

## Relationship between biometry and migration time among Blackcaps (*Sylvia atricapilla*) in central Italy

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The relationship between morphometric parameters as well as fat score and migration time was analysed in Blackcaps (*Sylvia atricapilla*) during the pre-breeding migration across Italy. After controlling for body size, age- and sex-related significant differences in wing length, wing shape and fat score were found, with birds passing towards the end of the season having longer and more pointed wings as well being fatter. Body size also explained part of the variation in morphometry. We suggest that as the migrating season progresses Blackcaps are more likely to be directed to breeding quarters increasingly further away from the study area, possibly in northern and eastern Europe. These results provide evidence that different populations of Blackcaps, which appear to be statistically distinguishable on the basis of morphometric and fat score variation, intersect Italy during migration.

Key words: Blackcap, *Sylvia atricapilla*, migration, migratory strategies, Italy.

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### 1. Introduction

Avian migratory behaviour is the target of considerable evolutionary pressures at the species level (BERTHOLD 1996), and many migrating species of birds show features which can be interpreted as adaptations to maximise migratory efficiency (YOUNG & MOORE 1994; review in WINKLER & LEISLER 1992). It is now well established that migratory behaviour is also subjected to important selective pressures that enable populations to survive environmental changes (BERTHOLD & HELBIG 1992, SENAR et al. 1994). Furthermore, factors like differential intensity of competition for food resources and sexual selection may explain part of the intraspecific phenotypic variation (ALDRICK & JAMES 1991, HANSKI & TIAINEN 1991, WIEDENFELD 1991, MØLLER 1995, NORBERG 1995), which might in turn increase the variation in migratory behaviour between populations. Thus, the development of traits associated with migratory efficiency might covary with the migratory behaviour within a species (HELBIG 1991, BERTHOLD & HELBIG 1992, CRAMP 1992, BERTHOLD 1993, MARCHETTI et al. 1995). However, relatively little is known about the relationship between intraspecific morphometric variability and the migratory strategies of populations (SMITH et al. 1990). This is due to (i) the fact that most studies have mainly focused on interspecific rather than intraspecific variation in morphology and migratory behaviour (e.g. LUNDGREN & KIESSLING 1988, YONG & MOORE 1994, HEDENSTRÖM 1995, MONKKONEN 1995), and (ii) the need for long-term studies to identify microevolutionary processes (BERTHOLD 1996).

The Blackcap (*Sylvia atricapilla*) is a widespread passerine of the western palearctic region, breeding in northwestern Africa, the Atlantic islands and much of continental Europe (CRAMP 1992). Within its range of distribution several populations occur, both migratory and resident (HARRISON 1982, LOVEI et al. 1985). For instance, the populations breeding in central Europe winter in southern Europe and Northern Africa (ZINK 1973, LOVEI et al. 1985), while others are known to winter south of the Sahara (SIMMS 1985, FINLAYSON 1992, STOATE & MOREBY 1995). A detailed study on an Italian population (SPINA et al. 1995) has highlighted that it was made almost exclusi-

vely of migrants, and the migratory activity has shown values intermediate between those of the Southern German (BERTHOLD & QUERNER 1981) and Southern French populations (BERTHOLD 1986). Studies under laboratory conditions and ringing surveys of free-ranging individuals have provided substantial evidence that microevolutionary processes might explain part of the intraspecific variation in the Blackcap migratory behaviour (e.g. BERTHOLD & TERRILL 1988, reviewed by BERTHOLD 1993, 1996). It is also known that such a high variability in migratory strategies is reflected in morphological differences between *S. atricapilla* populations (KLEIN et al., 1973; BERTHOLD et al., 1990; GLUTZ VON BLOTZHEIM & BAUER 1991). Because populations may cross an area at different times due to differential migratory behaviours (e.g. different migration routes), birds migrating over such an area at different times might also vary in their morphology and physiology. It would appear that the Italian peninsula is intersected by the migratory routes of several distinct Blackcap populations (LO VALVO et al. 1988, SPINA et al. 1993).

