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PLUMAGE POLYMORPHISM AND BREEDING PARAMETERS OF VARIOUS FERAL PIGEON (*COLUMBA LIVIA* GM.) MORPHS IN URBAN AREA (GDAŃSK, NORTH POLAND)

ABSTRACT: In 2007, the population of Feral Pigeons in Gdańsk City (almost 500,000 inhabitants) constituted 14 200 individuals. The population density in the built-up areas of Gdańsk (82.2 km^2) was estimated at an average of 17.2 birds 10^{-1} ha, however the highest density occurred in Gdańsk's city centre area (5.7 km^2) – 44 birds 10^{-1} ha. Blue plumage type pigeons dominated in the population (93%), while black, red and albinotic types were rarely observed. Melanistic birds were more frequently found than blue-bar birds, whose plumage is inherited from the Rock Pigeon. However, blue-bars were more numerous in Gdańsk compared with other pigeon populations in central and northern Europe. Old pre-war buildings were not confirmed as influencing the plumage pattern of pigeons. Melanistic birds were more numerous in old district of Oliwa, whereas blue bars in old Gdańsk city centre. The plumage of pigeons in small flocks of up to 50 birds did not differ from that of pigeons in flocks of over 50 and 100 birds. Blue-bars, checkers and dark checkers did not differ in body mass or breeding parameters. Other causes of polymorphism variation among pigeons in a population are discussed.

KEY WORDS: Feral Pigeon, *Columba livia*, plumage polymorphism, breeding parameters

1. INTRODUCTION

The Feral Pigeon is characterised by a strongly developed and diverse polymorphism, generally not found in the other birds living in the wild. At least 60 hereditary factors were shown to influence the pattern and colour of Feral Pigeon plumages in Basle and Vienna (Leiss and Haag-Wackernagel 1999). The great diversity of the Feral Pigeon's plumage is a result of its descent from the Domestic Pigeon (Haag-Wackernagel 1998), which has been selectively bred over thousands of years for various traits, including, among others, to achieve interesting plumage types. The predecessor of the Domestic and Feral Pigeon is the Rock Pigeon, which was domesticated 5,000–10,000 years ago in the Mediterranean region. The Rock Pigeon is characterised by uniform blue plumage and two bars on each wing. This type of plumage is called wild or blue-bar. Rock Pigeon populations are often no longer genetically pure, as they are crossed with Feral or Domestic Pigeons. However, studies have shown that Rock Pigeon living independently of humans is better adapted to harsher, more natural conditions than immigrants from cities or captive breeding.

In the Feral Pigeon studies conducted by Petersen and Williamson (1949), the number of birds with plumage types other than wild significantly fluctuated after harsh winters. The situation is reversed in large cities, where melanistic birds dominate and include the following morphs: checker, dark checker and spread (Murton *et al.* 1973). Pigeons in cities are dependent on humans, who not only provide them with breeding sites, but primarily provide them with food. A constant food base during the year and milder environmental conditions provide pigeons with the opportunity to breed year-round. Melanistic birds are better adapted to do so (Murton *et al.* 1973).

Studies on the polymorphism of Feral Pigeon were carried out in several European and American cities. The results achieved to date show significant diversity in pigeon plumages among populations (Johnston and Janiga 1995, Leiss and Haag-Wackernagel 1999). The reasons for this diversity are due to the different history of each population and the variations found in the plumages of Domestic Pigeon raised in the vicinity of the city (Leiss and Haag-Wackernagel 1999). Such Feral Pigeon studies have not been conducted yet in Poland, except for the city of Słupsk, with an area of 43.2 km^2 and 100,000 inhabitants (Hetmański 2004a). It is worth taking a closer look at these issues, as we expect this species to develop further in Polish cities (Nowakowski *et al.* 2006, own author's data).

In this study, we focused on establishing the plumage frequencies in the Feral Pigeon population of the largest Polish port city – Gdańsk. At the same time, we also studied the plumage variation within a population in relation to building type. We wanted to determine existing differences in body mass and breeding parameters among specific polymorphs.

In addition to polymorphism characteristics, we also studied the numbers and density of Feral Pigeons in Gdańsk. These data are important, as there is a growing problem in Poland of an abundance of pigeons in larger cities such as Warsaw, Kraków and Poznań, and even in small ones like Słupsk. The need to reduce Feral Pigeon numbers is often discussed in these cities. Data on numbers and distribution are essential to initiate the control of this species' population (Sol and Senar 1995). Several studies on the numbers of pigeons have been conducted in Poland – in Olsztyn (Dulisz and Nowakowski 1996, Nowakowski 1996, Nowakowski *et al.* 2006), Warsaw (Luniak 1996, Luniak *et al.* 2001, 2007, Nowicki 2001) and Poznań (Dabert 1987). However, they lack a more thorough analysis of the population distribution and plumage type variations. In this work, we analyse basic population characteristics, such as numbers and spatial distribution, but also the number of flocks, size of flocks and plumage variations. We also present the results of a different study methodology.

