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Cloud cover but not artificial light pollution affects the morning activity of Wood Pigeons

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Light pollution, especially artificial light at night, has been repeatedly found to affect bird behaviour, resulting in an earlier start of morning activities. However, as thus far only a limited number of species has been investigated, the generality of the effects of light pollution on animal behaviour is difficult to assess. As such effects may be less pronounced in species starting their activity at rather high light intensities, we here investigated the effects of artificial light on the morning activity of a late-active non-passerine, the Wood Pigeon (*Columba palumbus*), within the breeding period in north-eastern Germany. Additionally, we scored prevailing weather conditions, which typically also affect morning activity. Despite pronounced differences in the distance to the nearest artificial light source and in mean radiance between urban and rural Wood Pigeons, the onset of morning activity did not differ between the two habitat types. Instead, it was affected by prevailing weather conditions (temperature, cloud cover). We conclude that responses to light pollution are likely species-specific, and that species starting their activity late in the day may be in general less affected. For such species prevailing weather conditions are likely more important for daily activity patterns than light pollution.

1. Introduction

The impacts of urbanisation and sprawl are becoming ever more important, owing to the increasing human population as well as changes in human life styles (Kempenaers *et al.* 2010, Gaston *et al.* 2015). Urban environments are characterised by high levels of noise and light pollution, both of which may substantially alter animal behaviour (Kempenaers *et al.* 2010, Kyba *et al.* 2011). Light pollution through artificial light at night may easily affect bird behaviour, which is typically triggered by changes in the photoperiod (Lambrechts *et al.* 1997, Cinzano *et al.* 2001, Dawson *et al.* 2001). Accordingly, artificial light was found to cause earlier dawn song and activity in several songbirds (Kempenaers *et al.* 2010, Dominoni *et al.* 2014, Da Silva *et al.* 2015). As the above traits are related to fitness, with e.g., bird song affecting mate choice, intraspecific competition, and territory defence (York *et al.* 2014), such changes may feedback on population dynamics. Some authors speculated that artificial light at night might have positive effects on fitness, owing to the earlier seasonal and daily activity (Chamberlain *et al.* 2009, Byrkjedal *et al.* 2012, Dominoni *et al.* 2014, Da Silva *et al.* 2015). On the other hand, early activity may increase predation risk and stress levels, which may result in decreased fitness (Da Silva *et al.* 2015). Either way, the generality of the effects of light pollution on bird behaviour are currently difficult to assess, owing to a limited number of studies and potential variation among species (Byrkjedal *et al.* 2012).

Notwithstanding, the onset of morning activities in birds also varies for natural reasons, namely the timing of sun dawn and prevailing weather conditions including cloud cover, temperature, wind, precipitation, and atmospheric pressure (Kreithen & Keeton 1974). For instance, cloudy conditions typically delay the onset of dawn song due to reduced sky radiance, such that the critical light intensity is reached at a later time (Kyba *et al.* 2011, Bruni *et al.* 2014). Likewise, song activity is typically reduced under cool conditions (Nordt & Klenke 2013, Da Silva *et al.* 2015). In summary, while light is clearly important for the timing of dawn song activity, it is by no means the only factor affecting such behavioural patterns.

Here, we investigated the onset of dawn activity in the common Wood Pigeon (*Columba palumbus*, L.), inhabiting rural versus urban habitats, in north-eastern Germany in spring. We have deliberately decided to work on this species because (1) it occurs at high abundances in rural as well as urban habitats (Gedeon *et al.* 2014), (2) starts its daily activity much later than most other birds investigated within the context of light pollution thus far (e.g., Dominoni *et al.* 2013, Da Silva *et al.* 2015), and (3) as it comprises a non-passerine on which in general little is known within the given context to date. In our analyses, we included distance to artificial light sources, sky radiance, and prevailing weather conditions in order to assess which source of variation has the strongest impact on the onset of morning activity. Specifically, we test the following hypotheses: (1) In contrast to birds starting their morning activity at very low light intensities already, late active Wood Pigeons should not respond to artificial light at night. (2) Prevailing weather conditions have, overall, a stronger impact on the onset of morning activities than artificial light in Wood Pigeons.

