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Wing and body mass measurements in the Great Tit *Parus major* in Central Poland, errors and methods of standardization

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Abstract. Work done in the Warsaw area in the December — early April periods of the years 1994–96 involved the capture, measurement and weighing of 862 Great Tits (of which some were caught and measured many times). Studies were centred on old broad-leaved forest and nearby settlements. The mean wing lengths of males and females were 76.1 and 73.1mm respectively (SD of 1.5 and 1.3). A method was proposed by which to standardize the body masses of live birds through deduction of the mass of subcutaneous fat. Mean body mass was 18.2g (SD=0.9) in males and 16.9g (SD=0.9) in females. The respective lean body masses were 17.5g (SD=0.8) and 16.3g (SD=0.8). Among birds in the first year of life, the mean distance between the end of the first primary and the end of the longest primary covert was 10.1mm (SD=1.2), while the respective figure for older birds was 9.0mm (SD=1.3). Comparison of the body masses excluding subcutaneous fat among males and females of the same wing length revealed that males not only have longer wings on average, but also a more massive build. Comparisons of the body masses excluding subcutaneous fat among one-year-old and older birds showed that the process of growth in young birds is almost complete in winter. The studied population was found to be characterized by high body mass in comparison with birds migrating from the north and east along the southern shore of the Baltic. A review was carried out in relation to the factors producing errors and difficulties in the comparison of biometric measurements obtained by different researchers for different geographical populations. It was found that methodological differences made it impossible to compare the majority of the results obtained by different authors with one another. In any case, the drawing of conclusions regarding geographical variation in Great Tits on the basis of biometric data is very difficult due to genetically-based intrapopulational variability and local differences conditioned environmentally.

Key words: Great Tit *Parus major*, biometric differentiation, wing length, first primary, body mass, errors in measurements

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INTRODUCTION

The Great Tit occurs across an extensive area of Eurasia and North Africa in very different climatic and habitat conditions. The nominative subspecies *Parus major major* extends north of the Arctic Circle in northern Scandinavia (Haftorn 1971), while *P.m. cinereus* inhabits tropical parts of Asia and even extends south of the Equator in Indonesia (Gosler 1993). In the light of this, knowledge of the geographical variation within the species would allow for the formulation of general rules concerning the influence of different environment factors on the size of animals. It is noted in the subject literature (e.g. Haftorn 1976, Dhont *et al.* 1979), that wing length is a feature which characterizes the size of birds well. It is also a feature that is very easy to measure. Snow (1954) showed that wing length in great tits is inversely correlated with the temperature of the coldest month in the breeding area, and hence that the species conforms to Bergman's Rule. Alatalo (1982) and Ebenman (1986) presumed that the size of Great Tits was also influenced by competition with other species of tit. It may be also supposed that the distance between breeding and wintering grounds is a further factor exerting an influence on wing length, along with the pressure imposed on different populations by various predator species and the degree of synathropization of the population. Information on wing length and its interpopulational variability in different geographic regions would be useful in the identification of the origin of passage and wintering Great Tits. However, Pettersson (1981) noted that it was often impossible to use wing length alone to distinguish even geographically-distant populations. Furthermore, there is much evidence to suggest that measurements of wing length produced by different researchers are not comparable.

The use of a set of features is more precise in both studies of the causes of geographical variation and the identification of migrating populations. A second easily-measured feature is body mass, whose assessment is not in principal burdened with the error inherent in individual measurements. However, besides the size of birds which may characterize a population, a further constituent weight involves accumulated reserves of fat. Various authors (e.g. van Balen 1967, Haftorn 1976) have shown that these reserves vary in relation to factors which are very hard to standardize. For this reason, body mass is rarely used in research on geographical variation and the only possibilities for gaining comparable data involve either the weighing of birds deprived of fat or the use of conversion factors by which to reduce the body masses of birds with fat intact. Busse (1970,1983) also proposed the use of such conversion factors.

In the case of the nominative subspecies *Parus major major* there is abundant data on wing length and body mass from northern and western Europe, specifically Finland (Orell 1983), Norway (Haftorn 1976), Sweden (Dhont 1981 and Pettersson 1981), The Netherlands (Kluyver 1952, van Balen 1967), Belgium (Dhont *et al.* 1979) and Germany (Winkel 1973, 1980; Hudde 1985). In contrast, data from central, eastern and southern Europe are either lacking altogether or very limited — e.g. in the cases of the former Yugoslavia (Stresemann 1920 in Cramp & Perrins 1993), Turkey (Kiziroglu 1983) and Bulgaria (Jordans 1970). Data characterizing the Polish breeding population of Great Tits have not been published, with those published by Busse (1970) and Pettersson (1981) being confined to populations migrating through the country.

A third easily-measured biometric feature is the distance between the end of the first primary and the end of the longest primary covert. The length of the first primary has an influence on the aerodynamic properties of the wing (Alatalo *et al.* 1984) and may differ in connection with this between resident populations and those migrating varying distances to the wintering grounds. At this time there remains a lack of information on the geographical variation in this feature.

The subject of the present work is the biometric characterization of the central Polish population of Great Tits. A critical analysis was carried out in relation to the possibility of comparing data collected by various authors in different parts of the range of the species in question. A proposal was put forward for a method by which to standardize the body masses of live birds through a calculation of the mass of subcutaneous fat.

The study makes use of the following terminology and abbreviations:

MLW — maximal length of folded wing,

1pp — distance between the end of the first primary and the end of the longest primary covert,

real mass — the mass of the bird including that of subcutaneous fat,

real lean mass — the real mass of a bird free of subcutaneous fat,

calculated lean mass (CLM) — the mass of a bird excluding that of subcutaneous fat calculated using appropriate equation (see Material and Methods),

mean lean mass of an individual (mCLM) — mass of an individual excluding subcutaneous fat calculated as the mean of all measurements of its lean mass (both real and calculated).

