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MASTERARBEIT

Titel der Masterarbeit

"The influence of alternative diet composition in an urban habitat on the breeding success of Eurasian Kestrels (*Falco tinnunculus*) in Vienna"

Verfasserin

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Index

Abstract

Urbanisation alters landscapes and initiates a turnover of species composition. The Eurasian Kestrel (*Falco tinnunculus*) is known to exploit cities frequently and inhabits Vienna, Austria (415 km^2) with an outstanding density of 89-122 breeding pairs/100 km^2 during its breeding season. In contrast to their rural counterparts, specialised in feeding on voles, urban kestrels are generalistic, preying mainly upon passerines and small mammals, but also on reptiles and insects. The study aimed to detect the impact of an alternative diet composition on lower breeding success in urban populations. The analysis indicated a negative effect of avian prey on offspring survival rate, however other factors achieved better explanatory values: local weather conditions were considered the most influencing parameters in this context. Warm winters with low amounts of precipitation and a dry arrival and courtship period led to an increase in breeding success. Also a warm nesting stage was associated with higher chick survival. Furthermore earlier laying dates significantly encouraged larger clutches and more fledged offspring. Concerning diet composition, mild winters and dry arrival and courtship periods increased mammalian prey. The same was associated with more rainfall during incubation and nesting. A higher amount of avian prey was found after wet winters and arrival and courtship phases, dry incubation periods and warmer temperatures during nesting. Our research presents weather conditions surpassing diet composition as a highly complex influencing factor on breeding success, although indirect effects of temperature and rainfall parameters, operating through prey availability and laying date, are highly assumed.

Keywords: urbanisation, *Falco tinnunculus*, Vienna, alternative diet composition, breeding success, weather conditions, laying date

1. Introduction

Urbanisation is a global anthropogenic phenomenon which results in the increase of impervious surfaces, the loss of green spaces and a turnover of species composition within a highly fluctuating ecosystem. Among birds this means a population decline for many species (Sol et al. 2014), while others benefit from the altered conditions (Beissinger & Osborne 1982), that affect e.g. the availability of food and nest sites. Blair (1996) categorised bird communities along urban gradients and defined "urban avoiders", which are restricted to their native, undisturbed habitats, and on the contrary a small number of "urban exploiters", which are often non-native (Jokimäki & Suhonen 1998) and very successful in urbanised, human-dominated environments. This graduation within avian communities was titled "biotic homogenisation" and goes along with urbanisation processes all over the world (Blair 2001; Lockwood & McKinney 2002). More than 25 avian raptor species inhabit urban settings (Love & Bird 2000) which are often of superior quality to them (Cringan & Horak 1989). In order to satisfy all their ecological requirements, many raptors extend their home ranges beyond urban boundaries if possible (Chace & Walsh 2006), e.g. to hunt on rural grounds, while they breed in urban areas (Riegert 2007). There is a tendency for generalist species, which seem to possess more effective "pre-adaptations" to human environments (Kark et al. 2007), to be more abundant in highly urbanised areas than specialists. However many exceptions characterise the predators' complex response to an urban gradient (Sorace & Gustin 2009). Kark et al. (2007) focused on investigating differential traits in species, that had adapted to life in urban environments ("urban adaptors"), and true "urban exploiters". They found a certain flexibility in diet, often including human-related resources (e.g. supplementary feeding or garbage), sociality, sedentariness and the acceptance of artificial constructions for breeding (e.g. buildings and nest-boxes) to be typical for species exploiting urban areas.

The Eurasian Kestrel (*Falco tinnunculus* L., 1758) is known to inhabit urban environments for breeding at least since the second half of the 19th century (Cramp & Tomlins 1966). Studies on this species have been conducted in several cities, for example Bratislava (Darolová 1992), Warsaw (Rejt 2001) and Rome (Piattella et al. 1999), but drawing general conclusions is difficult as each of them represents unique qualities in terms of size (distances to potential rural hunting grounds), building structure (abundance of suitable nest sites), the composition of vegetation or the availability of prey. In Vienna, Austria, the population density is especially high not only compared to other European metropolis but also rural areas (Gamauf 1991; Kostrzewa & Kostrzewa 1993; Sumasgutner et al. 2014 a). Because of the kestrels' inability to construct nesting platforms, building cavities make attractive breeding sites for them. Especially roof openings, which can be found in Vienna's historical city centre only, are well sheltered and hardly accessible to ground predators and therefore preferred over other more open sites (Sumasgutner et al. 2014 a). However, kestrels are not truly "urban exploiters" as defined by Kark et al. (2007), because, apart from using artificial breeding sites, they do not profit from any other resource related to urban environments. In the contrary, the breeding success, measured as clutch size and the number of fledged offspring, decreases with the

progressivity of sealed soil (Sumasgutner et al. 2013). This has also been reported for passerine birds in urban environments (Chamberlain et al. 2009).

To successfully settle in an urban habitat, an appropriate food supply is one of the most important requirements (Witt 2000). While their rural conspecifics are specialised in hunting small rodents, urban kestrels are generalists, preying not only on mammals, but to a substantial proportion on birds (Galanos 1991; Piattella et al. 1999; Salvati et al. 1999; Sumasgutner et al. 2013) and also on reptiles and insects (Riegert et al. 2009). The amount of avian prey, mainly passerines, increases towards the city centre (Sumasgutner et al. 2013) and can even become the predominant diet category (Kübler et al. 2005; Düesberg 2012; Sumasgutner et al. 2013). Most rodent species inhabiting Vienna are nocturnal (Mitter et al. 2013) and therefore hardly accessible to a diurnal raptor like the Eurasian Kestrel. The distances to suburban areas, where diurnal mammalian prey is available, are longest from the city centre. Even though mammals have a higher nutritional value and can be caught with less effort by a ground hunter (Village 1990), it seems to be more efficient for urban kestrels to hunt within a smaller home range (Sumasgutner et al. 2013) and focus on alternative but available, mostly avian, prey. Not only the local food supply but also individual hunting techniques can lead to remarkable differences in diet composition concerning taxonomic groups of birds: Though passerines represent the most common avian prey, a few kestrels have been observed catching pigeons regularly, following an individually developed strategy (Sumasgutner et al. 2013). Beside the impact of the urban gradient, different diet compositions might also be attributed to varying weather conditions. The negative effect of cool and wet weather on the success rate of breeding birds might cause lower proportions of avian prey in the kestrels' diet (Sumasgutner et al. 2013) and, concerning mammals, e.g. a Norwegian study found a lower survival rate in small rodents under snow cover due to limited access to food resources (Korslund & Steen 2006).

The availability of food has often been mentioned as the ultimate impact factor on breeding success in birds (Lack 1968; Perrins 1970; Daan et al. 1989). Especially in Scandinavia, where food conditions are fluctuating, following a well pronounced 3 or 4 - year cycle (Hansson & Henttonen 1985; Korpimäki et al. 2005), breeding performance is strongly affected: During the increase and decrease phase of the vole cycle kestrels' egg-laying starts in average one week earlier, clutch sizes are larger and the number of fledged offspring is higher than in low vole years (Korpimäki & Wiehn 1998; Valkama et al. 2002). Concerning Vienna, starvation of chicks was hypothesised to be among the main causes for the kestrels' decreased breeding success (Sumasgutner et al. 2013).

This study aims (1) to examine the influence of an altered diet composition associated with urbanisation on the breeding success in the particular case of Eurasian Kestrels nesting in Vienna. Therefore feeding habits and breeding success of several kestrel pairs along the urban gradient had been analysed over a time span of five seasons. As a second approach also (2) the impact of weather conditions on the reproduction of these breeding pairs had been explored, because especially the local temperature and rainfall might affect the kestrels' reproduction (Kostrzewa & Kostrzewa 1990; Krüger 2002; Costantini et al. 2010). (3) Comparing the influence of

diet composition and weather conditions shall reveal their actual contribution to the breeding success of Eurasian Kestrels in an urban habitat.

2. Material and Methods

2.1. Study species

The Eurasian Kestrel, hereafter referred to as the kestrel, is widely distributed in Europe, Asia and Africa (Village 1990). With 89-122 breeding pairs (bp)/100 km² (Sumasgutner et al. 2014 a, b) it is constituted to be the most abundant bird of prey in Vienna, Austria. This population density is higher than in other European cities (e.g. Kupko et al. 2000; Malher et al. 2010) and rural parts of Central Europe (e.g. Gamauf 1991; Kostrzewa & Kostrzewa 1993; Mebs & Schmidt 2006). Kestrels are present in Vienna during their breeding season from late March until August (Sumasgutner et al. 2014 a, b). Their wintering grounds are not yet known, but kestrels supposedly migrate to Mediterranean areas, Western Europe or even Northern Africa (pers. comm. Matthias Schmidt, Birdlife Österreich).

2.2. Study area and nest sites

Our study was conducted in the municipal parts of the Austrian capital city, Vienna (48°12'N, 16°22'E; 415 km^2; 1.8 million inhabitants). As an urban environment Vienna can be defined by the percentage of its sealed soil extending from unsealed periphery to highly sealed areas in the city centre. To express this urban gradient (UG) the proportion of impervious surfaces was calculated for r = 500 m around each NS using ArcGIS 10 by ESRIc based on building densities and traffic areas (Sumasgutner et al. 2014 a, b). Kestrel nests were found from 89 % sealed soil in the inner-city districts to 18 % in the suburban parts. Areas with less than 1 % sealed soil, mostly forested or agriculturally farmed, were regarded as rural and excluded from the investigation. As a consequence the urban study area covered 243 km^2.

In total 56 distinct data sets of nest sites (NS) were available for the analysis conducted. The data had been collected from 47 NS of five consecutive breeding seasons (2010: n = 10 NS, 2011: n = 6 NS, 2012: n = 15 NS, 2013: n = 7 NS, 2014: n = 18 NS). Nine NS had been investigated in two different study years. The most commonly used nest types in the city are building cavities (bc), especially roof openings (Sumasgutner et al. 2013). Furthermore planters (pl), nest-boxes (nb) and abandoned crows' nests (cn) are occupied. All mentioned types are represented among the studied NS (bc: n = 35, pl: n = 10 , nb: n = 7 and cn: n = 4).

Additional illustrations are presented as Supplementary material 1.

2.3. Data acquisition on site

During breeding season every NS was visited 3-6 times in order to collect food remains and to monitor the breeding process: "laying date" (the day the first egg was laid), "clutch size" (total number of eggs laid), "number of hatched offspring" and

“number of fledged offspring”. Nestlings were weighed, morphological key characters, following Eck et al. 2011, were measured at wing, tail, culmen, tarsus, feet and claws and banding was conducted. Both a ring from Bird-Ringing-Centre Radolfzell, Germany and an electronic-coded TIPES-ring were applied. Blood samples were collected by puncturing the brachial vein and using a 75 µl haematocrit capillary to gain the emitted drop. Furthermore the skin coloration of feet, ceroma and eye-ring was noted and a superficial check for ecto-parasites was performed (see Supplementary material 2 for additional illustrations). These additional data were collected to continue methods of data collection for the purpose of further investigations within a long-term study.

If not observed directly the dates of egg-laying and hatching were calculated based on the age of the nestlings determined through morphometric measurement (Kostrzewa & Kostrzewa 1987). Using the breeding parameters recorded we calculated the clutch-hatch-ratio (number of hatched offspring relating to number of eggs laid), the clutch-fledge-ratio (number of fledged offspring relating to number of eggs laid) and the hatch-fledge-ratio (number of fledged offspring relating to number of hatched offspring), all of which given as proportions ranging between 0 and 1. NS included in this study are characterised by at least one egg laid. Successful hatching and/or fledging was not required.

2.4. Pellets collection and identification

Pellets, plucked feathers and prey remains were collected from the NS by taking one third of the nest’s content crosswise at each visit. Remains that could still be nourishing to the kestrels were identified on site and left at the nest. No distinction was made between pellets produced by adults or juveniles (see Supplementary material 2 for additional illustrations).

The pellets and prey remains (n = 627) were dried and dissected. A breakdown to lower taxonomic levels was performed if possible (e.g. through analysing enamel prisms in rodents) and items were sorted (e.g. jaws, number of molars, upper or lower mandibles in mammals; lower or upper beak, left or right foot in birds; tarsi, pairs of mandibles in insects; etc.) to determine the minimum number of different individuals they originated from. Occurring fur or feathers, if not clearly classifiable to a lower taxonomic level, were treated as originating from one individual (Sumasgutner et al. 2013).

For the ongoing analysis identified prey items were classified as “mammals” (M), “birds” (B), “reptiles” (R) and “insects” (I) and the minimum number of individuals per prey category was defined for each pellet. For further investigation pellets, fragments of pellets and prey remains were combined and diet diversity is presented as the percentage of the estimated biomass acquired for the respective prey category for each NS. Although it must be assumed that some prey species such as larger mammals and birds are only partially consumed (Redpath et al. 2001), considering the contribution of the biomass [g] seems important to evaluate the importance of prey categories as different as, for example, mammals and insects in the kestrels’ diet. The attribution of biomass was based on the model of Glutz von Blotzheim &

Bauer (1980) or estimated as average values for different prey categories following Sumasgutner et al. (2013).

2.5. Weather conditions of different seasons

Prey and breeding parameters are expected to be influenced by the present weather conditions. There are several meteorological stations in Vienna, operated by ZAMG (Zentralanstalt für Meteorologie und Geodynamik), of two of which, "Wien Innere Stadt" (1.3 km from city centre) and "Wien Donaufeld" (6.7 km from city centre), weather data were provided, covering the time period of December 2009 – August 2014. Each NS was allocated to the closest weather station; air temperature and rainfall were expressed in five different categories ("MaxT" = average maximum temperature; "MinT" = average minimum temperature; "Rain" = sum of rainfall; "RainD" = number of rain days and "RainI"= intensity of rain, meaning rainfall per rain day). For each NS of the studied breeding seasons these components were calculated for four time phases ("winter before" = December, January, February before breeding; "arrival & courtship" = March until laying date; "incubation" = from laying date until hatching (4 calendar weeks); "nesting period" = from hatching until fledging (4 calendar weeks); these periods are dependent on the calculated laying date and therefore different for each NS) (Supplementary material 3). For most of the analysis we focused on the three time periods covering the actual breeding season (excluding "winter before").

As Supplementary material 4 climate graphs representing the Viennese weather for all studied breeding seasons (December of year before – August of breeding season) are given. 2010 started rather cool with wet weather in late spring; 2011 offered warm weather with an especially wet March; 2012 was warm with a constant, low amount of rainfall; 2013 was the coldest of all studied seasons; and 2014 had very warm temperatures with a dry start of spring and some wet phases in late spring and summer.

2.6. Statistical analysis

All statistical analyses were performed using the software R version 3.0.3 (R Core Team, 2014). The confidence interval was set at 95 % (corresponds to a significance level of $p = 0.05$) for the tests conducted.

We checked data for correlations using the "cor.test" function ("stats" package, R Core Team 2014) calculating rank-based Spearman's rho, because most data was not normally distributed. Outcomes specified within the results section include the correlation coefficient (rs) and the significance level (p). Average values are presented ± standard error of the mean. Linear regression was performed with the "lm" command of the same package. For better visualization we used the "pairs.panels" function of the "psych" package (Revelle 2014) which shows bivariate scatter plots of matrices.

To avoid overrepresentation of yearly trends within laying dates the residuals of laying dates and study years were computed using the "resid" command ("stats" package, R Core Team 2014) after performing a linear regression.)

To reduce the number of different weather variables per category (“winter before”, “arrival & courtship”, “incubation” and “nesting period”) and assure them being uncorrelated a principal component analysis (PCA) was performed using the “prcomp” command (“stats” package, R Core Team 2014). The PCA produced two principal components for each category with Eigenvalues > 1 and explaining between 83.8 % and 94.5 % of data variance (Supplementary material 5).

For each NS the diet breadth (B) was determined computing Levin’s index (Levin 1968) as $B = 1/\Sigma p_i^2$, with p_i defining the proportion of diet contributed by prey category i. To get values ranging between 0 and 1 we used the standardised Levin’s index (Krebs 1989) which is calculated: $B_A=(B-1)/(N-1)$, with N defining the number of different prey categories. This facilitates further analysis because a binomial error structure can be applied to model selection involving B_A as response variable.

To evaluate the differences in breeding parameters and diet composition we built generalised linear mixed effects models (GLMM) using the “lmer” and the “glmer” function of the “lme4” package (Bates et al. 2014). Nest site ID and study year were included as random factors for all analysis to avoid pseudoreplication (Hurlbert 1984). A full model, involving the maximum number of explanatory variables, was firstly constructed and simplified by using backward elimination based on likelihood-ratio tests and Chisq-Statistics performed with the “drop 1” function of the “stats” package with $p<0.05$ as the selection criterion. At each step of fitting we calculated the AIC_c (Akaike Information Criterion, corrected for small sample size), including Akaike weights, with the “aictab”-function of the R package “AICcmodavg” (Mazerolle 2014) and considered the one with the minimum AIC_c value as final model (Burnham et al. 2011). All models were visualised as residuals versus fits plots to control goodness-of-fit and detect non-linearity. Using the “r.squaredGLMM” command of the “MuMIn” package (Barton 2014) the Pseudo-R-Squared for GLMM was computed. We chose the Conditional R^2 (variance explained by both fixed and random factors) to be quoted within the results section. The significance levels for certain fixed effects were calculated performing a likelihood-ratio test using the “anova” command (ANOVA = analysis of variance) of the “stats” package to compare the final model to a null-model from which the examined fixed effect was excluded. Outcomes presented within the results section include the respective correlation coefficient (t - for Gaussian distribution or z - for all other distributions chosen) and the significance level (p).

Error distribution was chosen according to the response variable: Examining breeding parameters we used Poisson distribution and log link function to determine the dependence of clutch size/NS and number of fledged offspring/NS, binomial distribution and logit link function for the hatch-fledge-ratio/NS and Gaussian distribution and identity link function for the variance in laying dates of different NS. The hatch-fledge-ratio was set using the “cbind” command of the “base” package (R Core Team, 2014) with the number of hatched offspring as binomial denominator (Crawley, 2007). As fixed effects diet composition (percentage of mammals or percentage of birds or Levin’s standardised index), UG and nest type (“building cavity”, “crow’s nest”, “nest-box” and ”planter”). The residuals of laying date and study year were also added to models that did not involve the laying date itself as response variable. The diet parameters and the UG were correlated, hence we chose

the interaction value of both variables to be fitted in the models. Another correlation was detected between the UG and the nest type, thus either the one or the other was included as fixed effect (Supplementary material 6).