2. STUDY AREA

Gdańsk (54^{0}22'N, 18^{0}38'E) is the largest city in Pomerania, as well as its regional capital. It has almost 500,000 residents. The city was founded in the 10th century, and its current administrative area encompasses 262 km^2. Urbanised areas account for 82.2 km^2 (31.3%), farmland – 102.3 km^2 (39.3%), forests and urban parks – 47.6 km^2 (18.2%), water 14.6 km^2 (5.6%) (on-line data from City Hall). Gdańsk has 30 districts. We divided the area of the city by the age of its buildings. We analysed pigeons from areas with old buildings erected before World War II and those constructed after the war. The City Centre of Gdańsk, Wrzeszcz and Oliwa are districts with old, pre-WWII buildings (Fig. 1). The remaining, younger neighbourhoods are made up of housing estates and villas. The research of Sacchi *et al.* (2002) showed that old buildings in the city centre were occupied by a significantly greater number of pigeons than areas at the outskirts of the city.

3. MATERIALS AND METHODS

Pigeons were counted at foraging sites in the autumn and winter of 2006/2007. Autumn and early winter are the best periods to study the distribution and numbers of pigeons in cities, because only a few birds are breeding or breeding stops altogether then (Hetmański 2004b). At this time, pigeons are found away from buildings at foraging sites (Rose *et al.* 2006). Pigeons reproduce

Fig. 1. Distribution of Feral Pigeon flocks in districts with old buildings (Gdańsk city centre, Wrzeszcz and Oliwa) and in surrounding districts with post-war buildings. Dark points indicate flocks where melanistic birds dominated; light points, where blue-bar birds dominated.

in spring and summer. The pigeon's breeding strategy requires the almost constant presence of parents at the nest, as the pair cares for two broods simultaneously (Burley 1980, Hetmański and Wołk 2005). Therefore, assessing plumage frequencies during the breeding season could lead to erroneous results. Additionally, a high production of fledglings occurs during the breeding season and survival is low in the first months after fledging (Hetmański 2007a). The flocks of birds at foraging sites during the breeding season are constantly changing in terms of their numbers and plumages.

The pigeon counts in Gdańsk were always conducted in the morning until about noon, as at this time hungry birds gathered in flocks at foraging sites. Birds were attracted to foraging sites by using finely ground grain or rice. Providing this food helped in counting the specific plumage types because the birds did not wander during feeding.

Birds with specific plumage patterns and colours were noted during counting. 8,082 specimens were analysed, accounting for about 57% of the estimated population in Gdańsk (n=14200). Plumage patterns were determined based on literature

data (Murton *et al.* 1973, 1974, Johnston and Janiga 1995). These included four basic morphs: wild (blue-bar), checker, dark checker (T-pattern) and spread. Blue-bar birds have the plumage of Rock Pigeon, characterised by the two black bars on both wings. Checkers are characterised by a pattern of dark feathers on a background of blue wings, covering up to 50% of the wing area. Dark checkers have more black feathers, covering more than 50% of wing area. Spread birds are completely black. We divided the pigeons into the categories of blue-bar birds (wild) and melanistic birds, which included checker, dark checker and spread. We also categorised the birds by plumage colour – blue, red, white and black (Johnston and Janiga 1995). Because a decided majority of the birds were blue pigeons, plumage pattern types refer to this colour. Red and albinotic birds were not analysed by plumage pattern and were automatically included into the „other" group.

Breeding research was conducted at one colony in 2006 and 2007. Birds from this colony were captured at night, ringed and weighed using a PESOLA-type scale, and their plumage type recorded. The breeding of over 40 pairs was followed for two breeding seasons. The location of specific pairs' nests was determined by observations from a hide. Nests were controlled once per week, with the number of eggs in a nest, number of hatchlings and fledglings recorded.

Student's t test was used to analyse the material and the ANOVA variance was used to compare average values (body mass, breeding parameters). Plumage frequencies in flocks were compared using the χ^2 test.