The aim of this paper is to investigate whether Blackcap populations can be discriminated during their pre-breeding migration across Italy, on the basis of their morphology and phenology. To do this, we examined the variation in morphometric and physiological parameters recorded during a ringing survey in relation to migration time.

## 2. Materials and methods

Blackcaps were captured and ringed during spring 1990 (6 March – 5 April) in a locality situated on the Adriatic coast, at about 1 km west of the Conero peninsula (Ancona), and about 2 km inland (43° 35' N – 13° 34' E). The vegetation of the study area is characterized by several shrub species (*Spartium junceum*, *Rosa canina*, *Crataegus monogyna* and *Rubus ulmifolius*), and deciduous oaks (mainly *Quercus pubescens*). The ringing station is situated in an olive grove of about 1 ha.

Birds were captured along a 300 m mist-net transect. They were weighed, measured and ringed before being released. The following morphometric measurements and parameters were recorded for each bird: wing length (max. chord, WL, SVENSSON 1992); length of the eighth primary (RL, BERTHOLD & FRIEDRICH 1979); wing formula (WF, TIAINEN & HANSKI 1985); fat accumulation in the interclavicular region (FA), estimated according to the scale of BUSSE (1974) with scores ranging from 0 to 5; body mass (BM) was estimated with a balance to the 0.1 g accuracy. All parameters but one (WF) were recorded during the whole sampling period, while WF was taken from the second pentade.

Data were grouped by pentades, standardized 5-day periods (BERTHOLD 1973). The survey took place between 14–19th pentads of the year. To avoid pseudoreplication bias caused by the effect of resident birds, individuals re-caught in more than one pentade were excluded from the analyses.

All statistical analyses were performed with an SPSS (version 6.0 for Windows, NORUSIS 1993) computer package, with all tests being two-tailed and set at 0.05 level of significance. Normality in the distribution of the variables was checked using the KOLMOGOROV-SMIRNOV test. When appropriate, variables were normalized and the variance structure stabilized using  $\text{Log}_{10}(x + 1)$  transformation (ZAR 1984). Most relationships between variables were examined using either PEARSON product-moment or SPEARMAN rank correlation coefficients. FISHER exact test was used to detect differences in the proportions of the various age and sex classes captured in the six pentades. We used BM as a measure of body size and controlled for allometric interrelationships between body size and morphometric traits by using the residuals of the regressions of WL, RL, WF on BW (RWL, RRL, and RWF, hereafter). Differences among sex and age classes were then investigated on the whole sample by means of a two-way ANOVA (see MASSI & SPINA 1996). The effect of migration time (i.e. capture period) was investigated using one-way ANOVA on individuals grouped by pentads and age. Being a categorical variable, FA was analysed independently by using KRUSKAL-WALLIS test.

A discriminant analysis was performed between pentades to divide the data in the multivariate space. To evaluate the statistical significance of the distances between the various groups, the Mahalanobis distance was used.