Furthermore GLMMs were fitted to analyse the dependence of diet composition on weather conditions including all principal components representing weather data as well as the laying date, presented as residuals of laying date and study year, and either the UG or the nest type (since both of them were correlated) as fixed effects. According to the response variables, which ranked between 0 and 1 for all tested variables (proportion of mammals in diet, proportion of birds in diet and Levin's standardised index), the error distribution was chosen as binomial in combination with the logit link function (Supplementary material 7).

The response variables clutch size, number of fledged offspring and hatch-fledge-ratio were analysed in another series of GLMMs to detect their dependence on weather conditions. Additional to the principal components, representing the weather data, the laying date, as residuals between laying date and study year, and either the UG or the nest type (again because of their correlation) were involved as fixed effects. In another GLMM, including the laying date as response variable and the principal components defining the weather conditions during the winter before and the arrival & courtship period, as well as either the UG or the nest type, as fixed effects, the dependence of the laying date on weather effects was analysed. Error distribution was again chosen according to the response variable as listed above (Supplementary material 8).

The final models explaining the variance in the clutch size, the number of fledged offspring or the hatch-fledge-ratio, either including variables describing the diet composition or the weather conditions as fixed effects, were tested against each other for each breeding success parameter using the "anova" command.

2.7. Ethical note

The study was performed under license from the Environmental Protection Bureau of Vienna (MA22/1263/2010/3), the Ministry for Science and Research BM.W_F (BM.WF – 66.006/0021-II/3b/2013) and the ethics committee of the University of Veterinary Medicine, Vienna (BGBI.Nr.501/1989i.d.g.F.). All data were acquired following strictly current Austrian and EU law as well as the Weatherall Report and the guidelines for treatment of animals in behavioural research and teaching (ASAB 2012).

3. Results

3.1. Studied nest sites

Table 1 gives an overview on characteristic features of the 56 data sets evaluated, including the study year, the urban gradient (UG) and the nest type. A minimum of 26 % sealed soil was detected for a nest site (NS) in the periphery and a maximum of 97 % was found for a NS in the city center. Considering the UG of all studied sites, the median value was 76 % of impervious surfaces within the NS surrounding (Figure 1).

Table 1:
Characterisation of all nest sites (NS) considered for analysis;
The features presented are: "ID"- number assigned to NS for identification, "year" = study year (9 NS were studied twice), "UG" = urban gradient (% of sealed soil within radius of 500 m around the nest) and "type" = nest type ("bc" = builiding cavity, "cn" = crow's nest, "nb" = nest-box, "pl" = planter).

ID	year	UG	type	ID	year	UG	type
1	2010	96	bc	25	2012, 2013	82	bc
2	2010, 2014	39	pl	26	2012, 2014	44	pl
3	2010	79	bc	27	2012	87	bc
4	2010	97	bc	28	2012, 2013	59	bc
5	2010, 2014	86	bc	29	2012, 2013	48	bc
6	2010, 2012	27	bc	30	2012	89	bc
7	2010	88	bc	31	2013, 2014	48	nb
8	2010	82	bc	32	2013	80	bc
9	2010	93	bc	33	2013	73	bc
10	2010	83	cn	34	2013	80	bc
11	2011, 2014	49	nb	35	2014	76	bc
12	2011	84	bc	36	2014	76	bc
13	2011	78	bc	37	2014	52	nb
14	2011	82	cn	38	2014	66	bc
15	2011	67	bc	39	2014	51	pl
16	2011	26	cn	40	2014	88	bc
17	2012	88	bc	41	2014	57	pl
18	2012	46	pl	42	2014	82	pl
19	2012	85	bc	43	2014	70	pl
20	2012	90	bc	44	2014	77	bc
21	2012	85	bc	45	2014	71	nb
22	2012	84	bc	46	2014	46	pl
23	2012	93	cn	47	2014	41	nb
24	2012	73	bc				

3.2. Diet composition

A minimum number of 1140 single prey items could be identified out of 627 pellets, plucked feathers and other prey remains. The main prey categories were mammals and birds. In three of five years avian prey was of higher importance than mammalian prey (2010: 47.3 %, 2012: 53.6 % and 2013: 50.1 %). In 2011 pellets consisted of 58.1 % mammals and 36.3 % birds. In 2014 diet analysis resulted in 75 % mammalian and 15.9 % avian prey, which was the widest difference detected between these two prey categories. The average yearly contribution of reptiles to diet composition was ranging between the minimum of 3.8 % (2012) and maximum of 10.8 % (2013). The highest value for reptiles found at a single NS was recorded in 2014 with 34.5 %. The least represented group contributing to diet were insects, which never got beyond a yearly average of 1 %. The highest value recorded at a single NS was 1.9 % (2012) (Figure 2). The determined standardised Levin's index of diet breadth (B_A) ranged between $B_A = 0$ and $B_A = 0.6$. A total of six NS had a diet composition of 100 % mammals, five of which were detected in 2014. Avian prey was above 93% at two NS, resulting in values between $B_A = 0.01$ and $B_A = 0.05$. The highest prey diversity, $B_A = 0.6$, was found at a NS in 2013 with a composition of 37.2 % mammals, 42.8 % birds, 19.1 % reptiles and 0.99% insects (Figure 3).

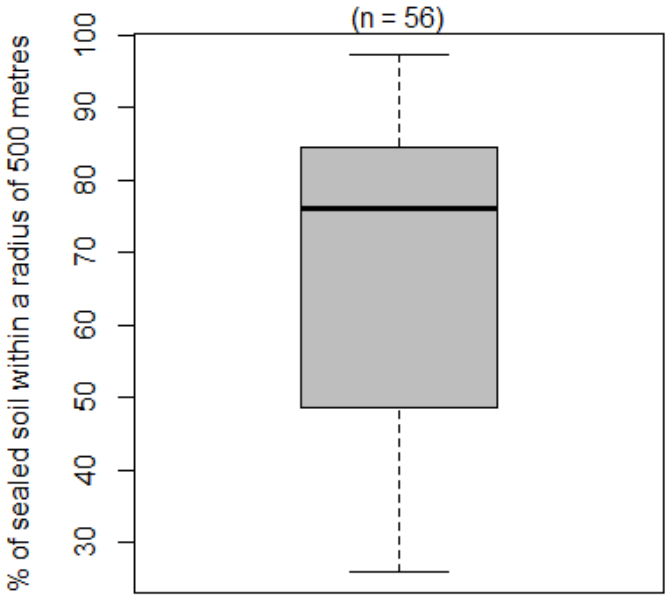

Figure 1:
Urban gradient at studied nest sites;
Boxplot presenting the expansion of the urban gradient, characterising the percentage of sealed soil within a radius of 500 meters, among all studied nest sites.

Regarding the studied breeding seasons separately it showed that 2013 did not only hold the maximum B_A but also the highest median ($B_A = 0.44$) and minimum ($B_A = 0.26$) compared to the other years. 2014 revealed the lowest values with more than a quarter (5 NS) of all sites analysed (18 NS) having an average diet breadth of $B_A = 0.0$ (Figure 4). A relatively high amount of reptiles in diet composition was the best predictor for a high Levin's index ($r_s = 11267.64$, $p < 0.001$).

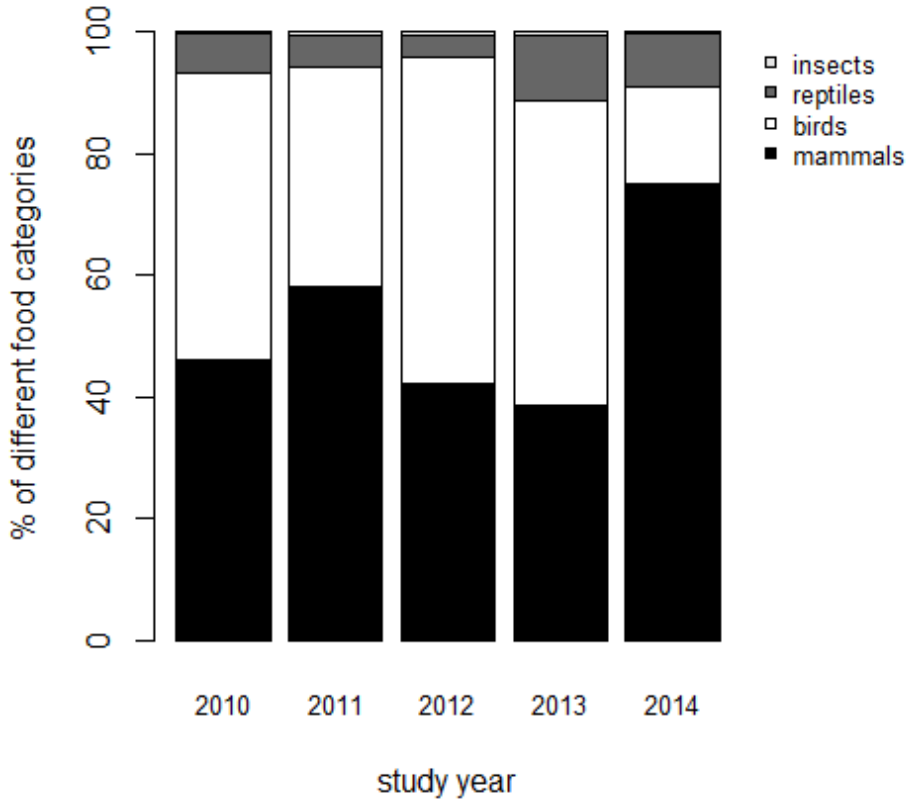

Figure 2:
Average amounts of prey categories within studied breeding seasons;
Bars showing yearly differences in average diet composition (% of biomass) classified into four different prey categories ("mammals", "birds", "reptiles" and "insects"). Analysis included a total of 1140 prey items from 56 nest sites.

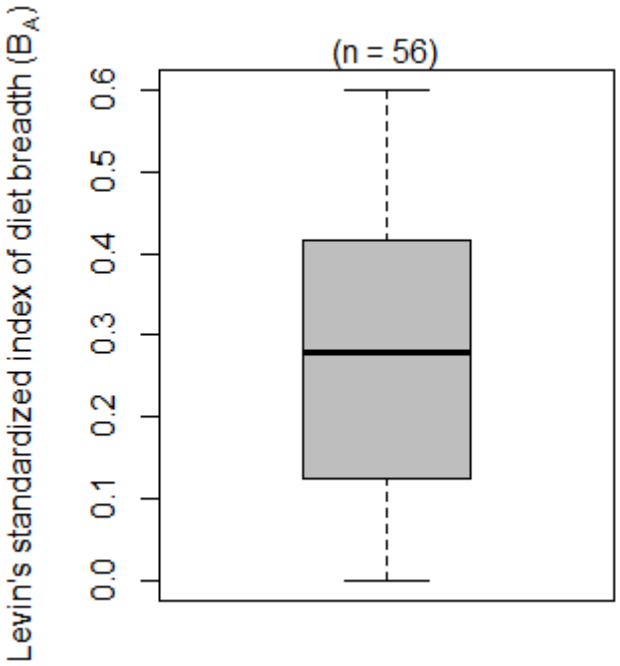

Figure 3:
Diet breadth at studied nest sites;
Levin's standardised index was used to express diet breadth. Boxplot includes data from all studied nest sites.

3.3. Breeding parameters

In 2014 both the earliest (March, 31st) and the latest laying date (May, 24th) was recorded. This season had furthermore a rather early laying date median (April, 25th), whereas the median values of all other years were located within an interval of five days (between May, 4th and May, 8th). The breeding pairs studied in 2013 started egg-laying within a period of 15 days (between May, 3rd and May, 17th), which is the shortest interval between laying date extremes comparing all seasons (Figure 5).

To analyse the breeding process we used clutch size, number of hatched offspring, number of fledged offspring as well as the clutch-hatch-ratio, the hatch-fledge-ratio and the clutch-fledge-ratio. Figure 6 presents the average breeding performance, in terms of clutch size and number of hatched and fledged offspring, for each study year. The breeding season 2014 stands out with the highest breeding success: clutch size = 5.5 ±0.2, hatching rate = 4.8 ±0.3 and fledging rate = 4.3 ±0.3. The smallest average clutch size (4.3 ±0.3), as well as the lowest hatching rate (3.4 ±0.3), were both detected in 2013. The clutch-hatch-ratio in 2013 was with 79.5 % ±4 % however higher than in 2010 (74.6 % ±10 %). The highest clutch-hatch-ratio was detected in 2014 (86.7 % ±3 %), as well as the maximum hatch-fledge-ratio (91.7 % ±4 %) and clutch-fledge-ratio (79.4 % ±5 %). In 2010 the average number of fledglings (2.2 ±0.4) was the smallest detected over all studied breeding seasons, the same is true for the hatch-fledge-ratio (56.3 % ±10 %) and the clutch-fledge-ratio (45.9 % ±9 %).

Regarding the clutch size at different nest types an average of 5.0 ±0.1 eggs was found for building cavities and 5.0 ±0.3 for nest boxes. In planters 5.3 ±0.3 eggs were laid. The average clutch size in crows` nests was 3.0 ±0.6. The number of fledged offspring was highest for broods in nest-boxes (4.0 ±0.4), closely followed by those in planters (3.9 ±0.3) and building cavities (3.0 ±0.3). The lowest value was found in crows' nests with 0.8 ±0.8.

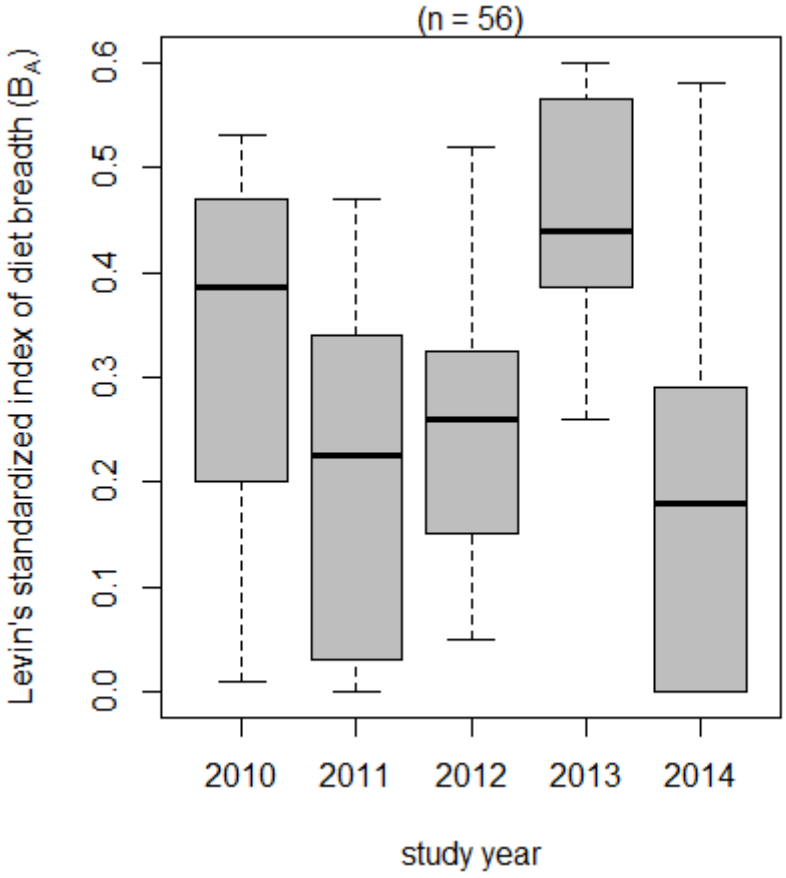

Figure 4:
Yearly differences in diet breadth;
Grouped boxplot showing Levin's standardised index of diet breadth for each studied breeding season.

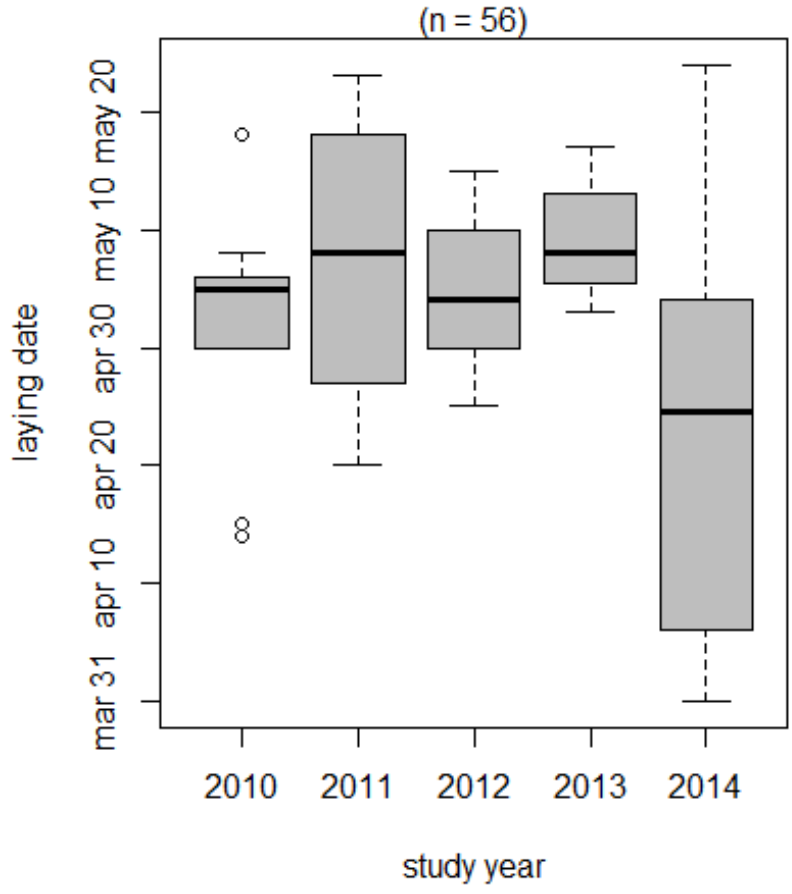

Figure 5:
Yearly differences in laying dates;
Grouped boxplot showing laying dates for each studied breeding season.

