

# ESTIMATED EFFECTS OF AGE AND SEX ON THE FAT-FREE BODY MASS OF AUTUMN MIGRATING BLUETHROATS

## *Luscinia s. svecica*

HANS ELLEGREN

**ABSTRACT** If constant and size-specific values of the fat-free body mass are used for estimating the fat content of migrating birds, it is required that the fat-free body mass does not vary considerable between age and sex groups. To test this requirement, body masses of autumn migrating Bluethroats from different age and sex groups were analysed when wing length and fat index had been compensated for. Age has significant effect on body mass among males (adults being 0.16 g heavier) while no other age or sex effects were observed. The impact of the observed situation on flight range estimates is discussed.

Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, P.O.Box 7055, S-750 07 Uppsala, Sweden

### INTRODUCTION

For elucidation of migration strategies in birds it is almost necessary to achieve estimates of possible flight ranges from different parts of the migration route. According to flight mechanical theory, the possible flight range a bird can cover varies intraspecifically due to body size (wing-span and body mass) and to fat content (Pennycuick 1975). Of these factors, the fat fraction of the body mass is by far the most important to take into consideration for intraspecific comparisons.

Exact determinations of fat contents require lipid extraction procedures of collected birds (see e.g. Odum & Connell 1956). However, this approach has practical as well as ethical disadvantages, and sample sizes tend to be notoriously small. On the other hand, if fat contents can be estimated from living birds, sample sizes can be greatly enlarged. Moreover, fat content estimates from living birds allow for studies of how the fat content varies over time (i.e. fat accumulation).

There are several ways to estimate the amount of fat on living birds (McCabe 1943, Baldassarre *et al.* 1980, Sokal & Rohlf 1981, Walsberg 1988, Castro *et al.* 1990). But if the aim is to calculate expected flight ranges, the common method of fat index classification cannot be utilized in a straight-

forward manner, since it does not give information about the actual fat content (recall that the ratio of fat mass to body mass is required in formulas for flight range calculations). Instead, and still not using complicated equipment, the total live body mass may be used as an estimator of the fat content provided that the approximate fat-free body mass is known. Thus, by first determining fat-free body masses of a given species (through lipid extraction or from apparently fat-less individuals, e.g. Perdeck 1985, Biebach *et al.* 1986, Bairlein 1987, Hedenström & Pettersson 1987, and Ellegren 1989), the fat content of living birds can later be obtained either by subtracting the total live body mass with the fat-free mass, or from formulas derived from multiple regressions of fat mass on body size parameters and total mass. Using species-specific values of the fat-free body mass, flight range estimates have been made on the basis of population averages of body mass and body size of living birds (e.g. Pettersson & Hasselquist 1985, Baggot 1986). The approach has also been extended to flight range estimates based on size-specific values of the fat-free body mass (e.g. Mascher & Marcström 1976, Davidson 1983, 1984, Biebach *et al.* 1986).

In the procedures described above, it is often assumed that there is a limited variation in the fat-free body mass between conspecifics of a given

size (provided that they are in the same physiological, e.g. migratory, state). Two factors that possibly may affect the fat-free body mass of migrating birds due to morphological or physiological adaptations, however, are age and sex. Whereas some studies show that age or sex do not affect the fat-free body mass of migrating birds (e.g. Connell *et al.* 1960) some do (e.g. Evans & Smith 1975 and Perdeck 1985). The role of these factors in affecting the fat-free body mass of migrating birds can thus not be considered as fully clarified.

The Red-spotted Bluethroat *Luscinia s. svecica* is a small nocturnal migrant breeding in northern Scandinavia and wintering in southern Asia (Ellegren & Staav 1990b). Recently, several aspects of the migratory strategy used by this species have been illuminated (Lindström *et al.* 1985, Ellegren 1990a,b, Ellegren & Staav 1990a,b, Lindström 1990, Lindström *et al.* 1990, Ellegren 1991, Ellegren & Wallin 1991). In this study the possible influence of age and sex on the fat-free body mass of autumn migrating Bluethroats was investigated using field data derived from a stop-over site in eastern Sweden.