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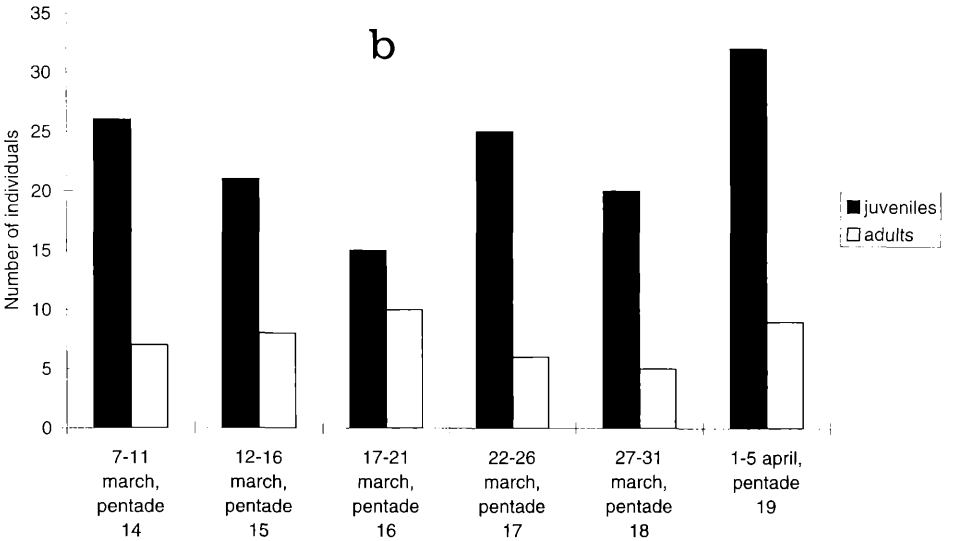
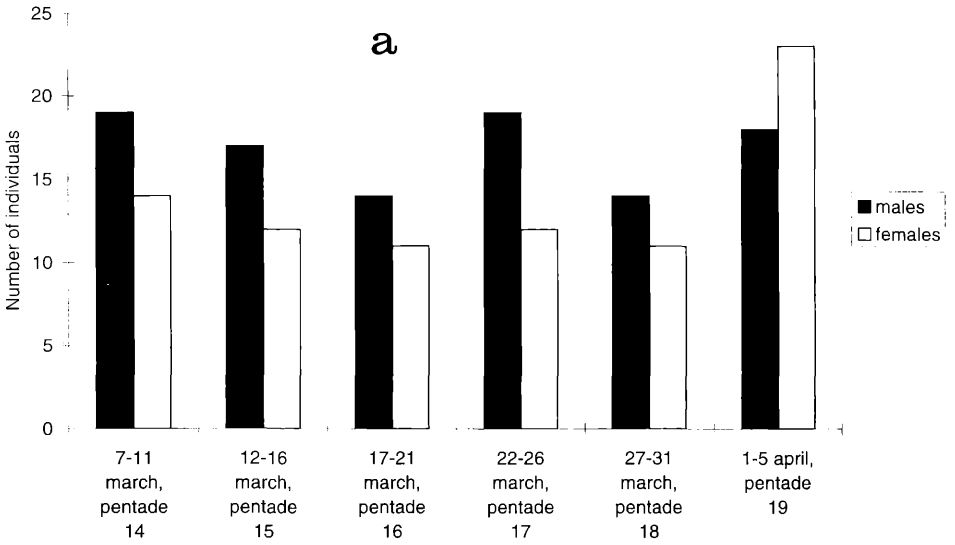


Figure 1a and b: Frequency of capture of individuals belonging to different classes of sex (a) and age (b) in the six capture periods.

Abb. 1a und b: Aufgliederung der erfassten Individuen nach dem Geschlecht (a) bzw. dem Alter (b) für 6 Fangperioden.

Table 1: Means and standard deviations of the measures taken on the captured individuals for each age and sex class.

Tab. 1: Mittelwerte und Standardabweichungen der erfaßten Parameter aufgegliedert nach Alter und Geschlecht. WL = Flügellänge, RL = Länge der 8. Handschwinge, BM = Körpermasse, WF = Flügelformel, Fat score = Fettdepot.

Males, juveniles	WL		RL		BM		WF		Fat score		
	N	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Pentade 14 (7-11 march)	14	73,07	2,01	54,43	1,76	18,20	1,12			2,57	1,65
Pentade 15 (12-16 march)	10	74,10	1,45	55,17	1,40	18,69	1,89	0,49	0,04	4,20	1,48
Pentade 16 (17-21 march)	8	74,44	2,41	55,30	2,28	18,16	1,44	0,46	0,04	4,13	1,13
Pentade 17 (22-26 march)	15	74,17	2,44	55,16	2,02	20,29	2,95	0,49	0,04	4,33	1,18
Pentade 18 (27-31 march)	11	74,20	2,47	55,85	2,40	18,09	1,50	0,48	0,04	3,82	1,40
Pentade 19 (1-5 april)	13	75,31	2,11	55,64	1,95	21,24	2,75	0,51	0,04	4,77	0,83
Total	71	74,19	2,22	55,23	1,97	19,25	2,41	0,49	0,04	3,94	1,46