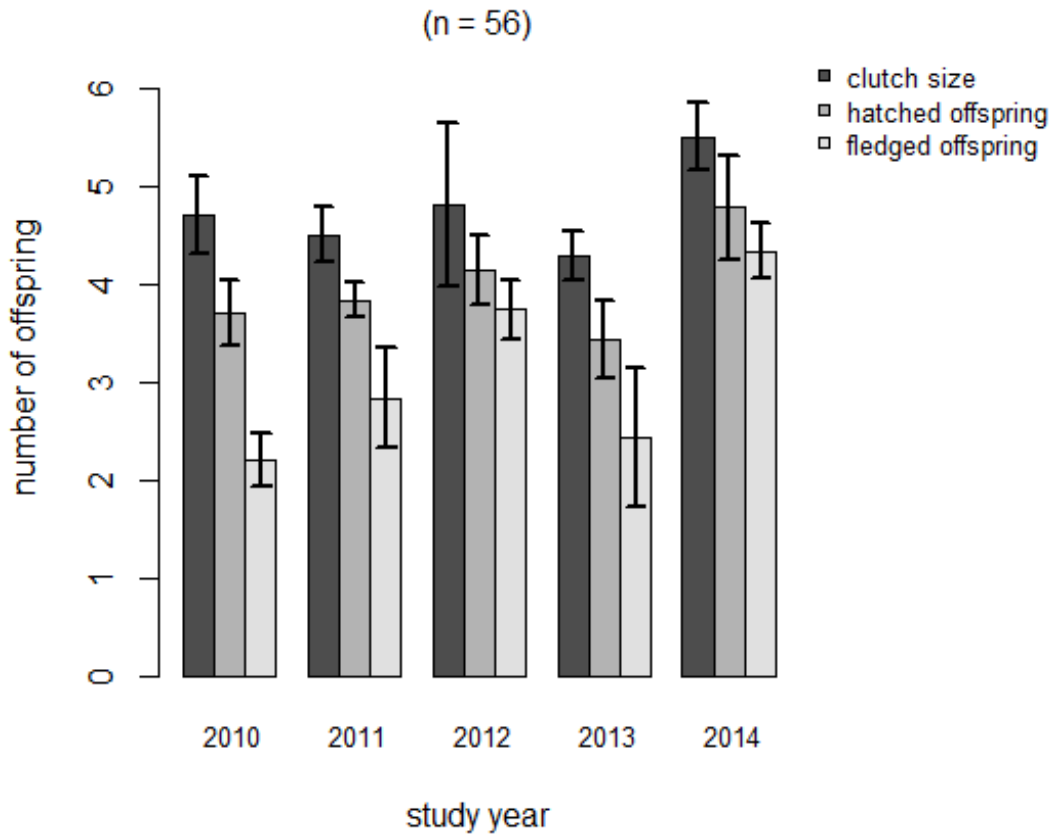

Figure 6:
Yearly differences in breeding performance;
Grouped barplot showing the average clutch size and number of hatched and fledged offspring for each studied breeding season.

3.4. Weather conditions

For two time periods (“arrival & courtship” and “nesting”) the highest maximum air temperature (16.9 °C ±0.4 °C and 28.1°C ±1.4 °C respectively), presented as the average overall NS, was reached in 2012. The same breeding season also revealed the highest intervals between maximum and minimum air temperature within the same time period (up to 10.5 °C during the nesting stage). In 2014 the lowest average minimum air temperature was reached during incubation and nesting period (11.1°C ±1.4 °C and 14.4 °C ±1.5 respectively); however for arrival & courtship the value was the second highest (7.3 °C ±1.4 °C). The average air temperature extremes (minimum and maximum) were for all time periods among the coldest in 2010 and 2013, whereas for 2011 the opposite was true (Figure 7). The total amount of rainfall, summarising the three time periods during each breeding season, was highest in 2010 (397.5 mm). The maximum value of total rain was measured during arrival & courtship in 2011 (128.2 mm). During incubation period the highest amount of rainfall was reached in 2010 (118.6 mm), for the nesting period 2013 holds the record (82.6 mm) (Figure 8).

An overview on the average weather conditions, regarding all parameters and breeding seasons (including “winter before” period), is given as Supplementary material 3. Climate graphs of the five study years are presented as Supplementary material 4.

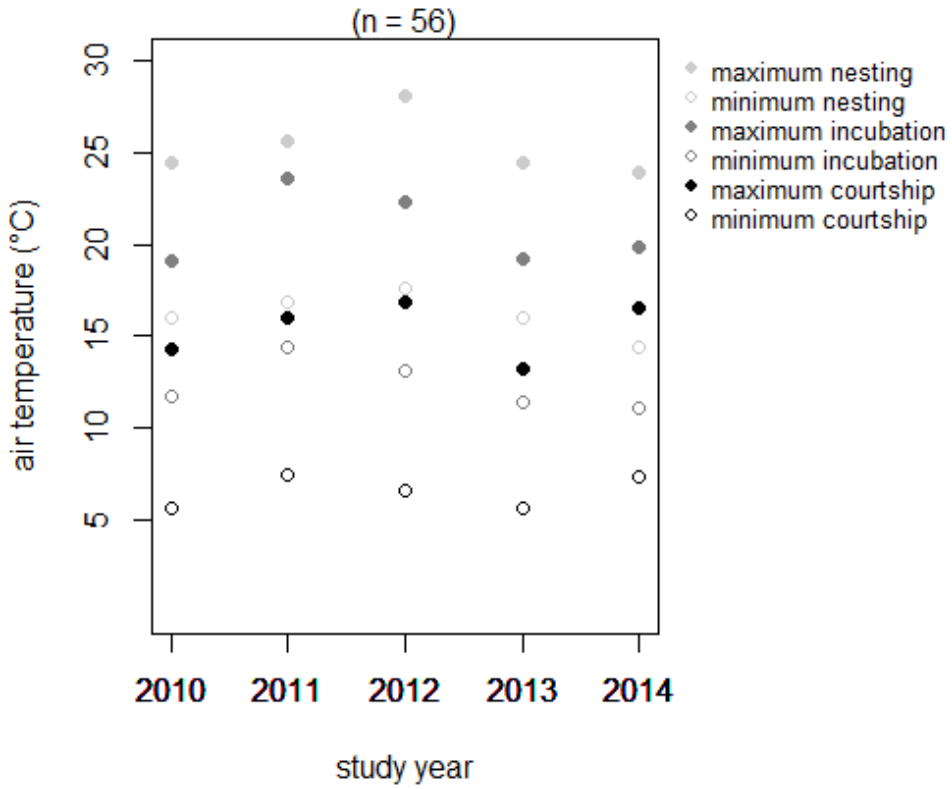

Figure 7:
Yearly differences in extreme temperatures for three time periods during breeding;
Average minimum and maximum temperatures during arrival & courtship, incubation and nesting phase are presented for each studied breeding season.

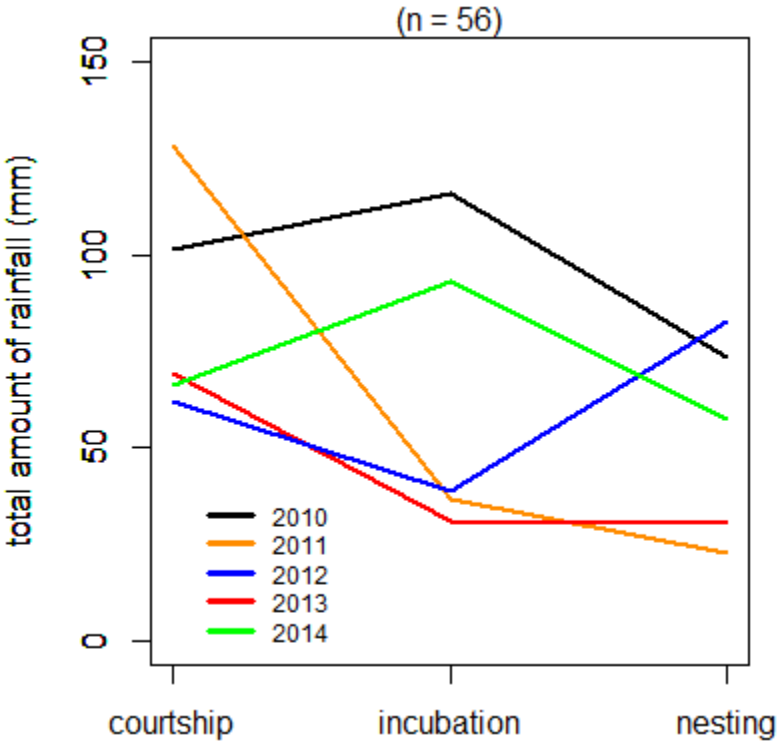

Figure 8:
Yearly differences in rainfall for three time periods during breeding;
Curves of total amount of rainfall are presented for arrival & courtship, incubation and nesting phase for each studied breeding season.

3.5. The impact of dietary composition on breeding parameters

Table 2 gives an overview on the selected generalised linear mixed effects models (GLMMs) presenting the dependence of different breeding parameters on diet composition. The number of fledged offspring depended significantly on the laying date ($z = -2.05, p = 0.0420$), with more fledged young in broods that had an earlier egg-laying start in the season (Figure 9). The final model also included the nest type as co-variable without having a significant effect. Differences in the laying dates and nest type could explain 25 % of the variance (R^2 for GLMM) in the number of fledged young. Regarding the clutch size later broods produced a lower number of eggs, although the influence of the laying date was not significant.

Table 2:
Final models presenting the dependence of breeding parameters on environmental impacts, including diet composition; The dependence of clutch size, number of fledged offspring, hatch-fledge-ratio and laying date was analysed in generalised linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. The nest ID and the study year were added as random factors. The error distribution was chosen according to the response variable. Fixed effects involved: "type"-character of nest, "ld"-residuals of laying date and study year ,"B:UG"-interaction of percentage of birds in diet and urban gradient and "Levin"-Levin's standardised index of diet breadth.

	Estimate	**Std.Error**	**z-value**	**Pr(Chisq)**	**R^2 for GLMM**	**Sign.**
clutch size					(0.03)	
ld	-0.01	<0.01	-1.28	0.2049		n.s.
(Intercept)	*1.59*	*0.06*	*26.27*			
number of fledged offspring					(0.25)	
type	-0.16	0.09	-1.79	0.0638		n.s.
ld	-0.01	0.01	-2.05	0.0420		*
(Intercept)	*1.40*	*0.18*	*7.58*			
hatch-fledge-ratio					(0.24)	
B:UG	<-0.001	<0.001	-1.86	0.0616		n.s.
(Intercept)	*2.16*	*0.52*	*4.17*			
			t-value			
laying date					(0.56)	
Levin	-7.57	9.13	-0.83	0.4673		n.s.
type	0.60	1.71	0.35	0.7505		n.s.
(Intercept)	*124.17*	*5.32*	*23.35*			

Significance codes: ***0.001, **0.01, *0.05, n.s. = not significant

The model with the second lowest AIC_c (Akaike Information Criterion corrected for small sample sizes) value was selected as final model because the one holding the lowest AIC_c was the null-model, excluding all fixed effects involved in the full model, indicating that none of the measured parameters could explain differences in clutch size. For both parameters, clutch size and number of fledged offspring, all dietary factors involved in the full model (percentage of mammals and birds as prey and the Levin's index of diet breadth) were excluded from the final model showing the influence of the laying date and the NS type to be better predictor variables than the diet composition. The interaction term of the amount of birds in diet and the UG,

which are significantly positively correlated (rs = 20535.98, p = 0.0256), was included in the final model presenting the dependence of the hatch-fledge-ratio. A higher proportion of birds and a higher soil sealing factor along the UG led to fewer fledged young in relation to the number of hatched offspring. This dependence was on the boarder of significance (z = -1.86, p = 0.0616). Variances in the laying date could be explained by 56% (R^2 for GLMM) involving Levin's index of diet breadth and the NS type as fixed effects. A higher diet breadth was found in earlier broods. Both of the included explanatory variables were not significant. Details on model selection are presented as Supplementary material 6.

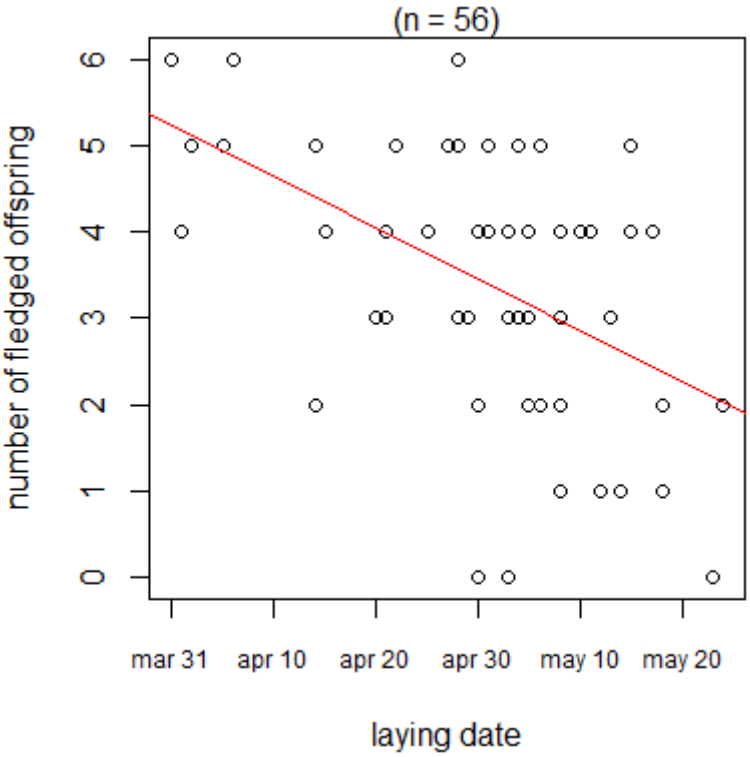

Figure 9:
The number of fledged offspring as a function of the laying date;
Data of all studied nest sites were included. The red line marks the degree of linear relationship between breeding success and egg-laying date.

Comparing six different univariate GLMMs including the number of fledged offspring as dependent variable reinforced that the laying date had the strongest influence among the tested explanatory variables (z = -2.09, p = 0.0382). The dependence of the number of fledged young on diet composition was highest for the percentage of avian prey, although with $\Delta AIC_c = 3.50$ ranging clearly behind the models including either the laying date or the NS type. Using the clutch size as response variable, was giving a similar result however with smaller distances within the model selection and no significant result. The laying date could be explained best by the proportion of birds in diet. The model involving the UG was for all breeding parameters analysed the worst-fitting one among the presented candidate models (Table 3).

Table 3:
Comparison of generalised linear mixed effects models (GLMMs) explaining differences in breeding performance; The dependence of clutch size, number of fledged offspring and laying date was tested with six different univariate model candidates including one of the following fixed effects: “M”-percentage of mammalian prey, “B”-percentage of avian prey, “Levin”-Levin’s standardised index of diet breadth, “type”-character of nest site, “UG”-urban gradient and (except for models involving laying date as dependent variable) “ld”-residuals of laying date and study year. Error distribution was chosen as Poisson with “log” link function for clutch size and the number of fledged offspring and as Gaussian with “identity” link function for the laying date. All nest sites (n = 56) and study years were included. Models are ranked based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to compare model adequacies. ΔAIC_c gives the differences in the AIC_c value between a certain model and the best candidate model with the lowest AIC_c. Akaike weights (ωi) give the probability that a certain model is the best-fitting one among all candidate models.

Explanatory variable	Dependent variable				
	clutch size				
	AICc	ΔAICc	ωi	Pr(>Chisq)	Sign.
ld	**211.78**	**0.00**	**0.26**	**0.2049**	**n.s.**
type	212.08	0.30	0.23	0.2533	n.s.
Levin	213.12	1.34	0.13	0.6032	n.s.
B	213.22	1.44	0.13	0.6810	n.s.
M	213.23	1.45	0.13	0.6889	n.s.
UG	213.31	1.53	0.12	0.7845	n.s.
	number of fledged offspring				
ld	**213.28**	**0.00**	**0.44**	**0.0382**	*****
type	213.98	0.70	0.31	0.0579	n.s.
B	216.79	3.50	0.08	0.3737	n.s.
M	217.14	3.86	0.06	0.5083	n.s.
Levin	217.23	3.95	0.06	0.5552	n.s.
UG	217.57	4.29	0.05	0.9398	n.s.
	laying date				
B	**442.78**	**0.00**	**0.24**	**0.3894**	**n.s.**
Levin	442.94	0.16	0.16	0.4472	n.s.
type	443.37	0.59	0.59	0.6980	n.s.
M	443.42	0.64	0.18	0.7553	n.s.
UG	443.50	0.72	0.72	0.8748	n.s.

Significance codes: ***0.001, **0.01, *0.05, n.s. = not significant

3.6. Weather effect on diet composition

Table 4 gives a summary of the final models (GLMMs) describing the dependence of dietary parameters. Differences in diet composition depended for all tested parameters, mammals and birds in diet and Levin’s index of diet breadth, with high significance, on the total amount of rain and the number of rain days during the arrival and courtship period ($p \leq 0.001$). The final model including the diet breadth as dependent variable also showed a significant dependence on the total amount of rain and the rain intensity during the winter before the breeding season.

Table 4:
Final models presenting dependence of different diet parameters on environmental impacts, including weather conditions; The dependence of the amount of mammals or birds as prey and the diet breadth was analysed using generalised linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. The nest ID and the study year were added as random factors. The error distribution was chosen according to the response variable. Fixed effects involved: "UG"-urban gradient, "ld"-laying date, presented as residuals of laying date and year, and "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature).

