	29
Accipiter nisus	31	31
Motacilla alba	28	23
Aquila chrysaetos	28	28
Strix aluco	25	25
Turdus philomelos	22	22
Strix uralensis	22	22
Accipiter gentilis	21	21
Streptopelia turtur	15	12
Haliaeetus albicilla	13	13
Turdus viscivorus	13	13
Poecile palustris	11	8
Cyanistes caeruleus	9	6
Dendrocopos major	5	5
Pernis apivorus	4	4
Phoenicurus ochruros	4	4
Milvus milvus	2	2
Dendrocoptes medius	2	2
Hirundo rustica	1	0
subbuteo	1	1
Falco peregrinus	1	1
Caprimulgus europaeus	1	1
Dryocopus martius	1	1
Periparus ater	1	1
Corcus cornix	1	1
Chloris chloris	1	1