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Winter night inspections of nest boxes affect their occupancy and reuse for roosting by cavity nesting birds

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Abstract. Overwintering strategies are important for the survival of resident birds in temperate climates and among the most important are adjustments in roosting behaviour. In cavity roosting birds, previous studies have frequently used contact checks of man-made nest boxes to quantify roost-site occupancy. However, there is a concern that occupancy rate estimated by this method may be biased due to procedural disturbance. In this study, we quantified this potential bias by examining the winter time occupancy of 182 nest boxes in a floodplain forest in the Czech Republic. Nest boxes were checked three times a month from November to February 2007–2010 by three methods with decreasing level of potential disturbance. We obtained 1319 records of roosting birds of three species, with 94% being Great Tits, *Parus major*. We found a considerable decline in nest box occupancy throughout the winter when using the contact method (capture and handling of the bird), whilst occupancy rates remained constant when using the two non-contact methods (visual inspection of the opened nest box; the inspection by Infra red light mini camera passed through the entrance). The contact method was also associated with lower reuse rate of individual nest boxes. In conclusion, the commonly used direct night checks of nest boxes caused a disturbance to roosting birds and thus can lead to biased conclusions when studying winter time roosting behaviour in birds. More generally, this study demonstrates that using nest boxes may introduce bias in studies conducted during the non-breeding season, similarly as has been demonstrated for studies conducted in the breeding season.

Key words: nest box, handling, mini-camera, Great Tit, *Parus major*, roosting, methods, hole nesting birds

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INTRODUCTION

Winter is a critical period for the survival of animals living at high latitudes. In particular, birds encounter here the multiple pressures of low food abundance, low temperatures and prolonged night time fasting, which imposes considerable requirements for efficient energy management (Moore 1945, Pravosudov & Grubb 1997, Carey & Dawson 1999, Brodin 2007). Illustratively, empirical studies report significant reductions in the populations of resident bird species during the winter period. Thus, understanding survival strategies during winter is critical for a deeper understanding of population regulation and also for conservation of natural populations (review in Newton 1998).

Winter survival strategies depend on the ability to manage energy in terms of increasing the availability and reducing the expenditure. Energy availability may be increased by seasonal acclimatization (Dawson & Smith 1986, Carey & Dawson 1999, Broggi et al. 2004), increased fat reserves (Lehikoinen 1987, Houston & McNamara 1993, Polo et al. 2007), switching to more energetic food or making food storages (Gibb 1960, Nilsson et al. 1993, Pravosudov & Grubb 1997), and/or flocking when foraging (Suhonen et al. 1993, Lima et al. 1999, Krams 2002). Energy expenditure may be reduced by hibernation (known in the Common Poorwill *Phalaenoptilus nuttallii*; Jaeger 1949, Withers 1977), night time hypothermia (Mayer et al. 1982, Reinertsen & Haftorn 1986, Cooper & Gessaman 2005), and/or selection of a suitable roost (Moore 1945, Webb & Rogers 1988, Cooper 1999), sometimes combined with grouping within a roost (Knorr 1957, McGovan et al. 2006).