	Estimate	Std.Error	z-value	Pr(>Chisq)	R^2 for GLMM	Sign.
mammals in diet					(0.66)	
UG	-0.05	0.02	-3.19	0.0018		**
ld	-0.04	0.01	-3.28	0.0016		**
PC2w (t+,t-)	-0.76	0.20	-3.89	< 0.0001		***
PC1c (r,rd)	1.04	0.15	6.76	< 0.0001		***
PC2c (t+,ri)	-0.21	0.13	-1.63	0.0938		n.s.
PC1i (r,rd)	-0.20	0.08	-2.50	0.0105		*
PC1n (t+)	0.67	0.12	5.82	< 0.0001		***
PC2n (ri)	0.62	0.09	6.62	0.0001		***
(Intercept)	*4.12*	*1.19*	*3.47*			
birds in diet					(0.76)	
UG	0.06	0.02	3.00	0.0033		**
ld	0.08	0.02	4.01	0.0012		**
PC2w (t+,t-)	0.46	0.14	3.43	0.0037		**
PC1c (r,rd)	-1.40	0.30	-4.66	< 0.0001		***
PC1i (r,rd)	0.39	0.10	3.92	0.0005		***
PC2i (t+,t-)	0.42	0.28	1.50	0.1203		n.s.
PC1n (t+)	-0.63	0.14	-4.38	< 0.0001		***
PC2n (ri)	-0.92	0.19	-4.97	< 0.0001		***
(Intercept)	*-5.88*	*1.60*	*-3.67*			
Levin's index of diet breadth (standardised)					(0.49)	
PC1w (r,ri)	-0.40	0.18	-2.28	0.0287		*
PC1c (r,rd)	-1.07	0.32	-3.39	0.0001		***
(Intercept)	*-7.74*	*0.71*	*-10.86*			

Significance codes: ***0.001, **0.01, *0.05, n.s. = not significant

More rain with a higher intensity in winter leads to a higher diet breadth value in the following season, whereas more rain and a higher number of rain days during the courtship phase resulted in a lower diet breadth and percentage of mammals in diet, but in a higher amount of birds as prey. For both, the percentage of mammals and the percentage of birds in diet, the weather conditions during the nesting period had

a highly significant impact ($p \leq 0.001$): A higher percentage of birds in diet along with higher maximum temperatures and lower rainfall intensities and the opposite for the contribution of mammals to the diet composition were detected. Furthermore, the amounts of both feeding categories, small mammals and passerines, were influenced significantly by the air temperature extremes during winter before and the total amount of rainfall and the number of rain days during the incubation period. A higher percentage of mammals and a lower percentage of birds in diet were found after warmer winters and a breeding season with a higher rainfall amount during the incubation stage. A higher percentage of mammalian prey was associated further with higher temperature extremes and less rainfall intensity during the arrival and courtship period, whereas analysing the differences of the percentage of birds in diet intended higher values along with warmer temperatures during the incubation period. These results were not significant however. Both, the percentage of mammals in diet and the percentage of birds in diet, were significantly influenced by the UG and the laying date. Breeding pairs nesting closer to the city centre fed on birds with higher percentages ($z = 3.00$, $p = 0.0033$) than those nearer to the periphery, the opposite was found for mammals as prey ($z = -3.19$, $p = 0.0018$). Earlier broods had higher percentages of mammals in their diet composition ($z = -3.28$, $p = 0.0016$), whereas later broods had higher scores in the contribution of birds as prey ($z = 4.01$, $p = 0.0012$). Differences in the mentioned variables explained 66 % of the variance (R^2 for GLMM) in the contribution of mammals to diet and 76 % of variance in the percentage of birds as prey. Details on model selection are presented as Supplementary material 7.

3.7. Breeding parameters in relation to weather conditions

Table 5 shows the final models (GLMMs) defining the dependence of different breeding parameters on weather effects among other variables. Details on model selection are given as Supplementary material 8.

The number of fledged offspring was significantly influenced by the nest type ($z = -2.24$, $p = 0.0194$). Furthermore the final model included rainfall parameters of the winter before the breeding season and the arrival and courtship phase. A higher intensity of rainfall during winter and more rain days during the courtship period, as well as a higher amount of rainfall in total for both time periods led to a lower number of fledged young, however the impact of the weather parameters was not significant within the model. The final model defining the differences in clutch size included the nest type and the total amount of rain, as well as its intensity, during the winter before. The determined fixed effects had no significant impacts. Regarding the hatch-fledge-ratio, in addition to the nest type, which had no significant impact, and the rainfall parameters of the winter before and arrival & courtship period, which negatively influenced breeding success, also the air temperature during the winter before and the nesting period were included as fixed effects. All of the mentioned weather parameters influenced the hatch-fledge-ratio significantly. The results indicated more fledged young in relation to hatched young along with warmer temperature extremes. Differences in the laying date could be explained to an extent of $R^2 = 98$ % involving the weather parameters characterising the winter before and the arrival & courtship period as fixed effects.

Table 5: **Final models presenting dependence of different breeding parameters on environmental impacts, including weather conditions;** The dependence of clutch size, number of fledged offspring and laying date was analysed using generalised linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. The nest site ID and the study year were added as random factors. The error distribution was chosen according to the response variable. Fixed effects involved: "type"-character of nest site and "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature).

	Estimate	Std.Error	z-value	Pr(>Chisq)	R^2 for GLMM	Sign.
clutch size					(0.08)	
type	-0.11	0.07	-1.59	0.1022		n.s.
PC1w (r,ri)	0.06	0.04	1.69	0.0929		n.s.
(Intercept)	*1.77*	*0.13*	*13.92*			
number of fledged offspring					(0.23)	
type	-0.21	0.09	-2.24	0.0194		*
PC1w (r,ri)	0.12	0.05	2.58	0.0670		n.s.
PC1c (r,rd)	-0.07	0.05	-1.59	0.1075		n.s.
(Intercept)	*1.52*	*0.16*	*9.69*			
hatch-fledge-ratio					(0.34)	
type	0.51	0.01	63.60	0.0908		n.s.
PC1w (r,ri)	0.33	0.01	41.46	0.0191		*
PC2w (t+,t-)	-0.33	0.01	-41.21	0.0261		*
PC1c (r,rd)	-0.56	0.01	-69.48	0.0005		***
PC1n (t+)	-0.56	0.01	-70.15	0.0004		***
(Intercept)	*1.08*	*0.01*	*133.76*			
			t-value			
laying date					(0.98)	
PC1w (r,ri)	-4.89	1.09	-4.47	< 0.0001		***
PC2w (t+,t-)	9.24	1.14	8.13	< 0.0001		***
PC1c (r,rd)	7.33	0.34	21.81	< 0.0001		***
PC2c (t+,ri)	5.33	0.66	8.04	< 0.0001		***
(Intercept)	*118.46*	*5.23*	*22.66*			

Significance codes: ***0.001, **0.01, *0.05, n.s.=not significant

Table 6:

Comparison of the final model candidates (GLMMs) analysing the dependence of success on environmental effects;

Models involved were considered the best-fitting ones of model selections based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) explaining differences in the clutch size, the number of fledged offspring and the hatch-fledge-ratio. Full models included either diet composition (final model 1) or weather parameters (final model 2) as additional explanatory variables.

Fixed effects involved: "type"-character of nest site, "ld"- laying date presented as residuals of laying date and year, "B:UG""- interaction of percentage of birds in diet and urban gradient

and “PC1/2”-first/second principal components (concerned time periods given as: “w”-winter before, “c”-arrival & courtship, “i”-incubation, “n”-nesting stage; highest factor loadings given in brackets: “r”-total rain, “rd”-number of rain days, “ri”-intensity of rain, “t+”-maximum air temperature, “t-“-minimum air temperature);
Studied nest sites (n = 56) of all breeding seasons were included. Nest ID and study year were added as random factors. Error distribution was chosen according to the response variable. The GLMMs referring to the same response variable were tested against each other performing an analysis of variance (ANOVA).

	AIC	R^2 for GLMM	Pr(>Chisq)	Sign.
clutch size			**0.1123**	**n.s.**
final model 1 (model selection included diet)	211.78	0.03		
ld				
final model 2 (model selection included weather)	211.26	0.08		
type **PC1w (r,ri)**				
number of fledged offspring			**0.0405**	*
final model 1 (model selection included diet)	211.85	0.25		
type **ld**				
final model 2 (model selection included weather)	209.65	0.23		
type **PC1w (r,ri)** **PC1c (r,rd)**				
hatch-fledge-ratio			**0.0018**	**
final model 1 (model selection included diet)	128.34	0.24		
B:UG				
final model 2 (model selection included weather)	119.19	0.34		
type **PC1w (r,ri)** **PC2w (t+,t-)** **PC1c (r,rd)** **PC1n (t+)**				

Significance codes: ***0.001, **0.01, *0.05, n.s. = not significant

All weather parameters had a highly significant influence ($p < 0.001$). Later broods could be associated with higher values of rainfall parameters during the winter before and the arrival & courtship period. Warmer temperature extremes during the winter before led to earlier egg-laying, whereas higher maximum air temperature values during the courtship phase resulted in later broods.

3.8. Comparison of different environmental impacts on the breeding success

Table 6 gives an overview on final models (GLMMs) defining the dependence of different breeding parameters (number of fledged offspring, clutch size and hatch-fledge-ratio) either including variables describing the diet composition or the weather conditions as fixed effects. Comparing the different model candidates for each breeding success variable showed that the GLMMs including weather effects had a lower AIC_c value in all three cases. The R^2 values for GLMM differed with a maximum of 10 % between the models tested against each other. Regarding the hatch-fledge-ratio models, the one including the diet parameters explained 24 % of the variance, whereas the other, including the weather conditions, explained 34 % of the variance, which was the highest value among all tested models explaining the dependence of breeding success parameters. The R^2 values for the final models explaining the variance in clutch size were the lowest (3 % - including diet vs. 8 % - including weather) and tested against each other, by performing an analysis of variance (ANOVA), did not achieve a significant output. Put through the same analysis the models explaining the variance of the number of fledglings ($p = 0.0405$) as well as the ones explaining variance in the hatch-fledge-ratio ($p = 0.0018$) differed significantly.

4. Discussion

4.1. Diet composition along an urban gradient

The diet of urban kestrels is much richer in variety than those of their suburban and rural conspecifics, specialised in hunting voles. As in other metropolis, mammals and birds are clearly the main prey categories in the city of Vienna (e.g. Kübler et al. 2005; Sumasgutner et al. 2013), whereas reptiles, insects and other groups play a minor part. With their rather short digits and strong claws kestrels are built as typical ground hunters (Village 1990). Therefore they are most efficient in hunting small mammals, which hold additionally a higher nutritional value than passerines (Kirkwood 1991), the main avian prey. The “Alternative Prey Hypothesis” states that a predator with strong preferences for a main prey will switch to an alternative prey only when the main prey is scarce (Lack 1954). Although rodents are abundant in Vienna, most are crepuscular and nocturnal *Apodemus* species (Mitter et al. 2013) and therefore barely available for the diurnal raptor. To hunt their preferred prey (Common Vole, *Microtus arvalis*), kestrels would have to fly to suburban and rural areas, which they do in smaller and medium-sized European cities (Romanowski 1996; Rejt 2001; Riegert et al. 2007). Raptors, that have the potential to extend their home ranges beyond urban boundaries, are not reliant on meeting all their ecological requirements within the urban setting (Chace & Walsh 2006). In large cities, like Vienna, however, the distance from city centre to periphery is distinctly longer (linear distance of about 10 km), which might enforce inner-city breeding pairs to hunt in their immediate nest surroundings (Sumasgutner et al. 2013). A switch to alternative prey resources could thus be interpreted as an energetically preferable consequence of the lack of accessible rodents within the kestrels’ hunting grounds (Korpimäki 1985; Sumasgutner et al. 2014 a, b). It is therefore not surprising that the location of

a nest site (NS) along the urban gradient (UG) has a significant effect on the diet composition (Table 4). An increasing soil sealing factor induces a shift from mammalian to avian prey increasing the overall diet breadth. Within the city centre NS locations close to green space, e.g.: large parks and the riverside of the Danube and its stream branches, offer the best requirements for preying on rodents, whereas small green patches like backyards in proximity to the NS supposedly offer a variety of avian prey, especially passerines (Sumasgutner et al. 2014 a). Another parameter negatively influencing the amount of mammals in diet is the laying date (Table 4). Explanations for this circumstance are speculative, but hunting rodents might be more successful in early spring, when vegetation is still sparse and treetops are less impeding to kestrels scanning the ground. Furthermore, among a smaller number of early breeding pairs, the intraspecific competition might be reduced; as a consequence, access to high quality nutrition is easier to achieve. The nearest neighbour distance between breeding kestrels is especially high in the city centre, due to the availability of attractive NS (Sumasgutner et al. 2014 b). This might lead to additional "dietary stress" among the competing pairs resulting in an overall poorer food supply in the inner-city parts (see density dependent breeding success, e.g. in Dhondt et al. 1992; Doligez et al. 2003; Fasce et al. 2011).

4.2. Breeding performance influenced by food choice

Sumasgutner et al. (2013, 2014 a, b) showed that breeding success, in terms of fledged brood size, was higher in the periphery than in the city centre. Although our data did not provide a significant dependence of breeding parameters on the UG the detected trend matches with these findings: Towards the inner-city a decreasing clutch size, a lower hatch-fledge-ratio and less fledged offspring were observed. Lower productivity in urban habitats was also found in a meta-analysis on passerine birds (Chamberlain et al. 2009).

The interaction term between the amount of avian prey in the kestrels' diet and the location of the NS along the UG showed a strong tendency to influence the hatch-fledge-ratio (Table 2). As this breeding parameter reflects the time period from hatching to fledging, the findings indicated that a higher proportion of birds in diet together with an increasing soil sealing factor negatively influenced nestlings' survival.

Kostrzewa & Kostrzewa (1990) detected a higher availability of voles having a positive effect on the number of fledglings but not on the clutch size. According to our findings, differences in neither the clutch size nor the number of fledged offspring could be explained adequately through diet composition (Supplementary material 4). The chosen method of diet determination represents the whole breeding season and did not allow differing between certain time periods. The influence of food supply during delimited phases - e.g. the courtship period - on the subsequent breeding performance might have been underestimated. Comparing diet compositions over all study years, the cyclical small mammal population dynamics must not go unmentioned and might even exert the superior influence in this context. Vole populations in Central Europe underlie a 3 to 4-years-cycle including seasons of ascending, moderate density alternating with "peak years" followed by a population

collapse (Kempter & Nopp-Mayr 2013). Regarding contribution of mammalian prey to kestrels' diet among our study years, 2011 and 2014 appear to be such "peak years" of vole density reflected in a higher proportion of mammals in the diet (Figure 2). Studying the Common Buzzards (*Buteo buteo*) of central Germany, Mebs (1964) found higher breeding densities, larger clutches and an increased nestlings' survival positively correlated with vole abundance. High-quality nutrition furthermore led to earlier laying dates and larger egg mass and volume associated with higher reproductive success in Florida scrub-jays (*Aphelocoma coerulescens*) (Reynolds et al. 2003). The "Food Supply Hypothesis", describing an increase in food availability as trigger for advanced egg-laying initiation, has been confirmed by several studies (Aecese & Smith 1988; Boutin 1990; Svensson 1994; Korpimäki & Wiehn 1998; Hörnfeldt et al. 2000; Aparicio & Bonal 2002; Dawson & Bortolotti 2002; Brommer et al. 2004). Also in our analysis the laying date highly influenced breeding success (Table 2): Earlier broods resulted in a higher breeding success (Figure 9). This result is consistent with Sumasgutner et al. (2014 b) and other avian raptor-studies on the northern hemisphere (Meijer et al. 1990; Carillo & González-Dávila 2009; Gienapp et al. 2010). In 2014 both the earliest and the latest laying date were detected (Figure 5). This leads to the conclusion that second breeding events within the same season, either in addition to a completed first brood or after a failed nesting attempt (see Fragallo et al. 1996), might have occurred, although not observed directly.

4.3. Weather conditions affecting prey availability and reproduction

Beside the UG and the initiation of egg-laying our findings suggest that weather effects, in terms of rainfall and air temperature during certain time periods, have a significant impact on kestrels' diet composition (Table 4). In the following we discuss potential explanations for weather conditions affecting food supply.

The rainfall parameters during arrival and courtship, starting in early March, appeared to be especially influential on diet composition: A higher amount of rainfall and number of rain days led to a significant decrease in diet breadth through an increase of the proportion of avian prey. Wet weather phases might lead to an unequal availability of different prey categories. While small mammals, reptiles and insects tend to hide and be inactive during rainy and often cold periods; birds are usually very active immediately after a shower (Bosch et al. 2014). Furthermore they might be easy to hunt with wet plumage and possibly weakened through the preceding winter.

Rainfall parameters during incubation appeared having the opposite impact on diet composition than they had during arrival and courtship: An increase in the amount of rainfall and the number of rain days resulted in a higher proportion of mammalian prey (Table 4). As temperature is rising, not only kestrels but also their main prey categories are reproducing. Broods of passerines are usually situated at sites more exposed to rainfall than those of small mammals, breeding underground. Taking this into account together with their rapid succession of generations and early maturity (Mayr 1970), rodent populations might be less affected by adverse weather conditions than passerines and therefore more frequently caught by kestrels.

Concerning the nesting phase higher maximum temperature levels provoked an increase of birds in diet and a higher intensity of rainfall favoured mammalian prey (Table 4). The impact of very high temperatures seems to be similar to those of wet weather phases in terms of prey availability. While small mammals might prefer to stay in their shaded burrows during periods of top temperatures, birds could be spotted more easily by hunting kestrels. Especially freshly fledged and inexperienced passerine offspring should be easy to hunt, as kestrels mostly catch their prey on the ground. The shift to birds as an important dietary category may also effect a delay in the kestrels' laying dates compared to rural populations, because certain seasonality in their food forces the timing of breeding to be adjusted (Burger et al. 2012).

An increased proportion of mammals in diet was found after warmer winters and wider diet breadth values were associated with a higher amount and intensity of precipitation during this time period (Table 4). Although snow cover depth was found to have a protective function for rodents in northern ecosystems (Terraube et al. 2014 b), a study in lower latitudes analysed the survival rate of overwintering rodents to be lower in response to snow cover due to limited access to food resources (Korslund & Steen 2006). This might indicate that kestrels, due to a lack of small mammals, are required to feed on a broader range of alternative prey after cold and snowy winters.

Even though the strong impact of the UG, the laying date and the weather conditions on diet composition is obvious, individual hunting preferences among kestrels, as possible influencing factor on varying diet breadth values within the same year (Figure 4), should not go unmentioned. Individual diet specialization, studied by Terraube et al. (2014 a) in Montagu's harriers (*Circus pygargus*), has been reported also in urban kestrel populations (Sumasgutner et al. 2013). Single individuals even developed hunting techniques to successfully prey on pigeons or bats regularly (Costantini et al. 2005; Sorace & Gustin 2009; Mahmood et al. 2012; Sumasgutner et al. 2013). Furthermore, we observed urban kestrels frequently delivering invertebrates to the NS. Although the consumption of insects as diet enrichment is known (Korpimäki 1985; Riegert et al. 2009), adult kestrels usually use this prey category to feed themselves, as it does not seem very efficient to bring such small items to the NS, according to the "Central-place foraging theory" (Kacelnik & Cuthill 1990; but see Sternalski et al. 2010 on the positive effect of carotenoïds provided through insects in the prey on offspring's growth and health). We found the lowest average diet breadth in 2014, mainly due to a high proportion of mammalian prey. The same year was associated with a relatively high breeding success, indicating that focusing on high quality food of a single category might be more efficient than preying on a wider range of different classes. High frequencies of feeding insects at the nest were recorded in Poland (Boratynski & Kasprzy 2005) and linked to an increased habitat heterogeneity. In the city centre of Vienna higher feeding rates were detected than in the periphery (see Düesberg 2012 for details). These findings confirm that high nestling feeding rates may reflect low quality of available prey rather than elevated abundance of food in the nest surroundings (Mägi et al. 2009)

If food resources are scarce, the smallest nestlings, potentially males and last chicks to hatch, are most likely to die (Sumasgutner et al. 2014 b). This leads to a switch in

sex-bias from male-dominated to female-dominated in the course of the nesting stage (Dijkstra et al. 1990; Rejt et al. 2005).

