Response of Grey Herons (*Ardea cinerea*) to human disturbance in a suburban village in Poland

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Human-caused disturbances affect, e.g., the spatial distribution and breeding performance of most organisms, including birds. Here, we assessed the response of Grey Herons (*Ardea cinerea*) to frequent human disturbance in a large heron colony in Poland during 2009–2012. The colony covered an area of 2.5 ha and had annually 174–220 occupied nests. We found that egg losses increased and nest occupancy decreased with an increase in the area covered by buildings nearby. The distances to the nearest building or road were not significantly related to egg losses.

1. Introduction

Natural and anthropogenic disturbances play critical roles in molding the structure and function of ecosystems. Disturbance may be considered any relatively discrete event in time (e.g. wind, fire, freeze, flood) that disrupts ecosystem or community population structure and changes resources, or habitat availability, within the local physical environment (White & Pickett 1985). Human disturbance is regarded as any human activity that changes the contemporaneous behaviour or physiology of one or more individuals of a given species (Nisbet 2000). This definition includes all short-term events and excludes the permanent effects of human development or habitat modification, such as urbanization.

Breeding colonies of herons and other waterbirds residing in close proximity to human population centers are frequently exposed to disturbances from people, pets, and vehicles passing near the breeding colony. Disturbed birds often flush from nests, exposing eggs or young to predation (An-derson & Keith 1980, Carney & Sydeman 1999). Disturbance may also increase incidence of adults accidentally pushing chicks out of nests or interruption of nestling feeding activities. Repeated intrusions can result in reduced productivity, nesting failure, or colony abandonment (Bjorklund 1975, Werschkul *et al.* 1976, Carlson & McLean 1996, Skagen *et al.* 2001).

However, responses to disturbance vary among individual species and populations. Some species tolerate regular human intrusion, while others do not respond well to such activities (Carney & Sydeman 1999, Nisbet 2000).

Life-history theory predicts that the costs of responding to disturbance should vary across species. Long-lived iteroparous animals like herons have many opportunities to breed in a lifetime and therefore should take less risk during the current breeding attempt than shorter-lived animals that have a lower potential for future reproduction (Stearns 1992). Under environmental challenges, such long-lived animals should redirect energy allocation to activities that will enhance long-term
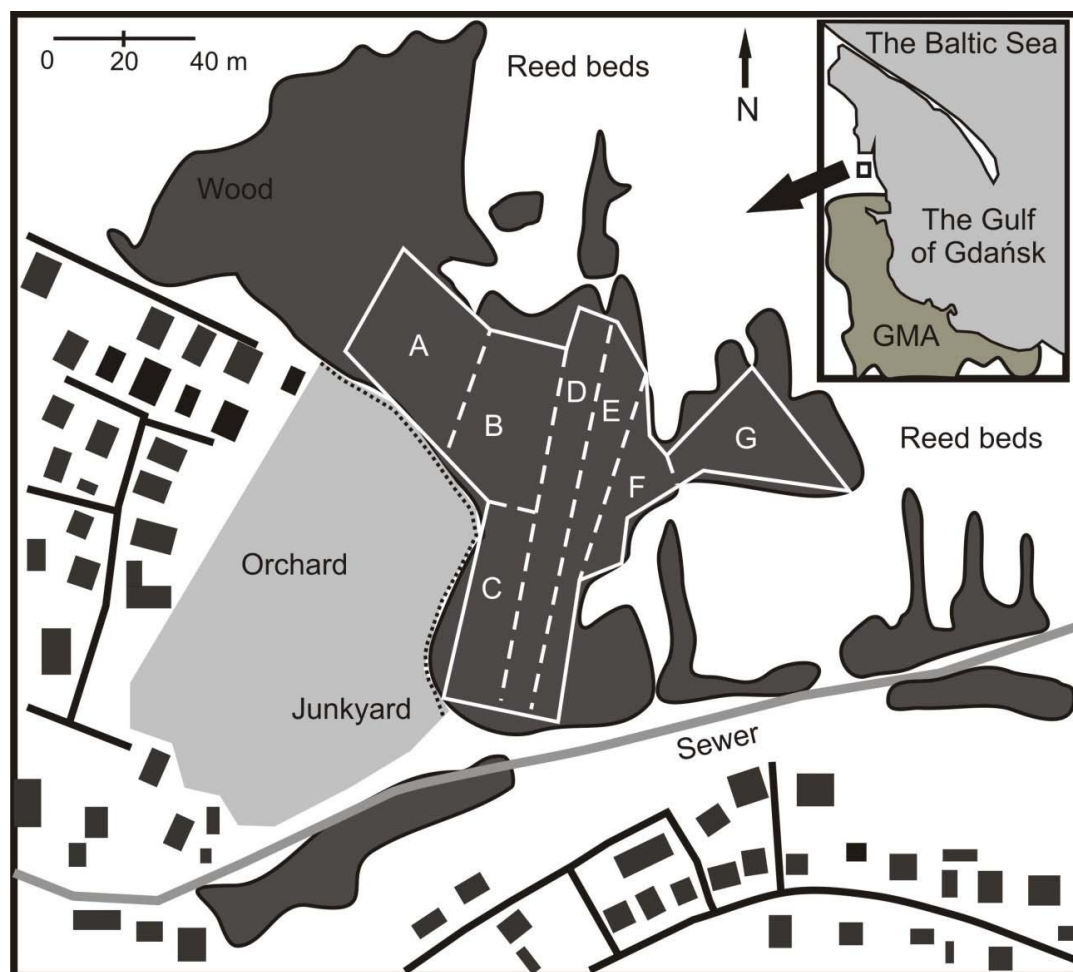
Fig. 1. The studied breeding colony of Grey Herons at Mosty, Poland during 2009–2012. The perimeter of the colony is marked with a white line. Letters A–G indicate sections of the colony (see text). Squares indicate buildings, solid lines are roads, dotted lines are fences, and grey line shows a sewer. GMA = Gdańsk metropolitan area.