4. RESULTS

In 2007, the Feral Pigeon population consisted of 14,200 birds living in the 82.2 km^2 urban area of the city of Gdańsk. The average density of Feral Pigeon within the administrative boundaries of the city comprised 5.4 individuals 10^{-1} ha. We confirmed an average of 17.2 individuals 10^{-1} ha in the built-up areas of the city. The greatest density was found in the district of old buildings in Gdańsk's city centre – 44 individuals 10^{-1} ha. Pigeons were also present in newer housing estate districts surrounding the older neighbourhoods of Wrzeszcz and Oliwa with their pre-WWII buildings (Fig. 1). However, there were very few pigeons in industrial areas and they were not observed in neighbourhoods of villas and communal gardens.

During the studies we counted pigeons from 289 flocks. Most numerous were flocks numbering up to 50 individuals, which comprised 73% of the flocks. Flocks of 51 to 100 birds represented 20.1%, while flocks of 101 to 150 represented 6.2% of the total number

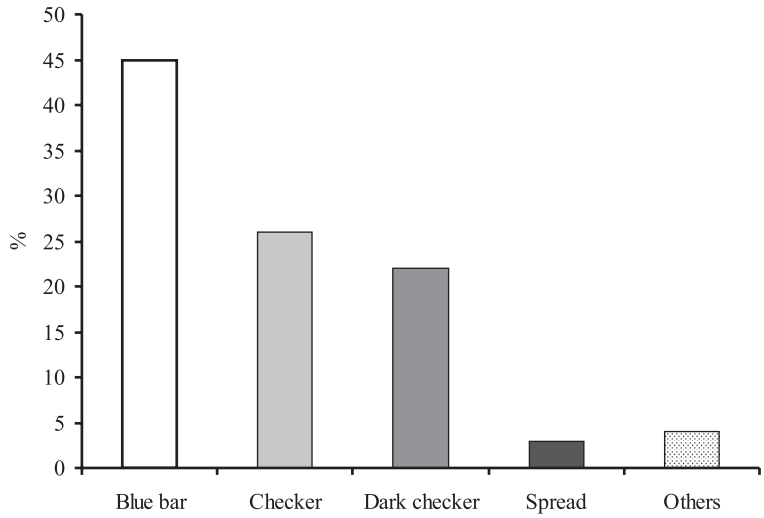

Fig. 2. Percent contribution of plumage patterns in the Feral Pigeon population of Gdańsk (n = 8082).

Table 1. Body mass (g) (± SD) of Feral Pigeon males and females of various plumage patterns in studied breeding colony in the area of Gdańsk (N Poland).

	Females			Males		
	Blue bar (n = 20)	Checker (n = 19)	Dark checker (n = 19)	Blue bar (n = 22)	Checker (n = 15)	Dark checker (n = 16)
Body mass (g)	372 ± 22	385 ± 28	372 ± 43	403 ± 34	407 ± 32	396 ± 32
	ANOVA F = 0.620 $P > 0.05$			ANOVA F = 0.325 $P > 0.05$		

Table 2. Average number of clutches and fledglings raised by Feral Pigeon females with different plumage patterns in the 2006–2007 season.

	Females (2006 season)			Females (2007 season)		
	Blue bar (n = 18)	Checker (n = 12)	Dark checker (n = 11)	Blue bar (n = 21)	Checker (n = 14)	Dark checker (n = 10)
N clutches	4.5 ± 1.8	4.5 ± 1.7	4.9 ± 2.0	4.2 ± 1.2	4.2 ± 1.3	4.7 ± 1.2
ANOVA	F = 0.26 $P > 0.05$			F = 0.89 $P > 0.05$		
N fledglings	3.9 ± 2.2	3.1 ± 2.5	3.2 ± 3.1	3.3 ± 2.3	3.4 ± 3.1	4.2 ± 2.7
ANOVA	F = 0.687 $P > 0.05$			F = 0.814 $P > 0.05$		

of flocks. There were only two flocks (0.7%) with more than 150 birds.

The frequency of plumage colours was as follows: 93% (n = 8082) were blue birds, 3% black birds, 1.4% red, 0.7% albinotic, and 2.0% of the birds were "others", difficult to classify. In analysing plumage patterns, we observed that melanistic birds (checker, dark checker and spread) dominated in the population (51%, n = 8082). However, blue-bar birds comprised 45% of the population (Fig. 2). Other birds represented 4% of the population. Particular flocks significantly differed in plumage frequencies. Wild birds constituted from 8% to 87% of individuals in a flock, checkers comprised from 0 to 68%, while dark checkers from 3 to 69%. The maximum number of spread birds in a flock was 41%.