Females, juveniles	WL		RL		BM		WF		Fat score		
	N	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Pentade 14 (7-11 march)	12	72,29	1,60	53,78	1,46	18,27	1,54			2,58	1,68
Pentade 15 (12-16 march)	11	72,68	2,52	54,05	1,75	19,23	1,84	0,46	0,03	4,45	0,82
Pentade 16 (17-21 march)	7	73,64	0,94	54,37	1,15	19,00	1,80	0,44	0,02	4,14	1,21
Pentade 17 (22-26 march)	10	71,85	0,71	53,74	1,43	17,82	1,64	0,47	0,04	3,70	1,34
Pentade 18 (27-31 march)	9	73,00	1,66	54,69	1,47	17,68	0,97	0,49	0,02	3,00	1,50
Pentade 19 (1-5 april)	19	75,47	2,18	55,75	1,92	21,36	2,70	0,50	0,03	4,84	0,50
Total	68	73,41	2,24	54,55	1,76	19,22	2,39	0,48	0,04	3,90	1,42

Males, adults	WL		RL		BM		WF		Fat score		
	N	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Pentade 14 (7-11 march)	5	75,30	0,97	56,44	1,07	19,86	2,75			4,40	1,34
Pentade 15 (12-16 march)	7	75,64	1,52	56,80	1,23	21,03	5,00	0,51	0,04	3,86	1,21
Pentade 16 (17-21 march)	6	74,67	2,82	55,88	2,85	20,57	2,97	0,50	0,05	3,50	1,38
Pentade 17 (22-26 march)	4	75,50	1,08	56,40	1,41	20,53	0,87	0,52	0,03	5,00	0,00
Pentade 18 (27-31 march)	3	78,17	2,25	57,67	2,25	22,57	2,18	0,57	0,01	5,00	0,00
Pentade 19 (1-5 april)	5	76,50	3,64	57,00	3,34	19,32	2,92	0,57	0,06	3,80	1,30
Total	30	75,77	2,30	56,62	2,06	20,54	3,18	0,53	0,05	4,13	1,20

Females, adults	WL		RL		BM		WF		Fat score		
	N	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Pentade 14 (7-11 march)	2	74,00	0,00	55,30	0,71	18,60	0,85			4,00	1,41
Pentade 15 (12-16 march)	1	73,00	0,00	53,70	0,00	20,70	0,00	0,47	0,00	5,00	0,00
Pentade 16 (17-21 march)	4	73,50	1,91	54,68	1,90	19,83	1,27	0,50	0,04	3,75	1,50
Pentade 17 (22-26 march)	2	76,50	0,71	57,50	0,71	18,85	1,48	0,56	0,01	3,00	1,41
Pentade 18 (27-31 march)	2	74,50	6,36	55,70	5,37	21,20	6,79	0,53	0,02	4,50	0,71
Pentade 19 (1-5 april)	4	78,25	0,96	58,13	0,85	21,23	1,32	0,51	0,00	5,00	0,00
Total	15	75,33	2,87	56,13	2,37	20,15	2,31	0,51	0,03	4,20	1,15

### 3. Results

184 individuals were captured, 101 (54.9%) of which were males (71 juveniles and 30 adults) and 83 (45.1%) females (68 juveniles and 15 adults, see Figure 1a and 1b). There was no significant difference in the proportion of juveniles/adults and males/females in any pentad (FISHER-exact test, age: at least  $p > 0.13$  in each pairwise comparison; sex: at least  $p > 0.16$ , in all cases  $df = 1$ ). Detailed report of the measures taken on the captured individuals is given in Table 1.