Although open roosts (e.g., in vegetation) are more frequent in birds (Moore 1945, Walsberg 1986, Webb & Rogers 1988), closed ones, especially tree cavities, seem to be more suitable in terms of temperature (Kendeigh 1961, Cooper 1999, Paclík & Weidinger 2007). Previous quantitative studies on cavity roosting in birds frequently focused on the occupancy of cavities (proportion of occupied cavities) and related factors, and were conducted almost exclusively on artificial nest boxes (Kluyver 1957, Czarnecki 1960, Busse & Olech 1968, Schmidt et al. 1985, Drent 1987, Winkel & Hudde 1988, Báldi & Csörgő 1994, Krištín et al. 2001, Veľký 2002, 2006, Dhondt et al. 2010), obviously because of their relative excellence in collecting vast amounts of data on both bird nesting and roosting (for review see Mainwaring 2011). Although patterns varied, nest box occupancy by roosting birds was usually found to decrease as the winter progressed (Kluyver 1957, Báldi & Csörgő 1994, 1997, Krištín et al. 2001, Veľký 2006; but see Schmidt et al. 1985, Prskavec 1989, 1996), and to increase with decreasing ambient temperatures (Busse & Olech 1968, Veľký 2002; but see Veľký 2006). However, the above results are based on the contact night checks of nest boxes, during which the birds were handled, usually for ringing, and thus disturbed (for references see above). Consequently, there is a concern that such checks may force birds to change their roosting places more often than they would do if left undisturbed or ultimately leave the study plot (Czarnecki 1960, Schmidt 1985, Drent 1987). As the checks are regularly repeated, the cumulative disturbing effect may lead to decreasing occupancy during the non-breeding season, although it may to some degree occur naturally due to winter mortality or emigration of individuals (Newton 1998). Fortunately, the availability of new technologies enable less invasive non-contact checking and hence, an opportunity to examine the bias of the contact check method; here we use Infra red (IR) mini cameras (Richardson et al. 1999, Huebner & Hurteau 2007, Steinmeyer et al. 2010). More generally, although nest box bias in studies of bird nesting has been widely discussed (Møller 1989, Lambrechts et al. 2010, Wesołowski 2011), potential biases in studies of winter time roosting of birds in nest boxes has been ignored.

In this study, we estimate the degree to which the commonly used contact method of night checks of boxes with catching and handling the birds biases the studies of winter time roosting by birds in nest boxes. We conducted a field experiment with one contact (capture and handling of the bird) and two non-contact (visual inspection of the opened nest box and the inspection by IR light mini camera passed through the entrance) methods of checks characterized by decreasing intensity of disturbance to birds. We made the following two predictions: first, the occupancy of nest boxes by roosting birds will decrease throughout the winter more steeply in the contact method than in the other two, non-contact methods. Second, the rate of reuse of individual boxes will be lowest in the contact method, presumably because birds will shift between roosts more often and may leave the boxes or even plots more frequently than in the non-contact methods.

MATERIALS AND METHODS

Study site and data collection

The fieldwork was carried out in managed floodplain forest Království near the village of Grygov (Olomouc district, 49°31'N, 17°18'E, altitude 204 m), in the Czech Republic. The canopy trees were about 60–120 years old and the dominant species were the Pedunculate Oak *Quercus robur*, Large-leaved Linden *Tilia platyphyllos*, Hornbeam *Carpinus betulus*, Black Alder *Alnus glutinosa*, and European Ash *Fraxinus excelsior*. Dominant understory species were the Bird Cherry *Prunus padus*, and Alder Buckthorn *Frangula alnus*. Three squared nest box plots, 50–200 m apart (the closest distance between neighbouring borders) were established in the middle of ca. 600 ha forest in 2004. Study plots consisted of more or less homogeneous forest stands, while some clear-cuts were present between plots. In total, we used 185 nest boxes (79, 58 and 48 boxes on the three respective plots) that were spaced in ca. 40 m-grid and placed about 160 cm high above the ground. Wooden nest boxes were of typical passerine dimensions 115 × 125 × 260 mm (internal width × length × height) with the entrance diameter of 32 mm directed mostly southwards, and the lower entrance rim at 17.5 cm above the nest box bottom (see Lambrechts et al. 2010). Each season, three boxes (each in the middle of the study plot) were equipped with data loggers (H8 Temp/External, Onset Computer Corp., Pocasset, MA, USA) for measuring ambient and inner temperature of the nest box (but only ambient temperature was used in analysis here), while the entrances were blocked by netting; thus, birds could use for roosting the remaining 182 boxes. The data loggers were programmed to take the temperature measurements every 12 minutes.

