

The influence of weather factors on the daily activity of urban populations of birds at their common roosts in Słupsk

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Received: 8 Dec., 1997

Accepted for publication: 26 June, 1998

GÓRSKA E. 1998. The influence of weather factors on the daily activity of urban populations of birds at their common roosts in Słupsk. *Acta zool. cracov.* **41**(1): 35-49.

Abstract. Under conditions of heavy cloudiness and during rains the activity phase of *Streptopelia decaocto*, *Passer domesticus*, *Turdus merula*, *Sturnus vulgaris*, *Pica pica* and *Corvus monedula* underwent a shortening – the morning departures from the roosts happened later and the evening arrivals earlier by about a dozen to several dozen minutes than on cloudless and rainless days (statistically significant differences). On days with morning temperatures below 0° C the Collared Doves, House Sparrows and Jackdaws left the roosting sites about a dozen to several dozen minutes earlier than they did on days with morning air temperatures above 0°C, when extended the activity phase of these birds. Under the conditions of persisting cloudiness and rainfall the species under study started and finished their daily activity at an illumination lower than that on fine days. On the other hand, when short-lived bright intervals and breaks in rainfall occurred at the time of morning departures from the roost and during evening arrivals, the beginning and end of daily activity took place at a higher illumination than on cloudless and rainless days.

Key words: urban birds, daily activity of birds, influence of weather conditions.

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I. INTRODUCTION

The objective of the presented work was to get to know the effect of weather factors (cloudiness, rainfall, fog, wind and air temperature) upon the beginning and end of daily activity in urban populations of the Collared Dove *Streptopelia decaocto* (FRIVALDSKY, 1838), House Sparrow *Passer domesticus* (LINNAEUS, 1758), Blackbird *Turdus merula* LINNAEUS, 1758, Starling *Sturnus vulgaris* LINNAEUS, 1758, Magpie *Pica pica* LINNAEUS, 1758) and Jackdaw *Corvus monedula* LINNAEUS, 1758 in Słupsk. The beginning and end of daily activity determine the length of the activity phase of birds and belong to the constant elements in the daily rhythm of these animals all through the year (ASCHOFF & WEWER 1962).

The daily and annual rhythms of birds are endogenously controlled by their biological clocks, whereas the rhythm regulators are cyclic changes in the lengths of day and night, which in the temperate zone belong among the dominant exogenous factors controlling the times of the beginning and end of daily activity in successive months and the annual life-cycles of these animals (ASCHOFF et al. 1962, WEWER 1962, ENRIGHT 1966, BERTHOLD et al. 1972, GWINNER 1975, 1986, GWINNER

& ERIKSSON 1977, BERTHOLD 1984, 1987, BINKLEY et al. 1985, KLEIN et al. 1985, BAIRLEIN 1986, BINKLEY & MOSHER 1986, DAVSON 1986, POHL 1988).

The distinction of the influence of exogenous phenomena from that of endogenous processes upon the daily and annual rhythms of animals living in the wild is very difficult, because both these groups of factors act upon the organisms complexly and, besides, in the free-living populations of birds there exists remarkable individual variation regarding their response to environmental stimuli, which is confirmed by the results of experimental studies (ASCHOFF 1958, 1960, GWINNER 1971, 1975, DOLNIK 1975, 1976, BINKLEY 1977, HALL et al. 1987, SZYMCAK 1987a, GÓRSKA 1992). Despite these difficulties the results of field studies on the activity of animals make it possible to verify the opinions made mostly on the basis of experimental works and to explain the unknown ecological aspects of the circadian rhythms of living organisms (CYMBOROWSKI 1975, 1984).

II. STUDY MATERIAL, AREA AND METHODS

Studies on the annual cycle of daily activity were made at the roosts of free-living populations of the Collared Dove, House Sparrow, Starling, Jackdaw, Magpie and Blackbird in Słupsk (SW Poland, 54°28' N, 17°10' E) in 1974-1977 and 1992.

The common roosting-site of Collared Doves, House Sparrows, Starlings and Jackdaws was situated in lime trees *Tilia sp.* growing along the busiest streets in the central part of the town, where heavy traffic lasted from about 6 am to about 9 pm everyday except Sundays and holidays. From 250 (June) to about 1100 (December) Collared Doves, from 130 (April) to about 600 (August) House Sparrows, from 50 (May) to about 26000 (August) Starlings and from 200 (April) to about 2800 (September) Jackdaws gathered there for resting (cf. GÓRSKA 1991).

One of the roost-sites of Blackbirds under study was in a grove situated on the periphery of the town – there the birds roosted in spruces *Picea abies* and pines *Pinus silvestris*. Neither the light of street lamps nor the town noise reached that place. Another roost of Blackbirds lay not far from the centre of the town, in an allotment area neighbouring upon the railway station and a busy street lit by lamps emitting the light of a 20-30 lx intensity. Dozen Blackbirds or so roosted in either of these places.

The roost of Magpies was located in a suburban grove, close to the roost of Blackbirds, in spruces and pines, and about 30 birds spent the night there all the year round.