2. Material and methods

2.1. Study organism

The Wood Pigeon is distributed from north-western Africa and Europe to West Siberia and China (Limbrunner *et al.* 2007). The species inhabits various landscapes ranging from coastal to mountainous areas. Essential habitat features include areas with low and sparse vegetation for foraging and at least some trees or shrubs for nesting. In Central Europe, the mating season starts at the end of March, during which males call and court females predominantly during morning hours (Glutz von Blotzheim & Bauer 2001). First settlements of Wood Pigeons in urban areas were observed in the early 19th century. Since the 1960s the species has increasingly colonized even the centres of cities (Glutz von Blotzheim & Bauer 2001). The German breeding population is currently estimated at 2.6–3.1 million pairs, with highest densities occurring in urban parks and floodplains (Gedeon *et al.* 2014).

2.2. Study area and data acquisition

The study area is located in north-eastern Germany, Mecklenburg – Western Pomerania, around the city of Greifswald. It covers an area of approximately 60 km^2 including the city itself as well as surrounding forests. Pigeon density is substantially higher in urban versus rural areas in this region (Starke 2010). Due to the influence of the nearby Baltic Sea summer and winter are relatively mild, averaging at an annual temperature of 8.2°C (Deutscher Wetterdienst 2013). The study area is mainly characterized by urban areas and crop fields, which are interspersed with forests, grassland, and wetlands.

Between 13th and 19th April Wood Pigeon territories (n = 48) were mapped by locating calling males. Territories were located in either rural or urban habitats (n = 24 each) to maximise differences in the exposure to artificial light sources. Thus, all rural territories were located in woodland, while all urban territories were located within the city of Greifswald. We did not carry out a complete inventory of pigeon territories, but simply aimed at finding a fair number of territories per habitat type. Each territory was afterwards visited twice between 20th April and 7th May to record the start of morning activities. We did not search for individual birds to avoid disturbance, but carefully approached the presumed centre of the respective territory. Fieldwork always started at least 90 minutes before sunrise, ensuring that first bird activities were not initiated by the observers. The first activities observed were typically calls, but in some cases Wood Pigeons took off before calling. Therefore, both the time of first calling and the time of first overall activity (including calling but not being restricted to it) were recorded. All time measures were calculated relative to the time of dawn, i.e., as minutes before or after sunrise.

To control for observer bias and variation in the onset of morning activities due to prevailing weather conditions, teams of four persons each were built. Additionally two territories each were “paired”, with each pair consisting of a rural and an urban territory. To rule out that results are affected by weather, both paired territories were always visited on the same morning by two persons each (i.e., each team was split into 2 × 2). For the second visit of the same pair of territories, locations were switched among groups. Thus, the two persons having visited the urban territory upon the first visit, switched to the rural territory and vice versa. Each four-person team scored activity data for six territory pairs.

To assess exposure to light pollution, the distance between the position of the first active Wood Pigeon per territory and the nearest light source illuminating all night (usually a street lamp) was measured. Street lamps were generally still active when pigeons started their activity. For short distances, a folding ruler was used and for longer distances digital maps (www.gaia-mv.de). A similar approach was used by Kempenaers *et al.* (2010) and Da Silva *et al.* (2014). Here, the authors compared territories close to and further away from street lamps, revealing that 4 out of 5 and 5 out of 6 common forest-breeding songbirds started singing significantly earlier at dawn at locations close to a street lamp than elsewhere in the forest. To further corroborate that urban and rural Wood Pigeons differed in the exposure to light pollution, we measured the mean radiance (10^{-9} Watt / cm^2 × steradian) for each individual territory in 2015 using a digital light pollution map (http://www.lightpollutionmap.info; accessed 4th January 2016). Within the respective map, light pollution is given in classes. We located the centre of each territory on the light pollution map, and scored the radiance at that point as the mean value of the respective category. Additionally, we scored for each observation day ambient temperature (°C), wind speed (m / sec), and cloud cover (number of eighths of the sky covered by clouds: 0 / 8 = cloudless, 8 / 8 = completely overcast) at sunrise (using WeatherPro Premium v3.0.2). WeatherPro provides high resolution weather records for over two million locations worldwide (see www.apkmirror-full.com).