In smaller flocks of up to 50 individuals, the proportion of melanistic birds was calculated at a total of 52.6%, and blue-bar birds – 42.7%. In flocks with over 51 individuals, melanistic birds constituted 49.5% and wild types 46.8% (n = 4604). The size of the flocks had no influence on plumage frequencies (χ^2 = 0.277, df = 1, $P > 0.05$).

We also studied the influence of building type on plumage frequencies. We compared the plumages of pigeons from three districts of Gdańsk (city centre, Wrzeszcz and Oliwa), characterised by old, pre-war architecture, with birds inhabiting neighbourhoods built up after the war. Dark points on the map indicate flocks where melanistic birds predominated, and they intermingle with light points, where blue-bar birds were dominant (Fig. 1). We noted that there were more blue-bar bird flocks in Gdańsk's centre city than in its surrounding areas (χ^2 = 21.784, df = 1, $P < 0.01$). On the other hand, we noted the opposite situation in Oliwa. In the area of old buildings in that city district, there were more melanistic birds than in the newer housing estate neighbourhoods (χ^2 = 11.205, df = 1, $P < 0.05$). However, the flocks in the old buildings of Wrzeszcz did not differ in plumage frequencies in relationship to flocks in neighbouring housing estate districts (χ^2 = 0.316, df = 1, $P > 0.05$) (Figs 1, 3).

We found no influence of plumage type on the birds' body mass. Blue-bar males and females weighed on average 386 ± 32.2 grams, similarly to dark checkers 389 ± 36.2 g, and checkers weighed 394 ± 30.1 g (ANOVA F = 0.202, df = 59, $P > 0.05$). Differences in body mass also did not occur among birds of the same sex. There were no significant differences among males or among females (Table 1).

Males were heavier than females by an average of 20–30 grams for all plumage types

(Table 1). Wild females had similar breeding rates as wild males (Student's T test: the first season t = 0.281 *P> 0.05*, the second season t = 1.028 *P> 0.05*). There were also no significant differences between checker males and females (Student's T test: t = 0.337 *P*> 0.05 and t = 0.915 *P> 0.05* respectively) or dark checker (t = 0.519 *P*> 0.05, t = 0.810 *P*> 0.05) (Table 2, 3).

Reproductive rates for females of different plumages are presented in Table 2, while for males in Table 3. All females had similar numbers of broods and produced a similar number of young in a season, regardless of plumage type (Table 2). This was the same for the males (Table 3).

5. DISCUSSION

The estimated population of Feral Pigeons in Gdańsk in the winter of 2006/2007 numbered 14200 individuals. Compared to other Polish cities, this is more than in Olsztyn, where the entire population was estimated at 4200 – 4400 individuals (Nowakowski *et al.* 2006). Feral Pigeons concentrate mainly in areas with older buildings, and their highest densities are regularly noted in cities' centres (Sacchi *et al.* 2002, Nowakowski *et al.* 2006), whereas they are rare or absent in parks and at the peripheries of cities (Lancaster and Rees 1979, Luniak 1983). In Gdańsk, the highest density of birds was also

Table 3. Average number of clutches and fledglings raised by Feral Pigeon male with different plumage patterns in the 2006–2007 season.

	Males (2006 season)			Males (2007 season)		
	Blue bar (n = 17)	Checker (n = 17)	Dark checker (n = 11)	Blue bar (n = 19)	Checker (n = 14)	Dark checker (n = 13)
N clutches	4.5 ± 1.7	4.3 ± 1.9	5.2 ± 1.8	3.8 ± 1.4	4.6 ± 1.4	3.9 ± 1.3
ANOVA	F = 1.55 *P*> 0.05			F = 2.604 *P*> 0.05		
N fledglings	4.0 ± 2.3	3.4 ± 2.6	3.7 ± 3.2	2.7 ± 2.1	4.2 ± 2.7	3.6 ± 2.7
ANOVA	F = 0.289 *P*> 0.05			F = 2.142 *P*> 0.05		

Fig. 3. Percent contribution of blue-bar birds in Feral Pigeon flocks in areas of old pre-war districts of Gdańsk (city centre, Wrzeszcz and Oliwa) (dark columns) and in flocks of neighbouring housing estate districts (white columns) (see Fig. 1).

found in the city's centre, with 44 individuals 10^{-1} ha. This value was higher than that noted in the centre of Olsztyn (30 individuals 10^{-1} ha) (Nowakowski *et al.* 2006) but decidedly less so than in Warsaw's city centre (240–400 individuals 10^{-1} ha) (Nowicki 2001). In some European cities, the Feral Pigeon population significantly exceeds the one found in Gdańsk. In the urbanised area of Milan (Italy), the average population density was estimated at 85 individuals 10^{-1} (Sacchi *et al.* 2002), whereas in the built-up areas of Gdańsk, it was barely 17.2 individuals 10^{-1} ha.