We collected data during three winter periods from November to February 2007–2010. The night checks of all nest boxes were performed regularly in ca. 10-day intervals (median, range = 5–16 days), starting 30 minutes after sunset. We carried out 12 night checks in each winter; the first check was conducted on 5–6 November and the last on 23–26 February. We concurrently applied three methods of nest box checks with varying intensity of disturbance to birds, each method on a different plot in a given year, while the methods were rotated among plots in successive winters. In effect, all three methods were used on every plot during the three winters. In the supposedly most disturbing contact method (see also Czarnecki 1960, Busse & Olech 1968, Báldi & Csörgő 1994, 1997, Krištín et al. 2001, Veľký 2006), hereafter called "Capture", we carefully opened the nest box, caught and handled the bird for time necessary to ring it and determine its age and sex. Finally, we put the bird back through the entrance to the closed nest box and waited usually 10–15 seconds until it calmed down. The other two methods of checks were non-contact as the bird was not handled (Table 1). In the "Open & look" method, we carefully opened the nest box and observed the interior while using red visible light to determine the roosting bird (white light was used in Capture method). The lowest level of disturbance was presumed for the "Camera" method consisting of carefully inserting a miniature IR light camera through the entrance to the closed nest box and checking the content from the monitor. Each winter, we performed the Capture method on all three plots during the final check to find out if some ringed birds from a plot with the contact method moved to other plots.

Data analysis

First, we examined if changes in nest box occupancy (i.e., proportion of occupied boxes) throughout the winter were influenced by the method of night checks. We used a general linear mixed-model fitted in the MIXED procedure in SAS 9.2 (SAS Institute Inc.). The occupancy of all boxes on an individual plot at each check event was set as the dependent variable. The method of night check (Capture, Open & look, and Camera), ambient temperature in the date of check treated as night time mean, and the difference between daily maximum and the night time minimum (as night time we took the period between sunset and the following sunrise; see Paclík & Weidinger 2007), the order of the check in the season, i.e., check number 1 (early November) to 12 (end of February) and an interaction between the order of the check and the method were included as fixed effects. Independent random effect variables included the season (2007/08, 2008/09, 2009/10) and plot (1–3; in each season we used the same three plots). As a repeated effect, we set the series of the 12 seasonal checks on every plot in every season (Series) resulting in nine subjects (three plots × three seasons = 1 to 9).

Second, we tested if the re-use rate of individual nest boxes (i.e., the number of roosting events per nest box and season out of 12 checks) was influenced by the method of night checks. We fitted Poisson model with a correction for over-dispersion in the GLIMMIX procedure in SAS 9.2. Independent variables included the method (fixed effect), plot, and season (both random effects). Denominator degrees of freedom were calculated in both models by the Satterthwaite method. The variability in re-use rate of individual boxes among methods was tested by Bartlett test on variances.

Table 1. Types of disturbance of roosting birds across three methods of night checks used in the present study. * — less disturbing red (instead of white) visible light was used.

	Capture	Open & look	Camera
Handling	+	–	–
Visible light stimulus	+	+/–*	–
Opening the nest box (temperature and rustle stimuli)	+	+	–

RESULTS

Altogether, we obtained 1319 roosting records of three bird species out of the total of 6552 box × nights during the three winters (524 roosting records in the winter 2007/2008, 449 in 2008/2009, and 346 records in 2009/2010, respectively). These included 1237 records of roosting Great Tits *Parus major* (94%; 24 to 47 individuals per check of all three plots, mean = 34.4), 68 records of Nuthatches *Sitta europaea* (5%; 0 to 8 individuals per check, mean = 1.9), and 14 records of Blue Tits *Cyanistes caeruleus* (1%; 0 to 3 individuals per check, mean = 0.4). Of the total, the Capture method provided the lowest number of 250 roosting records, followed by the Open & look method with 525 records, and the Camera method with 544 records.