MATERIALS AND METHODS

The material was obtained in the course of the 1994/5 and 1995/6 winter seasons. The study area covered about 150 hectares in the suburbs of Warsaw. It includes about 100 ha of old (60–150 year-old) broadleaved and mixed forests, which mainly includes oak *Quercus robur*, lime *Tilia cordata*, hornbeam *Carpinus betulus* and pine *Pinus sylvestris*. In the period 1992–96, the density of Great Tits in this area ranged between 7.2 and 9.2 pairs/ha (authors' data). The remaining 50 hectares included housing with large gardens. Birds were caught in ornithological nets between December and the beginning of April, at 5 points in the woodland and 2 in the area of houses. Catching was carried out once a week at each point, with a total of 862 Great Tits caught. In the course of each season, the majority of individuals were checked a number of times (with the total number of checks being 1692).

The maximal length of a folded wing (MLW) was measured in accordance with the standard described by Svensson (1992), to an accuracy of 1 mm. The measurement was repeated at the time of each repeat capture. In 95% of cases, the successive measurements either did not differ or differed within the limits of accuracy of the measurement (1 mm). Further calculations made use of the length noted most frequently for a given individual, or — where two figures were obtained equally often — of the mean obtained from the two.

The distance between the end of the first primary and the end of the longest primary covert (1pp) was measured to an accuracy of 0.5 mm, in accordance with the method from Svensson (1992). The measurement was repeated every time a repeat capture occurred. In 91% of cases, successive measurements either did not differ or differed within the limits of accuracy of the measurement (0.5mm). Further calculations involving 1pp made use of a value obtained in the same way as for MLW. In the generation of figures for the distribution of wing lengths (Fig. 1)and 1pp (Fig. 2), measurements were rounded off to full millimetres.

Great Tits were weighed with a 50g Pesola balance to an accuracy of 0.25g, and the degree to which they had laid down fat was determined with the aid of a 10-point scale from T_0 to T_5 (after Nowakowski & Rowiński 1995). All the body masses were reduced by the weight of subcutaneous fat calculated on the above basis, to obtain data for calculated lean mass (CLM). Applied for data from the 1994/5 winter season were

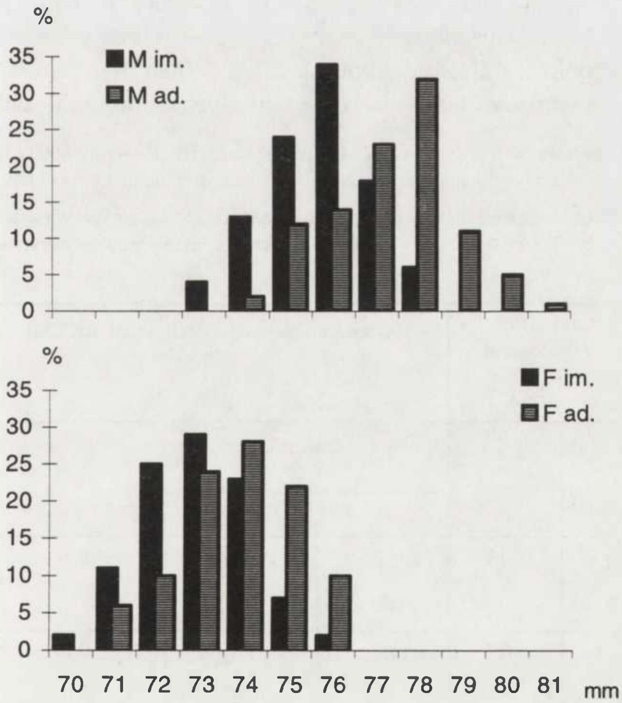

Fig. 1. Distribution of wing lengths (MLW) in relation to sex and age. For explanation see Tab. 1.

[Ryc. 1. Rozkład długości skrzydła (MLW) w zależności od płci i wieku. Objaśnienia — patrz tabela 1.]

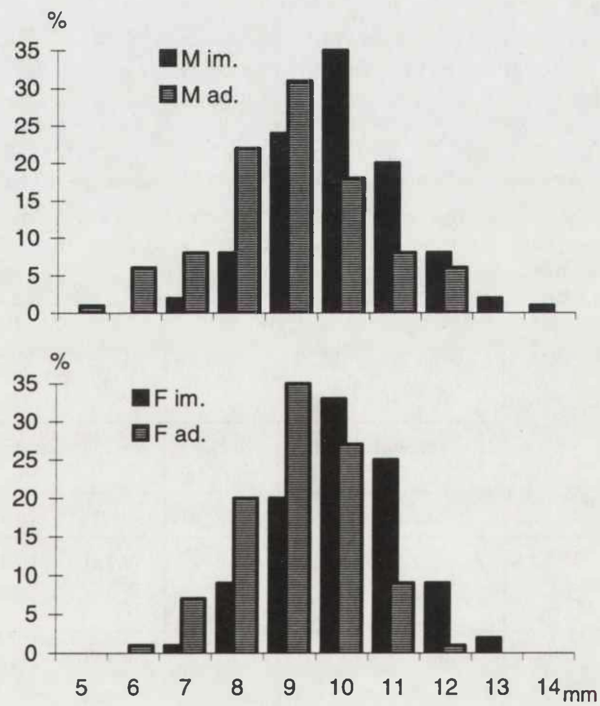

Fig. 2. Distribution of distances between end of 1st primary and end of longest primary covert (1pp), in relation to sex and age. For explanation see Tab. 1.

