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Using nest-boxes in pine stands of the Augustów Forest

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Abstract. In 2011–2014, the occupancy of nest-boxes by secondary hole-nesting birds and their breeding success was investigated in pine stands of the Augustów Forest (North-Eastern Poland). In the studied area of 12600 ha, the share of Scots Pine *Pinus sylvestris* L. in the stands was 92%. On average, birds occupied 54% and bats 3% of the 224–317 nest boxes controlled yearly. Nest boxes were also used by the Pygmy Owl *Glaucidium passerinum* L. as food caches. In total, broods of nine secondary hole-nesting species were observed, but only four bird species nested in each year of study. The most numerous species, occupying 53–60% of all boxes each year was the Pied Flycatcher *Ficedula hypoleuca* Pall. The Great Tit *Parus major* L. occupied 15–24% and the Coal Tit *Periparus ater* L. 10–12% of available nest-boxes, while the Redstart *Phoenicurus phoenicurus* L. used 2–7% of nest boxes. The yearly breeding success was highest for tits (Great Tit – 52–84%, Coal Tit – 50–72%) and strongly variable for the Pied Flycatchers – 38–78%. Broods were lost due to predation by martens Martes sp. (38%) and great spotted woodpeckers *Dendrocopos major* L. (6%) as well as nest competition (2%). The nest-boxes were occupied at a constant rate during the following four years after their exposition. Over 67% of the new nest-boxes were occupied annually which means new nest-boxes (up to 4 years) were occupied significantly more often than boxes older than 4 years.

Keywords: breeding success, coniferous forest, north-eastern Poland, secondary hole-nesting birds

1. Introduction

In economy forests, availability of breeding places for secondary hole-nesting birds is limited, especially in forest stands of younger age class. Nesting possibility of this group of birds is dependent on the presence of hollows which are essential for breeding (Walankiewicz et al. 2014; Zawadzka et al. 2016; Zawadzka 2018). The number of breeding places for secondary hole-nesting birds is regularly being increased by creating 'artificial hollows',that is, hanging nest-boxes (Jabłoński et al. 1979; Graczyk 1992; Zawadzka, Zawadzki 2005).

In forests under the jurisdiction of the State Forests the duty of hanging nest-boxes results from the provisions listed in Forest Protect Guidelines (InstrukcjaOchronyLasu) (2012). Despite the fact that nest-boxes are being hung regularly, there is very few information on its use by birds. This means there is no evaluation of the effectiveness of the undertaken protection actions. Polish ornithological literature discusses mainly the results of nesting in boxes hung in towns, gardens and urban parks (Luniak 1992; Luniak et al. 1992; Nowicki 1992). Studies regarding forest areas focus on several species of tits *Parus* sp. and flycatcher *Ficedula* sp. Most often they are oriented on a chosen aspect of secondary hole-nesting birds biology, such as reproduction strategy, nest competition (Merila, Wiggins 1995; Walankiewicz, Mitrus 1997; Mazgajski 2000) and interspecies broods (Busse, Gotzman 1962; Nowakowski et al. 1997). Published were studies ich which discussed were in detail parameters of nest-boxes and suggested methodology of research conduction (Lambrechts et al. 2010; Wesołowski 2011). Broods of secondary hole-nesting birds in nest-boxes were examined in studies dedicated to specific bird species (Alabrudzińska et al. 2003; Mitrus 2003; Czeszczewik 2004). The use of nest-boxes was evaluated within planned environmental compensations while cutting

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down forest for highway (Leniowski, Węgrzyn 2013). Majority of data regarding occupancy of nest-boxes in forests was published decades ago (for instance Borczyński, Sokołowski 1953; Busse, Gotzman 1962; Graczyk, Wąs 1966; Wąs 1966; Graczyk et al. 1968; Oko 1974; Klejnotowski, Sikora 1988). Still poorly known is the influence of different parameters of nest-boxes, for example, their dimensions and age, on their choice for nesting place by birds (Ekner-Grzyb et al. 2014). In scientific publications there is too little practical conclusion discussing the meaning and role of nest-boxes in economy forests (Mänd et al. 2005). Few researches show that hanging nest-boxes favour development of species diversity of groups of secondary hole-nesting birds (Sikora 2010; Sikora et al. 2013; Kudelska et al. 2017). There is no long-term monitoring of nest-boxes and effects of broods hatched inside them (Kudelska et al. 2017).