Significant effects of age were found on RWL, RRL, BW and RWF (Table 2), while differences between sexes were less important in the obtained model. Thus, the sample was divided into two age classes: (I) juveniles and (II) adults.

We detected significant effects of capture period on all but one (RRL) of the morphometric parameters for juveniles (one-way ANOVA: BM:  $F_{5,133} = 8.96$ ,  $P < 0.000001$ ; RWL:  $F_{5,133} = 2.26$ ,  $P < 0.05$ ; RRL:  $F_{5,133} = 1.57$ ,  $P > 0.17$ ; RWF:  $F_{5,133} = 2.42$ ,  $P < 0.04$ ). A TUKEY post-hoc test revealed which pentads differed significantly from each other (BM: Pentad 17 > Pentad 14; RWL: Pentad 19 > Pentad 14; RWF: Pentad 19 > other pentads). Despite the scarce number of individuals, an effect of capture period was also detected in adults (one-way ANOVA: BM:  $F_{5,39} = 0.44$ ,  $P > 0.81$ ; RWL:  $F_{5,39} = 2.54$ ,  $P < 0.05$ ; RRL:  $F_{5,39} = 1.18$ ,  $P > 0.33$ ; RWF:  $F_{4,24} = 13.62$ ,  $P < 0.0000002$ ). A TUKEY post-hoc test revealed which pentads differed significantly from each other (RWL: Pentad 19 > Pentad 15; RWF: Pentad 14 < other pentads). When pooling together individuals of both classes, significant differences were still found between two (i.e. BM and RWL) the examined parameters (one-way ANOVA: BM:  $F_{5,178} = 5.07$ ,  $p > 0.0002$ ; RWL:  $F_{5,178} = 2.52$ ,  $P < 0.03$ ; RRL:  $F_{5,178} = 1.28$ ,  $P > 0.27$ ; RWF:  $F_{4,145} = 0.92$ ,  $P > 0.47$ ; Tukey HSD post-hoc test: BM: Pentad 19 > Pentad 14; RWL: Pentad 19 > other pentads, Figure 2).

All but one (i.e. RWF) the recorded parameters were positively correlated with the capture period (BM:  $n = 184$ ,  $r = 0.250$ ,  $P = 0.002$ ; RWL:  $n = 184$ ,  $r = 0.225$ ,  $P = 0.001$ ; RRL:  $n = 184$ ,  $r = 0.159$ ,  $P = 0.002$ ; RWF:  $n = 151$ ,  $r = 0.024$ ,  $P > 0.76$ ).

FA was independent of both age and sex (KRUSKAL-WALLIS test,  $n = 184$ ;  $df = 1$ ; age:  $H = 0.31$ ,  $P = 0.58$ ; sex:  $H = 0.33$ ,  $P = 0.56$ ). Pooling together all the captured individuals, significant diffe-

Table 2: Results of a two-way ANOVA analysis performed on the morphometric parameters taken on the captured blackcaps. Factors were age and sex, but only the former was of importance in the obtained model.

Tab. 2: Faktorenanalyse (2-Wege ANOVA) für die Variablen „Alter“ und „Geschlecht“ hinsichtlich ihrer Bedeutung zur Varianzerklärung der erfaßten morphometrischen Parameter; Abkürzungen s. Tab. 1.