Melanistic birds dominated in Gdańsk, but the proportion of blue-bar birds was relatively high (45%). There were more blue-bars in Gdańsk than in the population of Manchester, England, where only 21% were noted together with 68% of melanistic birds (Murton *et al.* 1973). This was also more than in the Bratislava population (23%) (Janiga 1991b). On the other hand, the population of blue-bars was smaller in Gdańsk than in populations of southern Europe (for example Barcelona, Piacenza), where their proportion reaches up to 75% (review: Johnston and Janiga 1995). Johnston and Janiga (1995) observed that melanistic birds (checker, dark checker, and spread) occur with greater frequency than blue-bars at higher latitudes. The causes of this plumage variability among populations are poorly known. Undoubtedly, genetic factors of the founding population and of immigrants – often Domestic Pigeons or synanthropised Rock Pigeons – are decisive in determining plumage patterns and colour frequencies (Johnston and Janiga 1995). Important factors determining the polymorphism of a population are the environment and selection. According to Lofts *et al.* (1966), melanistic birds are seen more often in cities because their gonads are active even in winter, as opposed to blue-bars. In effect, melanistic birds can also breed in winter, allowing them to produce more progeny during a longer breeding season. Murton *et al.* (1973, 1974) believe that dark checker males and spread-pattern males have a reproductive advantage, whereas males favour females of the blue-bar and blue-checker morphs.

The founding effect is also evident in the polymorphism variation among flocks in one population. We confirmed significant differences in plumage phenotypes among Feral Pigeon flocks from districts with old and new buildings. Melanistic birds dominated in some flocks, while blue-bars dominated in others. Flock size did not influence the distribution of the phenotypic morphs. Obukhova and Kreslavskii (1985a) arrived at other conclusions, as they found that blue-bar birds occur in small flocks, while dark checker birds dominate in large ones. An analysis of polymorphism in Gdańsk shows that there are neighbourhoods within the city's boundaries where blue-bars dominate, while in others, melanistic birds were more numerous. Such an uneven distribution of plumage polymorphism in a population is probably due to the independent development of a local flock that does not have much contact with other flocks in a district. Hetmański (2007b) shows that pigeons have strong fidelity to their breeding sites. Dispersal of birds from the colony is small, occurring only in young birds during their first year of life and then disappearing among adult birds. Additionally, pigeons exhibit strong fidelity to foraging sites and are sedentary (Rose *et al.* 2006). A good example confirming the high isolation of flocks is the existence of two extensively varied flocks in central Sopot, a city abutting Gdańsk. In 2008, we noticed two, very different flocks appearing quite close to each other, separated by 250–300 meters. We confirmed 52% blue-bars and 2% partial albinos (n = 83) in one flock. The second flock consisted of an almost opposite combination – blue-bars constituted 15% and partial albinos – 44% (n = 78). This is a good example showing the isolation of neighbouring colonies, directly due to the behaviour of the birds. Plumage variation in colonies is also explained by a different selection process occurring in cities (Johnston and Janiga 1995). It is believed that there are more melanistic birds in the centres of large cities than in small cities (Obukhova and Kreslavskii 1984). However, we found the opposite situation in Gdańsk, as blue-bar birds dominated in the old city centre, while melanistic birds dominated in the more recently built housing estate districts surrounding the city centre.

We did not find any differences in body mass or breeding parameters among birds of different plumages. Janiga (1991b) also did not find any significant differences in body mass or length of tarsometatarsus among the morphs. However, his studies showed that blue-bars had slightly longer wings than melanistic birds. Janiga (1991a, b) also observed that melanistic fledglings had a greater chance to reach maturity than blue-bar fledglings. On the other hand, Hetmański (2004a) did not find any differences in survival among adult birds, their nestlings and young birds joining the breeding population in the city of Słupsk (N Poland). There were no differences in breeding success among males of various morphs in this city. However, a statistically significant difference emerged in the number of broods between blue-bar and dark checker females (Obukhova and Kreslavskii 1985b). They found small differences in breeding success, but did not confirm any difference in the survival of young. The data presented above show that morphs can differ in breeding characteristics and parameters, which was proven in only some populations (Bratislava, Moscow). However, all the differences were weak or marginally significant. Specific morphs most likely have slight differences in adaptability, which are not always apparent during observations. These may strengthen under special conditions, for example during harsh winters, in times of food scarcity and in highly dense populations.

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