The aim of this study was the examination of nest-boxes hung by foresters and species composition of birds occupying them in the conifer forest of Augustów Forest. Breeding success was evaluated, as were also changes in occupancy of boxes during three seasons. This examination was undertaken in order to define the role and importance of nest-boxes for birds in economy forests. It is expected that it will allow for formulating practical recommendations regarding hanging nest-boxes within forest protection actions in State Forests. Because of the absence of published data on occupancy of nest-boxes in Augustów Forest and limited information on the subject in Poland, the obtained results may become comparative data for future research.

2. Materials and methods

2.1. Area of research

Augustów Forest (23°15′E, 53°54′N) is localized in Podlasie Province , on East Suwałki Lakeland and Augustów Plain. The whole forest complex of area 115,000 ha is situated on sandy, flat sandrow plain with immersions from which were created lakes and marshlands (Kondracki 1994). Among the site types the largest area is covered by fresh coniferous forest (40%) and fresh mixed coniferous forest (31%), and then fresh mixed broadleaved forest (6%) and alder swamp forest (5%). Share of the remaining site types is lesser than 5%.The dominant species is Scots pine *Pinus sylvestris* L., which covers 78% of the forest area. Black alder *Alnus glutinosa* Gaertn. covers 9% of area, Norway spruce *Picea abies* (L.) H. Karst. covers 8% and birch *Betula* sp. covers 5%. Average age of forest stand on the area of research amounted to 65 years. Augustów Forest is localized in the area of coldest climate in lowland part of the country. It is an area covered with program Natura 2000 Birds Protection PLB200002.

The research was conducted in the north of the forest complex, on the area of five forest districts of Pomorze forest division (Okółek, Dworczysko, Rygol, Muły, Szlamy) and three forest districts of Głęboki Bród forest division (Ostęp, Chylinki, Gulbin), with a joint area of 12,600 ha. In both forest divisions, dominant are conifer forests, jointly covering 86% of the forest area. The most important forest species is Scots pine, and its share amounts to 92% (PUL 2011, PUL 2012). The area of examination was covered 90% by pine forest stands with juniper shrub layer *Juniperus comunis* L., and spruce and birch underwood of 10–30% area share, on grounds of fresh coniferous forest. Forest stands with higher share of spruce and underwood of spruce, birch and pedunculate oak *Quercus robur* L. covered around 10% of area, on grounds of fresh mixed coniferous forest.

2.2. Field work

Controls were run in nest-boxes, hung by forest division employees along forest roads and compartment lines,with 5–70 m distance between each other. They were hung usually linearly, in some places singly, at a height of 5–6 m above ground. Nest-boxes were localized in forest stands of all classes of age, from the youngest (1–20 years), to old forest of VI (101–120 years) and VII (121–140) class age.

In years 2011, 2012 and 2014, jointly 364 nest-boxes of A type and 18 of B type were controlled, in which 224 nest -boxes were in 2011, 244 in 2012 and 317 in 2014. This different number of controlled nest-boxes was a result of hanging of some new ones by employees of forest divisions and bad technical condition of some nest-boxes already hanging for a couple of years. Controls were run 2–5 times during breeding season, in 10–14 days intervals. Each nest-box was opened from the ladder at least twice due to the possibility of second brood and repetitions of brood after loss. The number of controls of each brood was dependent on the stage of brood development during first control. Inspection was done more than two times in case of early stage of brood during first control, in order to get information on brood condition before planned flight of young birds. Controls were made in days without any fall, so that after scaring birds away, the brood would not freeze. Time of presence at nest-boxes was reduced to minimum to limit the stress of nesting birds.