survival rather than invest energy in activities associated with reproduction (i.e. breeding can be shifted in time or space) (Stearns 1992). Thus, a short-term disturbance may have little long-term affect on local population dynamics. In the case of long-term events (e.g. urbanization) animals may (1) develop tolerance to increased disturbance levels; (2) stay and suffer decreased recruitment and population decline; or (3) abandon the breeding site which may negatively affect species population size, if no alternative sites are available (Nisbet 2000).

Our study was designed to assess the response of Grey Herons (*Ardea cinerea*) to frequent hu-

man disturbance in a large heron colony. Despite that this species regularly breeds in close proximity to human residences (Kushlan & Hafner 2000), the issue of disturbance potentially effecting reproductive success has never been studied in depth. It has only been reported anecdotally that corvids take advantage of human disturbance and prey on the Grey Heron eggs and chicks if parents leave the nest during the colony intrusion (reviewed in Milstein *et al.* 1970). Other studies reported noisy human activities caused a decrease in the number of breeding individuals, or abandonment of colonies due to increased egg and chick predation and premature nest abandonment by

Table 1. Numbers, densities and occupancy of available nests observed within different sections of a Grey Heron colony at Mosty, Poland. Letters A–G refer to different sections of the colony (see text).

Variable	Year	A	B	C	D	E	F	G	Total
Number of occupied nests									
	2009	45	34	11	15	14	36	24	179
	2010	43	37	10	21	13	54	42	220
	2011	41	32	2	18	17	52	42	204
	2012	42	16	0	12	14	49	41	174
Density of occupied nests (nests/ha)									
	2009	107.1	79.1	36.7	37.5	30.4	180.0	72.7	70.5
	2010	102.4	86.0	33.3	52.5	28.3	270.0	127.3	86.6
	2011	97.6	74.4	6.7	45.0	37.0	260.0	127.3	80.3
	2012	100.0	37.2	0.0	30.0	30.4	245.0	124.2	68.5
Changes in density of occupied nests 2009–2012 (%)									
		–6.7	–52.9	–100.0	–20.0	0.0	36.1	70.8	–2.8
Occupancy of available nests (%)									
	2009	76.3	47.9	15.7	30.0	24.6	41.4	42.1	39.7
	2010	69.4	61.7	20.8	47.7	38.2	75.0	80.8	59.1
	2011	77.4	78.0	9.1	51.4	70.8	78.8	89.4	70.8
	2012	84.0	44.4	0.0	57.1	73.7	72.1	85.4	69.0

chicks (Kitowski 2001, Kitowski & Krawczyk 2005).