Inspections at the roosts were carried out at 7- to 10-day intervals (exceptionally the interval was 14 days). Each inspection consisted of a series of three observations made in the morning, in the evening and in the morning of the next day (only in the case of the Magpie four observations were made – in the morning and evening on two successive days). At each inspection the times of departures from and arrivals at the roost of the first and the last individual (or group of individuals) of particular species were recorded and the illumination at these moments was measured. The time of departure of the first individual (or a group of individuals) was assumed to be the onset of daily activity of the populations studied, while the arrival of the last individual (or group) at the roost as the end of the active phase (after BOHNSACK 1968). The illumination was measured every 5 minutes (from the time of the onset of departures to the end of arrivals) at constant points which were not reached by the light of the street lamps and the lit house windows. .

A luxmeter with a 0-50000 lx sensitivity range was used

During each observation the data concerning the weather factors, including cloudiness, rainfall, fog, wind and temperature were recorded.

The influence of weather conditions on the onset and end of the daily activity of birds was analysed, by comparing the times of morning departures on two successive days and the times of evening arrivals on two days from the same half of the month. Only pairs of observations made under clearly differing conditions in respect of the intensity of one of the weather factors (e.g. on one day

the departure or arrival with a clear sky and on the other – during the rain) and they were designated conventionally as “natural experiments”. Moreover, the data from two successive days (for departures) or two days in the same half of the month (for arrivals) obtained under similar weather conditions were compared and these were defined conventionally as “controls”. Owing to this method the influence of other external factors than the weather conditions on the results of studies were minimized (among these the numbers of roosting birds changing in successive months and the lengths of day-light periods – see GÓRSKA 1990, 1991).

Cloudiness was taken into account only in the cases when on one day it was 80-100% and the sun disk was invisible and on the other day the sky was clear. Rainfall and fog were considered when they occurred only in one of a pair of observations and reduced visibility to several or a dozen or so metres. Since cloudiness, rainfall and fog usually occurred at the same time, their effect on the activity of birds was analysed jointly. The influence of temperature was analysed for the cases when on one of the days under comparison it was above 0° and on the other it was freezing, while the influence of the wind – if one observation of a pair was made with its speed exceeding 17 m/sec. (about 60 km/hr) and the other in windless circumstances. The data concerning the air temperature and wind speed were obtained from the Hydrological-Meteorological Institute at Słupsk.

For the pairs of observations referred to as a natural experiment and for control observations the influence of weather factors was set up in the form of means, which were compared in respect of the factor under analysis and establishing the statistical significance of differences (Student's *t* test or Cochran-Cox's test). No statistical calculations were applied when the number (*n*) of pairs of observations in an experiment or control was smaller than three. The small number of observations used in analysing some factors was due to causes beyond the observer's control, because the changes in the weather from day to day usually occurred as a complex unit (very rarely two successive days differed in only one factor), unchanged conditions subsisted for several days in succession and, besides, the weather often changed in the course of the morning or evening observations. The effect of the weather factors on illumination at the time of the morning departures and evening arrivals was analysed by comparing percent differences in illumination for pairs of observations carried out under different weather conditions with the mean differences from the pairs of observations conducted on days with identical or similar weather conditions. The differences in illumination are given in percentages, because in the annual cycle it changed in all species by several orders of magnitude (see GÓRSKA 1991); in this connection the calculation of means from absolute values and their comparison made no sense.

Since the intensity of natural light during the day-time depends to a great degree on the sky overcast, intensity of rainfall and also the density of fog, in order to analyse the impact of these factors on illumination at the time of departures and arrivals, three variants of the action of these phenomena were distinguished: cloudiness or rainfall persist from early morning to late evening hours with a great and unchanging intensity; – temporary bright spells occur during departures and arrivals; – a rapid and lasting bright interval takes place just before or during departures or arrivals (a leap by several hundred and even several thousand luxes), caused by the dissipation of clouds by the wind and the appearance of the sun.

The methods applied did not allow a regular assemblage of data for all the species and questions under analysis. The richest material was collected for the influence of cloudiness, rainfall and fog on the times of departures from and arrivals at the roost and the illumination accompanying them. Considerably fewer data were attained as regards the influence of the wind and air temperature.

III. RESULTS

At the time of heavy overcast, intense rainfall and dense fog the departures from the roost were observed to be delayed (Table I). A similar effect at the onset of the daily activity of the Collared Dove, House Sparrow, Magpie and Jackdaw was produced by the galé (Table II). During the heavy

Table I

Cumulative effect of cloudiness, rainfall and fog upon the delay and lengthening of morning departures of the bird species roosting in Słupsk. Explanations: mean values of times and lengths of departures from the roosts (in minutes) for pair of observations carried out in different conditions (natural experiment) and for pair of observations not differing in the degree of cloudiness, intensity of rainfall and density of fog (control). Explanations: (+) delay and (–) acceleration of departures in comparison with the times of sunrise and (<) lengthening and (>) shortening of the departure