2.3. Statistical analyses

All statistical analyses were carried out using SPSS 21.00 (SPSS Inc., Chicago, IL, USA). Distances to artificial light sources and in radiance across habitat types (rural versus urban) were compared using Mann–Whitney U-tests. For the first variable, the same test was used to test for differences between first and second records (termed “blocks”) per territory. Variation in the onset of calling and overall activity was explored using linear mixed models with block, habitat type, and team as categorical factors and temperature, wind speed, cloud cover, and distance to artificial light sources as covariates. Team was included as a random factor. Models based on a stepwise forward selection of variables yielded results qualitatively identical to those reported in Table 1. All correlation coefficients among the continuous variables included within the same model were below 0.31. Throughout the text all means are given ± 1 SE.

3. Results

Pigeons in rural areas were found at larger distances to artificial light sources compared with those in urban areas (662.5 ± 341.4 m versus 27.9 ± 7.7 m; $Z_{96} = 8.4, p < 0.001$; blocks: $Z_{96} = 0.02, p = 0.985$). Likewise, radiance was much higher in urban (21.5 ± 1.4 10^{-9} Watt / cm^2 × steradian) than in rural habitats (1.8 ± 1.4 10^{-9} Watt / cm^2 × steradian; $Z_{48} = 5.7, p < 0.001$). The onset of first calling activities though was significantly affected by cloud cover and team only, but not by habitat type or the distance to the next artificial light source (Table 1a, Fig. 1). Additionally, calling activity tended to be affected by temperature. A qualitatively identical pattern was found for the onset of first overall activities (Table 1b). Higher temperatures tended to cause earlier morning activity, while cloudier conditions delayed morning activity.

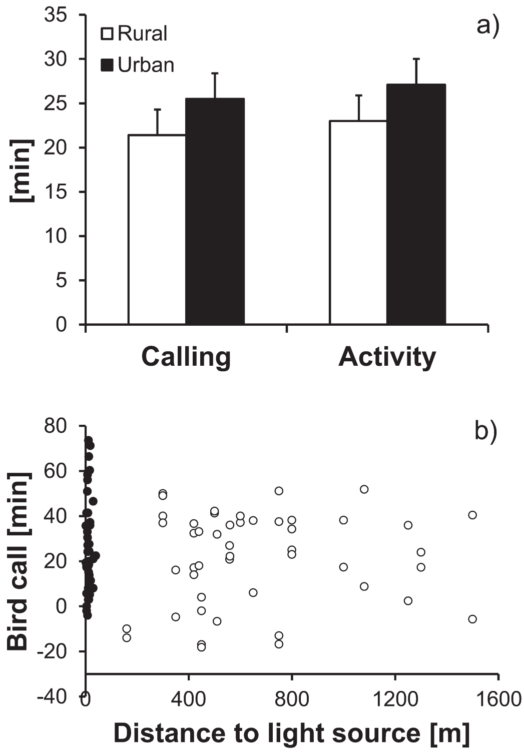

Fig. 1. The onset of Wood Pigeon calling activity and overall activity given as minutes before sunrise (means + 1 SE) in relation to habitat type (rural versus urban; a), and the onset of Wood Pigeon calling activity in relation to the distance to the next artificial light source (filled symbols: urban habitat; open symbols: rural habitat).