The goal of our study was to determine whether increased human disturbance (more intense pedestrian traffic in the vicinity, and more frequent intrusions into the colony) due to development of a suburban village adjacent to the existing Grey Heron colony affect the breeding performance. We hypothesized that herons would develop a tolerance against increasing disturbance. However, we expected nest losses due to nest predators to be higher in areas with higher probability of disturbance, and that birds would settle last in the zones of greatest human disturbance.

2. Material and methods

2.1. Study site

We performed our study on a breeding colony of Grey Herons at Mosty (54°37'N, 18°29'E), situated 1.7 km from the Gulf of Gdańsk coast of the Baltic Sea, in northern Poland (Fig. 1). Mosty is a suburban village that recently developed and has rapidly expanded on the outskirts of the Gdańsk metropolitan area. Between 2000 and 2008, the number of inhabitants and population density

more than doubled from 953 to 1,916 people and from 54.1 to 108.8 people per km^2, respectively (Rada Gminy Kosakowo 2009). Nests of Grey Herons were situated in Common Alder (*Alnus glutinosa*) trees in a small woodlot where the soil was wet and muddy. Stagnant water filled drainage ditches and lower areas of the colony during the whole breeding season. In 2009–2012, the colony covered an area of 2.5 ha. There were 174–220 nests in 2009–2012 (Table 1).

Due to its location close to buildings, the heronry was continually at risk of disturbance from human intrusion into the colony and human activities along the colony edge (Table 2). Evidence of human intrusion into the colony, was mainly indirect signs of human activity, such as footprints in the mud and piles of rubbish. Foot traffic in the colony (including investigators) always caused adult herons to flush from nests. This was often followed by the arrival of opportunistic corvids. These birds – mainly Ravens (*Corvus corax*) and Hooded Crows (*Corvus corone cornix*) – were observed during all of our 12 site visits during the incubation and hatching periods in 2009, either flying above the colony, or sometimes trying to predate heron nest contents. Human disturbance activities along the colony edge included daily pedestrian traffic around houses and along

Table 2. Types of human disturbance recorded at a Grey Heron colony at Mosty, Poland. Letters A–G refer to different sections of the colony (see text). "+" indicates that a given type of disturbance was recorded.

Types of human disturbance	A	B	C	D	E	F	G
Intrusion into the colony							
– Footprints, rubbish			+	+	+		
– Investigator visits*	+	+	+	+	+	+	+
– Tree logging**			+				
Activities along the colony edge							
– Pedestrian traffic	+		+	+	+		
– Regular work of machines nearby and on building sites			+	+	+		
– Sewer renovation***			+	+	+		

* Nest counting and egg-shell collection.
** During the early incubation period in 2010, at least 20 trees were logged.
*** For the whole breeding season of 2009 with daily variation in the intensity of human activity (includes work of men, machines and trucks on a dirt road along the sewer).

the walkway above the sewer (plus during 6 of 12 visits, groups of pupils from a local school were observed exercising here), and also work of machines in the orchard, and at adjacent building sites (Table 2).

2.2. Field methods and analyses

We investigated the spatial distribution of nests in the colony across four breeding seasons (2009–2012). We counted Grey Heron nests in the whole colony each year. Nests with visible chicks inside or with fresh feces on construction twigs were classified as occupied. We counted nests in the second half of April when chicks were visible in the majority of nests.

Considering the spatial structure of the colony, we divided it into six sections (A–G), each section

based on a network of drainage ditches dividing the colony area into parts of similar total area and nest density (Tables 1–3, Fig. 1).

We collected data on breeding success and phenology in 2009. The collection of eggs destroyed by predators which had been dropped on the ground below the nests allowed the estimation of the egg losses (such shells had distinct crevices made by a predator's beak). We also collected all dead chicks found on the ground. To compare the hatching success and dynamics among different sections, we collected all post-hatching eggshells (removed from nests by parent birds shortly after hatching; Milstein *et al.* 1970) on the ground below the nests, every 7–10 days. In total, we collected 677 post-hatching eggs, 175 predated eggs, and 14 dead chicks. We estimated hatching success and egg losses as the ratio of post-hatching/all

Table 3. Selected characteristics of each section (letters A–G) of the Grey Heron colony at Mosty, Poland (total area, area covered by buildings within 200 m of the section perimeter, distance to the nearest building and road).