Variables	WL			RL			BM			WF		
	DF	F	P-level	DF	F	P-level	DF	F	P-level	DF	F	P-level
Main effects	2	8,47	0,000	2	9,45	0,000	2	3,53	0,03	2	0,26	0,77
age	1	11,14	0,001	1	12,07	0,001	1	6,04	0,02	1	0,15	0,70
sex	1	2,20	0,14	1	2,71	0,101	1	0,12	0,73	1	0,18	0,67
2-way interactions	1	0,41	0,52	1	0,16	0,69	1	0,09	0,76	1	0,26	0,77
Explained	3	6,11	0,001	4	6,61	0,000	4	2,45	0,07	4	9,94	0,001
Residual	180			180			180			147		
Total	183			183			183			150		

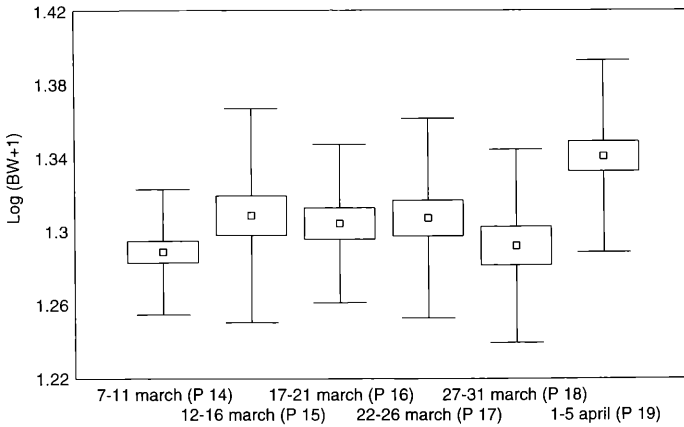


Figure 2: Mean (small square), standard error (rectangle) and standard deviation of body weight for each pentade. The distribution of the variable was normalized by using  $\text{Log}(x + 1)$  transformation.

Abb. 2: Körpermasse und Fangzeitpunkt, erfaßte Daten  $\text{log}(x + 1)$ -transformiert: Mittelwert (kleines Quadrat), mittlerer Fehler (Rechteck) und Standardabweichung.

rences were detected between the six pentads (KRUSKAL-WALLIS test,  $n = 184$ ;  $df = 5$ ;  $H = 28.55$ ,  $P = 0.00001$ ). Comparison of mean of ranks revealed that fat scores of the individuals captured in the sixth pentad significantly exceeded the others (Figure 3).

The proportion of long winged birds (i.e. with  $WL > 76$  mm) was positively correlated with the capture period ( $n = 6$ , SPEARMAN  $r = 0.943$ ,  $P = 0.005$ ; see Figure 4). This character has been employed by several authors in southern and central Italy to distinguish between resident and migrating Blackcaps (see LO VALVO et al. 1988).

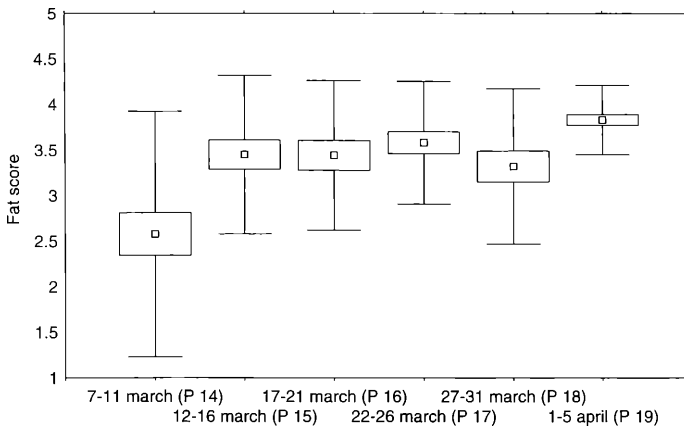


Figure 3: Mean (small square), standard error (rectangle) and standard deviation of fat score values for each pentade.

Abb. 3: Fettdepot und Fangzeitpunkt. Symbolerklärung s. Abb. 2.