[Ryc. 2. Rozkład odległości końca 1 lotki pierwszorzędowej od końca najdłuższej pokrywy pierwszorzędowej (1pp) w zależności od płci i wieku. Objaśnienia — patrz tabela 1.]

appropriately transformed formulae given in the aforementioned study, specifically:
for males:

$$y = x + 0.0243z^4 - 0.2199z^3 + 0.5892z^2 - 0.8701z$$

for females:

$$y = x + 0.0949z^4 - 0.5907z^3 + 1.0525z^2 - 0.8411z$$

where:
y is the calculated lean mass (CLM) in g;
x is the body mass of a bird with fat in g;
z is the degree of fatness — a designated value

The estimation of the amount of fat deposited was improved for the 1995/6 winter season, through the introduction of the new differentiation between degrees of fatness T_0 and T_{05}, as it was suggested by Nowakowski and Rowiński (1995). Hence, the new formulae applied to reduce the mass of birds with fat were:
for males in the first year of life (M im.):

$$y = x - 0.0681z^3 + 0.1954z^2 - 0.556z$$

for males after the first year of life (M ad.):

$$y = x - 0.0931z^3 + 0.3518z^2 - 0.759z$$

for females in the first year of life (F im.):

$$y = x - 0.0024z^3 - 0.1234z^2 - 0.0953z$$

for females after the first year of life (F ad.):

$$y = x - 0.0092z^3 - 0.0451z^2 - 0.2402z$$

The correctness of the method presented to calculate CLM was checked by comparing the masses of birds with fat reduced to the level T_0 with the aid of the formulae given (calculated lean mass), with the masses of birds really free of fat (real lean mass). This revealed no significant differences for either the comparison of mean masses by t test (for males p=0.73; females p=0.73), or the distribution of masses examined using a χ^2 test (for males p=0.10; for females p=0.17).

The method was also tested on 57 individuals which were caught on a number of occasions (221 times in total) including at least once without fat. In 70% of cases, successive measurements of the real lean mass of the same individual either did not differ, or differed within the limits of the accuracy of measurement (i.e. 0.25g). In 10% of cases, the differences were greater — at 0.5g, and in 20% of cases even greater — at 0.75g or more. The mean difference between measurements amounted to 0.33g, and this resulted from the varying degrees to which the gut was filled with food, as well as from assessments of the amounts of fat laid down made in accordance with the Nowakowski and Rowiński scale — whose successive points differ by about 0.25 g. When the real and calculated lean masses of a given individual were

Table 1. Comparison of biometric data on local Great Tits (A) and those of unknown origin — probably mainly local (B). P — probability that differences in means occur by chance (t test), M — males, F — females, im. — birds in the first year of life, ad. — birds after the first year of life.

[Tabela 1. Porównanie danych biometrycznych bogatek miejscowych (A) i o nieznanym pochodzeniu, prawdopodobnie w większości miejscowych (B). P — prawdopodobieństwo, że różnice w średnich są przypadkowe (*t* test), M — samce, F — samice, im. — ptak w pierwszym roku życia, ad — ptaki po pierwszym roku życia]

	Maximal length of folded wing (MLW) (mm)			Distance between the end of first primary and the end of the longest primary covert (1pp) (mm)			Mean lean mass of an individual (mCLM) (g)		
	Mean ±SD (N)		P	Mean ±SD (N)		P	Mean ±SD (N)		P
	A	B		A	B		A	B	
M im.	75.7 ±1.2 (124)	75.6 ±1.3 (234)	0.87	9.9 ±1.3 (121)	10.1 ±1.3 (213)	0.14	17.5 ±0.7 (121)	17.5 ±0.9 (227)	0.97
M ad.	77.4 ±1.5 (52)	77.3 ±1.4 (62)	0.70	8.9 ±1.6 (50)	8.9 ±1.4 (50)	0.99	17.8 ±0.7 (52)	17.6 ±0,8 (55)	0.16
F im.	72.8 ±1.3 (97)	73.0 ±1.2 (197)	0.19	10.1 ±1.2 (94)	10.1 ±1.2 (189)	0.91	16.3 ±0.6 (98)	16.3 ±0.7 (190)	0.78
F ad.	7.38 ±1.3 (48)	7.38 ±1.4 (40)	0.87	9.0 ±0.9 (45)	9.2 ±1.1 (37)	0.31	16.3 ±0.7 (47)	16.6 ±0.8 (40)	0.09

compared, it was found that there were no differences, or else differences within the limits of measuremental accuracy, in 58% of cases. In 20% of cases, the difference amounted to 0.5g and in a further 22% of cases to 0.75g or more. The mean difference between these measurements was of 0.38g and did not differ significantly from the mean difference between two measurements of real lean mass. Calculated subsequently for the same group of 57 birds — and individually for each level of fat deposited from T_{05} to T_{25} — was the mean lean mass (CLM). This was compared with the mean real lean mass, and the differences were not found to achieve statistical significance when the t test was applied (probability levels were p=0.99 for T_{05}, p=0.40 for T_1, p=0.66 for T_{15}, p=0.62 for T_2 and p=0.84 for T_{25}).

Calculated in turn for each tit, on the basis of all the lean masses (CLM) calculated for it, was the mean lean mass of the individual (mCLM). Only these values were employed in further calculations.

Birds wintering in central Poland are not merely local individuals, but also include some from the north-east (Lihachev 1957). This fact gained confirmation in the course of the present study, in two pieces of information regarding returns of birds. One came from southern Lithuania (54°03'N; 24°03'E) and the other from the Tver' area, north-west of Moscow (56°52'N; 35°55'E). 38% of individuals were known to be local, i.e. ringed as nestlings and/or recorded during the breeding period. The remaining 62% of Great Tits were birds of undetermined origin, which could also have been local, or else only spending the winter in the study area. The groups of birds in question were compared from the point of view of the aforementioned biometric features — separately for each age and sex group. The t-test did not reveal significant differences between averages in any case (Tab. 1). On this basis, it was accepted that all the birds wintering in the study area formed a uniform group from the biometrical point of view, and that the mean results obtained concerned a local population (breeding in the studied area).

RESULTS

Differences between the years of study were small and not statistically significant for any of the age/sex groups or any of the features analyzed. For this reason, biometric data from the two seasons were worked upon and presented together (Tabs 2, 3 and 4, Figs. 1, 2 and 3). The majority of authors present real weights of birds (i.e. those with no reduction made for the degree to which fat is deposited), so such a characterization of the population has also been presented (Tab. 5).