Weather conditions, in terms of rainfall and air temperature, did have a remarkable influence on reproduction (Table 5). The hatch-fledge-ratio, reflecting the time span from hatching to fledging, depended significantly on rainfall parameters during arrival and courtship. A higher amount of rainfall and more rain days had a negative effect on the nestlings' survival rate and also the total number of fledged offspring. This indicates that weather conditions at the beginning of the breeding period might already lay the foundation for the seasons' reproductive success. Kostrzewa & Kostrzewa (1990) detected that the density of breeding pairs depended with high significance on rainfall in March and April. Our analysis showed that periods of rain during arrival and courtship delay egg-laying initiation with high significance (Table 5), which is consistent with the findings of Costantini et al. (2010). Female kestrels need to increase their body mass before laying (Newton 1986; Village 1990). In adverse weather the male might not be able to provide enough food to his mate, which might delay the onset of egg-laying (Kostrzewa & Kostrzewa 1990). Later broods were associated with smaller clutches and fewer fledged young (Table 2). Going along with the findings of Kostrzewa & Kostrzewa (1990), higher temperature levels during the nesting period had a significantly positive impact on the hatch-fledge-ratio. The increased proportion of birds in diet, that is also associated with these weather conditions (Table 4), seems therefore not to be related to poor food supply and less breeding success. The contemporaneous presence of juvenile passerines might play an important part in this matter. Kostrzewa & Kostrzewa (1990) suggested that temperature levels during hatching period and the subsequent two weeks are the most important for chick survival, whereas rainfall parameters did not show a significant impact, which is consistent with our findings.

All of the analysed breeding parameters showed a dependence on weather conditions of the winter before: Smaller clutches and fewer fledged young, also in relation to the number of hatchlings, were consequent on higher amounts of rain and more rain days (Table 5). This finding is converse to Costantini et al. (2010), who found unexpectedly smaller clutches after dry and mild winters. Rain as an influencing factor might be too complex to measure it through its total amount only (as in Costantini et al. 2010). A study in the Booted Eagle (*Aquila pennata*) suggested that the frequency of rainfall has a more direct impact on chick survival than the total amount of rain (Bosch et al. (2014). Our data indicated all of the included rainfall parameters, describing amount, frequency or intensity, to be influential. A higher nestling survival rate was moreover found after warmer winters going along with larger amounts of mammals in diet, probably due to a higher survival rate and therefore increased abundance of overwintering rodents (Korslund & Steen 2006).

The findings of weather effects shaping breeding performance are consistent with the recorded influence of weather conditions on the timing of egg-laying, enhancing the important linkage from laying date to breeding success (Table 3) (Sumasgutner et al. 2014 b). The positive impact of warm and dry conditions during winter and early spring could explain as much as 98 % of the differences in laying dates. A review

comparing productivity of urban and non-urban passerine birds found an earlier laying date in the former (Chamberlain et al. 2009), which was linked to the effect of the urban microclimate in winter, turning cities into “heat islands” for resident species (Root et al. 2003). As kestrels are only present in Vienna during breeding season their onset of egg-laying is not directly affected by the urban microclimate (Sumasgutner et al. 2013). Due to global warming processes however, the kestrels’ absence in Vienna is prospectively assumed to shorten in time, which might after all advance the laying date in further consequence (Sergio et al. 2003; Terraube et al. 2014 b). The high abundance of passerines in cities during winter increases the fitness of bird hunting raptors, e.g. goshawks (Rutz et al. 2006). Taking these factors into account, a further shift from mammalian to avian prey in urban kestrels’ diet and the tendency to stay longer within the urban setting or even become a resident might be expected. In Warsaw’s kestrels similar trends could have been observed already (Rejt 2001).

In addition to weather effects, we also found a linkage between nest type and breeding performance (Table 5). Although there was negligible difference between the average clutch size of five eggs, found in building cavities, planters and nest-boxes, broods raised in the latter were most successful. This is not surprising as nest-boxes, constructed for kestrels, are well sheltered and protect the brood from environmental influences and, in contrast to roof openings, fall from heights. Moreover they are usually placed at well established sites, often after a semi-natural breeding site was destroyed by renovations. Even though warm weather is associated with higher breeding success, very high temperatures and direct sun exposure can put kestrel chicks under heat stress (pers. obs. Gaspar T., Kreiderits A., Sumasgutner P.), especially in the first two weeks after hatching, when the young are not yet capable of regulating their own body temperature (Village 1990). Heat exhaustion and mortality due to high temperatures have been found in broods of the Lesser Kestrel (*Falco naumanni*) in Israel before (Bobek et al. 2003). Due to a lack of shade on most planters, this nest type can be negatively affected; however it is still the second most successful. For Vienna, nest-boxes and planters - occupied by kestrels - are mostly located at the periphery and seldom close to the city centre. A better food supply in this area might partly be accountable for the enhanced breeding performance. Furthermore these nest-types are often looked after by humans and supplementary feeding with beef or chicken, which cannot be detected during pellet analysis, may support the breeding performance. In building cavities on average two young died before fledging. We found roof openings, the most popular breeding sites among Viennese kestrels (Sumasgutner et al. 2014 b), exclusively in the city centre. This part of the city is generally associated with lower breeding success and increased nest predation through crows (Carrion Crow, *Corvus corone corone* and Hooded Crow, *C. c. cornix*), especially during the egg stage (Sumasgutner et al. 2014 b). Of all nest types recorded, crows’ nests were the least successful. Smaller clutches – in average three eggs laid - and a lower number of fledglings may have been due to increased predation risk (Skutch 1949; Snow 1962, 1978) on an open NS. Birds under such threats may benefit from a reduction in clutch size, as the nestlings’ individual quality was found to be higher, increasing the post-fledging survival rate, and earlier and more successful re-nesting attempts were initiated

(Slagsvold 1982). Charter et al. (2007) strongly suggest studies to report raptor breeding performance by different nest types, as they might pose a major impact on reproductive success.

4.4. Dependence of the breeding success – diet or weather as decisive factor?

A shift in diet composition is one of the most obvious characteristics of urban kestrels compared to their rural counterparts (e.g. Galanos 1991; Piattella et al. 1999; Salvati et al. 1999; Riegert et al. 2009; Sumasgutner et al. 2013). To assume a linkage between these altered conditions and the lower breeding success in the city seems apparent. Other falcon species, e.g. Peregrine Falcon (*Falco peregrinus*), Lesser Kestrel (*Falco naumanni*), but see also Tella et al. (1996), and American Kestrel (*Falco sparverius*), have been reported to attain increasing reproduction rates in urban habitats (Chace & Walsh 2006). This might be as they are less focused on hunting small mammals than the Eurasian Kestrel, but better adapted to birds or insects as main prey. Sumasgutner et al. (2014 b) suggested that Vienna as an urban habitat could be an "ecological trap" to kestrels. This term describes a mismatch between certain cues used in settlement decision and the fitness consequences. The availability of food might be such a misleading cue, overestimated by kestrels in the stage of habitat selection, as it is difficult to be evaluated and predicted correctly for the subsequent breeding season (Török et al. 2004; Hollander et al. 2013). A mismatch between habitat preference and actual habitat quality might be the result (Kloskowski 2012; Hollander et al. 2013).

Although the influences of diet and weather on reproduction are obviously highly entangled (Table 4), as weather conditions do not only exert direct but also indirect influence on the breeding success by affecting prey availability, our analysis detected a relatively higher importance of weather effects for the explanation of differences in productivity of the Viennese kestrel population (Table 6). Especially the weather situation of time periods before egg-laying (winter, arrival and courtship) seems to be essential for the ongoing breeding performance (Table 5). It has been suggested that environmental impacts during laying and incubation operate through an influence on breeding failure rather than on clutch size or nestling survival (Newton 1979; Herfindal et al. 2014). Nest failure was not included in our studies, but Sumasgutner et al. (2014 b) observed that most broods were abandoned during the stage of incubation. The clutch size was the breeding parameter least affected by environmental conditions during early breeding phases, which might support Newton's (1979) finding. However we found a significant response in the survival rate during nesting period (Table 5), implying that weather effects at an early stage may have consequences for the whole subsequent breeding season's productivity. There is evidence that environmental variation during laying and hatching might even induce life-history changes for the offspring: Herfindal et al. (2014) found a connection of warmer temperature levels during this time period to a reduced lifetime reproductive success in female goshawks (*Accipiter gentilis*). As these conditions are also related to a higher reproductive success for breeding pairs within the same year, the effect seems to be opposite for offspring and parents. Less intraspecific competition for especially nourishing food and high quality offspring due to tighter

selection of “silver spoon individuals” (Stamps 2006; Van de Pol et al. 2006) in adverse weather conditions might be the reason behind.

In order to reveal more distinct patterns of environmental conditions influencing the breeding success, further investigations in the individual quality of Viennese kestrels and their offspring would be necessary. Recovery of formerly ringed individuals would moreover allow considering possible effects on their life-history. In 2014 we were, for the first time, able to record the successful breeding of a female that was ringed as a nestling in Vienna three years earlier. Gaining further such breeding evidences would initialise a new field of research opportunities, e.g. if habitat-imprinting in kestrels, reared in an urban environment, occurs, increasing their preference for cities as breeding habitats (see Vallin & Qvarnström 2011). Thus, for several reasons, a long-term study in this system is highly suggested.

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6. Zusammenfassung

Global zunehmende Urbanisierungsprozesse verändern die Landschaft und damit die Zusammensetzung der Artenvielfalt in den betroffenen Gebieten. Der Turmfalke (*Falco tinnunculus* L., 1758) ist der häufigste Greifvogel in Wien (415 km^2, 1,8 Mio. Einwohner) und als Kulturfolger spätestens seit der zweiten Hälfte des 19. Jahrhunderst bekannt. Während seiner Brutsaison besiedelt er die österreichische Hauptstadt mit 89-122 Brutpaaren/100 km^2. Diese Dichte ist die höchste, die die Spezies im innereuropäischen Vergleich erreicht. Im Gegensatz zu ihren Artgenossen im Umland, die auf die Jagd von Wühlmäusen spezialisiert sind, ernähren sich städtische Turmfalken generalistisch: Kleinsäuger und –vögel machen die Hauptkategorien der Nahrung aus, aber auch Reptilien und Insekten werden erbeutet. In der vorliegenden Studie wurde der Zusammenhang zwischen der alternativen Ernährungsform und dem herabgesetzten Bruterfolg im urbanen Lebensraum untersucht. Ein hoher Vogelanteil in der Nahrung der Turmfalken wirkte sich tendetiell negativ auf das Überleben der Nestlinge aus, allerdings erzielten andere Einflussfaktoren deutlichere Erklärungswerte. Allen voran schienen lokale Wetterverhältnisse, gemessen als Regen- und Temperaturparameter, maßgeblich für den Reproduktionserfolg verantwortlich zu sein. Milde und niederschlagsarme Winter, eine trockene Balzzeit und warme Temperaturen während der Nestlingsphase führten zu erhöhtem Bruterfolg. Einen signifikant positiven Einfluss auf die Gelegegröße und die Anzahl der ausgeflogenen Jungen hatte außerdem ein möglichst frühes Gelegedatum. Auf die Verfügbarkeit von Kleinsäugern als Beute wirkten sich milde Winter und eine trockene Balzzeit förderlich aus, ebenso mehr Niederschlag während Inkubation und Nestlingszeit. Ein erhöhter Anteil an Kleinvögeln in der Nahrung wurde nach feuchten Wintern und Balzzeiten, sowie bei trockenen Inkubations- und vergleichweise warmen Nestlingsperioden gefunden. Unsere Ergebnisse zeigen an, dass die vorherrschenden Wetterverhältnisse einen bedeutenderen Einfluss auf den Bruterfolg der Wiener Turmfalkenpopulation haben, als die alternative Nahrungszusammensetzung in der Stadt. Allerdings scheint der Zusammenhang äußerst komplex zu sein und auch indirekte Effekte, wie etwa der Einfluss des Wetters auf die Beuteverfügbarkeit und das Gelegedatum, müssen berücksichtigt werden. Eine Langzeitstudie im vorliegenden System wird daher u.a. zur weiteren Erforschung dieses Interaktionsgefüges stark empfohlen.

7. References

Aparicio, J.M. and Bonal, R. (2002): Why do some traits show higher fluctuating asymmetry than others? A test of hypotheses with tail feathers of birds. - Heredity 89: 139–144.

ASAB: Guidelines for the treatment of animals in behavioural research
and teaching. Animal Behaviour 2012, 83:301–309.

Arcese, P. and Smith, J.N.M. (1988): Effects of population density and supplemental food on reproduction in Song Sparrows. - Journal of Animal Ecology 57: 119-136.

Barton, K. (2014): MuMIn: Multi-model inference. - R package version 1.10.5., http://CRAN.R-project.org/package=MuMIn.

Bates, D.; Maechler, M.; Bolker, B.; Walker, S. (2014): *lme4: Linear mixed-effects models using Eigen and S4*. - R package version 1.1-7.

Beissinger, S.R. and Osborne, D.R. (1982): Effects of Urbanization on Avian Community Organization. – The Condor 84: 75-83.

Blair, R.B. (1996): Land use and avian species diversity along an urban gradient. - Ecological applications 6: 506-519.

Blair, R.B. (2001): Creating a homogeneous avifauna. Avian ecology and conservation in an urbanizing world (ed. by J.M. Marzluff, R. Bowman and R. Donelly). – Kluwer Academic Publishers (pp. 459–486), Boston, MA.

Bobek, M.; Pojer, F.; Peske, L.; Simek, J. (2003): African Odyssey project. Research on the black stork migration and ecology and its presentation on the internet. – Aves 40: 212–221.

Boratynski, Z. & Kasprzyk, K. (2005): Does urban structure explain shifts in the food niche of the Eurasian Kestrel (*Falco tinnunculus*)? – Buteo 14: 11-17

Bosch, J.; Martínez, J.E.; Calvo, J.F.; Zuberogoitia, I.; Jiménez-Franco, M.V. (2014): Does rainfall affect the productivity of the Booted Eagle (*Aquila pennata*) during the breeding period in Mediterranean environments? – Journal of Ornithology 156: 1-8.

Boutin, S. (1990): Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. - Canadian Journal of Zoology 68: 203-220.

Brommer, J.E.; Karell, P.; Pietiäinen, H. (2004): Supplementary fed Ural owls increase their reproductive output with a one year time lag. – Oecologia 139: 354-358.

Burger, C.; Belskii, E.; Eeva, T.; Laaksonen, T.; Mägi, M.; Mänd, R.; Qvarnström, A.; Slagsvold, T.; Veen, T.; Visser, M.E.; Wiebe, K.L.; Wiley, C.; Wright, J.; Both, C. (2012): Climate change, breeding date and nestling diet: how temperature differentially affects seasonal changes in pied flycatcher diet depending on habitat variation. - Journal of Animal Ecology 81: 926-936.

Burnham, K.P.; Anderson, D.R.; Huyvaert, K.P. (2011): AIC model selection and multimodel inference in behavioural ecology: some background, observations, and comparisons. – Behavioral Ecology and Sociobiology 65: 23-35.

Carrillo, J. & González-Dávila, E. (2009): Latitudinal variation in breeding parameters of the common kestrel *Falco tinnunculus*. – Ardeola 56: 215-228.

Chace, J.F.; Walsh, J.J. (2006): Urban effects on native avifauna: a review. – Landscape and Urban Planning 74: 46–69.

Chamberlain, D.E.; Cannon, A.R.; Toms, M.P.; Leech, D.I.; Hatchwell, B.J. and Gaston, K.J. (2009): Avian productivity in urban landscapes: a review and metaanalysis. – Ibis 151: 1–18.

Charter, M.; Izhaki, I.; Bouskila, A.; Leshem, Y.; Penteriani, V. (2007): The Effect of Different Nest Types on the Breeding Success of Eurasian Kestrels (*Falco tinnunculus*) in a Rural Ecosystem. - Journal of Raptor Research 41: 143-149.

Costantini, D.; Casagrande, S.; Di Lieto, G.; Fanfani, A.; Dell'Omo, G. (2005): Consistent differences in feeding habits between neighbouring breeding kestrels. – Behaviour 142: 1409-1421.

Costantini, D.; Carello, L.; Dell'Omo, G. (2010): Patterns of covariation among weather conditions, winter North Atlantic Oscillation index and reproductive traits in Mediterranean kestrels. – Journal of Zoology 280: 177-184.

Cramp, S.; Tomlins, A.D. (1966): The birds of inner London 1951–65. - Br Birds 59: 209–233.

Crawley, M.J. (2007): Proportion Data. In The R Book. - John Wiley & Sons (pp. 569–591), London.

Cringan, A. T. and Horak, G. C. (1989): Effects of urbanization on raptors in the western United States. In Proceedings of the western raptor management symposium and workshop. -

National Wildlife Federation (pp. 219-228), Washington, DC.

Daan, S.; Dijkstra, C.; Drent, .RH.; Meijer, T. (1989): Food supply and the annual timing of avian reproduction. - Acta XIX Congressus Internationalis Ornithologici: 392–407.

Darolová, A. (1992): Nesting of *Falco tinnunculus* (Linnaeus, 1758) in the urban agglomeration of Bratislava. - Biologia (Bratislava) 47: 389–397.

Dawson, R.D. & Bortolotti, G.R. (2002): Experimental evidence for food limitation and sex-specific strategies of American kestrels (*Falco sparverius*) provisioning offspring. - Behavioral Ecology and Sociobiology 52: 43-52.