Species	Activity form		Natural experiment			Control			Level of statistical significance of differences CC-Cochran-Cox test, t-Student's test
			\bar{x}	SD	n	\bar{x}	SD	n	
<i>Streptopelia decaocto</i>	Beginning	of time of departures	+19.9	16.9	7	2.8	1.6	16	p<0.05 (CC)
	End		+36.0	21.8	14	1.8	1.2	9	p<0.001 (CC)
	Length		<29.2	20.5	7	2.9	2.5	9	p<0.05 (CC)
<i>Passer domesticus</i>	Beginning		+11.0	7.4	6	4.3	2.5	9	NS (CC)
	End		+29.2	10.0	6	2.6	2.1	7	p<0.01 (CC)
	Length		<28.9	16.5	6	3.3	2.1	4	p<0.05 (CC)
<i>Turdus merula</i>	Beginning		+16.2	5.8	9	1.9	0.6	8	p<0.001 (CC)
	End		+16.3	5.0	6	2.3	1.5	6	p<0.01 (CC)
	Length		<4.2	3.3	4	3.0	1.4	5	NS (t)
<i>Sturnus vulgaris</i>	Beginning		+21.1	10.6	7	2.5	0.7	3	p<0.01 (CC)
	End		+33.0	26.5	10	2.0	1.4	3	p<0.01 (CC)
	Length		<19.9	27.3	7	3.5	2.1	3	NS (CC)
<i>Pica pica</i>	Beginning		+14.9	6.7	10	4.9	3.3	13	p<0.001 (t)
	End		+25.9	9.5	9	4.1	1.7	11	p<0.001 (CC)
	Length		<11.9	7.1	8	5.1	3.0	11	p<0.05 (CC)
<i>Corvus monedula</i>	Beginning		+17.7	14.1	6	1.9	1.5	11	NS (CC)
	End		+35.0	28.6	7	2.5	1.2	9	p<0.05 (CC)
	Length		<38.2	31.4	7	1.6	1.9	9	p<0.05 (CC)

overcast, rainfall, and dense fog as well as a gale the birds started and ended the morning departures from a dozen or so to a few dozen minutes later than they did on the day when these factors did not occur (e.g. with the sky overcast and rainfall the Collared Doves started their departures on the average 19 and ended 36 minutes later). Besides, the departures under such weather conditions lasted several dozen minutes longer in comparison with those on fine days, which was particularly distinct in the Jackdaw (on the average 38.2 minutes longer). Earlier departures from the roosts were found in the Collared Dove, Sparrow and Jackdaw on the days with below-zero temperatures in the morning hours. The departures began a dozen or so minutes and ended even 20 minutes earlier as compared with the mornings with above-zero temperatures (Table III).

The evening arrivals at roost were earlier in all the species under study and lasted longer on days on which in the afternoon and in the evening the sky was heavily overcast or when it was raining

Table II

Effect of strong winds on the time and length of morning departures of bird species roosting in Słupsk. The symbol “x” placed for the results for which the statistical significance of differences was not calculated because of too small a number of observations. The other explanations as for Table I

Species	Activity form		Natural experiment			Control			Level of statistical significance of differences CC-Cochran-Cox test, t-Student's test
			\bar{x}	SD	n	\bar{x}	SD	n	
<i>Streptopelia decaocto</i>	Beginning	of time of departures	+10.0	1.4	3	2.8	1.6	16	p<0.001 (t)
	End		+ 8.0	2.8	3	1.8	1.2	9	NS (CC)
	Length		<5.5	6.4	3	2.8	2.5	9	NS (CC)
<i>Passer domesticus</i>	Beginning		+14.0	12.7	3	4.3	2.5	9	NS (CC)
	End		+26.7	20.6	3	2.6	2.1	7	NS (CC)
	Length		<22.0	16.0	3	3.3	2.1	4	NS (CC)
<i>Pica pica</i>	Beginning		+20.0	–	1	4.9	3.3	13	x
	End		+18.0	–	1	4.1	1.7	11	x
	Length		>2.0	–	1	5.1	3.0	11	x
<i>Corvus monedula</i>	Beginning		+ 6.5	6.3	3	1.9	1.5	11	NS (CC)
	End		+24.0	7.0	3	2.5	1.2	9	p<0.05 (CC)
	Length		<10.5	4.9	3	1.6	1.9	9	NS (CC)

Table III

The influence of below-zero temperatures on the acceleration and shortening of morning departures of birds roosting in Słupsk. Explanations as for Tables I and II

Species	Activity form		Natural experiment			Control			Level of statistical significance of differences CC-Cochran-Cox test, t-Student's test
			\bar{x}	SD	n	\bar{x}	SD	n	
<i>Streptopelia decaocto</i>	Beginning	of time of departures	–13.0	6.1	3	2.8	1.6	16	NS (CC)
	End		–10.0	–	1	1.8	1.2	9	x
	Length		> 1.0	–	1	2.8	2.5	9	x
<i>Passer domesticus</i>	Beginning		– 13.6	5.9	5	4.3	2.5	9	p< 0.05 (CC)
	End		– 21.8	8.2	5	2.6	2.1	7	p< 0.01 (CC)
	Length		>8.6	7.7	5	3.3	2.1	4	NS (CC)
<i>Corvus monedula</i>	Beginning		–14.5	0.7	3	1.9	1.5	11	p<0.001 (t)
	End		–21.3	0.6	3	2.5	1.2	9	p<0.001 (t)
	Length		>6.5	0.7	3	1.7	1.9	9	p<0.01 (t)

(Table IV). Then the birds started their arrivals a few dozen minutes earlier (the Sparrow earliest – mean difference: 53 minutes), ended them earlier (Collared Dove earliest – mean difference: 23 minutes) and their arrivals lasted from a dozen or so to a few dozen minutes longer (the House Sparrow longest – mean difference: 51.5 minutes) in comparison with the days when the weather was cloudless in the afternoon and evening hours.