Table 2. Length (mm) of wing (MLW). For explanations see Tab. 1.

[Tabela 2. Długość (mm) skrzydła (MLW). Objaśnienia — patrz tab. 1.]

	N	Mean ±SD	Min–Max
M im.	358	75.7 ±1.2	73.0–79.0
M ad.	114	77.3 ±1.4	74.0–81.0
ΣM	472	76.1 ±1.5	73.0–81.0
F im.	294	72.9 ±1.3	70.0–76.0
F ad.	88	73.8 ±1.3	71.0–76.0
ΣF	382	73.1 ±1.3	70.0–76.0

Table 3. Distance (mm) between the end of the 1st primary and the end of the longest primary covert (1pp). For explanations see Tab. 1.

[Tabela 3. Odległość (mm) końca 1 lotki pierwszorzędowej od końca najdłuższej pokrywy pierwszorzędowej (1pp). Objaśnienia — patrz tab. 1.]

	N	Mean ±SD	Min–Max
M im.	334	10.0 ±1.2	7.00–14.00
F im.	283	10.1 ±1.2	6.00–13.75
Σim.	617	10.1 ±1.2	6.00–14.00
M ad.	100	8.9 ±1.5	5.00–12.00
F ad.	82	9.1 ±1.1	6.50–12.00
Σad.	182	9.0 ±1.3	5.00–12.00

It has been confirmed many times (e.g. van Balen 1967, Haftorn 1976, Winkel 1980, Hudde 1985) that Great Tits in the first year of life have shorter wings than older birds (Tab. 2). Such a difference is observed in the majority of passerine species. However, the results of winter measurement of birds reflect differences from the period of moulting, and hence from the end of spring and summer and not from winter. Comparison of lean body masses (mCLM) shows that differences in growth between birds of different ages are relatively limited in winter (Tab. 6). This points to the fact that the process of muscle and bone growth is almost complete at this time in young birds. On the other hand, the period between December and the end of March did not see an increase in the body masses of young birds. Thus a 0.2g

Table 4. Mean lean mass (g) of individuals (mCLM). For explanations see Tab. 1.
[Tabela 4. Średnia masa (g) chuda osobnika (mCLM). Objaśnienia — patrz tab. 1.]

	N	Mean ±SD	Min–Max
M im.	348	17.5 ±0.8	15.25–20.00
M ad.	107	17.7 ±0.8	15.75–19.75
ΣM	455	17.5 ±0.8	15.25–20.00
F im.	288	16.3 ±0.7	14.50–18.75
F ad.	87	16.5 ±0.7	15.00–18.50
ΣF	375	16.3 ±0.8	14.50–18.75

Table 5. Real mass (g) of birds. For explanation see Tab. 1.
[Tabela 5. Rzeczywista masa (g) ptaków. Objaśnienia — patrz tab. 1.]

	N	Mean ±SD	Min–Max
M im.	744	18.1 ±1.0	15.50–21.50
M ad.	203	18.4 ±0.8	16.50–21.00
ΣM	947	18.2 ±0.9	15.50–21.50
F im.	599	16.9 ±0.9	14.50–20.00
F ad.	136	17.0 ±0.9	14.75–19.50
ΣF	735	16.9 ±0.9	14.50–20.00

difference between one-year-old and older Great Tits was maintained for the whole period and it is probable that full maturity of the organism, along with a proper adult weight, is only reached in spring, under the influence of sex hormones.

Comparisons were made between the lean body masses (mCLM) of males and females with a wing length of 74 mm, as well as of 75 mm (Tab. 7). Statistically significant differences were noted in both cases, which means that males more massively-built, than females. This may result from a greater muscle mass, more massive bones or the sizes of the internal organs. Thus greater real body masses among males cannot be explained solely by reference to linear dimensions and the level of fat, as van Balen (1967) suggested.

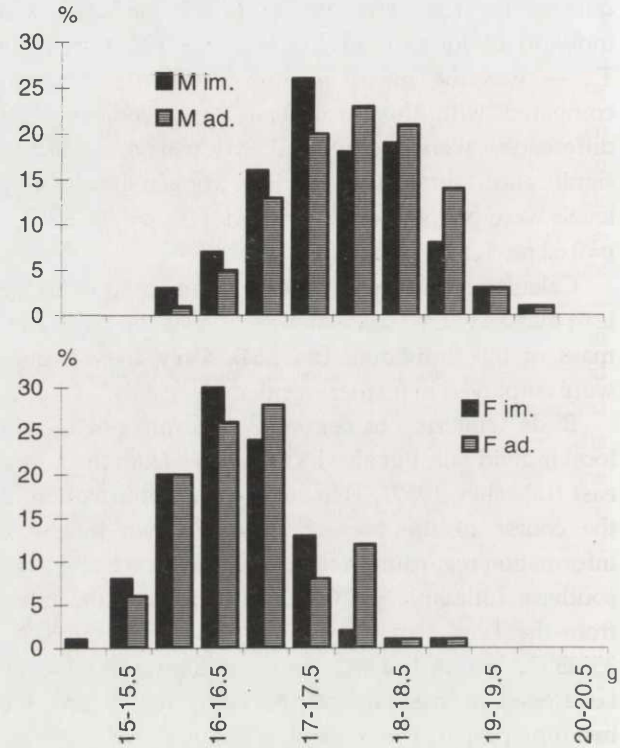

Fig. 3. Distribution of mean lean masses of individuals (mCLM) in relation to sex and age. For explanation see Tab. 1.

[Ryc. 3. Rozkład średniej masy chudej osobników (mCLM) w zależności od płci i wieku. Objaśnienia — patrz tabela 1.]