Per check occupancy of nest boxes varied from 0 to 0.30 (mean = 0.11, n = 36 checks) in the Capture method, from 0.13 to 0.44 (mean = 0.24) in Open & look method, and from 0.14 to 0.34 (mean = 0.25) in the Camera method. We found a considerable decline in the occupancy of nest boxes with throughout the winter in the Capture method, but not in the two less disturbing non-contact methods, and this pattern was consistent among seasons (Table 2, Fig. 1). When using the Capture method, nest box occupancy steeply decreased during the first five checks in the season and then continued to be steadily depressed (Fig. 1). The Capture method lowered the average re-use rate of individual nest boxes (Table 3, Fig. 2) and also its variance (Bartlett test: $F_{2,542} = 100.3$, $p < 0.001$; Fig. 2), because comparatively low number of reuses was found in this method.

None of the two measures of ambient temperature (night time means and day-to-night fluctuations) influenced the occupancy of nest boxes by roosting birds (Table 2). Finally, none of 68 individual birds ringed/controlled on the Capture plots in the three winters (59 Great Tits, 6 Nuthatches, and 3 Blue Tits) was found on non-contact plots during the final check in each season, suggesting low importance of bird movements among plots.

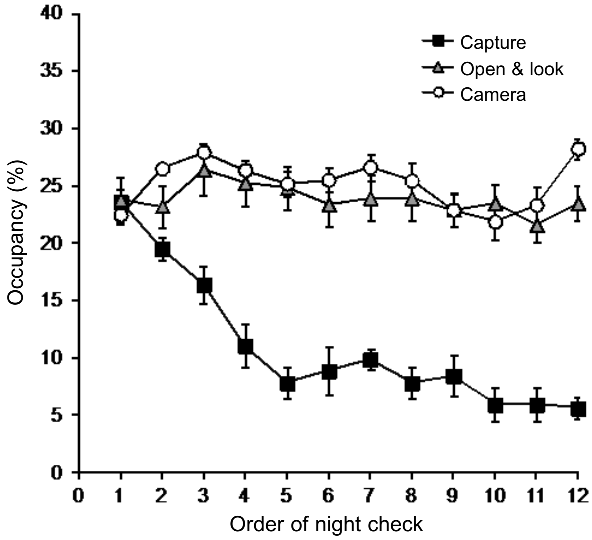

Fig. 1. Changes of the nest box occupancy (percentage of occupied boxes, total n = 182 boxes) by roosting birds throughout the winter. Data are shown as mean ± SE (calculated from raw data) for the same order of a check across three seasons/plots separately for three methods with decreasing level of disturbance to birds (Capture, Open & look, and Camera). Checks were done every ca. 10 days; the first check (1) was conducted on 5–6 November, while the last (12) on 23–26 February.

DISCUSSION

This study showed that disturbance caused by the contact night checks of nest boxes including handling the birds biases the patterns of birds´ winter time roosting behaviour. We found that both the decline in occupancy of nest boxes throughout the winter and the lower re-use rate of individual nest boxes were caused by the disturbance associated with the contact method of night checks.

The steep decline in nest box occupancy throughout the winter in the contact method agrees with several previous studies that used the contact method. Potential explanations come from

Table 2. General linear mixed model of the changes in nest box occupancy (i.e., proportion of occupied boxes) throughout the winter (order of a check being an explanatory variable) as a function of the method of night checks (Capture method being a reference category). Ambient night time temperature was treated as night time mean (T_{mean}) and difference between daily maximum and the following nitghttime minimum (T_{diff}). For variable explanations see Methods.

	F	df	p	Level	Estimate	SE
Fixed effects						
Intercept					0.1958	0.0447
T_{mean}	0.85	1, 95.3	0.3594		0.0009	0.0010
T_{diff}	0.35	1, 95.7	0.5556		0.0008	0.0013
Method (Capture)	3.65	2, 95.0	0.0296	Camera	0.0626	0.0247
				Open & look	0.0495	0.0241
Order of check	15.29	1, 95.1	< 0.0002		–0.0139	0.0235
Order of check × Method (Capture)	9.55	2, 95.0	< 0.0002	Check×Camera	0.0126	0.0033
				Check×Open & look	0.0123	0.0033
Random effects	Z					
Season	0.98		0.1636		0.0033	0.0034
Plot	0.96		0.1681		0.0016	0.0017
Residual – Series	6.89		< 0.0001		0.0023	0.0003

Table 3. Generalized linear mixed model (Poisson distribution, logit link) of the individual box re-use rates (number of roosting events in one box during the 12 checks in the season) as a function of the method, season and plot.