Table IV

Cumulative effect of cloudiness and rainfall on the accelerations and lengthening of the times of evening arrivals of bird species roosting in Słupsk. Explanations as for Tables I and II

Species	Activity form		Natural experiment			Control			Level of statistical significance of differences CC-Cochran-Cox test, t-Student's test
			\bar{x}	SD	n	\bar{x}	SD	n	
<i>Streptopelia decaocto</i>	Beginning	of time of arrivals	-45.8	16.5	14	4.5	3.1	6	P<0.001 (CC)
	End		-23.0	9.7	11	5.7	3.4	6	P<0.01 (CC)
	Length		<33.0	14.3	11	6.5	4.5	6	p<0.01 (CC)
<i>Passer domesticus</i>	Beginning		-53.5	16.1	8	4.2	2.6	5	P<0.001 (CC)
	End		-19.6	11.5	5	3.7	1.2	4	p<0.05 (CC)
	Length		<51.5	18.6	5	5.2	3.2	4	p<0.01 (CC)
<i>Turdus merula</i>	Beginning		-36.0	7.2	3	2.0	1.4	3	p<0.02 (t)
	End		-19.7	13.2	3	4.0	2.8	4	NS (t)
	Length		<16.3	6.5	3	6.2	2.1	3	NS (t)
<i>Sturnus vulgaris</i>	Beginning		-45.0	19.9	9	1.0	–	1	x
	End		-18.0	9.0	5	9.0	–	1	x
	Length		<30.0	17.2	5	10.0	–	1	x
<i>Pica pica</i>	Beginning		-35.5	21.7	9	7.1	4.4	7	p<0.01 (CC)
	End		-12.3	10.9	7	5.4	3.3	10	NS (CC)
	Length		<25.7	13.4	8	7.0	5.0	8	p<0.05 (CC)
<i>Corvus monedula</i>	Beginning		-29.3	9.0	3	5.3	4.5	7	p<0.01 (CC)
	End		-13.5	9.9	4	7.6	4.2	7	NS (CC)
	Length		<15.7	17.7	3	5.6	4.8	7	NS (CC)

In the case of a gale the Collared Dove, House Sparrow, Blackbird, Magpie and Jackdaw started to arrive at roost a few dozen minutes earlier (the Blackbird most early – mean difference: 71 minutes) than on windless days). During the strong wind the end of arrivals occurred earlier only in the Magpie and Jackdaw (mean differences, respectively, 13.5 and 19.0 minutes), whereas in the Collared Dove, Blackbird and Starling – it occurred later (mean differences, respectively: 32, 79 and 49 minutes). At the time of strong winds the birds were coming to the roosting-site from a dozen or so to several dozen minutes longer than they were on windless days (the Collared Dove took longest – mean difference: 86 minutes – Table V).

If the afternoon and evening air temperatures were below 0°C, the onset and end of the arrivals of Collared Doves took place later – mean differences, respectively, 16 and 33 minutes, whereas under these conditions the Jackdaws began to rally 29 minutes later but ended 50 minutes earlier than

Table V

Effect of strong winds on the times and duration of evening arrivals of birds roosting in Słupsk. Explanations as for Tables I and II

Species	Activity form		Natural experiment			Control			Level of statistical significance of differences CC-Cochran-Cox test, t-Student's test
			\bar{x}	SD	n	\bar{x}	SD	n	
<i>Streptopelia decaocto</i>	Beginning	of time of arrivals	-54.0	32.0	2	4.5	3.1	6	x
	End		+32.0	8.5	2	5.7	3.4	6	x
	Length		<86.0	24.7	2	6.5	4.5	6	x
<i>Passer domesticus</i>	Beginning		-54.0	26.2	2	4.2	2.6	5	x
<i>Turdus merula</i>	Beginning		-71.0	—	1	2.0	1.4	2	x
	End		+79.0	—	1	4.0	2.8	4	x
	Length		<50.0	—	1	6.0	4.2	2	x
<i>Sturnus vulgaris</i>	Beginning		+1.0	—	1	1.0	—	1	x
	End		+49.0	—	1	9.0	—	1	x
	Length		<50.0	—	1	10.0	—	1	x
<i>Pica pica</i>	Beginning		-24.4	15.5	5	7.1	4.4	7	NS (CC)
	End		-13.3	5.7	4	5.4	3.3	10	p<0.01 (CC)
	Length		<16.0	10.0	5	7.0	5.0	8	NS (CC)
<i>Corvus monedula</i>	Beginning		-47.0	—	1	5.3	4.5	7	x
	End		-19.0	—	1	7.6	4.2	7	x
	Length		<32.0	—	1	5.6	4.8	7	x

on a day with above 0° C temperatures. At a temperature below 0° C the evening rally of Collared Doves took 17 minutes longer, while in the case of the Jackdaws it was shorter by 79 minutes. The data concerning the influence of low temperatures on the times of the end of daily activity in both these species were not included in the table because only one pair of observations was attained regarding this factor for either species.