4. Discussion

Light pollution has been repeatedly found to affect bird behaviour, amongst other species, resulting in an earlier start of dawn song (Rowan 1938, Partecke *et al.* 2005, Miller 2006, Kempenaers *et al.* 2010, Nordt & Klenke 2013, Da Silva *et al.* 2014, Dominoni *et al.* 2014, Gaston *et al.* 2015). This is not surprising, as light intensity is considered to be the proximate cue initiating the dawn chorus of birds (Miller 2006, Dominoni *et al.* 2014). Our results on Wood Pigeons in north-eastern Germany, though, suggest that morning activity in this particular species is not significantly affected by light pollution, but rather by prevailing weather conditions (temperature, cloud cover). This pattern prevailed despite the fact that the distances to the next artificial light source and sky radiance differed greatly between individuals inhabiting rural or urban habitats. Note, the highly controlled design of our study, accounting for variation in weather conditions as well as observer bias, rendering it unlikely that our results are confounded by methodological shortcomings in spite of the rather high number of observers involved. What may explain the obvious discrepancy between our and other studies on the effects of light pollution on bird activity?

First and perhaps most likely, Wood Pigeons may differ from other bird species investigated in the given context thus far. Hitherto, effects of light pollution have been almost exclusively investigated in song birds, starting to sing at very low light intensities, such as European Robins (*Erithacus rubecula*), Song Thrushes (*Turdus philomelos*) and Common Blackbirds (*Turdus merula*) (Miller 2006, Kempenaers *et al.* 2010, Nordt & Klenke 2013, Da Silva *et al.* 2014, Dominoni *et al.* 2014, Gaston *et al.* 2015). In contrast, Wood Pigeons start daily activity rather late at relatively high light intensities (Murton 1965). In our study, pigeon activity started on average only 25 min before sunrise, i.e., at a point in time when it was already light. While it is easily conceivable that light pollution changes light intensities early in the morning, i.e., when it is still dark or at the beginning of civil twilight, its impact is expected to di-

Table 1. Results of linear mixed models for the onset of first calling (a) and first overall activity (b) in wood pigeons in relation to block (first vs. second records), habitat type (rural vs. urban), team of investigators, temperature, wind speed, cloud cover, and distance to the next artificial light source. The variables “block” and “habitat” were considered fixed, the variable “team” random, and the remaining variables were considered covariates. Significant *p*-values are given in bold. MS: mean square; Beta: standardised coefficient; Eta^2: effect size, partial squared Etas.

(a)	*df*	*MS*	Beta ± SE	Eta^2	*F*	*p*
Intercept	1	10436,027	–	0.118	6.84	**0.012**
Block (fixed)	1	869,777	–	0.010	0.66	0.417
Habitat (fixed)	1	240	–	< 0.001	< 0.01	0.989
Team (random)	3	4,818,930	–	0.112	3.68	**0.015**
Temperature	1	4,676,987	0.20 ± 0.11	0.043	3.57	0.062
Wind	1	269,956	–0.05 ± 0.11	0.003	0.21	0.651
Cloud cover	1	7,683,092	–0.25 ± 0.10	0.065	5.86	**0.018**
Light distance	1	719,763	–0.13 ± 0.18	0.005	0.55	0.461
Error	86	1,310,103	–	–	–	–
(b)	*df*	*MS*	Beta ± SE	Eta^2	*F*	*p*
Intercept	1	14,096,492	–	0.157	8.96	**0.004**
Block (fixed)	1	273,056	–	0.004	0.21	0.652
Habitat (fixed)	1	60,698	–	< 0.001	0.05	0.831
Team (random)	3	5,252,639	–	0.119	3.94	**0.011**
Temperature	1	4,084,346	0.19 ± 0.11	0.036	3.07	0.083
Wind	1	549,197	–0.07 ± 0.11	0.006	0.41	0.522
Cloud cover	1	5,767,337	–0.22 ± 0.10	0.048	4.33	**0.040**
Light distance	1	1,319,855	–0.18 ± 0.18	0.009	0.99	0.322
Error	86	1,331,690	–	–	–	–