The distance between the end of the first primary and the end of the longest primary covert (1pp) was greater in birds in the first year of life than in older ones (Tab. 3). The difference between means, as tested by t test individually for the two sexes, is highly statistically significant for both males and females ($p<<0.0001$). On the other hand, differences between the sexes are not statistically significant, even though the sample sizes were large.

Table 6. Differences (D) in linear measurements and body masses between birds after (ad.) or in the first year of life. "–" — value of feature lower in one-year-old birds, "+" — value of feature lower in older birds. Remaining explanations as in Tab. 1.

[Tabela 6. Różnice (D) pomiarów liniowych i mas ciała pomiędzy ptakami po pierwszym roku życia (ad.) i w pierwszym roku życia. „–" — wartość cechy mniejsza u ptaków jednorocznych, „+" — wartość cechy mniejsza u ptaków starszych niż jednoroczne. Pozostałe objaśnienia — patrz tab. 1.]

	Maximal length of folded wing (MLW) (mm)			Distance between the end of first primary and the end of the longest primary covert (1pp) (mm)			Mean lean mass of an individual (mCLM) (g)		
	ad. Mean±SD	D	P	ad. Mean±SD	D	P	ad. Mean±SD	D	P
M	77.3 ±1.4	–1.6	<<0.0001	8.9±1.5	+1.1	<<0.0001	17.7 ±0.8	–0.2	=0.03
F	73.8 ±1.3	–0.9	<<0.0001	9.1±1.1	+1.0	<<0.0001	16.5 ±0.7	–0.2	=0.04

Table 7. Comparison of body mass (g) of lean birds (mCLM), for males and females of the same wing length (mm). For explanation see Tab. 1.

[Tabela 7. Porównanie masy ciała (g) ptaków nieotłuszczonych (mCLM) dla samców i samic o tej samej długości skrzydła (mm). Objaśnienia — patrz tab. 1.]

	Wing length 74 mm			Wing length 75 mm		
	N	Mean ±SD	P	N	Mean ±SD	P
M im.	47	17.1 ±0.8	<0.0001	85	17.3 ±0.7	<0.0001
F im.	64	16.6 ±0.6		22	16.6 ±0.7	

DISCUSSION OF METHODS OF MEASUREMENT

It is possible to identify three types of factor which lead to non-comparability in the measurements obtained by different researchers, and hence give an improper picture of geographical variation in the species:

1) **Methodological differences** generally make comparisons impossible. Errors resulting from measurement techniques are particularly frequent where the measurement of the wing is concerned. Van Balen (1967) showed that results differing by as much as 2.84mm were possible, depending on the degree to which, and manner in which, a wing is stretched out along a ruler. Great differences result from the different ways in which a bird may be held during measuring (e.g. head towards the person doing the measurement or pointing away). The shape and width of the ruler used also has a significant influence on the result obtained. The authors' experience suggests that different persons obtain results differing systematically by even as much as more than 1 mm even when the same technique and ruler are used, with a standard deviation of the measured feature of 1.3 mm (see Tab. 2). Such individual differences between those carrying out measurements are also indicated by other researchers (Dhont *et al.* 1979). Only where there is joint measurement of several tens of birds by researchers is it possible to obtain a satisfactory degree of agreement. However, even in this case it is necessary to have further joint measurement sessions if this level of agreement is to be maintained over longer periods of time. If it becomes desirable for results already obtained to be made comparable, it is possible to establish an appropriate correction factor through joint measurement of birds along with members of other research teams. Such a method was employed by van Balen (1967). Without such checking, no comparisons can be justified methodologically. Thus some old results which cannot now be verified can only be discarded.

In contrast, the measurement of the distance between the end of the first primary and that of the longest primary covert (1pp) is burdened with only limited observer error (authors' own data), though initial joint measurement of birds is indicated in this case too. In turn, weighing is entirely lacking in errors of the kind resulting from measurement technique (assuming of course that the scales are in order).

2) **Non-uniformity of the parameter** studied makes the drawing of conclusions more difficult. An example here is the measure "bill to feathers", which concerns the distance from the end of the upper part of the beak to the bases of the feathers on the forehead, and which thus includes two features bill length and the degree of wear of feathers over the bill.

Distortions of this kind also occur in relation to the measurement of body mass. In weighing a bird one simultaneously researches two features. The first is the mass of the bird excluding fat — a relatively stable value in adult individuals outside the breeding season, and one which is characteristic and at least partly reflective of interpopulational geographical variation. The second feature is the mass of fat itself, which is a variable quantity in the course of both the day and the season. Average daily variations in the fat mass of Great Tits amount to between 7% of morning body mass in males and 9% in females (Hilden 1977), but may even exceed 10%, i.e. 2g (Hilden 1977, Haftorn 1989, Bednekoff *et al.* 1994). The amplitude of variations changes not only in relation to daylength, atmospheric conditions, the environment and the availability of food (Haftorn 1976,1989), but also for example in relation to the degree of variability of atmospheric conditions (Bednekoff *et al.* 1994). Between October and December, the mean value for fat measured at the same time in the same bird rose by about 2% of its body mass (Haftorn 1989). However, this rise is very variable, depending as it does on temperature, snow cover, precipitation, the biotope, additional food sources, the presence of predators and probably also many other factors (Owen 1954, Van Balen 1967, Haftorn 1976,1989, Gosler *et al.* 1995). Still greater changes are noted on passage, when the Great Tit may even weigh 15% more than at other times of the year (authors' own data). On account of the great variability in the size of the accumulated reserves of fat, it will only be with comparisons of body masses of birds lacking such reserves that proper conclusions can be drawn regarding geographical variation in the sizes of Great Tits. A similar conclusion was arrived at previously by Haftorn (1976).

3) **Intrapopulational variation and local differences with an environmental basis** often hinder or prevent the identification of interpopulational variability.