Variable	A	B	C	D	E	F	G
Area (ha)	0.42	0.43	0.30	0.40	0.46	0.20	0.33
Area covered by buildings (within 200 m; ha)	1.33	0.68	2.10	0.74	0.76	0.36	0.22
Distance to the nearest...							
– Building, median (m)	77.8	116.0	135.6	159.2	156.0	169.6	177.8
– Building, min (m)	20.0	79.1	114.8	100.0	79.7	125.5	153.4
– Road, median (m)	87.1	123.6	125.2	144.4	137.4	152.6	170.0
– Road, min (m)	50.8	102.2	102.4	75.1	58.4	100.0	148.0

Table 4. Numbers of egg shells (predated and hatched) and dead chicks found, occupied nests and esti-mated hatching success, egg losses, and clutch sizes in a Grey Heron colony at Mosty, Poland, in 2009, and a comparison between estimated and actual clutch size (recorded by direct nest control in 2002; Jakubas 2003). Letters A–G refer to different sections of the colony (see text).

Variable	A	B	C	D	E	F	G	Total
Hatched egg shells (a)	110	103	16	24	48	120	81	502
Predated egg shells (b)	39	27	15	9	19	42	24	175
Hatching success (c)[1]	0.74**	0.79**	0.52^{ns}	0.73*	0.72**	0.74**	0.77**	0.74**
Egg-loss rate (d)[2]	0.26**	0.21**	0.48^{ns}	0.27*	0.28**	0.26**	0.23**	0.26**
No. occupied nests (e)	45	34	11	15	14	36	24	179
Estimated clutch size (f)[3]	3.3	3.8	2.8	2.2	4.8	4.5	4.4	3.8
No. dead chicks	1	2	6	2	0	2	1	14

Test for estimated (f) vs observed clutch size in 2002 (3.8 eggs/nest)

χ^2		0.35	0.00	0.61	2.44	0.43	0.40	0.22	0.00
p		0.55	1.00	0.43	0.12	0.51	0.53	0.64	0.95

1) a/(a+b)
2) b/(a+b)
3) (a+b)/e. * $p < 0.05$; ** $p < 0.001$; ns $p > 0.05$

found eggshells, and predated/all found, respec-tively. All predated eggs found were excluded from hatching dynamics analysis. To estimate clutch size, we divided the number of all eggshells found by the number of occupied nests. To check whether the calculated initial clutch size was bi-ased in any section we compared it with the actual clutch size recorded directly in a group of 41 nests in the same colony in 2002 (Jakubas 2003).

To describe the level of urbanization in areas that adjoin the colony, we measured the following variables: area covered by buildings within 200 m radius circle of each section, distances between the section and the nearest building and road (Table 3). All variables described were calculated from aerial photographs using tools available at http://www.geoportal.gov.pl. Distance to the nearest building or road was calculated for 5 points in the section – one central and four at the edges. We pre-sented median and minimal values.

To investigate the relationship between egg losses, nest density, occupancy of available nests and area covered by buildings within 200 m of each section, and distances between the sections and the nearest building and road we used Spearman rank correlation coefficients. We pres-ent only those results showing significant relation-ships. – All tests were run using STATISTICA 8.0 (StatSoft Inc., USA).

3. Results

3.1. Density and occupancy of available nests

Between 2009 and 2012, the total density of occu-pied nests decreased by 2.8%. However, changes in density of occupied nests varied among sec-tions. Nest densities declined in sections C (by 100%), B (by 53%), D (by 20%) and A (by 7%) while they increased in sections G (by 71%) and F (by 36%) (Table 1). This evidence implies that there may be a tendency for a decrease in the den-sity of occupied nests with increasing area covered by buildings within 200 m of the section in 2011 (r_s = –0.75, $p = 0.052$, $n = 7$).