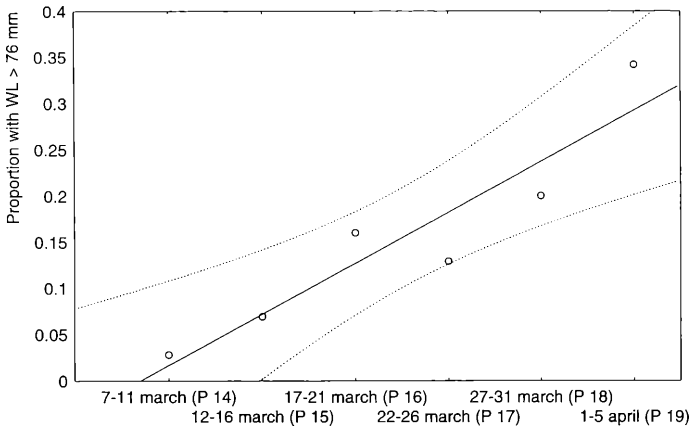


Figure 4: Relationship between the proportion of individuals with WL > 76 mm and the respective pentade. The correlation was statistically significant ( $n = 6$ , Spearman  $r = 0.943$ ,  $p = 0.005$ ).

Abb. 4: Korrelation zwischen dem Anteil an Vögeln mit einer Flügelänge > 76 mm und dem Fangzeitpunkt ( $n = 6$ , Spearman  $r = 0,943$ ,  $p = 0,005$ ).

Because the proportion of individuals belonging to different classes of age and sex did not vary significantly between the six different capture periods, we performed a discriminant analysis by pooling individuals of each pentad. WF was excluded from the analysis, as this parameter was not recorded during the first pentad. The discriminant analysis computed four functions, one of which was statistically significant (Function 1: eigenvalue = 0.251, canonical correlation = 0.448, WILK's lambda = 0.768,  $df = 15$ ,  $p < 0.00001$ ). The obtained model provided a good discrimination between the five groups (WILK's Lambda: 0.769,  $F_{15,486} = 3.24$ ,  $p < 0.0001$ ). In Table 3 the Mahalanobis distances (and relative F values and p levels) between the six groups are given. Note that the sixth pentad was significantly distant from each other.

#### 4. Discussion

Our main finding was that Blackcaps passing early in the migration season were likely to have significantly shorter and rounder wings, lower fat reserves and lighter body mass than conspecifics migrating towards the end of the survey period. These results were independent from age, sex and body mass.

In the northern hemisphere the need to migrate is expected to exert a stronger selective pressure on populations breeding further north (i.e. in the form of longer migratory routes, harsh winter conditions in the breeding quarters) where adaptations to migrate are therefore more developed. Body size being equal, wing is known to be longer the further north the breeding quarters of a population, in several birds (e.g. SMITH et al. 1990, WIEDENFIELD 1991). In *S. atricapilla* wing length shows a clinal variation increasing latitudinally from south to north (KLEIN et al. 1973, BERTHOLD et al. 1990, GLUTZ VON BLOTZHEIM & BAUER 1991) and altitudinally from low to high localities (LO VALVO et al. 1988). LOVEI et al. (1985) found that Blackcaps wintering in southern Italy tended to have longer wings than local birds. They suggested that local breeders migrated further south in autumn, leaving the area to wintering birds from northern Europe with longer wings.

Since pointed wings allow faster and more efficient flight, more pointed wings have been interpreted as a response to stronger selective pressures exerted by the need for a more efficient flight

Table 3: Results of discriminant analysis performed between individuals grouped by capture period. The squared Mahalanobis distance between groups (and relative F-values and P levels) are given.

Tab. 3: Diskriminanzanalyse zwischen Individuen, die nach ihrer Fangpentade gruppiert wurden.