	F	df	p	Level	Estimate	SE
Fixed effects						
Intercept					0.1912	0.2667
Method (Capture)	15.35	2, 540.7	< 0.001	Camera	0.8819	0.1694
				Open & look	0.8301	0.1694
Random effects						
Season					0.0835	0.0957
Plot					0.0679	0.0832
Residual					4.6415	0.2831

two interrelated perspectives, namely the intrinsic perspective that includes winter time mortality, migration of individuals to/from study plots (Kluyver 1957, Drent 1987, Báldi & Csörgő 1994, Krištín et al. 2001, Veľký 2002), and the extrinsic perspective that includes environmental correlates such as habitat or weather (Busse & Olech 1968, Schmidt et al. 1985, Veľký 2002). However, we suggest that the method of nest box checks itself should be considered when interpreting the findings of such studies. More generally, decline in nest box occupancy throughout the winter found in the present study may be considered an indirect methodical artefact of nest boxes (see Møller 1989, Lambrechts et al. 2010, Wesołowski 2011), because they enable easier checking and capturing the roosting birds compared to natural cavities. However, particularly in the season 2007/2008, the moderate decline in box occupancy throughout the winter was recorded in both non-contact plots (twice we recorded moderate increase, data not presented; for details see Tyller 2010), suggesting some role of the above-mentioned intrinsic or extrinsic factors.

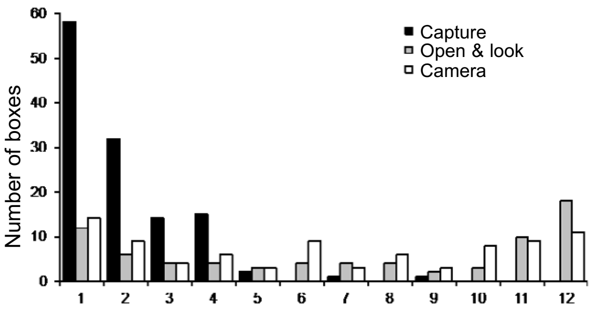

Fig. 2. Distribution of the individual nest box reuse rates by roosting birds. Shown are numbers of cases for particular numbers of roosting events in the same boxes observed during the 12 night checks in the season. Data summed across all three seasons/plots separately for each of three methods (for total numbers of records for each method see Results).

Birds disturbed by repeated handling probably switched roosts more often and/or left the boxes and started to roost on alternative sites (natural cavities or dense vegetation, which were both available on study plots) as suggested by lower reuse rate of individual boxes. However, the previous quantitative evidence for this effect is rare. Some studies report only infrequent occasions on which the same bird roosted in the same nest box on more than one occasion (Czarnecki 1960). Elsewhere, some Great Tits that roosted in natural cavities and were not disturbed stayed more than two months at the same roost (Drent 1987), and lower frequency of nest box checks or daily checks according to a presence of droppings is thus known to obtain less-biased conclusions (Schmidt et al. 1985, Prskavec 1989, 1996). This agrees with our observations that the reuse rate was higher in the two non-contact methods than in the contact method. Immigration of new individuals may mask the consequences of disturbance to roosting birds, but the overall potential immigration was controlled for in our field experiment. However, our conclusions might be biased if birds left the disturbed plot and immigrated to non-disturbed plots, but we believe that this is not important as none individual ringed/controlled on the contact plots in any winter was found on non-contact plots during the final check in each season, which was exclusively done by the contact method. Therefore, we suggest that immigration from disturbed plots would not mask the potential decrease in occupancy and a reduction of nest box reuse on non-contact plots.