Grey Herons occupied existing nests in various sections at rates varying from 0 to 89% of available nests in 2009–2012 (Table 1). There was a signifi-cant negative relationship between occupancy of available nests and the area covered by buildings within 200 m of the given section in 2010 (r_s = –0.79, $p = 0.04$, $n = 7$) and 2011 (r_s = –0.86, p = 0.01, $n = 7$). The density of occupied nests in-creased with occupancy of available nests in 2010 ($r_s = 0.96, p = 0.0004, n = 7$) and 2011 ($r_s = 0.89, p$ = 0.007, $n = 7$).
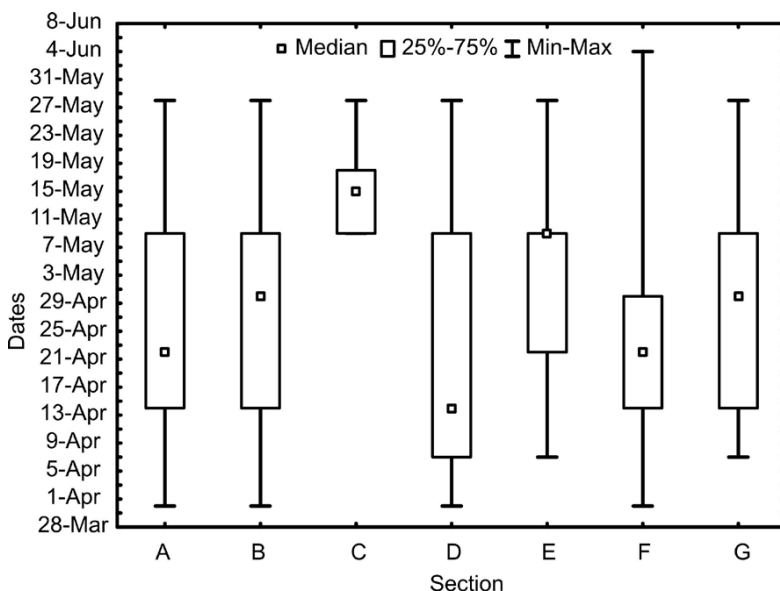
Fig. 2. Timing of hatching in different sections (A–G) of the Grey Heron colony at Mosty, Poland in 2009.

3.2. Breeding losses

Estimated hatching success for the whole colony was 74% with highest values recorded in sections B (79%) and G (77%). In sections A, B, D, E, F, and G hatching success was significantly higher than egg loss. The highest egg loss was found in section C (48%), the only section where egg loss and hatching variables were similar (Table 4).

The rate of egg losses in given sections correlated positively with an increase in the area covered by buildings within 200 m of those sections ($r_s = 0.79$, $p = 0.04$, $n = 7$). We found a significant negative relationship between egg loss rates and increased rates of occupancy of available nests ($r_s = -0.79$, $p = 0.04$, $n = 7$).

In total, we found 14 dead chicks in the whole colony. Of these, 43% were recorded within section C, which also had the highest egg loss rates (Table 4).

3.3. Breeding phenology

Hatching dates extended from the end of March until early June (median date 30 April). The earliest commencement of hatching (31 March) was recorded in the sections A, B, D, and F. In sections E and G, first post-hatching egg shells were recorded one week later (7 April). The latest start of hatching (9 May) was recorded in section C (Fig. 2).

Timing of hatching differed significantly among sections (Kruskal-Wallis test, $H_{6,502} = 44.30$, $p < 0.0001$; Fig. 2). In section C, chicks hatched later than in sections A, B, D, F and G (Dunn test, $p < 0.001$). The median hatch date in section C (15 May) was 23 days later than the median date of 22 April found for all sections other than section E. In section E, chicks hatched (9 May) significantly later than in sections D, F and A (Dunn test, $p < 0.05$; Fig. 2).

4. Discussion

Our results suggest that the proportion of buildings in an area of 200 m from different sections of the colony was significantly correlated with increasing egg losses, and reduced the occupancy of available nests. However, the distances to the nearest building or road were not significantly related to egg losses. This suggests that the risk of human disturbance was a function of increased human activity. We did not monitor human intrusions, however. Section C, with the highest proportion of area with buildings within 200 m from its perimeter, with the smallest area of wet ground (easiest access), and with adjacent paved sewer pathways and highest occurrence of footprints and rubbish, suggest that this section faced the highest rate of disturbance (Table 2). Birds nesting there

suffered the highest egg losses, which is probably attributable to nest predation induced by human intrusion. Moreover, herons did not breed there in 2012 despite ten available nests. Section A also adjoined a built-up area, but nest density remained relatively stable there. This fact can be explained by wet ground, and the occurrence of a fence and a deep canal, which are effective barriers against human intrusion (Carlson & McLean 1996). During 2009–2012, the number of occupied nests increased only in sections F and G, i.e., the sections situated farthest from built-up areas and with wettest ground. Other studies have reported shifting of nesting activity away from the location of disturbance (logging in those cases) in the Great Blue Heron (*Ardea herodias*) colonies (Bjorklund 1975, Werschkul *et al.* 1976).