minish with increasing natural light intensity, owing to the much higher intensity of solar radiation as compared with artificial light sources. Therefore, the additional illumination caused by artificial light sources may in general have little impact on animals starting their activity at high light intensities. Testing this prediction was a principal motivation of our study, which is why we decided to work on a late-active non-passerine. Such species might be in general more strongly affected by prevailing weather conditions than light pollution, as has been found in our study. While cloud cover directly impacts on light intensity, there is also firm evidence that other factors such as temperature, precipitation and wind result in a later start of singing activity in birds (Hasan 2010, Nordt & Klenke 2013, Bruni *et al.* 2014, Da Silva *et al.* 2015). To what extent such patterns may be additionally affected by food type or body size, with the rather large Wood Pigeons being potentially energetically less constrained than smaller species, is currently unclear. Also, little is known on the factors determining whether a given species is active rather early or late in the morning, though visual capabilities and especially eye size seems to have a strong impact, with species having larger eyes starting to sing earlier than those with smaller eyes (Thomas *et al.* 2002).

Second, levels of light pollution may have been too small to detect biological effects in our study area. Note that Greifswald is a rather small city compared with other urban areas in which similar studies have been performed (e.g., Nordt & Klenke 2013, Dominoni & Partecke 2015). Also, we did not measure light intensity directly at the observation points, but used the distance to the next artificial light source instead as a proxy. However, sky radiance was highly divergent between rural and urban habitats. While urban Wood Pigeons occurred always in the vicinity of artificial light sources, this was never the case for rural Wood Pigeons, because all respective territories were located within woods without sight on any artificial light sources. Other studies did find an impact of such differences on the morning activity of several songbird species (Kempenaers *et al.* 2010, Da Silva *et al.* 2014).

Third, our behavioural observations took place end of April / beginning of May, i.e., during a time of year when day length is already quite long in central Europe. Longer day lengths though may release the pressure on animals to start their daily activity particularly early. Concomitantly, effects of light pollution on bird activity have been found to be more pronounced early in spring, making it difficult to pick up such an effect late in the season (Nordt & Klenke 2013). Russ *et al.* (2014), for instance, found that the difference between urban and rural blackbirds in the end of foraging activity was highest in March but had decreased considerably by the middle of April. Moreover, Wood Pigeons had already formed pairs and occupied territories during the study period, which typically reduces calling activity (Glutz von Blotzheim & Bauer 2001).

To sum up, we could not detect an impact of light pollution, measured as distance to the next artificial light source and sky radiance, on the onset of morning activities in Wood Pigeons in northeastern Germany. Although methodological issues (lack of data on light intensities, rather small city, and timing of fieldwork) may have contributed to this negative result, we tentatively suggest that light pollution does not uniformly affect all wildlife, but that effects are mainly to be found in species starting their morning activities at low light intensities. In contrast, species starting their activity later in the day should be in general less affected. We further suggest that in late-active animals prevailing weather conditions may have a larger impact on daily activity patterns than light pollution. As environmental factors may influence dawn song activity differentially across species (Bruni *et al.* 2014), including a wider range of species is desirable in order to assess the generality of the effects of light pollution on animal behaviour. Furthermore, the fitness consequences of artificial light pollution are largely unknown, also indicating that more research is necessary (Kempenaers *et al.* 2010, Kyba *et al.* 2011). Finally, it would be important to investigate whether and how fast-moving species are able to adapt genetically to artificial light at night and urban environments in general. Potential target traits include eye size but also genes related circadian rhythms (Thomas *et al.* 2002, Dominoni *et al.* 2013, Swaddle *et al.* 2015).