Recognized as occupied was every nest-box in which was founda fresh nest with at least one egg, storeroom of pygmy owl *Glaucidium passerinum* or bat colony. While calculating breeding success, included were broods with at least one 14-day-old nestling (age was established on the basis of plumage development, based on the unpublished key of Ornithological Station, Museum and Institute of Zoology Polish Academy of Life Sciences, W. Kania, unpublished).

Causes of loss were defined on the basis of nest appearance: distorted nest, bitten nestling or leftovers of egg on the rooftop –considered to be marten *Martes* sp.predation; damaged or shattered inlet hole, nest intact – great spotted woodpecker *Dendrocopos major* (Nowakowski, Boratyński 2000). Causes for remaining damages were not established.

During field works, nest-boxes of different ages were controlled; the newest have hung for 1 year and the oldest in the last year of field work had reached 8 years. In each year of research new nest-boxes were hung and were also controlled. Data on year of their hanging was collected from employees of individual forest division. In analysis checked was how on settlement in given nest-box influence had its age (years of exposition on tree). On the basis of change of nest-boxes condition and observed degree of occupancy, the nest-boxes were divided into new (hanging up to 4 years) and old (hanging for over 4 years). Not controlled were nest-boxes of bad technical condition (rotten, with damaged rooftop, strongly shattered, deflected from the trunk, with falling off doors, etc.); that is why the number of nest-boxes in the following years changed.

2.3. Statistical analysis

For distribution of variables Shapiro–Wilk test was used. Because of lack of normal distribution, the non-parametric Kruskal–Wallis test was used. Spearman correlation coefficient was used to check to what extent brood effects are related to degree of nest-box occupancy. All calculations were made with the use of R program (R Core Team 2018).

3. Results

3.1. Use of nest-boxes

In the whole period of research, nine species of birds were jointly found in controlled nest-boxes. They were pied flycatcher *Ficedula hypoleuca* Pall., great tit *Parus major* L., coal tit *Peripa rusater* L., redstart *Phoenicurus phoenicurus* L., crested tit *Lophophanes cristatus* L., blue tit *Cyanistes caeruleus* L., willow tit *Poecile montanus* L., nuthatch *Sitta europaea* L. and wryneck *Jynx torquilla* L. In 2011 the nest-boxes had nesting of four species, in 2012 seven and in 2014 six. Definitely dominant was the pied flycatcher occupying, in the whole period, on average 61% of nest-boxes (69% in 2011 and 59% in 2012 and 2014), which is more than that of the remaining eight species together. Four species breeding each year – pied flycatcher, great tit, coal tit and redstart – jointly settled in 98.4% nest-boxes used for breeding. The composition of the group of birds occupying controlled nest-boxes changed in the following years. The number and share of breeding species changed. In 2011 the share of pied flycatcher was higher and great tit lower than in the following seasons. The share of coal tit ranged from 10 to 13%. The strongest change in number was noted for redstart, from 2 to 7% (Tab. 1). The share of the four main species in following years differed significantly ($KW\chi^2 = 10.202$, $p=0.017$). Broods of remaining species were sporadic in following years (Tab. 1).

Nest-boxes were also used by pygmy owl. In nest-boxes of A type shattered by great spotted woodpecker, pygmy owl created pantries. The composition of hunted prey was noted four times. In 23 nest-boxes (4%), presence of bats was stated. Usually there were bigger groupings of those mammals (usually brown long-eared bat *Plecotus auritus* L.), up to 10 individuals. In some nest-boxes there were only one or two individuals (Tab. 1).

Annually controlled nest-boxes were from 224 to 317. Inside stated were annually from 123 to 187 began broods (Tab. 1). In the following years 55 to 63% of available nest-boxes were used.