The pattern of observed changes in nest density represents a continuation of processes which began in the 1990s. At that time, the range of the colony was restricted to the area adjoining the sewer (section C and the southern part of section D). During 1999–2001, concurrent with establishment of new houses in the vicinity of the colony, herons expanded the colony towards the northwestern part of the woodlot (sections A, B, D, E, and F) and occupied lower numbers of nests in section C. In 2002, herons built new nests (29 in 2003) in the previously unoccupied eastern part of the woodlot dominated by young alder (*Alnus*) trees (section G) (Jakubas 2003, authors' unpubl. data).

The latest hatching – one month later than in the other sections – was recorded in section C, which also faced highest egg-loss rates and lowest occupancy of available nests. This suggests that pairs breeding in this section were young, low-status individuals which often occupy peripheral, sub-optimal areas of colonies (e.g., Spurr 1975, Gibbs *et al.* 2000), and start to breed later in the season (Milstein *et al.* 1970, after Verwey 1930). Late hatching may represent replacement clutches after early-season losses. However, in the section C no egg shells were found early in the season, i.e., when 25–75% of chicks had hatched in the other sections. As this section was the main part of the colony in the past (Jakubas 2003), it seems that the decline in its status (the highest egg losses, the latest hatching, lowest occupancy of available nests) may be attributed to increased levels of human disturbance.

Low numbers of dead chicks found could have been underestimated due to the activity of scavengers. On the other hand, low levels of chick losses may have resulted from the fact that siblicide did not occur at the studied colony at Mosty, in contrast to other heronries (Jakubas 2005). Considering that nest predation has been reported to be a negligible cause of chick mortality in heronries in northern Poland (Jakubas 2005), the highest number of dead chicks found in the section C might have been attributed to increased level of human disturbance (e.g., through an increased risk of pushing chicks out of nests by flushing parental birds).

The small overall decrease in density of occupied nests (2.8%) in the whole colony, during the study period, suggests that herons breeding at Mosty have become tolerant towards human activity. This has been reported for many colonial waterbirds in suburban areas (Nisbet 2000). In our study, only the few birds nesting in the most frequently-disturbed areas suffered from increased breeding loss. However, even those birds may respond to disturbance without negative consequences for the population size by shifting to breeding in other sections (not all available nests were occupied) or to more distant heronries in the following seasons.

Our estimates of hatching success, egg losses and clutch size may have been slightly biased because an unknown number of eggs were carried away from the colony by nest predators or were trampled by Wild Hogs (*Sus scrofa*). The number of dead chicks we found was also certainly underestimated as the colony was regularly patrolled by Wild Hogs, Red Foxes (*Vulpes vulpes*) and Raccoon Dogs (*Nyctereutes procyonoides*) all of which regularly foraged on chicks that fell from nests. However, considering the relatively small area of the colony (allowing predators to patrol the whole colony at once) and lack of significant differences between estimated and actual clutch size in particular sections, we assume that estimation error was comparable in all studied sections.

When assessing the impacts of human disturbance on wildlife, it is important to consider several additional factors, such as environmental and climatic changes, and species interactions, which can either mask or intensify the effects of human activity (Skagen *et al.* 2001). The investigated col-

ony was occupied by only one species, and nesting habitat did not change considerably during the study period. Thus, changes in the colony structure and the highest losses in sections adjoining buildings may have been strongly influenced by urbanization and related disturbances, such as pedestrian traffic and mechanical disturbance.

Harmaahaikaroiden vaste ihmisen aiheuttamiin häiriöihin puolalaisessa esikaupunkikylässä

Ihmisen aiheuttamat häiriöt vaikuttavat niin linnuilla kuin muilla eliölajeilla mm. tilalliseen jakaumaan ja jälkeläistuottoon. Selvitimme tässä työssä harmaahaikaran (*Ardea cinerea*) vastetta toistuvaan häiriöön suuressa Puolalaisessa haikarakoloniassa vuosina 2009–2012. Kolonia oli laajuudeltaan 2,5 ha ja käsitti vuosittain 174–220 asuttua pesää. Havaitsimme, että munahävikki kasvoi ja pesien asuttaminen väheni lähistöllä olevien rakennusten peittämän pinta-alan kasvun myötä. Pesän etäisyys lähimmästä rakennuksesta tai tiestä ei vaikuttanut munahävikkiin.

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