In the pairs of control observations the mean differences for departure times did not exceed 5 and for the arrivals 8 minutes (only in Starlings – 10 minutes) and in a considerable number of cases their comparison with the mean differences obtained for the pairs of observations carried out under different weather conditions showed the statistical significance of mean differences (Tables I – V).

On days with heavy overcast and rainfall persisting all day long or when in the morning or in the afternoon a distinct and lasting worsening of weather ensued, the birds started their morning departures and ended the evening arrivals at lower values of illumination than on cloudless and rainless days (e.g. the mean difference for the beginning of departure of the Collared Dove by 40%, the House Sparrow by 31.6% and the Magpie by 66%; and for the end of arrivals by 84, 41.6 and 37%, respectively) (Table VI). It was observed, for instance, that with a very slow increase in natural illumination in the morning hours caused by thick rainclouds, the departure of House Sparrows started at 13.5 lx, whereas on the preceding day with the cloudless sky at 333 lx.

If in the morning the overcast sky cleared up and the rain stopped for a short time, the birds started to leave the roost at a higher illumination than on cloudless days (e.g. the Collared Dove

Table VI

Influence of cloudiness (C), rainfall (R), fog (F) and temperature (T) on the illumination at the onset of departures and the end of arrivals of birds roosting in Słupsk. Explanations: (o) weather factor of unchangeable intensity all day long; (oo) short bright intervals and breaks in rain; (ooo) abrupt and lasting clearings up during the departures or arrivals; mean value of illumination during departure or arrivals lower (>) or higher (<) on days with the occurrence of the given weather factor than on days without that factor.

Species	Behaviour of weather factor	Mean differences (in %) within pairs of differing observations (Natural Experiment) and pairs of observations with similar intensity of factor under consideration (Control)					
		Natural experiment			Control		
		\bar{x}	SD	n	\bar{x}	SD	n
Cumulative influence of C,R and F on illumination at the onset of departures							
<i>Streptopelia decaocto</i>	(o)	>40.0	19.8	4	15.6	8.7	16
	(oo)	<49.2	28.0	3	15.6	8.7	16
<i>Passer domesticus</i>	(o)	>316.5	—	1	13.9	9.4	9
	(oo)	<35.5	12.8	5	13.9	9.4	9
<i>Pica pica</i>	(o)	>66.0	18.0	6	21.0	13.0	13
	(oo)	<32.0	19.0	4	21.0	13.0	13
Cumulative influence of C, R and F on illumination at the end of departures							
<i>Streptopelia decaocto</i>	(o)	>84.0	19.8	6	8.8	6.0	6
	(ooo)	<35.0	21.0	8	8.8	6.0	6
<i>Passer domesticus</i>	(o)	>41.6	18.0	6	30.6	17.5	5
	(ooo)	<19.0	11.3	2	30.6	17.5	5
<i>Pica pica</i>	(o)	>37.0	31.0	5	16.8	7.7	12
	(ooo)	<20.3	17.8	4	16.8	7.7	12
Influence of T on illumination at the onset of departures.							
<i>Passer domesticus</i>	(o)	>39.0	19.0	5	13.0	9.4	8

when it was higher on the average by 49.2%, House Sparrow by 35.5%, Magpie by 32% – Table VI). A similar phenomenon was observed during thick fog. At the time of the rain varying in intensity, the Collared Doves and House Sparrows left the roost during short breaks between waves of rain or snow, when the visibility was improving. If in the morning hours a blizzard broke out or there was thick fog, the Collared Doves, House Sparrows and Starlings did not fly away quickly and in masses before the subsidence of the blizzard or fog. Single birds that tried to leave the roost at a very low state of visibility, having flown about ten metres returned to the place they had started from. If the thick fog appeared suddenly when the departures of the Collared Doves and Starlings were already in progress, the last Doves flew away at an illumination 50 lx higher and the last Starlings 450 lx higher than what it was when they were leaving on the previous day (cloudless and without fog). The birds behaved similarly in the evening, if thick, heavy clouds and rainfalls became interrupted by a sudden and long-lasting clearing-up and during fog – under such conditions they ended their rally to roost at a higher state of illumination than on fine days (e.g. the Collared Dove at illumination higher on the average by 35%, the House Sparrow by 19%, and the Magpie by 20% –

Table VI). During an observation of arrivals, when a considerable number of the Collared Doves and House Sparrows were already roosting quietly in the roosting trees and the wind abruptly dispersed the clouds and uncovered the sun, the illumination rose from 500 to 6000 lx. The birds sitting on branches remained on them, while further individuals continued arriving and alighted on the roost but at an illumination about 250 lx higher than on other days when in the afternoon the sky was almost cloudless.