The degree of occupancy of nest-boxes hanging for a period of 1–4 years amounted annually over 67%. In the first year, new occupancy degree of thenest-boxes amounted to 71% and in the second year 78%. In the following years the percentage of occupied nest-boxes dropped below

Table 1. Species composition of hole-nesters occupied of nest boxes and their share in the community in 2011–2014

Year / Species	2011		2012		2014	
	N	[%]	N	[%]	N	[%]
Ficedula hypoleuca	81	66	88	57	100	53
Parus major	18	15	36	24	38	21
Periparus ater	12	10	19	12	18	10
Phoenicurus phoenicurus	8	7	3	2	11	6
Cyanistes caeruleus			1	1		
Sitta europaea			1	1		
Jynx torquilla			1	1		
Poecile montanus					1	1
Lophophanes cristatus					3	2
Glaucidium passerinumm			1	1	2	1
Chiroptera	4	3	4	3	14	8
Number of nest boxes controlled	224	100	244	100	317	100
Number of nest boxes occupied	123	55	154	63	187	59

70% and amounted to 68% in the third year and 67% in the fourth. These differences were not significant statistically (KWχ^2=3.951, p=0.556). In older nest-boxes the degree of occupancy dropped below 50%. Nest-boxes up to 4 years old were occupied visibly often than older ones (KWχ^2=8.31, p=0.004). There were only a few cases of breeding twice in the same nest-box in one season. Such situation occurred in only 10 nest-boxes (1.5%), of which were 3 repeated broods of great tit and 7 of pied flycatcher.

During research, birds began broods on average in 54% of nest-boxes, but only in 36% of them young birds hatched (Tab.2). In 27 cases pied flycatchers and in 3 cases great tits had built nests in which brood was not continued. In the following years the share of nest-boxes in which young birds were hatched got lower, from 42% in 2011 to 28% in 2014 (KWχ^2=7.2, p=0.027). This phenomenon was visualized in the value of Spearman correlation coefficient. Share of nest-boxes with hatched nestlings dropped despite their increased control in the following years (r=–0.52, p=0.33) and increased number of broods inside them (r=–0.495, p=0.41) (Tab. 2). Increase in the number of nests without hatched nestlings resulted from brood damage by predators and abandonment of nests by birds.

3.2. Breeding success

Breeding success of individual species of secondary hole-nesters was diversified. The highest breeding success was with tits. Pied flycatcher had half of the broods successful (Tab. 3). No significant differences were stated, however (KWχ^2=0.267, p=0.875). On average, for all 265 broods, 55% ended with success. Effectiveness of broods dropped in the following years of research.

3.3. Causes of loss

Stated were eight cases of interspecies nest competition when occupied nest-box was overtaken by other species. In six cases it meant building a nest on already existing brood and therefore its loss. In two cases interspecies brood occurred. One of those broods in 2011 was composed of one egg of coal tit and nine added eggs of great tit. The nest was left by coal tit and eight great tits. The second interspecies brood occurred in 2014, where to the redstart nest with three eggs eight eggs were added by great tit. Eggs of redstart were unhatched, while the brood of great tit was successful. Besides nest competition, which was the cause for 2% of loss, broods were damaged by marten and great spotted woodpecker. Marten caused 38% of all loss in broods, the most in case of pied flycatcher (47%). Predation of great spotted woodpecker was assigned to 6% of damaged broods. Other causes were not defined.