		Pentade 15	Pentade 16	Pentade 17	Pentade 18	Pentade 19
Pentade 14	Distance	0,189	0,252	0,155	0,307	2,002
	F value	0,932	1,138	0,792	1,390	11,728
	P level	0,427	0,335	0,500	0,248	<b>0,000</b>
Pentade 15	Distance		0,099	0,007	0,274	1,113
	F value		0,420	0,035	1,165	6,040
	P level		0,739	0,991	0,324	<b>0,001</b>
Pentade 16	Distance			0,146	0,315	0,855
	F value			0,643	1,245	4,225
	P level			0,588	0,295	<b>0,007</b>
Pentade 17	Distance				0,284	1,292
	F value				1,246	7,301
	P level				0,295	<b>0,000</b>
Pentade 18	Distance					1,635
	F value					8,085
	P level					<b>0,000</b>

(CHANDLER & MULVIHILL 1990, WIEDENFIELD 1991, BERTHOLD 1993, SENAR et al. 1994, YONG & MOORE 1994, MONKKONEN 1995). According to BERTHOLD (1993) wing pointedness must have developed as an adaptation to migration during pre-glacial times.

A high phenotypic plasticity of wing features, possibly associated with a strong genetic component (GOSLER 1988), would confirm the high evolutionary potential of wing morphology in birds (BERTHOLD 1996). Similarly, the ability to store fat reserves as fuel for migration through hyperphagia and endogenous body rhythms (BERTHOLD 1993), is an important adaptation to long migration and thus more developed among those species or those populations that migrate longer (HEDENSTRÖM & PATTERSON 1986). In particular, Blackcaps of northern populations are characterised by a higher degree of fat accumulation during migration than their conspecifics from lower latitudes (BERTHOLD & QUERNER 1981).

It is conceivable that Blackcaps caught at the beginning of the season were breeding relatively close to the study area and had wintered nearby. Conversely, Blackcaps passing at the end of the season were likely to be directed to breeding quarters further away, possibly in northern and northern-eastern Europe, and had also wintered further away than earlier birds, as they showed characteristics proper of longer distance migrants. However, data from different breeding areas are needed to verify the above hypothesis.

Body size and age had an effect on the variation in several morphological traits. Body size of migrating Blackcaps tended to increase towards the end of the migration season. According to the Bergmann's rule body size increases with latitude within a species. This supports our hypothesis that the Blackcaps migrating later belonged to populations breeding in northern Europe. Also differential sexual selective pressures often account for age/sex-specific differential migration both directly (e.g. GUSTIN & PIZZARI 1998) or through differential morphological (e.g. HEDENSTRÖM & MØLLER 1992) and physiological adaptations (e.g. fat accumulation, see HEDENSTRÖM & PETTERSSON 1986).



Thus, temporal intraspecific variation observed in morphology and physiology during migration is often the complex result of differential timing of passage both among different populations (CHANDLER & MULVIHILL 1990) and age and/or sex classes (e.g. MURILLO & SANCHO 1969). Hence the need to be cautious about the causation of potential covariance between morphology and migration time: variation in the morphology of individuals migrating at different times might be due to migration pressures, to other ecological pressures that affect morphology and thus indirectly migratory behaviour, or maybe to an interaction of these factors.

## 5. Zusammenfassung

Während des Frühjahrszuges wurden in Zentral-Italien Mönchsgrasmücken (*Sylvia atricapilla*) gefangen und dabei mehrere morphometrische Merkmale und die Ausprägung des Fettdepots registriert. Die vorliegende Arbeit analysiert Beziehungen zwischen den erfaßten Parametern und dem Fangtermin.

Nach Korrektur hinsichtlich der Körpergröße wurden signifikante Alters- und Geschlechtsunterschiede bei der Flügelgröße, der Flügelformel und im Fettdepot gefunden. Vögel, die gegen Ende der Saison durchzogen, hatten längere und spitzere Flügel und waren fetter. Die Autoren vermuten, daß später durchziehende Mönchsgrasmücken weiter vom Fanggebiet entfernte (vielleicht im nördlichen und östlichen Europa gelegene) Brutgebiete ansteuern. Die Befunde sprechen dafür, daß verschiedene Mönchsgrasmücken-Populationen durch Italien ziehen, die sich auf der Basis morphometrischer Merkmale und der Ausprägung des Fettdepots statistisch auch voneinander unterscheiden lassen.

## 6. References

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