Finally, studies of environmental factors influencing the roosting behaviour of resident birds in winter should widely implement non-contact methods of night checks. However, only non-contact methods that allow individual identification may fully replace the commonly used contact night checks. Meanwhile, the knowledge of the birds´ identity remains a valuable contribution of the contact method.

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STRESZCZENIE

[Sposób nocnych kontroli skrzynek lęgowych wpływa na ich wykorzystanie przez nocujące dziuplaki podczas zimy]

Przy ocenie częstości wykorzystania skrzynek lęgowych przez nocujące dziuplaki w okresie jesienno-zimowym ptaki są najczęściej jednocześnie łapane i obrączkowane. Jednak analiza częstości zajmowania skrzynek z zachowaniem takiej procedury może być obarczona błędem, ponieważ podczas takich kontroli ptaki są płoszone, co z kolei może wpływać na niższe zajmowanie skrzynek w trakcie kolejnych kontroli.

Badania miały na celu ocenę, jak sposób kontroli skrzynek wpływa na ich wykorzystywanie przez nocujące w nich dziuplaki w okresie zimy. Prace prowadzono w Czechach, w lesie liściastym, na terenie którego powieszono blisko 200 skrzynek lęgowych tworząc trzy powierzchnie. Na każdej z nich w danym roku stosowano inną metodę kontroli, zmieniając ją pomiędzy powierzchniami w kolejnych latach obserwacji. Zastosowano trzy metody różniące się stopniem niepokojenia nocujących ptaków: 1) standardowa nocna kontrola skrzynki — obejmująca otwarcie skrzynki, świecenie do środka latarką, chwytanie nocującego ptaka, obrączkowanie oraz określanie jego wieku i płci; 2) kontrola skrzynki obejmująca otwarcie skrzynki i świecenie do wnętrza latarką o czerwonym świetle; 3) sprawdzenie wnętrza skrzynki przy pomocy kamery na podczerwień wkładanej przez otwór wejściowy skrzynki. Metoda z wykorzystaniem kamery na podczerwień powinna w założeniu autorów w najmniejszym stopniu powodować niepokojenie ptaków (Tab. 1). W okresie zimowym, między listopadem a lutym 2007–2010 r. skrzynki były sprawdzane 3 razy w miesiącu. Zbierano także dane o temperaturze w nocy, podczas której wykonywano kontrole. Na koniec obserwacji w danym roku łapano ptaki na wszystkich powierzchniach, aby sprawdzić, czy ptaki z powierzchni, na której były łapane podczas kontroli nie przeniosły się do innych skrzynek.

W sumie uzyskano 1319 obserwacji nocujących ptaków, najwięcej przy użyciu kamery na podczerwień, najmniej dla metody wiążącej się z łapaniem ptaków. Większość ptaków stanowiły bogatki (94%), w skrzynkach nocowały także kowaliki i modraszki. Stwierdzono, że metoda, w której ptaki są łapane powoduje, że w kolejnych kontrolach coraz mniej skrzynek jest zajmowanych przez nocujące ptaki. W przypadku innych metod wykorzystanie skrzynek było na podobnym poziomie przez całą zimę (Fig. 1, Tab. 2). Nie stwierdzono związku z wykorzystywaniem skrzynek do noclegu a temperaturą nocy (Tab. 2). Wykorzystywanie tych samych skrzynek przez nocujące ptaki także zachodziło rzadziej w przypadku metody związanej z łapaniem ptaków, w porównaniu do innych metod (Fig. 2, Tab. 3). Nie stwierdzono przemieszczania się ptaków schwytanych w trakcie nocnych kontroli na inne powierzchnie.

Autorzy konkludują, że dotychczas najczęściej stosowana metoda nocnej kontroli skrzynek lęgowych związana z badaniem nocujących ptaków, podczas której ptaki są łapane, może silnie wpływać na uzyskiwane wyniki.