By intrapopulational variation, the authors understand genetically-based differences in mean measurements between local populations. These result from the action of local agents of natural selection. Part of the variation in the body measurements of Great Tits has been found to be genetic in origin. Noordwijk *et al.* (1980) calculated that the genetic influence in the case of body mass is about 60%. Populations of Great Tits are subject to many, often local, microevolutionary changes. For example, Dhont *et al.* (1979) noted that — as a consequence of reduced competition for nesting places (nesting boxes put up) — there was a gradual reduction in the dimensions of Great Tits in the population they studied. A similar result may be due to changes in migratory behaviour as a consequence of the synanthropization of the species. Local differences in body sizes not having a genetic basis may for example result from an abundance of food resources in the period of nestling growth, or — as Dufva (1996) noted — from the degree of infection of the population by blood parasites of the genus *Trypanosoma.* Wing length probably depends on feeding and atmospheric conditions during the moult (van Balen 1967), and on the timing of the moult, which is in turn influenced by the number of broods produced by a pair (Dhont 1981). A further factor hindering proper interpretation of data may be the intrapopulational selection of individuals from the point of view of size. As Ulfstrand *et al.* (1981) noted in a mosaic-like environment, larger Great Tits occupy better biotopes and small birds worse ones. This may lead to a situation in which even the mean body dimensions of birds caught in large study areas will be unrepresentative of the geographic region.

In conclusion, the authors consider that methodological considerations ensure that the majority of the biometric data gathered by different researchers cannot be compared with each another. The drawing of conclusions regarding geographical variation in the Great Tit is also made difficult by local differences in the nature of the environment, and by intrapopulational variation. In consequence, any such interpretations must be made with caution.

DISCUSSION OF THE RESULTS

Great Tits in the first year of life have longer first primaries than older birds. This confirms the observations made by Alatalo *et al.* (1984). Measuring the first primary by another method, these authors showed similar differences for several species of small passerine. However, in the case of Great Tits, these differences were not statistically significant — perhaps because of the small size of the sample used. Alatalo *et al.* concluded that a long first primary is of considerable adaptive significance to young birds. It increases the manoeuverability of flight, and hence increases possibilities for escaping from predators in the first period of life, when inexperienced birds are especially vulnerable to these attacks. On the other hand, a wing of the kind under discussion is less suitable for long-distance flight, thus explaining why it is more useful for adult birds to have a shorter first primary. This thesis is confirmed directly in the present study by the lack of any difference between young males and females. There is a lack of published data concerning geographical variation in the lengths of the first primary, but it is probably shorter in populations migrating longer distances, and longer in sedentary birds.

The abundant literature on wing length in different European populations of the Great Tit will not be discussed here because of the aforementioned reservations which must be expressed in relation to methodology.

Data in litt. on body mass in Great Tits are generally concerned with fat birds. Only two studies available to the authors contained data on lean mass obtained from larger samples. In both cases, means are calculated from data on birds that are truly deprived of fat. Dolnik & Blyumental (1967) presented the body masses of birds caught on the Kuronskiy Spit in Russia's Kaliningrad District during autumn passage along the southern Baltic coast. These were 17.3g for males and 16.3g for females. Data from Busse (1970) were derived mainly from the spring passage of Great Tits along the Polish section of the Baltic coast. These included figures of 16.3g for males and 15.6g for females. Neither works give sample sizes (numbers of lean Great Tits). However, on the basis of the overall numbers of Great Tits weighed by these authors (over 3000 in each case), it may reasonably be concluded that the samples were satisfactory.

Both samples included birds from different populations. It may however be accepted that these were mostly birds from the east and north-east, at distances of up to several hundred kilometres (Alerstam 1994), and hence in areas with a harsher climate. It is thus surprising that the mean body masses of birds caught on the Kuronskiy Spit (Dolnik & Blyumental 1967) are so very similar to those given for central Poland (Tab. 4). The mean body masses of birds caught on the Polish Baltic coast (Busse 1970) are smaller, though such a result does not accord with Bergman's Rule. The lower body masses obtained by Busse may not be explained by reference to differences in estimated amounts of subcutaneous fat. The scale applied by the authors of the present work (Nowakowski & Rowiński 1995) is even more rigorous in defining the lowest level of fat deposited (T_0) than the method of estimation used by Busse (1970, 1983). As was discussed above, birds from richer environments (broadleaved forest) are larger than those from poor habitats (coniferous forest). The environment in which the material for the present study was collected is optimal for Great Tits and it may be supposed that the birds were relatively large, and did not characterize mean dimensions of Great Tits in central Poland. In contrast, coniferous forest prevails in the north and east of Europe, and it is thus highly probable that the Great Tits caught on the Polish Baltic Coast and the Kuronskiy Spit originated in poorer habitats. However, it seems to the authors that this is not a good enough explanation, and it may rather be presumed that the geographical variation in the size of Great Tits is much more complicated than has hitherto been thought, and depends on a larger number of factors than merely temperature in the coldest month of the year at the breeding site. Petersson (1981) confirmed these observations when he failed to find differences in the wing lengths of Great Tits from southern Sweden and others in the same area flying through in autumn — most probably from Russia.

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REFERENCES

Alatalo R.V. 1982. Evidence for interspecific competition among European tits Parus spp.: a review. Ann. zool. fenn. 19: 309–317.

Alatalo R.V., Gustafsson L., Lundberg A. 1984. Why do young passerine birds have shorter wings than older birds. Ibis 126: 410–415

Alerstam T. 1994. Bird Migration. Cambridge.

Cramp S., Perrins C. M. (eds.) 1993. Handbook of the Birds of Europe the Middle East and North Africa. vol. VII. Oxford – New York

Balen van J.H. 1967. The significance of variations in body weight and wing length in the great tit, *Parus major*. Ardea 55: 1–59.

Bednekoff P. A., Biebach H. Krebs J. R. 1994. Great Tit fat reserves under unpredictable temperatures. J. Avian Biol. 25: 156–160.

Busse P. 1970. Measurements of weight and fatness in migrating populations of birds. Not. orn. 11: 1–15

Busse P. 1983. Biometrical standars in the Operation Baltic work. Ring 10: 126–138.