The effect of the subzero temperature upon the illumination at the time of the beginning of daily activity was analysed only for the onset of the departure of the House Sparrow, because no data concerning this factor were obtained for the remaining species and for the end of activity. In the mornings with subzero temperatures the House Sparrows were leaving the roost at a lower illumination level (on the average by 39%) than on warmer days (Table VI).

The means from differences between the illumination values found in the pairs of control observations were lower than those on days with different weather conditions regarding both the beginning of departures (Collared Doves -15.6%, House Sparrow -13.9%, Magpie 21%) and the end of arrivals (Collared Dove - 8.8%, House Sparrow - 30.6%, Magpie - 16.8% - Table VI).

Observations of the behaviour of the birds at the roosting-site showed that rapid changes in weather did not evoke identical responses in all the species. During violent blizzards, which broke out several times when Magpies were returning in the evening, the Magpies that had been roosting in the trees for several to more than ten minutes took wing and circled restlessly over the roost, together with those just arriving. They did not get quiet and alight on the roosting-trees until the blizzard, lasting sometimes several dozen minutes, had ended. On the other hand, the Collared Doves, House Sparrows and Starlings, which ended their daily activity before the arrival of the first Magpies, did not respond to the worsening of the weather and slept quietly.

All the year round the Blackbirds spending nights in the allotments began their vocal activity on the average 40 minutes earlier and at lower illumination than did the Blackbirds roosting in the suburban grove. In the first half of the breeding season the mean differences in the time of the first calls and songs between these two sites increased to 55 minutes and in the second half of this season it decreased to about 25 minutes. In the first half of the breeding season the mean differences in illumination at which the Blackbirds roosting in the centre of the town and those in the suburban grove started their daily activity was the highest in the annual cycle (Table VII).

Table VII

Mean differences in times of beginning of voice activity and the meanvalue of illumination of Blackbirds roosting in inner-city allotments (A) and in the suburban grove (B). The means were calculated on the basis of the differences (in minutes) recorded in both those areas on the same days of observations

Season of observations	Mean difference (in minutes) in times of the onset of daily activity between A and B			Mean illumination (lx) of the earliest voice or song	
	\bar{x}	SD	n	A	B
All through the year	40.0	22.5	33	0.04	0.8
Breeding season	42.0	23.2	24	0.05	0.75
First part of breeding season (April till mid-May)	55.0	15.4	13	0	0.15
Second part of breeding season (mid-May throughout July)	25.5	11.5	11	0.11	1.23

IV. DISCUSSION

In addition to the regular changes in the factors of external environment (e.g. regular changes in the lengths of day and night), free-living birds are affected by irregularly occurring atmospheric phenomena, which may act upon the length of phases of the circadian cycle by accelerating or delaying the beginning and end of daily activity (ASCHOFF 1955, 1958, BOGUCKI 1972, JONES 1986, REEBS & MROSOVSKY 1990, DOUCETTE & REEBS 1994).

Field investigations carried out so far have shown that the rain delays the beginning of the vocal activity of birds irrespective of illumination, and that in winter and autumn an increase in the cloudiness and – in the Arctic – also dense fog induce a lowering in the activity level of these animals (ASCHOFF & HOLST 1958, SCHEER 1952). Moreover, it was established on the basis of experimental studies that the length and intensity of the photoperiod may change the global time and pattern of activity of the House Sparrow (BINKLEY & MOSHER 1986, 1987). The results obtained at Słupsk indicate that under the influence of the weather factors which decrease the natural light intensity (cloudiness and rainfall, fog) the active phase of free-living birds undergoes a shortening and that the beginning and ending of daily activity occur at lower luminosity in comparison with cloudless days.

Birds begin and end their daily activity at the so-called threshold illumination – characteristic of each species – whose value is lower in the morning than in the evening and different in successive months, owing to continuous changes in the functional state of the organisms of these animals, producing a different response to the cyclic stimuli of the environment within 24-hour periods and in the annual cycle (ASCHOFF 1957, 1960, ENRIGHT 1966, BERTHOLD 1968, GWINNER 1975, DOLNIK 1976, NICHOLLS & STOREY 1977, MATT et al. 1984, NICHOLLS et al. 1984, DAWSON et al. 1985, BRENSING 1988, GWINNER et al. 1988, GÓRSKA 1990, 1991). In the case of the species under study the beginning of daily activity at a very low illumination on cloudy days may have been controlled endogenously, because during small changes in illumination, other factors, including the endogenous rhythm decisive of the length of phases of the daily cycle, become the regulators of the diurnal rhythm of the birds (ARMSTRONG 1954, ASCHOFF 1954, GRACZYK 1961, ENRIGHT 1966). Moreover, the sleep of birds is interrupted by short waking periods and at the same time they are able to adapt themselves actively to the environmental conditions and decide whether the illumination is suitable for them to start daily activity (KARPLUS 1952, ASCHOFF & HOLST 1958, LENDREM 1984). On days when the rise in the natural illumination in the morning hours was very slow the birds roosting at Słupsk probably stayed at the roosting-site until the luminosity in the surroundings reached the threshold value, characteristic of particular species, and when the weather conditions inhibited the rise in illumination for rather a long time they eventually left the roost; the departure was however delayed and at lower luminosity than of the days when the sky was cloudless. If the time of the beginning of daily activity had depended only on astronomic and weather phenomena, the birds would probably have remained at roost till the appropriate rise in illumination in the surroundings, which might have shortened the activity phase even by several hours or made the commencement of daily activity entirely impossible. An additional stimulus was undoubtedly starvation, especially severely felt by the birds in the morning after a long and chill night.