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Pilvipeite vaikuttaa sepelkyyhkyn aamuaktiivisuuteen toisin kuin kenotekoinen valosaaste

Valosaaste, varsinkin öinen keinovalo, on toistuvasti todettu vaikuttavan lintujen käyttäytymiseen, johtaen aamutoimien aikaistumiseen. Valosaasteen yleisiä vaikutuksia eläimiin on kuitenkin vaikea arvioida, sillä tähän mennessä tarkastelun kohteena on ollut pienehkö määrä lajeja. Havaitut vaikutukset saattavat olla heikommat lajeilla jotka aktivoituvat vasta myöhemmin aamulla, valoisammissa olosuhteissa. Tässä tutkimuksessa tarkastelimme miten keinovalo vaikutti myöhään aktivoituvan lajin – sepelkyyhkyn – aamuaktiivisuuden ajoittumiseen pesimäaikaan Koillis-Saksassa. Tarkastelimme lisäksi vallitsevia säätekijöitä, jotka tyypillisesti myös vaikuttavat aamuaktiivisuuteen.

Etäisyydessä lähimpään kenovalon lähteeseen oli suuria eroja reviirien välillä. Myös urbaanien- ja maaseudun alueiden reviirien välillä oli suuria eroja keskikirkkaudessa. Siitä huolimatta, aamuaktiivisuuden aloitus ei eronnut merkitsevästi valosaasteen määrän tai habitaattien välillä. Sen sijaan, siihen vaikutti sääolosuhteet, kuten lämpötila ja pilvipeite. Päättelemme, että valosaasteen vasteet ovat lajikohtaisia, ja että lajit jotka aloittavat aamuaktiivisuutensa suhteellisesti myöhemmin saattavat olla vähemmän herkkiä keinovalolle. Näillä lajeilla, sääolosuhteet ovat todennäköisesti valosaastetta tärkeämpi tekijä päivän rytmittämisessä.

References

Bruni, A., Mennill, D.J. & Foote, J.R. 2014: Dawn chorus start time variation in a temperate bird community: relationships with seasonality, weather, and ambient light. — Journal of Ornithology 155: 877–890.

Byrkjedal, I., Lislevand, T. & Vogler, S. 2012: Do passerine birds utilise artificial light to prolong their diurnal activity during winter at northern latitudes? — Ornis Norvegica 35: 37–42.

Chamberlain, D.E., Cannon, A.R., Toms, M.P., Leech, D.I., Hatwell, B.J. & Gaston, K.J. 2009: Avian productivity in urban landscapes: a review and meta-analysis. — Ibis 151: 1–18.

Cinzano, P., Falchi, F. & Elvidge, C.D. 2001: The first world atlas of the artificial night sky brightness. — Monthly Notices of the Royal Astronomical Society 328: 689–707.

Da Silva, A., Samplonius, J.M., Schlicht, E., Valcu, M. & Kempenaers, B. 2014: Artificial night lighting rather than traffic noise affects the daily timing of dawn and dusk singing in common European songbirds. — Behavioral Ecology 25: 1037–1047.

Da Silva, A., Valcu, M. & Kempenaers, B. 2015: Light pollution alters the phenology of dawn and dusk singing in common European songbirds. — Philosophical Transactions of the Royal Society B 370: 20140126.

Dawson, A., King, V.M., Bentley, G.E. & Ball, G.F. 2001: Photoperiodic control of seasonality in birds. — Journal of Biological Rhythms 16: 365–380.

Deutscher Wetterdienst 2013: www.dwd.de (accessed 19th June 2015).

Dominoni, D.M. & Partecke, J. 2015: Does light pollution alter daylength? A test using light loggers on free-ranging European blackbirds (*Turdus merula*). — Philosophical Transactions of the Royal Society B: 370: 20140118.

Dominoni, D.M., Helm, B., Lehmann, M., Dowse, H.B. & Partecke, J. 2013: Clocks for the city: circadian differences between forest and city songbirds. — Proceedings of the Royal Society B 280: 20130593.

Dominoni, D.M., Carmona-Wagner, E.O., Hofmann, M. & Kranstauber, B. 2014: Individual-based measurements of light intensity provide new insights into the effects of artificial light at night on daily rhythms of urban-dwelling songbirds. — Journal of Animal Ecology 83: 681–692.

Gaston, K.J., Visser, M.E. & Hölker, F. 2015: The biological impacts of artificial light at night: the research challenge. — Philosophical Transactions of the Royal Society B 370: 20140133.