Dhont A.A.1981. Postnuptial moult of the Great Tit in southern Sweden. Ornis Scand. 12: 127–132.

Dhont A.A., Eckerman R., Huble J. 1979. Will Great Tits become Little Tits? Biol. J. Linn. Soc. 11: 289–294.

Dolnik V. R., Blyumental T. I. 1967. Autumnal premigratory and migratory periods in the Chaffinch (*Fringilla coelebs coelebs*) and some other temperate-zone passerine birds. Condor 69: 435–468.

Dufva R. 1996. Blood parasites, health, reproductive success, and egg volume in female Great Tits *Parus major*. J. Avian Biol. 27: 83–87.

Ebenman B. 1986. Sexual size dimorphism in the great tit Parus major in relation to the number of coexisting congeners. Oikos 47: 355-359

Gosler A. 1993. The Great Tit. Hamlyn, London, pp: 1–128.

Gosler G. A., Greenwood J.J.D., Perrins C. 1995. Predation risk and the costs of being fat. Nature 377: 621–623.

Haftorn S. 1971. [Birds of Norway]. Oslo-Bergen-Tromso, pp: 729–733

Haftorn S. 1976. Variation in the body weight, wing length and tail length in the Great Tit *Parus major*. Norw. J. Zool. 24: 241–271.

Haftorn S. 1989. Sesonal and diurnal body weight variations in titmice, based on analyses of individual birds. Wilson Bull. 101: 217–235

Hilden O. 1977. [Weight loss of roosting Great Tits]. Ornis Fenn. 54: 135–137.

Hudde H. 1985. Individuelle Unterschiede im Längenwachstum der Flügel bei Kohl-, Blau-, Sumpf- und Weidenmeise (Parus major, P. caeruleus, P. palustris und P. montanus). Vogelwelt 106: 50–58.

Jordans von A. 1970. Die westpalearktischen Rassen des Formenkreises Parus major (Aves, Paridae). Zool. Abh. Mus. Tierk. Dresden. 31(11): 205–225.

Kiziroglu von I. 1983. Biometrische Untersuchungen an vier Meisen-Arten (Parus spp.) in der Umgebung von Ankara. Bonn. zool. Beitr. 34(4):453–458.

Kluyver H. 1952. Notes on body weight and time of breeding in the Great Tit, *Parus m. major* L. Ardea 40: 123–141.

Lihachev G. N. 1957. [Residence and migratin of Great Tit (*Parus major* L.)]. Trudy byura kolcevaniya 9: 242-256.

Noordwijk van A. J., Balen van J. H., Scharloo W. 1980. Heritability of ecologically important traits in the great tit. Aredea 68: 193–203.

Nowakowski J. K., Rowiński P. 1995. An expanded scale for the assessment of fatness in Great Tits *Parus major* in the non-breeding period. Acta orn. 30: 135-144.

Orell M. 1983. Nestling growth in the Great Tit *Parus major* and the Willow Tit *P. montanus*. Ornis fennica 60: 65–82.

Owen D.F. 1954. The winter weights of titmice. Ibis 96: 299–309.

Pettersson J. 1981. Wing length, moult, and geographic origin of Great Tits *Parus major* at Ottenby. Var Fagelvärld 40: 461–466.

Snow D.W. 1954. Trends in geographical variation in palaearctic members of the genus *Parus*. Evolution 8: 19–28.

Swenson L. 1992. Identification guide to European passerines. Stockholm.

Ulfstrand S., Alatalo R.V., Carlson A., Lundberg A. 1981. Habitat distribution and body size of the Great Tit *Parus major*. Ibis 123: 494–499.

Winkel W. 1980. Über die Flügellänge von Kohl-, Blau- und Tannenmeisen (Parus major, P. caeruleus und P. ater) in Beziehung zu Geschlecht und Alter. Beitr. Vogelkd. 26: 213–221.

STRESZCZENIE

[Pomiary skrzydła i masy ciała środkowopolskiej populacji bogatki *Parus major*, błędy i metody standaryzacji pomiarów]

W latach 1994–96 od grudnia do początku kwietnia schwytano w okolicach Warszawy, zmierzono i zważono 862 bogatki. Część ptaków była chwytana i ważona wielokrotnie (łącznie 1692 kontrole). Badania prowadzono głównie w starym lesie liściastym i w pobliskich osiedlach. Maksymalną długość skrzydła złożonego (MLW) i odległość końca pierwszej lotki pierwszorzędowej od końca najdłuższej pokrywy pierwszorzędowej (1pp) mierzono według standardu opisanego przez Svenssona (1992), odpowiednio z dokładnością do 1mm i do 0,5mm. Bogatki ważono z dokładnością do 0,25g, a stopień ich otłuszczenia określano w 10-stopniowej skali od T_0 do T_5 (Nowakowski & Rowiński 1995). Wszystkie masy ciała ptaków redukowano o wagę tłuszczu podskórnego obliczoną na podstawie stopnia ich otłuszczenia, i w ten sposób uzyskiwano masę ptaka bez tłuszczu podskórnego (CLM) zwaną dalej obliczoną masą chudą. Dla danych z sezonu 1994/95 zastosowano przekształcone wzory podane w pracy Nowakowskiego i Rowińskiego (1995):

dla samców:

$$y = x + 0{,}0243z^4 - 0{,}2199z^3 + 0{,}5892z^2 - 0{,}8701z$$

dla samic:

$$y = x + 0{,}0949z^4 - 0{,}5907z^3 + 1{,}0525z^2 - 0{,}8411z$$

gdzie:

y — obliczona masa chuda (CLM) w gramach

x — masa ciała ptaka otłuszczonego w gramach

z — stopień otłuszczenia — wielkość niemianowana

W sezonie zimowym 1995/96 ulepszono metodę oceny otłuszczenia. W związku z tym zastosowano nowe wzory redukujące masę ptaków otłuszczonych:

dla samców w pierwszym roku życia (M im.):

$$y = x - 0{,}0681z^3 + 0{,}1954z^2 - 0{,}556z$$

dla samców po pierwszym roku życia (M ad.):

$$y = x - 0{,}0931z^3 + 0{,}3518z^2 - 0{,}759z$$

dla samic w pierwszym roku życia (F im.):

$$y = x - 0{,}0024z^3 - 0{,}1234z^2 - 0{,}0953z$$

dla samic po pierwszym roku życia (F ad.):

$$y = x - 0{,}0092z^3 - 0{,}0451z^2 - 0{,}2402z$$

Sprawdzono poprawność przedstawionej metody wyliczania CLM porównując masy ptaków z otłuszczeniem zredukowanym do stopnia T_0 za pomocą podanych wzorów (obliczona masa chuda) z masami ptaków rzeczywiście nieotłuszczonych (rzeczywista masa chuda). Nie zanotowano różnic istotnych statystycznie.

Dla każdej sikory, na podstawie wszystkich jej obliczanych mas chudych (CLM) wyliczono średnią masę chudą osobnika (mCLM) i dopiero te wartości przyjmowano jako podstawę do dalszych obliczeń.

W środkowej Polsce zimują nie tylko ptaki miejscowe, ale również osobniki z północnego wschodu (Lihachev 1957). Potwierdzone to zostało również dwoma własnymi wiadomościami powrotnymi. O 38% osobników było wiadomo, że są miejscowe tzn. były obrączkowane jako pisklęta lub/i stwierdzone w czasie lęgów. Pozostałą grupę 62% bogatek stanowiły ptaki o nie ustalonym pochodzeniu. Opisane grupy ptaków porównano pod względem analizowanych w niniejszym artykule cech biometrycznych i w żadnym przypadku nie stwierdzono istotnych różnic między średnimi (Tab. 1). Na tej podstawie przyjęto, że podawane w niniejszej pracy średnie wyniki pomiarów dotyczą populacji miejscowej.

Dla wszystkich grup wiekowo-płciowych i dla wszystkich analizowanych cech, różnice średnich między badanymi latami były niewielkie i we wszystkich przypadkach nieistotne statystycznie. Dlatego dane biometryczne z obu sezonów opracowano i przedstawiono łącznie (Tab. 2, 3, 4 i 5; Ryc 1, 2 i 3).

Porównanie mas ciała bez tłuszczu podskórnego (mCLM) ptaków jednorocznych i starszych wykazało że zimą proces wzrostu ptaków młodych jest prawie zakończony (Tab. 6). Pomiędzy grudniem, a końcem marca nie odnotowano u młodych ptaków przyrostu masy ciała. Przez cały ten okres były one o około 0,2 g lżejsze od ptaków starszych.

Porównanie chudych mas ciała (mCLM) samców i samic o tej samej długości skrzydła wykazało, że samce mają nie tylko średnio dłuższe skrzydła, ale są również masywniej zbudowane od samic (Tab. 7). Większych rzeczywistych mas ciała samców nie można więc tłumaczyć tylko rozmiarami liniowymi i otłuszczeniem jak sugerował van Balen (1967).

Odległość końca pierwszej lotki pierwszorzędowej od końca najdłuższej pokrywy pierwszorzędowej (1pp) była większa u ptaków w 1 roku życia niż u ptaków starszych. Różnica średnich jest istotna statystycznie zarówno dla samców jak i dla samic (*t* test; $p<<0{,}0001$). Natomiast różnice między płciami są, pomimo dużych prób, nieistotne statystycznie.

Badana populacja charakteryzowała się dużą chudą masą ciała (mCLM) w stosunku do bogatek wędrujących przez polskie wybrzeże Bałtyku (Busse 1970) i przez Mierzeję Kurońską (Dolnik & Blyumental 1967). Wynik taki jest niezgodny z regułą Bergmana — prawdopodobnie geograficzna zmienność wielkości bogatki zależy od dużej liczby czynników, a nie tylko od temperatury w najzimniejszym miesiącu roku na jej terenie lęgowym, jak podawał Snow (1954).

Można wyróżnić trzy rodzaje czynników powodujących, że pomiary zebrane przez różnych badaczy są nieporównywalne i nie dają prawidłowego obrazu zmienności geograficznej bogatki:

1) Różnice metodyczne w ogóle uniemożliwiające prowadzenie porównań. Błędy wynikające z techniki pomiarów są szczególnie częste przy pomiarze skrzydła.

2) Niejednorodność badanego parametru co znacznie utrudnia wnioskowanie. Np. ważąc ptaka badamy jednocześnie dwie jego cechy. Po pierwsze masę ptaka bez tłuszczu, która jest u osobników dorosłych w okresie pozalęgowym wielkością względnie stałą i przynajmniej częściowo odzwierciedlającą międzypopulacyjną zmienność geograficzną. Po drugie masę samego tłuszczu będącą wielkością zmienną w cyklach dziennych i sezonowych. Z tego powodu, jedynie porównywanie mas ciała ptaków bez zapasów tłuszczu podskórnego może prowadzić do formułowania poprawnych wniosków o geograficznej zmienności wielkości bogatki.

3) Zmienność wewnątrzpopulacyjna o podłożu genetycznym i lokalne różnice o uwarunkowane czynnikami środowiskowymi, co utrudnia a często uniemożliwia uchwycenie zmienności międzypopulacyjnej.

Konkludując autorzy uważają, że ze względów metodycznych większość danych biometrycznych zgromadzonych przez różnych badaczy nie może być między sobą bezpośrednio porównywana. Konieczne jest stosowanie odpowiednich poprawek. Wnioskowanie o zmienności geograficznej bogatki jest dodatkowo bardzo utrudnione z powodu lokalnych różnic o charakterze środowiskowym i zmienności wewnątrzpopulacyjnej o podłożu genetycznym.

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