Dhondt, A.A.; Kempenaers, B.; Adriaensen, F. (1992): Density-Dependent Clutch Size Caused by Habitat Heterogeneity. – Journal of Animal Ecology 61: 643-648.

Dijkstra, C.; Daan, S.; Buker, J.B. (1990) : Adaptive seasonal variation in the sex ratio of kestrel broods. – Functional Ecology 4:143–147.

Doligez, B.; Cadet, C.; Danchin, E.; Boulinier, T. (2003): When to use public information for breeding habitat selection? The role of environmental predictability and density dependence. - Animal Behaviour 66: 973-988.

Düesberg, J. (2012): Video analysis versus prey analysis – method comparison to study feeding ecology of urban Kestrels *Falco tinnunculus* [German with English summary]. – Bachelor thesis. Humboldt Universität zu Berlin, Berlin.

Eck, S.; Fiebig, J.; Fiedler, W.; Heynen, I.; Nicolai, B.; Töpfer, T.; Van den Elzen, R.; Winkler, R. F.; Woog, F. (2011): DO-G Deutsche Ornithologen-Gesellschaft: Measuring Birds – Vögel vermessen. – Chist Media Natur.

Fasce, P.; Fasce, L.; Villers, A.; Bergese, F.; Bretagnolle, V. (2011): Long-term breeding demography and density dependence in an increasing population of Golden Eagles *Aquila chrysaetos*. – Ibis 153: 581-591.

Fragallo, J.A.; Blanco, G.; Soto-Largo, E. (1996): Possible second clutches in a Mediterranean montane population of the Eurasian kestrel (*Falco tinnunculus*). – Journal of Raptor Research 30: 70-74.

Galanos, I. (1991): Beitrag zur Lebensweise des Turmfalken (*Falco tinnunculus*) in urbanen Ökosystemen und zur Kenntnis anthropogener Einfl üsse auf die Population am Beispiel der Stadt Frankfurt am Main. – Dissertation. Universität Frankfurt/Main, Frankfurt/Main.

Gamauf, A. (1991): Greifvögel in Österreich. Bestand – Bedrohung – Gesetz. - Umweltbundesamt Wien, Wien.

Gienapp, P.; Väisänen, R.A.; Brommer, J.E. (2010): Latitudinal variation in breeding time reaction norms in a passerine bird. - Journal of Animal Ecology 79: 836-842.

Glutz von Blotzheim, U. N. and Bauer, K. M. (1980): Handbuch der Vögel Mitteleuropas Columbiformes – Piciformes (9) Wiesbaden: Aula-Verlag.

Hansson, L. & Henttonen, H. (1985): Gradients in density variations of small rodents: the importance of latitude and snow cover. – Oecologia 67: 394-402.

Herfindal, I.; Pol, M.; Nielsen, J.T.; Sæther, B.E.; Møller, A.P. (2014): Climatic conditions cause complex patterns of covariation between demographic traits in a long-lived raptor. - Journal of Animal Ecology.

Hörnfeldt, B.; Hipkiss, T.; Fridolfsson, A.K.; Eklund, U.; Ellegren, H. (2000): Sex ratio and fledging success of supplementary-fed Tengmalm's owl broods. - Molecular Ecology 9: 187-192.

Hollander, F.A.; Titeux, N.; Van Dyck, H. (2013): Habitat-dependent prey availability and offspring provisioning explain an ecological trap in a migratory bird. - Functional Ecology 27: 702-709.

Hurlbert, S.H. (1984): Pseudoreplication and the design of ecological field experiments. - Ecological Monographs 54: 187-211.

Jokimäki, J. & Suhonen, J. (1998): Distribution and habitat selection of wintering birds in urban environments. - Landscape and Urban Planning 39: 253-263.

Kacelnik, A. & Cuthill, I. (1990): Central Place Foraging in Starlings (*Sturnus vulgaris*). II. Food Allocation to Chicks. - Journal of Animal Ecology 59: 655-674.

Kark, S.; Iwaniuk, A.; Schalimtzek, A.; Banker, E. (2007): Living in the city: can anyone become an 'urban exploiter'? Journal of Biogeography 34: 638–651.

Kempter I. & Nopp-Mayr U. (2013) : Small mammal population dynamics in different mountain forest ecosystems in Austria and referring impacts on regeneration dynamics. - Silva fera 2: 94-99.

Kirkwood, J.K. (1991): Energy requirements for maintenance and growth of wild mammals, birds

and reptiles in captivity. – The Journal of nutrition 121: 29–34.

Kloskowski, J. (2012): Fish stocking creates an ecological trap for an avian predator via effects on prey availability. – Oikos 121: 1567-1576.

Korpimäki, E. (1985): Diet of the Kestrel *Falco tinnunculus* in the breeding season. – Ornis Fennica 62: 130– 137.

Korpimäki, E. & Wiehn, J. (1998): Clutch size of Kestrels: Seasonal decline and experimental evidence for food limitation under fluctuating food conditions. – Oikos 83: 259-272.

Korpimäki, E.; Oksanen, L.; Oksanen, T.; Klemola, T.; Norrdahl, K.A.I.; Banks, P.B. (2005): Vole cycles and predation in temperate and boreal zones of Europe. - Journal of Animal Ecology 74: 1150-1159.

Korslund, L. and Steen, H. (2006): Small rodent winter survival: snow conditions limit access to food resources. - Journal of Animal Ecology 75: 156-166.

Kostrzewa, R. & Kostrzewa, A. (1987): Zur Jugendentwicklung des Turmfalken (*Falco tinnunculus*) ein Altersbestimmungsschlüssel. - Ökologie der Vögel *9:* 119-125.

Kostrzewa, A. & Kostrzewa, R. (1990): The relationship of spring and summer weather with density and breeding performance of the Buzzard *Buteo buteo*, Goshawk *Accipiter gentilis* and Kestrel *Falco tinnunculus*. – Ibis 132: 550-559.

Kostrzewa, R. and Kostrzewa, A. (1993): Der Turmfalke. Überlebensstrategien eines Greifvogels. – Aula Verlag, Wiesbaden.

Kübler, S.; Kupko, S.; Zeller, U. (2005): The kestrel (*Falco tinnunculus*) in Berlin: investigation of breeding biology and feeding ecology. – Journal of Ornithology 146: 271–278.

Kupko, S.; Schlottke, L.; Rinder, J. (2000): Der Turmfalke (*Falco tinnunculus* L.) im Berliner Stadtgebiet – Eine Auswertung unter besonderer Berücksichtigung der Monitoringfl äche Nr. 376 (Berlin-West). – Populationsökologie Greifvogel- und Eulenarten 4: 359–372.

Krebs, C.J. and Singleton, G.R. (1993): Indexes of condition for small mammals. - Australian Journal of Zoology 41: 317-323.

Krüger, O. *(*2002*):* Dissecting common buzzard lifespan and lifetime reproductive success: the relative importance of food, competition, weather, habitat and individual attributes*.* – Oecologia 133*:* 474–482.

Lack, D. (1954): The Natural Regulation of Animal Numbers. - Clarendon Press, Oxford.

Lack, D. (1968): Ecological adaptations for breeding in birds. – Methuen, London.

Levins, R. (1968): Evolution in changing environments; some theoretical explorations. – Princeton University Press, Princeton, N.J.

Lockwood, J.L. & McKinney, M.L. (2002): Biotic homogenization. - Kluwer Academic Publishers, New York, NY.

Love, O. P., & Bird, D. M. (2000).: Raptors in urban landscapes: A review and future concerns. In R. D. Chancellor, & B.-U. Meyburg (Eds.), Raptors at risk (pp. 425–434). - WWGBP/Hancock House, Washington, DC.

Mägi, M.; Mänd, R.; Tamm, H.; Sisask, E.; Kilgas, P.; Tilgar, V. (2009): Low reproductive success of Great Tits in the preferred habitat: A role of food availability. – Ecoscience 16: 145-157.

Mahmood, T.; Hussain, R.; Rais, M.; Hussain, I.; Nadeem, M.S. (2012): Habitat analysis and population estimates of three falcon species, red-headed merlin (*Falco chicquera*), common kestrel (*Falco tinnunculus*) and saker falcon (*Falco cherrug*), inhabiting district Chakwal, Pakistan. - Pakistan Journal of Zoology 44: 787-798.

Malher, F.; Lesaffre, G.; Zucca, M. and Coatmeur, J. (2010): Oiseaux nicheurs de Paris. Un atlas urbain. – Corif. Delachaux et Niestlé, Paris.

Mayr, E. (1970): Population, Species, and Evolution: An Abridgment of Animal Species and Evolution. – Harvard University Press, Cambridge, M.A.

Mazerolle, M.J. (2014): AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). - R package version 2.0-1.

Mebs, T. (1964): Zur Biologie und Populationsdynamik des Mäusebussards (*Buteo buteo*): Unter besonderer Berücksichtigung der Abhängigkeit vom Massenwechsel der FeldmausMicrotus arvalis. - Journal für Ornithologie 105: 247-306.

Mebs, T. & Schmidt, D. (2006): Die Greifvögel Europas, Nordafrikas und Vorderasiens. - Franckh-Kosmos Verlag, Stuttgart.

Meijer, T.; Daan, S.; Hall, M. (1990): Family Planning in the Kestrel (*Falco tinnunculus*): the Proximate Control of Covariation of Laying Date and Clutch Size. – Behaviour 114: 117-136.

Mitter G, Sumasgutner P, Gamauf A: City centre or periphery? Distribution and morphological adaptation of Apodemus taxa along an urban gradient. - Beiträge Zur Jagd Und Wildforschung 2013, 38:305–319.

Newton, I. (1979). Population ecology of raptors. – Buteo Books, Vermillion, SD, USA.

Newton, I. (1986): The Sparrowhawk. - Poyser, Calton

Perrins, C.M. (1970): The timing of birds 'breeding seasons. - Ibis, 112: 242-255.

Piattella, A.; Salvati, L.; Manganaro, A. and Fattorini, S. (1999): Spatial and temporal variations in the diet of the Common Kestrel (*Falco tinnunculus*) in Rome, Italy. – Journal of Raptor Research 33: 172–175.

R Core Team (2014): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Redpath, S.M.; Clarke, R.; Madders, M.; Thirgood, S.J. (2001): Assessing raptor diet: Comparing pellets, prey remains, and observational data in Hen Harrier nests. - The Condor 103: 184-188.

Rejt, L. (2001): Peregrine Falcon and Kestrel in urban environment – The case of Warsaw.
In Gottschalk, E.; Barkow, A.; Muhlenberg, M.; Settele, J. (Eds.): Naturschutz
und Verhalten (Vol. 2/2001), UFZ-Bericht: 81-85.

Revelle, W. (2014): psych: Procedures for Personality and Psychological Research, Northwestern University, Evanston, Illinois, USA.

Reynolds, J.; Schoech, S.; Bowman, R. (2003): Nutritional Quality of Prebreeding Diet Influences Breeding Performance of the Florida Scrub-Jay. - Oecologia 134: 308-316.

Riegert, J.; Fainová, D.; Mikeš, V.; Fuchs, R. (2007): How urban Kestrels *Falco tinnunculus* divide their hunting grounds: partitioning or cohabitation? - Acta Ornithologica 42**:** 69-76.

Riegert, J.; Lövy, M.; Fainová, D. (2009): Diet composition of Common Kestrels *Falco tinnunculus* and Long-eared Owls *Asio otus* coexisting in an urban environment. – Ornis Fennica 86: 123–130.

Romanowski, J. (1996): On the diet of urban Kestrels (Falco tinnunculus) in warsaw. - Buteo 8: 123–130.

Root, T.L.; Price, J.T.; Hall, K.R.; Schneider, S.H.; Rosenzweig, C.; Pounds, J.A. (2003): Fingerprints of global warming on wild animals and plants. - Nature 421: 57-60.

Rutz, C., & Bijlsma, R.G. (2006): Food-limitation in a generalist predator. - Proceedings of the Royal Society B: Biological Sciences 273: 2069-2076.

Salvati, L.; Manganaro, A.; Fattorini, S.; Piattella, E. (1999): Population features of kestrels *Falco tinnunculus* in urban, suburban and rural areas in central Italy. – Acta Ornitholigica 34: 53–58.

Sergio, F. (2003): Relationship between laying dates of black kites *Milvus migrans* and spring temperatures in Italy: rapid response to climate change? – Journal of Avian Biology 34: 144-149.

Skutch, A.F. (1949): Do tropical birds rear as many young as they can nourish. – Ibis 91: 430-458.

Slagsvold, T. (1982): Clutch size variation in passerine birds: the nest predation hypothesis. – Oecologia 54: 159-169.

Snow, D.W. (1962): A field study of the Black and White Manakin, *Manacus manacus*, in Trinidad. – Zoologica 47: 65-104.

Snow, D.W. (1978): The nest as a factor determining clutch-size in tropical birds. – Journal of Ornithology 119: 227-230.

Sol, D.; González-Lagos, C.; Moreira, D.; Maspons, J.; Lapiedra, O. (2014): Urbanisation tolerance and the loss of avian diversity. - Ecology Letters 17: 942-950.

Sorace, A. and Gustin, M. (2009): Distribution of generalist and specialist predators along urban gradients. - Landscape and Urban Planning 90: 111–118.

Stamps, J.A. (2006): The silver spoon effect and habitat selection by natal dispersers. - Ecology Letters 9: 1179-1185.

Sternalski, A.; Mougeot, F.; Eraud, C.; Gangloff, B.; Villers, A.; Bretagnolle, V. (2010): Carotenoids in nestling Montagu's harriers: variations according to age, sex, body condition and evidence for diet-related limitations. - Journal of Comparative Physiology B 180: 33-43.

Sumasgutner, P.; Krenn, H.W.; Düesberg, J.; Gaspar, T.; Gamauf A. (2013): Diet specialisation and breeding success along an urban gradient: the kestrel (*Falco tinnunculus*) in Vienna, Austria. - Beiträge Zur Jagd Und Wildforschung 38: 385–397.

Sumasgutner, P.; Schulze, C.H.; Krenn, H.W.; Gamauf, A. (2014 a): Conservation related

conflicts in nest-site selection of the Eurasian Kestrel (*Falco tinnunculus*) and the distribution of its avian prey. – Landscape and Urban Planning 127: 94-103.

Sumasgutner, P.; Nemeth, E.; Graham, T.; Krenn, H.W.; Gamauf, A. (2014 b): Hard times in the city – attractive nest sites but insufficient food supply lead to low reproduction rates in a bird of prey. - Frontiers in Zoology 11: 48.

Svensson, E. (1994): Avian reproductive timing: when should parents be prudent? - Animal Behaviour 49: 1569-1575.

Terraube, J.; Guixé, D.; Arroyo, B. (2014 a): Diet composition and foraging success in generalistpredators: Are specialist individuals better foragers? – Basic and Applied Ecology 15: 616-624.

Terraube, J.; Villers, A.; Ruffino, L.; Iso-Iivari, L.; Henttonen, H.; Oksanen, T.; Korpimäki, E. (2014 b): Coping with fast climate change in northern ecosystems: mechanisms underlying the population-level response of a specialist avian predator. – Ecography 37: 1-10.

Tella, J.L.; Hiraldo, F.; Donazar-Sancho, J.A.; Negro, J.J. (1996): Costs and benefits of urban nesting in the lesser kestrel: Raptors in Human Landscapes, Adaptations to Built and Cultivated Environments (eds D.M. Bird, D.E. Varlan & J.J. Negro). - Academic Press (pp. 53-60), New York.

Török, J.; Hegyi, G.; Tóth, L.; Könczey, R. (2004): Unpredictable food supply modifies costs of reproduction and hampers individual optimization. – Oecologia 141: 432-443.

Valkama, J.; Korpimäki, E.; Wiehn, J.; Pakkanen, T. (2002): Inter-clutch egg size variation in kestrels *Falco tinnunculus*: seasonal decline under fluctuating food conditions. - Journal of Avian Biology 33: 426-432.

Van De Pol, M.; Bruinzeel, L.W.; Heg, D.I.K.; Van Der Jeugd, H.P.; Verhulst, S. (2006): A silver spoon for a golden future: long-term effects of natal origin on fitness prospects of oystercatchers (*Haematopus ostralegus*). - Journal of Animal Ecology *75*: 616-626.

Vallin, N. & Qvarnström, A. (2011): Learning the hard way: imprinting can enhance enforced shifts in habitat choice. - International Journal of Ecology.

Village, A. (1990): The Kestrel. – T & A D Poyser, London.

Witt, K. (2000): Situation der Vögel im städtischen Berlin. – Vogelwelt 121: 107–128.

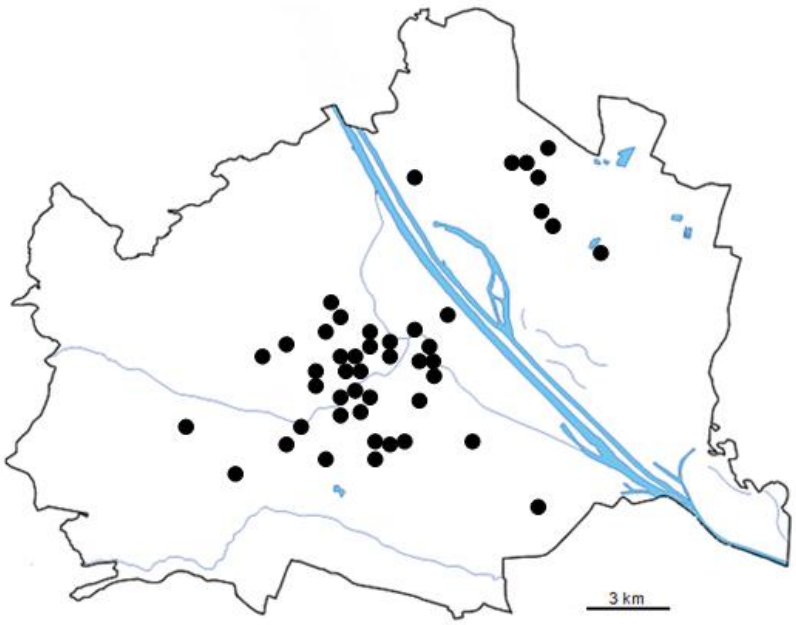
8. Appendix

8.1. Glossary

abbreviation	definition
bp	breeding pair
NS	nest site
type	type or character of nest site
ID	consecutive numbers assigned to NS for identification
UG	urban gradient; gives the proportion of impervious surfaces for the radius of 500m around a nest site
ld	laying date
year	study year in which data was collected
CW	calendar week
<u>nest types</u>	
bc	building cavity
pl	planter
nb	nest-box
cn	crow's nest
<u>dietary parameters</u>	
M	mammals
B	birds
R	reptiles
I	insects
Levin	Levin's standardised index of diet breadth
<u>weather data</u>	
MaxT	average maximum air temperature
MinT	average minimum air temperature
Rain	sum of rainfall
RainD	number of rain days
RainI	intensity of rain; rainfall per rain day
PCA	Principal Component Analysis
PC 1/2	First/Second Principal Component
w/c/i/n	Time periods referred to in PCA: winter before/arrival & courtship/incubation/nesting
t+/t-/r/rd/ri	Factor loadings of PC: maximum air temperature/minimum air temperature/sum of rainfall/number of rain days/intensity of rainfall
<u>time periods</u> (concerning breeding seasons)	
winter before	December, January and February before breeding
arrival & courtship	March until laying date
incubation	from laying-date until hatching (4 calendar weeks)
nesting	from hatching until fledging (4 calendar weeks)
<u>breeding parameters</u>	
clutch size	number of eggs within a nest
hatched young	number of hatched offspring within a nest
fledged young	number of fledged offspring within a nest
clutch-hatch-ratio	number of hatched offspring relating to number of eggs laid
clutch-fledge-ratio	number of fledged offspring relating to number of eggs laid
hatch-fledge-ratio	number of fledged offspring relating to number of hatched offspring

8.2. Supplementary material

Supplementary material 1:



Map shows locations of studied nest sites (NS) within the boundaries of Vienna, Austria (48°12'N, 16°22'E; 415 km^2; 1.8 million inhabitants). 56 distinct data sets of 47 NS, investigated during five consecutive breeding seasons (2010-2014), were available for analysis. Nine NS had been studied in two different years.