4. Discussion

In controlled nest-boxes of Augustów Forest, stated were nine broods of secondary hole-nesting birds. It is a relatively high species diversification of a group. The result is theoretically similar to the ones given from other localizations,

Table 2. Occupation of nest boxes by hole-nesters and their breeding success in 2011–2014

	Number of controlled nest boxes	Number of occupied nest boxes		Number of nest boxes with young		Breeding success	
Year	N	N	[%]	N	[%]	N	[%]
2011	224	110	49	94	42	52	75
2012	244	141	58	90	37	84	61
2014	317	159	50	91	29	111	44
Average	261.7	136.3	54	91.7	36	82.3	60.3

Table 3. Effects of broods of the most numerous secondary hole-nesters (take into account only broods of known results)

Species	*Ficedula hypoleuca*		*Parus major*		*Periparus ater*	
Year	number of broods	success [%]	number of broods	success [%]	number of broods	success [%]
2011	23	78	13	84	11	72
2012	41	66	24	58	14	50
2014	63	38	25	52	14	57

where eight or nine nesting species were stated (Graczyk et al. 1966, 1968; Wąs 1966; Oko 1974). In those researches nest-boxes of all types (A, B, D, P, K) were used; non-forest species also nested in them which makes it difficult to compare the results. After taking into account those differences and rejecting from cited results species incapable of settling A-type nest-boxes in forest complex, the comparable number of species stated on other localizations is lower and amounts from five to seven. Similar results were obtained in researches in Podkarpacie (Leniowski, Węgrzyn 2013) or in Lublin upland (Wiącek et al. 2014). It was stated that there were, respectively, five and four species occupying A-type nest-boxes. In Wielkopolska National Park, in nest-boxes only four species of secondary hole-nesting birds (Kudelska et al. 2017) nested. Clearly the number of species was higher in the 1980s in Sabibór Forests, where broods of 11 bird species were stated (J. Zawadzki, unpublished data).

Composition of the group of secondary hole-nesting birds in nest-boxes of conifer forests in Augustów in the following years was diversified with permanent presence of pied flycatcher, great tit, coal tit and redstart. Differences in occurrence of the remaining, not so numerous species in the following years may result from their preference for other sites. Blue tit and nuthatch inhabit broadleaved and mixed broadleaved forests which constituted only a few percent of research area. Wryneck is not a numerous species in forest complexes (Zielińska 2007). Willow tit and crested tit occupy mostly natural hollows (Mielczarek 2014). Nesting of the above five species in nest-boxes in conifer forest areas is therefore sporadic and probably results from deficiency of hollows in the examined area, but also attractiveness of nest-boxes as substitute for breeding places. In pine stands of Augustów Forest aged 70–100 years the number of hollows is very small – 0.7 hollows per ha – and in stands below 70 years hollows were found occasionally (Zawadzka et al. 2016). When considered is above dependence, arranging nest-boxes in younger forest stands, where there is not enough breeding places for secondary hole-nesting birds, seems justified.

In Augustów Forest most of the nest-boxes were occupied by pied flycatcher, followed, in terms of numerosity, by great tit, coal tit and redstart. The most numerous species were the ones most often inhabiting nest-boxes as stated in the research (Gotzman, Jabłoński 1972; Jabłoński et al. 1979; Zawadzka, Zawadzki 2000; Mizera, Gwiazdowicz 2005). Strong domination of pied flycatcher is rarely met in research on secondary hole-nesting birds in forest areas, despite it being a species willingly inhabiting nest-boxes (Kuczyński, Chylarecki 2012). In Sobibór Forests pied flycatcher constituted 49%, and the next species was great tit, constituting 30% of all examined broods (J. Zawadzki, unpublished data). Majority of authors examining the share of species in a group indicate the dominance of great tit (Leniowski, Węgrzyn 2013; Wiącek et al. 2014; Kudelska et al. 2017) or with similar numerosity of great tit and pied flycatcher (Knistautas, Łutkus 1984). Changes in numerosity of both species are correlated, despite visible competition between them (Kuczyński, Chylarecki 2012). High numerosity of pied flycatcher in the area of research may be connected with geographical location. In the east of Poland, the population of this species is stable, whereas in the west it shows moderate drop. Northeast of Poland belongs to areas of highest density of pied flycatcher in the country (Chylarecki et al. 2018).