Gedeon, K., Grüneberg, C., Mitschke, A., Sudfeldt, C., Eikhorst, W., Fischer, S., Flade, M., Frick, S., Geiersberger, I., Koop, B., Kramer, M., Krüger, T., Roth, N., Ryslavy, T., Stübing, S., Sudmann, S.R., Steffens, R., Vökler, F. & Witt, K. 2014: Atlas of German breeding birds. — Stiftung Vogelmonitoring Deutschland & Dachverband Deutscher Avifaunisten, Münster. (In German)

Glutz von Blotzheim, U.N. & Bauer, K.M. 2001: Handbuch der Vögel Mitteleuropas, vol. 9. — Aula Verlag, Wiesbaden. (In German)

Hasan, N.M. 2010: The effect of environmental conditions on the start of dawn singing of blackbirds (*Turdus merula*) and bulbuls (*Pycnonotidae*). — Jordan Journal of Biological Sciences 3: 13–16.

Kempenaers, B., Bergström, P., Loës, P., Schlicht, E. & Valcu, M. 2010: Artificial night lighting affects dawn song, extra-pair siring success, and lay date in songbirds. — Current Biology 20: 1735–1739.

Kreithen, M.L. & Keeton, W.T. 1974: Detection of changes in atmospheric pressure by the homing pigeon, *Columba livia*. — Journal of Comparative Physiology A 89: 73–82.

Kyba, C.C.M., Ruhtz, T., Fischer, J. & Hölker, F. 2011: Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. — PLOS ONE 6: e17307.

Lambrechts, M.M., Blondel, J., Maistre, M. & Perret, P. 1997: A single response mechanism is responsible for evolutionary adaptive variation in a bird's laying date. — Proceedings of the National Academy of Sciences of the United States of America 94: 5153–5155.

Limbrunner, A., Bezzel, E., Richarz, K. & Singer, D. 2007: Enzyklopädie der Brutvögel Europas. — Franckh-Kosmos, Stuttgart. (In German)

Miller, M.W. 2006: Apparent effects of light pollution on singing behavior of American robins. — The Condor 108: 130–139.

Murton, R.K. 1965: The wood-pigeon. — Collins, London.

Nordt, A. & Klenke, R. 2013: Sleepless in town – drivers of the temporal shift in dawn song in urban European blackbirds. — PLOS ONE 8: e71476.

Partecke, J., Van't Hof, T.J. & Gwinner, E. 2005: Underlying physiological control of reproduction in urban and forest-dwelling European blackbirds *Turdus merula*. — Journal of Avian Biology 36: 295–305.

Rowan, W. 1938: London starlings and seasonal reproduction in birds. — Proceedings of the Zoological Society of London 108: 51–78.

Russ, A., Rüger, A., & Klenke, R. 2014: Seize the night: European blackbirds (*Turdus merula*) extend their foraging activity under artificial illumination. — Journal of Ornithology 156: 123–131.

Starke, W. 2010: Die Brutvögel der Stadt Greifswald. — Natur und Naturschutz in Mecklenburg-Vorpommern 40: 1–173.

Swaddle, J.P., Francis, C.D., Barber, J.R., Cooper, C.B., Kyba, C.C.M., Dominoni, D.M., Shannon, G., Aschehoug, E., Goodwin, S.G., Kawahara, A.Y., Luther, D., Spoelstra, K., Voss, M. & T. Longcore 2015: A framework to assess evolutionary responses to anthropogenic light and sound. — Trends in Ecology and Evolution 30: 550–560.

Thomas, R.J., Székely, T., Cuthill, I.C., Harper, D.G.C., Newson, E., Frayling, T.D. & Wallis, P.D. 2002: Eye size in birds and the timing of song at dawn. — Proceedings of the Royal Society B: 269: 831–837.

York, J., Young, A. & Radford, A.N. 2014: Singing in the moonlight: dawn song performance of a diurnal bird varies with lunar phase. — Biology Letters 10: 20130970.