The atmospheric factors speeding darkening towards the end of the day made the birds stop foraging earlier and arrive at the roost at lower illumination than on cloudless days.

In cases when the overcast and intensity of rainfall were changeable or when dense fog reduced visibility, the species under study left the roosts at higher luminosity than on days on which the sky was cloudless and the visibility good. That was so owing to a considerable delay of the beginning of daily activity in comparison with fine days – the birds left the roosts almost immediately after a sudden brightening caused, for instance, by an instantaneous appearance of the sun in a gap in the clouds or the dispersion of fog and improvement in visibility, at the moment of a distinct increase in illumination (because of the delayed departure in relation to that on bright days, after the improve-

ment of the weather it was lighter in the surroundings). The beginning of daily activity at higher illumination on cloudy days was observed in birds also by LUTZ (1931), HINDE (1952), SCHEER (1952), FRANCK (1954), GRIMM (1957), and ASCHOFF & HOLST (1958).

On cloudy, rainy days on which during the evening arrivals at the roost-site a sudden brightening took place (the wind dispersed the clouds and the sun appeared), the species under study ended daily activity earlier and at higher illumination than on cloudless days. After it became bright the coming birds settled at the roosts and did not fly away to feeding grounds any more. Neither did a rapid rise in illumination cause an increase in the locomotor or vocal activity of individuals (the largest number of observations was that of the House Sparrow), which had been asleep and sitting quietly among the branches of the roosting trees. This suggests that the end of the active phase of birds is also to some degree controlled by endogenous factors.

In the case of species departing early in the morning the degree of sky overcast and illumination is a poor indicator of the beginning of day activity (DOUCETTE & REEBS 1994). This is explained by the lack of influence of these factors on illumination during the morning departures of the Blackbird, Starling and Jackdaw – species leaving the roosts in the morning much earlier than do the Collared Dove, House Sparrow and Magpie and at a very low level of illumination (GÓRSKA 1991).

The later departures from and earlier arrivals at the roosts during stormy winds as compared with windless days may have had a disadvantageous influence on the total time of feeding. A similar dependence was found in these animals by FRANZ (1943), SHEER (1952), ARMSTRONG (1954) and DOUCETTE & REEBS (1994). At the time of strong winds the birds roosting at Słupsk woke up earlier than on windless days and showed great anxiety (frequent flights among moving branches and a considerable vocal activity); however, they stayed at the roosting-site for a long time. It seems that the main cause of such behaviour were difficulties in taking wing, which was particularly so in the case of the birds roosting downtown, where the gale was additionally strengthened by drafts. Difficulties in the flight of Rooks from roosting sites during strong winds were also observed by GRODZIŃSKI (1971). On the other hand, in the evening the tree branches tossed by the wind made it distinctly difficult, often simply impossible for the birds to alight on them. These difficulties increased in the course of arrivals, as it was getting darker, which the Jackdaws, arriving latest, felt most intensely. Weak winds, however, did not influence the behaviour of the species observed at the roosts, which was also noted for other birds by GRODZIŃSKI (1971), REEBS (1986) and WARKENTIN (1986).

The lengthening of the duration of morning departures and evening arrivals at the time of heavy sky overcast, rainfall, dense fog and gale was probably due to differences in particular individuals' responses to external stimuli, which differences may have increased in unfavourable weather circumstances. In free-living populations there exists a considerable range of individual variation in reacting to unexpected changes and disturbances of the factors of external environment (ASCHOFF 1957, 1960, 1965, MAYERSBACH 1967, MILLS 1973), and it varies in the course of the year in dependence on the physiological state of particular individuals and on the conditions of the external environment (ASCHOFF & HOLST 1958, DOLNIK 1976, LENKIEWICZ et al. 1977, MATT et al. 1984, DAWSON et al. 1985, GÓRSKA 1987, 1992, GWINNER et al. 1988, POHL 1988).

At lowered temperatures the activity phase of diurnal organisms, inclusive of many bird species, undergoes a lengthening (MORSE 1956, ASCHOFF 1960, ENRIGHT 1966), which has also been found in the species under study. Increased calorific requirements during cold weather, particularly badly felt by the birds in the morning, after nocturnal cooling, made them leave earlier for feeding-grounds than on warmer days. The foregoing suggestions can be additionally supported by the results of experimental studies carried out by LENKIEWICZ et al. (1977), who established that at low temperatures the morning maximum activity overtops the evening maximum, whereas towards the end of the day a low temperature made the birds feed longer and in this connection they ended daily activity later than on warmer days. Late arrivals at a low temperature suggest a strategy consisting in the gathering of energy indispensable to survive a cool night (ARMSTRONG & NOAKES 1981,

DOUCETTE & REEBBS 1994). A longer time of feeding, even by four minutes, may be of significant importance to the survival of a chill night by the bird (TERRES 1982, DOUCETTE & REEBBS 1994). It seems therefore that the lengthening of the active phase in the species under study by a dozen or so and sometimes several dozen minutes and the time of feeding by the same value, particularly in the case of easily available food (Collared Dove, House Sparrow), exerted a positive influence on the condition and survivability of birds during autumn and winter nights.