(Outline and hydrography: http://d-maps.com/carte.php?num_car=34264&lang=en)

Roof openings are the most commonly used nest types of kestrels breeding in Vienna. The picture shows a male delivering prey (*Lacerta bilineata*) to the almost fledged offspring at an inner-city nest site. Breeding cavities are easily recognisable by remains of feces on the exterior wall.

(Photo: Dr. W. Kraus)

Supplementary material 2:

Two newly hatched Eurasian Kestrel chicks on their nest site. As females lay an egg every second day, but start incubating in average after the third egg was laid, the offspring hatches staggered.

(Photo: J. Glaser)

Banding had just been conducted at a three-week-old nestling. The orange TIPES-ring is visible on the right leg. After the measurements and the check for ecto-parasites were performed and a blood sample was taken, the young kestrel gets weighed.

(Photo: K. Leitner, Vienna Wildlife)

Pellets and prey remains at a nest site with two eggs laid so far. On the left-hand side in the picture a part of a chicken wing is visible. The consumption of such human-related resources as supplementary diet is rather exceptional among urban kestrels.

(Photo: A. Kreiderits)

Supplementary material 3:

Overview on average weather conditions for each category ("winter before", "arrival & courtship", "incubation" and "nesting period") measured at two meteorological stations of ZAMG "Wien Innere Stadt" and "Wien Donaufeld". Data are arranged in five parameters ("MaxT"-maximum air temperature, "MinT"-minimum air temperature, "Rain" = sum of rainfall, "RainD" = number of rain days and "RainI" = intensity of rain) for each of the studied breeding seasons (2010-2014). The average starting point of egg-laying is represented as calendar week ("CW") and actual laying date ("ld") for each study year.

n (total) = 56

winter before

Wien Innere Stadt										Wien Donaufeld								
CW	ld			MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)			MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)		ld	CW
17.7	May,3rd	(n = 9)	**2010**	3.7	-0.4	111.3	31	3.6		**2010**	2.9	-2.1	97.5	29	3.4	(n = 2)	Apr,24th	16.5
18.6	May,8th	(n = 5)	**2011**	3.3	-1.2	55.8	24	2.3		**2011**	-	-	-	-	-	(n = 0)	-	-
18.2	May,4th	(n = 13)	**2012**	5.2	0.8	115.7	35	3.3		**2012**	4.8	-0.8	63.8	30	2.1	(n = 2)	May,10th	19.0
19.2	May,10th	(n = 6)	**2013**	4.0	0.5	138.9	33	4.2		**2013**	3.1	-1.2	128.4	43	3.0	(n = 1)	May,3rd	18.0
17.8	Apr,30th	(n = 9)	**2014**	6.5	2.2	81.0	30	2.7		**2014**	6.3	0.6	39.8	24	1.7	(n = 9)	Apr,15th	15.9

arrival & courtship

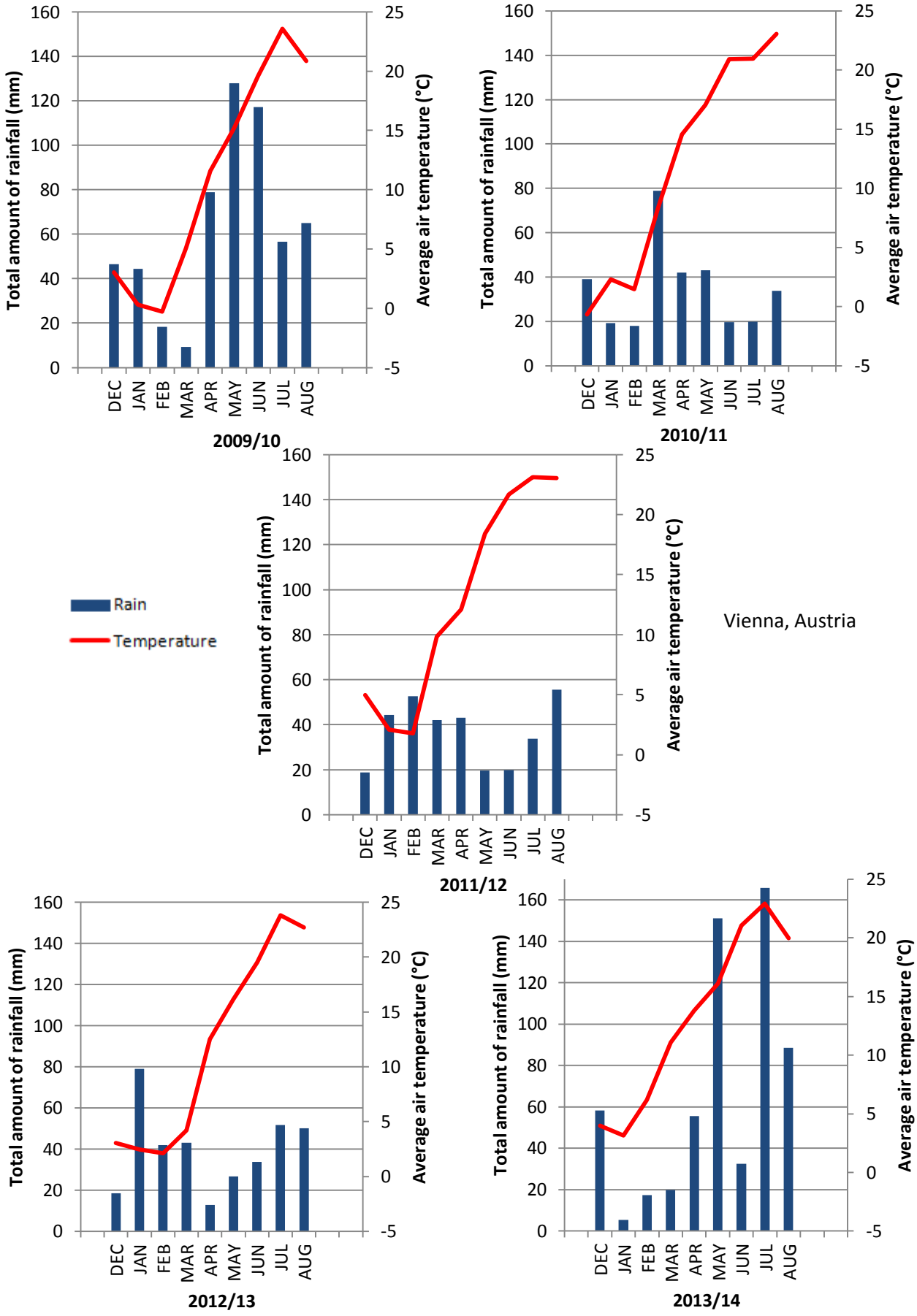
	MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)		MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)
2010	14.6	6.9	111.4	19.9	5.6	**2010**	14.0	4.2	90.9	17	5.5
2011	16.1	7.5	128.2	28.8	4.4	**2011**	-	-	-	-	-
2012	16.5	7.3	88.3	20.2	4.4	**2012**	17.2	5.7	50.0	18	2.8
2013	13.8	6.9	69.6	22.3	3.1	**2013**	12.6	4.3	54.4	19	2.9
2014	16.7	8.7	96.5	22.2	4.2	**2014**	16.4	5.9	35.6	12.9	2.6

incubation

	MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)		MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)
2010	19.4	12.9	146.7	17.6	8.4	**2010**	18.8	10.4	90.5	15	5.9
2011	23.7	14.4	36.9	9.4	3.8	**2011**	-	-	-	-	-
2012	22.5	13.9	16.9	8.8	1.9	**2012**	22.2	12.3	44.9	10	4.5
2013	19.0	11.9	15.5	6.5	2.3	**2013**	19.4	11.0	62.4	13	4.8
2014	20.5	12.5	107.4	13	8.3	**2014**	19.3	9.7	78.3	14.7	5.6

nesting period

	MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)		MaxT (°C)	MinT (°C)	Rain (mm)	RainD	RainI (mm/ RainD)
2010	25.0	17.2	73.7	10.2	7.4	**2010**	23.8	14.9	73.0	12.5	6.0
2011	25.7	16.8	22.8	8.8	2.6	**2011**	-	-	-	-	-
2012	26.7	17.5	20.5	7.7	2.6	**2012**	29.5	17.7	41.0	11	3.7
2013	25.3	17.2	44.2	11.7	3.7	**2013**	23.6	14.8	121.0	8	15.1
2014	250,78	159,32	639,67	7,44	83,41	**2014**	22.9	12.9	51.2	11.2	3.7



Supplementary material 4:
Climate graphs representing monthly sum of rainfall and average air temperature for all studied breeding seasons. Weather data were collected by ZAMG meteorological station "Wien Innere Stadt", Vienna, Austria.

Supplementary material 5:
Matrix of factor loadings of Principal Component Analysis (PCA) of weather variables concerning categories “winter before”, “arrival & courtship”, “incubation period” and “nesting period” of breeding seasons 2010-2014. Weather data were collected at meteorological stations “Wien Innere Stadt” and “Wien Donaufeld” operated by ZAMG. Loadings are based on a correlation matrix.

winter before variables	PC 1	PC 2	total variance explained
	(60.0%)	(34.5%)	**94.5%**
maximum temperature	0.38	**-0.57**	
minimum temperature	0.15	**-0.72**	
total rain	**-0.56**	-0.19	
rain days	-0.47	-0.33	
rain intensity	**-0.55**	-0.10	

arrival & courtship variables	PC 1	PC 2	total variance explained
	(55.8%)	(28.2%)	**83.9%**
maximum temperature	0.21	**0.70**	
minimum temperature	0.48	0.38	
total rain	**0.56**	-0.24	
rain days	**0.53**	0.02	
rain intensity	0.36	**-0.56**	

incubation period variables	PC 1	PC 2	total variance explained
	(63.0%)	(27.5%)	**90.5%**
maximum temperature	0.43	**0.50**	
minimum temperature	0.32	**0.66**	
total rain	**-0.51**	0.37	
rain days	**-0.50**	0.12	
rain intensity	-0.46	0.41	

nesting period variables	PC 1	PC 2	total variance explained
	(62.3%)	(24.7%)	**87.0%**
maximum temperature	**-0.51**	-0.27	
minimum temperature	-0.45	-0.39	
total rain	0.49	-0.41	
rain days	0.45	0.24	
rain intensity	0.30	**-0.74**	

Supplementary material 6:

Dependence of different breeding parameters on diet composition, the urban gradient, the nesting site type and the laying-date analysed with generalised linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. Model selection by ranking different model candidates based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to compare adequacies. AIC_c differences between the final model, which is the best-fitting, and another particular model are defined by ΔAIC_c. Akaike weights (ωi) give the probability that a certain model is the best-fitting one among the given candidates and K is the number of parameters involved. Variables are tagged with "0" (not included) or "1" (included) in a particular model. Good model candidates (ΔAICc < 2) are printed in bold.

6a:

Dependence of clutch size;

Error distribution chosen according to response variable: Poisson + log link function.

	variables included									model selection based on AICc			
clutch size													
	M	B	Levin	UG	type	ld	M:UG	B:UG	Levin:UG	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**211.39**	**0.00**	**0.10**
	0	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**4**	**211.78**	**0.39**	**0.08**
	0	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**4**	**212.08**	**0.69**	**0.07**
	0	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**5**	**212.35**	**0.96**	**0.06**
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**4**	**212.81**	**1.42**	**0.05**
	0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**213.12**	**1.73**	**0.04**
	0	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**4**	**213.18**	**1.79**	**0.04**
	0	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**213.22**	**1.83**	**0.04**
	1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**213.23**	**1.84**	**0.04**
	0	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**4**	**213.30**	**1.91**	**0.04**
	0	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**5**	**213.30**	**1.91**	**0.04**
	0	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**4**	**213.31**	**1.93**	**0.04**
	0	0	1	0	0	1	0	0	0	5	213.47	2.08	0.04
	0	0	1	0	1	0	0	0	0	5	213.60	2.21	0.03
	0	0	0	0	0	1	0	1	0	5	213.69	2.31	0.03
	1	0	0	0	0	1	0	0	0	5	213.70	2.32	0.03
	0	1	0	0	1	0	0	0	0	5	213.70	2.32	0.03
	1	0	0	0	1	0	0	0	0	5	213.73	2.35	0.03
	0	1	0	0	0	1	0	0	0	5	213.73	2.35	0.03
	0	0	0	1	0	1	0	0	0	5	213.74	2.35	0.03
	0	0	0	0	0	1	1	0	0	5	213.74	2.35	0.03
	0	0	1	0	1	1	0	0	0	6	214.17	2.43	0.03
	1	0	0	0	1	1	0	0	0	6	214.12	2.74	0.03
	0	1	0	0	1	1	0	0	0	6	214.17	2.78	0.02

"M"-percentage of mammals in diet, "B"-percentage of birds in diet, "Levin"-Levin's standardised index of diet breadth, "UG"-urban gradient, "type"-character of nest site, "ld"-residuals of laying date and study year , "M:UG"-interaction of M and UG, "B:UG"-interaction of B and UG, "Levin:UG"-interaction of Levin and UG;

6b:
Dependence of number of fledged offspring;
Error distribution chosen according to response variable: Poisson + log link function.

	variables included									model selection based on AICc			
number of fledged offspring													
	M	B	Levin	UG	type	ld	M:UG	B:UG	Levin:UG	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**5**	**211.85**	**0.00**	**0.17**
	0	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**6**	**213.10**	**1.26**	**0.09**
	1	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**6**	**213.27**	**1.43**	**0.08**
	0	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**4**	**213.28**	**1.44**	**0.08**
	0	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**6**	**213.83**	**1.98**	**0.06**
	0	0	0	0	1	0	0	0	0	4	213.98	2.13	0.06
	0	0	0	0	0	1	0	1	0	5	214.26	2.41	0.05
	0	0	0	0	0	1	1	0	0	5	214.32	2.47	0.05
	0	1	0	0	0	1	0	0	0	5	214.71	2.87	0.04
	1	0	0	0	0	1	0	0	0	5	214.84	2.99	0.04
	0	1	0	0	1	0	0	0	0	5	215.10	3.25	0.03
	0	0	1	0	0	1	0	0	0	5	215.22	3.37	0.03
	0	0	0	0	0	1	0	0	1	5	215.26	3.41	0.03
	0	0	0	1	0	1	0	0	0	5	215.28	3.44	0.03
	1	0	0	0	1	0	0	0	0	5	215.51	3.66	0.03
	0	0	0	0	0	0	0	0	0	3	215.58	3.73	0.03
	0	0	1	0	1	0	0	0	0	5	215.74	3.89	0.02
	0	0	0	0	0	0	0	1	0	4	216.26	4.41	0.02
	0	0	0	0	0	0	1	0	0	4	216.65	4.80	0.02
	0	1	0	0	0	0	0	0	0	4	216.79	4.94	0.01
	1	0	0	0	0	0	0	0	0	4	217.14	5.29	0.01
	0	0	1	0	0	0	0	0	0	4	217.23	5.38	0.01
	0	0	0	0	0	0	0	0	1	4	217.49	5.65	0.01
	0	0	0	1	0	0	0	0	0	4	217.57	5.73	0.01

"M"-percentage of mammals in diet, "B"-percentage of birds in diet, "Levin"-Levin's standardised index of diet breadth, "UG"-urban gradient, "type"-character of nest site, "ld"-residuals of laying date and study year, "M:UG"-interaction of M and UG, "B:UG"-interaction of B and UG, "Levin:UG"-interaction of Levin and UG;

6c:
Dependence of hatch-fledge-ratio;
Error distribution chosen according to response variable: Binomial + logit link function.

	variables included									model selection based on AICc			
hatch-fledge-ratio													
	M	B	Levin	UG	type	ld	M:UG	B:UG	Levin:UG	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**4**	**128.34**	**0.00**	**0.15**
	0	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**129.21**	**0.87**	**0.10**
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**129.84**	**1.49**	**0.07**
	0	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**5**	**129.88**	**1.54**	**0.07**
	0	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**4**	**130.13**	**1.79**	**0.06**
	0	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**5**	**130.25**	**1.91**	**0.06**
	1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**130.30**	**1.96**	**0.06**
	0	0	0	0	1	0	0	0	0	4	130.46	2.12	0.05
	1	0	0	0	1	0	0	0	0	5	130.89	2.55	0.04
	0	0	1	0	0	0	0	0	0	4	131.05	2.70	0.04
	0	1	0	0	0	1	0	0	0	5	131.13	2.78	0.04
	0	0	0	0	0	0	0	0	1	4	131.52	3.17	0.03
	0	0	0	0	0	0	1	0	0	4	131.52	3.18	0.03
	0	0	0	0	0	1	0	0	0	4	131.70	3.36	0.03
	0	0	1	0	1	0	0	0	0	5	131.73	3.39	0.03
	0	1	0	0	1	1	0	0	0	6	131.78	3.43	0.03
	0	0	0	1	0	1	0	0	0	5	132.08	3.74	0.02
	1	0	0	0	0	1	0	0	0	5	132.14	3.80	0.02
	0	0	0	0	1	1	0	0	0	5	132.32	3.98	0.02
	1	0	0	0	1	1	0	0	0	6	132.71	4.37	0.02
	0	0	1	0	0	1	0	0	0	5	132.93	4.58	0.02
	0	0	0	0	0	1	0	0	1	5	133.33	4.99	0.01
	0	0	0	0	0	1	1	0	0	5	133.34	5.00	0.01
	0	0	1	0	1	1	0	0	0	6	133.62	5.27	0.01