The degree of nest-box occupancy in the research areas in Poland ranged from 33 to 78% (Kozłowski 1992, Leniowski, Węgrzyn 2013, Ekner-Grzyb et al. 2014, Kudelska et al. 2017). This study showed a very high level of occupancy of nest-boxes. For the first 4 years at least 67% of them were occupied, suggesting that their bright colour in the first year did not matter. Brood preferences were also shown in Wielkopolska, indicating that one of the reasons may be lack of brood parasites (Ekner-Grzyb et al. 2014). In nest-boxes older than 4 years, the degree of occupancy was lower, probably due to deterioration of their technical condition or presence of parasites. Part of the oldest nest-boxes (around 20) had smaller sizes than recommended (Jabłoński et al. 1979; Zawadzka, Zawadzki 2000; Instrukcja… 2012). It may have resulted in lack of space for nestlings and higher threat from predatory martens, which could easily reach the nest. Nest-boxes of smallest dimensions had the smallest degree of occupancy. The lowered occupancy of older nest-boxes may have been enlargement of input hole by woodpeckers, resulting in increment of brood accessibility. The nest-box occupancy was also influenced by way of hanging. Majority of the nest-boxes localized on the edge of cutting area or on the edge of left forest stand remain empty. They were usually used not by birds but by wasps *Vespidae* and hornets *Vespa crabro* L. Another mistake was hanging the nest-boxes on the edge of roads and compartment lines; extensive exposition to sunlight and vehicles passing by scared the birds away. Nest-boxes should be hanged several dozen metres away from the edge of forest stand, with input hole directed towards the northeast sun in order to minimize insolation, accordingly to recommendations from Forest Protect Guidelines (2012).

In this research, the percentage of nest-boxes in which nestlings were hatched decreased in the following years. This proves a bigger loss than on early stage of brood. The increased level of loss might have been influenced by environmental (less alternative food for brood predators, predators' specialization in other districts) and anthropogenic factors – in the following years of research, less new nest-boxes were hung, which resulted in decrease in nest-boxes in good condition. Altogether 55% of broods with known effect ended with success, and 45% with loss. This result differed from results from other research areas. The losses

were smaller and the success higher than in Białowieża Forest (Czeszczewik 2004). In Lublin upland 100% of broods ended with success, but research was run only for two seasons since hanging nest-boxes (Leniowski, Węgrzyn 2013). In Sobibór Forest joint breeding success for all examined broods amounted to 69%. The highest success was observed in case of redstart (100%); for pied flycatcher and tits it amounted from 71 to 83% (J. Zawadzki, unpublished data). In Augustów Forest the highest breeding efficiency was stated in case of tits. Worse breeding effects were for pied flycatcher and redstart. Identified causes of loss in this research were predation by martens and woodpecker and nest competition. Abandoning broods may have been connected with death of adult individuals as a result of predation besides place of breeding. No flooding or freezing of eggs was stated, which was presented as causes of loss in other studies, regarding mainly broods in natural hollows (Rowiński 2013).

5. Conclusions

1. High degree of nest-boxes occupancy indicates that in economy forests there is no enough natural breeding place for secondary hole-nesting birds. The most nest-boxes should be hung in forests stands of II and III age classes.

2. Nest-boxes are occupied by birds in majority in the year of hanging of nest-box and for the following 3 years, until they are in good technical condition.

3. Nest-boxes should be replaced after 5–6 years since hanging, due to gradual decline of its technical condition.

4. Research results from one season do not bring complete data on group of birds using nest-boxes since in the following years species composition may change.

Conflict of interest

Authors declare there are no potential conflicts.

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Authors'contribution

G.Z. contributed to field work, conception of article, methods, statistical analysis, graphic materials, preparation of the script, literature review, J.Z. to methods and field work, D.Z. to revision, edition and literature review and A.S.to field work.