It has been pointed out in experimental studies that only appropriately intense stimuli can exert an effect on the length of phases of the circadian cycle of birds and that the effectiveness of their action is dependent on whether the organism is in the phase of sensitivity to these stimuli (ASCHOFF 1954, 1960, GWINNER & ERIKSSON 1977). This type of responding of animals to the external factors may explain why moderate changes in the weather did not significantly influence the length of the active phase of the species under study. A similar phenomenon was observed at the common roosting-sites of the House Sparrow and Starling in Poznań (GÓRSKA 1975). On the other hand, rapid and decisive changes in the weather distinctly influenced the length of the active phase.

A quick and abrupt weather change after the decline of the active phase, when the birds had already become quiet at the roosting-site did not as a rule disturb the rest of the species under study. A rise in the illumination even by several thousand lux or the outbreak of a violent snowstorm after the termination of the arrivals of Collared Doves and House Sparrows and their becoming quiet, did not brought about their response – they continued sleeping quietly. These observations suggest that after starting the resting phase these birds become less sensitive to external stimuli for some time and their sensitivity does not increase again until towards the end of this phase. The responses of birds to environmental factors in the course of a day-and-night cycle are controlled by the endogenous rhythm similarly to the lengths of phases of the circadian cycle (ASCHOFF & WEWER 1962). Even under conditions of arctic summer all birds living in high geographical latitudes have a definite minimum of demands concerning the length of sleep – three to about five hours a day, and they sleep most soundly in the first hours of the inactive phase (PALMGREN 1949, KARPLUS 1952, CULLEN 1954). The cyclic nature of the changes in the soundness of sleep in birds was also pointed out in experimental studies (SZYMCAK 1986, 1987a,b). The results of studies conducted at two roosting-sites of the Blackbird may provide an additional proof of the occurrence of variable sensitivity of free-living birds to environmental factors in both the circadian and the annual cycle. The Blackbirds roosting in allotments in the town centre slept quietly for several night hours despite the noise made by trains passing nearby and artificial lighting reaching their roosts. They were probably woken up by these anthropogenic factors only towards the end of the resting phase and in consequence began the vocal activity a few tens of minutes earlier than did the Blackbirds in the shaded and quiet roosting-site in the suburban wood. This difference increased considerably in the first half of the breeding season – the population spending the night downtown started their activity still earlier (when it was quite dark in the surroundings) than did the population roosting in the wood (when the natural illumination level began to rise). This was probably caused by an increase in the physiological sensitivity of the birds to external stimuli in this period of the annual cycle, for at the beginning of the breeding season the sensitivity of birds to changes in illumination rises, whereas towards the end of breeding it lowers again (DOLNIK 1976, BERTHOLD 1984, MATT et al. 1984, DAWSON et al. 1985, GWINNER et al. 1988, GÓRSKA 1991, 1992). Moreover, LENKIEWICZ et al. (1977) established experimentally that in the summer season some *Passeriformes* respond differently to an increase in cloudiness than in the autumn-winter season. In autumn and winter an increase in cloudiness induces a fall in the general level of their activity, whereas it is followed by a rise in summer. The decrease in the sensitivity to environmental stimuli in the second part of the breeding season may account for the highest means of illumination in the annual cycle accompanying the beginning of daily activity of the Blackbirds and the highest difference in illumination between the beginnings of their daily activity in those two roosting-sites.

The light emitted by street lamps permitted the early waking Blackbirds, Collared Doves and House Sparrows to feed at the time when the natural illumination was still nearly zero and, on the

other hand, it did not prevent these birds from sleeping quietly at the urban roosting-sites in the night. Such behaviour evidences the birds' great ability to adapt, particularly to activity in dimmed light, which is confirmed by earlier studies carried out by other authors (e.g. DĄBROWSKA 1976).

Recapitulating the influence of irregularly recurring factors of the external environment on the daily activity of the species under study, it can be stated that they disturbed the length of phases of the circadian cycle of the birds only to a limited extent, because the decisive role in the regulation of the daily rhythms of animals is probably played by endogenous rhythms and the synchronization of the rhythm of a biological organism with the rhythm of the exogenous factor may occur only in certain limits and may fluctuate from 21 to 27 hours in different organisms, the greater fluctuations being unusually rare (ASCHOFF 1958). Furthermore, it seems that the stimuli of the external environment lengthening the active phase of birds can attenuate the condition of these animals and negatively influence their survival during long and chill autumn-winter nights, if the longer activity is not connected with longer feeding time but with additional waste of energy (for instance, a long and uneasy circling over roosts at the time of a snow storm).

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