“M”-percentage of mammals in diet, “B”-percentage of birds in diet, “Levin”-Levin’s standardised index of diet breadth, “UG”-urban gradient, “type”-character of nest site, “ld”-laying date presented as residuals of laying date and study year, “M:UG”-interaction of M and UG, “B:UG”-interaction of B and UG, “Levin:UG”-interaction of Levin and UG;

6d:
Dependence of laying date;
Error distribution chosen according to response variable: Gaussian + identity link function.

	variables included								model selection based on AICc			
laying date												
	M	B	Levin	UG	type	M:UG	B:UG	Levin:UG	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**6**	**431.49**	**0.00**	**0.56**
	0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**5**	**432.51**	**1.01**	**0.34**
	0	0	0	0	1	0	0	0	5	436.35	4.86	0.05
	0	0	0	0	0	0	0	0	4	437.44	5.94	0.03
	0	1	0	0	1	0	0	0	6	441.50	10.01	0.00
	0	0	0	0	0	0	0	1	5	441.57	10.08	0.00
	1	0	0	0	1	0	0	0	6	442.01	10.51	0.00
	0	0	0	1	0	0	0	0	5	442.49	10.99	0.00
	0	1	0	0	0	0	0	0	5	442.65	11.16	0.00
	1	0	0	0	0	0	0	0	5	443.12	11.63	0.00
	0	0	0	0	0	1	0	0	5	451.80	20.30	0.00
	0	0	0	0	0	0	1	0	5	451.90	20.41	0.00

“M”-percentage of mammals in diet, “B”-percentage of birds in diet, “Levin”-Levin’s standardised index of diet breadth, “UG”-urban gradient, “type”-character of nest site, “M:UG”-interaction of M and UG, “B:UG”-interaction of B and UG, “Levin:UG”-interaction of Levin and UG;

Supplementary material 7:

Dependence of diet composition on weather conditions, the urban gradient and the nesting site type analyzed with generalised linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. Model selection by ranking different model candidates based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to compare adequacies. AIC_c differences between the final model, which is the best-fitting, and another particular model are defined by ΔAIC_c. Akaike weights (ωi) give the probability that a certain model is the best-fitting one among the given candidates and K is the number of parameters involved. Variables are tagged with "0" (not included) or "1" (included) in a particular model. Good model candidates ($\Delta AICc < 2$) are printed in bold.

7a:

Dependence of the percentage of mammals in diet;

Error distribution chosen according to response variable: Binomial + logit link function

	variables included											model selection based on AICc			
mammals in diet															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**1**	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**11**	**503.92**	**0.00**	**0.67**
	1	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**13**	**505.82**	**1.91**	**0.26**
	1	0	0	1	1	1	1	1	0	1	1	11	510.47	6.56	0.03
	1	0	0	1	1	1	1	1	1	1	1	12	511.68	7.76	0.01
	0	1	1	1	1	1	1	1	1	1	1	13	511.78	7.87	0.01
	0	1	1	0	1	1	1	1	0	1	1	11	511.80	7.89	0.01
	0	0	0	1	1	1	1	1	1	1	1	11	516.94	13.03	0.00
	0	1	0	1	1	1	1	1	1	1	1	12	517.37	13.45	0.00
	0	0	1	1	1	1	1	1	1	1	1	12	524.06	20.15	0.00
	0	0	1	0	0	0	0	0	0	0	0	4	546.99	43.08	0.00
	1	0	0	0	0	0	0	0	0	0	0	4	623.01	119.10	0.00
	0	0	0	0	0	0	0	0	0	0	0	3	624.14	120.22	0.00
	0	1	0	0	0	0	0	0	0	0	0	4	625.37	121.46	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature);

7b:
Dependence of the percentage on birds in diet;
Error distribution chosen according to response variable: Binomial + logit link function.

	variables included											model selection based on AICc			
birds in diet															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**11**	**476.57**	**0.00**	**0.60**
	1	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**12**	**478.42**	**1.84**	**0.24**
	1	0	1	1	1	1	1	1	1	1	1	13	480.37	3.80	0.09
	0	0	1	0	1	1	0	1	1	1	1	10	483.23	6.66	0.02
	1	0	0	0	1	1	0	1	0	1	1	9	484.02	7.44	0.01
	1	0	0	0	1	1	1	1	0	1	1	10	484.38	7.81	0.01
	1	0	0	0	1	1	1	1	1	1	1	11	485.71	9.14	0.01
	1	0	0	1	1	1	1	1	1	1	1	12	486.10	9.53	0.01
	0	0	1	1	1	1	1	1	1	1	1	12	486.44	9.87	0.00
	0	1	1	1	1	1	1	1	1	1	1	13	486.68	10.11	0.00
	0	0	0	1	1	1	1	1	1	1	1	11	490.51	13.93	0.00
	0	1	0	1	1	1	1	1	1	1	1	12	491.68	15.11	0.00
	0	0	1	0	0	0	0	0	0	0	0	4	514.87	38.30	0.00
	1	0	0	0	0	0	0	0	0	0	0	4	577.87	101.30	0.00
	0	0	0	0	0	0	0	0	0	0	0	3	580.14	103.57	0.00
	0	1	0	0	0	0	0	0	0	0	0	4	581.44	104.87	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature);

7c:
Dependence of Levin's standardized index on diet breadth;
Error distribution chosen according to response variable: Binomial + logit link function.

	variables included											model selection based on AICc			
Levin's index of diet breadth (standardised)															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**5**	**42.02**	**0.00**	**0.26**
	0	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**43.07**	**1.05**	**0.15**
	0	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**43.31**	**1.30**	**0.13**
	0	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**7**	**43.75**	**1.73**	**0.11**
	1	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**43.94**	**1.92**	**0.10**
	0	0	1	1	0	1	0	0	0	0	0	6	44.02	2.00	0.09
	0	0	0	1	1	1	0	0	0	0	1	7	44.72	2.70	0.07
	0	0	0	1	1	1	1	0	0	0	1	8	46.00	3.98	0.03
	0	1	0	1	1	1	0	0	1	1	0	9	46.86	4.94	0.02
	0	0	0	1	1	1	1	0	0	1	1	9	48.49	6.47	0.01
	0	1	0	1	1	1	0	0	1	1	0	10	48.61	6.59	0.01
	0	0	0	1	1	1	1	0	1	1	1	10	49.25	7.23	0.01
	0	0	0	1	1	1	1	1	1	1	1	11	51.40	9.38	0.00
	0	1	0	1	1	1	1	1	1	1	1	12	51.84	9.82	0.00
	1	0	0	1	1	1	1	1	1	1	1	12	52.85	10.83	0.00
	0	0	1	0	0	0	0	0	0	0	0	4	52.96	10.94	0.00
	0	0	1	1	1	1	1	1	1	1	1	12	54.22	12.20	0.00
	1	0	0	0	0	0	0	0	0	0	0	4	54.37	12.35	0.00
	1	0	1	1	1	1	1	1	1	1	1	13	54.95	12.93	0.00
	0	1	0	0	0	0	0	0	0	0	0	4	55.12	13.10	0.00
	0	1	1	1	1	1	1	1	1	1	1	13	55.12	13.11	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature);

Supplementary material 8:

Dependence of breeding parameters on weather conditions, the urban gradient, the nest type and the laying date analysed with generalized linear mixed effects models (GLMM). Studied nest sites (n = 56) of all breeding seasons were included. Model selection by ranking different model candidates based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to compare adequacies. AIC_c differences between the final model, which is the best-fitting, and another particular model are defined by ΔAIC_c. Akaike weights (ωi) give the probability that a certain model is the best-fitting one among the given candidates and K is the number of parameters involved. Variables are tagged with "0" (not included) or "1" (included) in a particular model. Good model candidates (ΔAICc < 2) are printed in bold.

8a:

Dependence of clutch size;

Error distribution chosen according to response variable: Poisson + log link function.

	variables included											model selection based on AICc			
clutch size															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**211.26**	**0.00**	**0.13**
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**211.39**	**0.13**	**0.12**
	0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**211.78**	**0.52**	**0.10**
	0	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**211.93**	**0.67**	**0.09**
	0	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**212.08**	**0.82**	**0.09**
	0	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**212.35**	**1.09**	**0.08**
	0	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**212.67**	**1.41**	**0.06**
	0	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**6**	**212.80**	**1.54**	**0.06**
	0	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**213.09**	**1.83**	**0.05**
	1	0	0	0	0	0	0	0	0	0	0	4	213.31	2.05	0.05
	0	0	0	1	1	0	0	0	0	0	0	5	213.49	2.23	0.04
	0	1	0	1	1	0	1	0	0	0	0	7	214.05	2.78	0.03
	0	0	0	1	1	0	1	0	0	0	0	6	214.13	2.87	0.03
	0	1	1	1	1	0	0	0	0	0	0	7	214.45	3.19	0.03
	0	0	1	1	1	0	1	0	0	0	0	7	215.91	4.65	0.01
	0	1	0	1	1	1	1	0	0	0	0	8	215.98	4.72	0.01
	0	0	0	1	1	1	1	0	0	0	0	7	216.04	4.78	0.01
	0	0	1	1	1	0	1	1	0	1	1	10	221.36	10.10	0.00
	0	1	0	1	1	1	1	1	1	1	1	12	223.37	12.11	0.00
	0	0	0	1	1	1	1	1	1	1	1	11	223.45	12.19	0.00
	0	0	1	1	1	1	1	1	1	1	1	12	225.07	13.81	0.00
	0	1	1	1	1	1	1	1	1	1	1	13	225.26	14.00	0.00
	1	0	0	1	1	1	1	1	1	1	1	12	225.45	14.19	0.00
	1	0	1	1	1	1	1	1	1	1	1	13	227.05	15.79	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature)

8b:
Dependence of number of fledged offspring;
Error distribution chosen according to response variable: Poisson + log link function.

	variables included											model selection based on AICc			
number of fledged offspring															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**209.65**	**0.00**	**0.24**
	0	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**7**	**209.79**	**0.14**	**0.22**
	0	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**8**	**210.44**	**0.79**	**0.16**
	0	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**9**	**211.53**	**1.89**	**0.09**
	0	0	0	1	1	1	0	0	0	0	0	6	211.92	2.27	0.08
	0	1	0	1	1	1	0	0	0	1	1	9	212.12	2.47	0.07
	0	0	0	1	1	1	0	0	0	1	0	7	212.35	2.70	0.06
	0	1	1	1	1	1	0	0	0	1	1	10	212.69	3.04	0.05
	0	0	0	0	0	0	0	0	0	0	0	3	215.58	5.93	0.01
	0	0	0	1	1	1	1	0	0	1	1	9	215.97	6.32	0.01
	0	1	0	1	1	1	1	1	1	1	1	12	217.66	8.01	0.00
	0	1	1	1	1	1	1	1	1	1	1	13	218.04	8.39	0.00
	0	0	1	1	1	1	1	1	1	1	1	12	219.11	9.46	0.00
	0	0	0	1	1	1	1	1	1	1	1	11	219.69	10.04	0.00
	1	0	1	1	1	1	1	1	1	1	1	13	221.04	11.40	0.00
	1	0	0	1	1	1	1	1	1	1	1	12	221.38	11.73	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature)

8c:
Dependence of hatch-fledge-ratio;
Error distribution chosen according to response variable: Binomial + logit link function.

	variables included											model selection based on AICc			
hatch-fledge-ratio															
	UG	type	ld	PC1 w (r,ri)	PC2 w (t+,t-)	PC1 c (r,rd)	PC2 c (t+,ri)	PC1 i (r,rd)	PC2 i (t+,t-)	PC1 n (t+)	PC2 n (ri)	K	AICc	ΔAICc	ωi
final model	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**8**	**119.19**	**0.00**	**0.22**
	0	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**9**	**119.70**	**0.52**	**0.17**
	0	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**7**	**120.05**	**0.86**	**0.14**
	1	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**8**	**120.95**	**1.77**	**0.09**
	0	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**8**	**120.96**	**1.78**	**0.09**
	0	0	1	1	1	1	0	0	0	1	0	8	121.92	2.74	0.06
	0	0	1	1	1	1	0	0	1	1	0	9	122.68	3.49	0.04
	1	0	0	1	1	1	1	1	1	1	0	11	123.98	4.79	0.02
	0	1	0	1	1	1	1	1	1	1	1	12	125.52	6.34	0.01
	0	0	0	1	1	1	1	1	1	1	1	11	125.87	6.69	0.01
	1	0	0	1	1	1	1	1	1	1	1	12	125.98	6.79	0.01
	0	1	1	1	1	1	1	1	1	1	1	13	127.52	8.34	0.00
	0	0	1	1	1	1	1	1	1	1	1	12	127.84	8.66	0.00
	1	0	1	1	1	1	1	1	1	1	1	13	127.98	8.79	0.00
	0	0	0	0	0	0	0	0	0	0	0	3	129.84	10.65	0.00
	1	0	0	0	0	0	0	0	0	0	0	4	130.13	10.95	0.00
	0	1	0	0	0	0	0	0	0	0	0	4	130.46	11.28	0.00
	0	0	1	0	0	0	0	0	0	0	0	4	131.70	12.51	0.00

"UG"-urban gradient, "type"-character of nest site, "ld"- laying date presented as residuals of laying date and study year, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before, "c"-arrival & courtship, "i"-incubation, "n"-nesting stage; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature);

8d:
Dependence of laying date;
Error distribution chosen according to response variable: Gaussian + identity link function.

	variables included						model selection based on AICc			
laying date										
	UG	type	PC1w (r,ri)	PC2w (t+,t-)	PC1c (r,rd)	PC2c (t+,ri)	K	AICc	ΔAICc	ωi
final model	**0**	**0**	**1**	**1**	**1**	**1**	**8**	**316.39**	**0.00**	**0.54**
	1	**0**	**1**	**1**	**1**	**1**	**9**	**317.91**	**1.52**	**0.21**
	0	**1**	**1**	**1**	**1**	**1**	**9**	**318.31**	**1.92**	**0.25**
	0	0	0	0	1	1	6	356.82	40.42	0.00
	0	0	0	0	1	0	5	373.45	57.06	0.00
	0	0	0	0	0	1	5	436.15	119.76	0.00
	0	0	1	0	0	0	5	436.19	119.79	0.00
	0	0	1	1	0	0	6	437.65	121.26	0.00
	0	0	0	0	0	0	4	441.52	125.13	0.00
	0	0	0	1	0	0	5	442.67	126.28	0.00
	0	1	0	0	0	0	5	443.37	126.98	0.00
	1	0	0	0	0	0	5	443.50	127.10	0.00
"UG"-urban gradient, "type"-character of nest site, "PC1/2"-first/second principal components (concerned time periods given as: "w"-winter before and "c"-arrival & courtship; highest factor loadings given in brackets: "r"-total rain, "rd"-number of rain days, "ri"-intensity of rain, "t+"-maximum air temperature, "t-"-minimum air temperature);										

8.3. Curriculum vitae

Personal information:

Surname/First name/Academic Title
Kreiderits Anna, BSc.

Date/Place of birth
April, 30th 1991 in Vienna

Nationality
Austrian

E-mail
a9671370@unet.univie.ac.at

Education:

since November 2012
University of Vienna, Master's program, Evolutionary Biology

October 2009 – November 2012
University of Vienna, Bachelor's program, Biology (Zoology)

June 2009
Higher school graduation with honors (Matura)
Bundes-Gymnasium/-Realgymnasium II, Zirkusgasse 48, A-1020 Wien

Scientific projects:

since February 2014
Master thesis
"The influence of alternative diet composition in an urban habitat on the breeding success of Eurasian Kestrels (*Falco tinnunculus*) in Vienna"
University of Vienna & Vienna's Museum of Natural History

March – July 2012
Bachelor thesis
"Verhaltensänderungen des Indischen Panzernashorns (*Rhinoceros unicornis*) zum Zeitpunkt des Östrus"
University of Vienna & Zoo Vienna Schönbrunn

March - September 2012
Sea Turtle Project Turkey-Austria
Protection of sea turtles (*Caretta caretta*) in Turkey/Fethiye
University of Vienna & Pamukkale University, Turkey

Employment history:

since March 2013
Zoo Vienna, Schönbrunner Tiergarten GesmbH, A-1130 Wien
visitor service, guide

August 2011 - February 2013
KLAVIER*galerie*, Wendl & Lung, Klavierbau und Vertriebs GmbH, A-1070 Wien
receptionist, office, events, customer service

May – June 2011

NPO Verein UmweltBildungAustria – Grüne Insel, A-2301 Groß Enzersdorf
workshop administration, child care

August - October 2010

Bakery, Bäckerei Ströck GmbH, A-1020 Wien, A-1110 Wien
sale

July – August 2009

Restaurant, Panorama-Gasthaus Rosenheim, A-9123 St. Primus
service, waitress

Additional experience:

since December 2013

(on a freelance basis)
Event location Colosseum XXI, Cater-Carlo-Catering GmbH, A- 1210 Wien
service, waitress, wardrobe

since March 2013

(on a freelance basis)
KLAVIER*galerie*, Wendl & Lung, Klavierbau und Vertriebs GmbH, A-1070 Wien
receptionist, office, events, customer service

Member of staff at „Handicraft work with children“
(on a freelance basis)
Austrian Forest Products Research Society, summer fête 2014
Vienna City Festival, 2014
Vienna City Festival, 2012
Vienna City Festival, 2011
Festival of Lights at Donaukanal, 2010
Vienna City Festival, 2010

Mentoring for beginners of Bachelor's program "Biology", 2011
University of Vienna

Private tuition for teaching subjects Mathematics, German and English, 2005-2009

Language skills:

German
Mother Tongue

English
Fluent

French
Intermediate