## MATERIAL AND METHODS

Data were gathered at a stop-over site in eastern Sweden (Inre Fjärden, Gävle, 60°42'N 17°11'E) during the years 1988-1991. Bluethroats were captured in mist-nets during the main migration period, 20 August - 20 September, according to routines as described (Ellegren 1991). Age and sex determinations followed Svensson (1984). For age that is examination of the greater covers either tipped rusty-buff (juveniles) or edged brown-grey (adults). The amount and distribution of blue and red feathers on chin and throat reveal sex (the colour pattern of some adult females resemble juvenile males - the problem is solved by age determination). Wing length (left wing) was measured to the nearest mm according to method 3 of Svensson (1984). Body mass was registered with a Pesola spring balance to the nearest 0.1g. The visual amount of subcutaneous fat was classified accord-

ing to Pettersson (1983). The fat classification constitutes a seven-graded scale where index 0 is no visual fat and index 6 is extensive fattening on the abdomen and in the interclavicular fossa (furcular cavity). In order to avoid mass effects of food consumed during the day, only data collected before 11.00 were used in the analysis. Data were gathered by two experienced ringers who regularly calibrated their wing length measurements and fat index classifications during the study. The total sample size was 1407, distributed among 734 juvenile males, 427 juvenile females, 155 adult males and 91 adult females. The annual sample sizes were 111, 357, 526 and 413, respectively.

The influence of age and sex on the fat-free body mass in Bluethroats was indirectly investigated by comparing the total body mass of birds from different age and sex categories when wing length and fat index had been compensated for. The main test was designed as an analysis of covariance (ANCOVA) using the following model:

$$\text{body mass} = a + b \cdot \text{wing length} + c \cdot \text{fat index} + d \cdot \text{age} + e \cdot \text{sex}$$

Here, wing length and fat index are covariates (since they vary approximately linearly with body mass), whereas age and sex are factors.

## RESULTS AND DISCUSSION

Summary statistics for the outcome of the analysis of covariance designed to test the influence of age and sex on body mass are given in Table 1. According to the adjusted mean values, there were only small differences in the fat-free body mass between male and female birds ( $\Delta = 0.071$  g,  $SE = 0.069$ ) and between adult and juvenile birds ( $\Delta = 0.11$  g,  $SE = 0.062$ ). Whereas the effect of sex clearly was non-significant, the effect of age tended to reach significance (see Table 1).

Although there was no significant interaction between age and sex ( $F$ -test,  $p = 0.16$ ), the effect of age was further examined by separate covariance analyses for males and females. In males, this

**Table 1.** Summary statistics for the analysis of covariance of the influence of various variables on the body mass among autumn migrating Bluethroats. Age and sex are factors, wing length and fat index are covariates ( $df = 1$  in all cases).

Variable	<i>F</i>	<i>p</i>
Age	3.2	0.07
Sex	1.1	0.30
Wing length	65.1	<0.0001
Fat index	715.0	<0.0001

revealed a significant influence of age on body mass ( $F$ -test,  $p = 0.039$ ; for adjusted means  $\Delta = 0.16$  g,  $SE = 0.078$ , adults being heavier). Contrarily, in females, no significant effect was found ( $F$ -test,  $p = 0.83$ ; for adjusted means  $\Delta = 0.022$  g,  $SE = 0.11$ ).

These data indicate that the fat-free body mass of autumn migrating Bluethroats differ between age groups among males but not among females. No difference in the fat-free body mass of males and females was indicated. Connell *et al.* (1960) and Rogers & Odum (1964) demonstrated that age and sex had no or only negligible effect on the fat-free body mass of some migrating New World passerines. In migrating Bar-tailed Godwits *Limosa lapponica*, however, juveniles had a lower fat-free body mass than adults, a consequence of a smaller pectoralis muscle in juveniles (Evans & Smith 1975). Similar situations, although without closer examinations of the underlying reason, are reported for other waders (Davidson 1983), as well as for the Coot *Fulica atra* (Perdeck 1985) and the Rook *Corvus corone cornix* (Slagsvold 1982). A common feature of the studies demonstrating an age effect is that they all concern medium- or large-sized birds.

The validity of my approach for testing age and sex effects on fat-free body mass in Bluethroats relies, among other things, on a non-erroneous sampling of the covariates. Thus, the fat index classification should be a good estimator of the fat content (and birds equally fat-classified should have a similar fat content) and variations in wing length

should accurately mirror variations in the overall body size. Several investigators have shown that fat index classification show a strong linear correlation with the total body mass (for Bluethroats, see Ellegren 1989). Moreover, if the data are collected in standardized manners, a good correlation between fat index and the actual fat mass has also been demonstrated (Krementsz & Pendleton 1990).

Wing length is generally accepted as a good estimator of body size in birds. However, one has to take care for systematic, intraspecific errors due to either abrasion (Ginn & Melville 1983) and/or to age-dependent feather development (Alatalo *et al.* 1984). Regarding abrasion, it could be noted that adult Bluethroats make a complete primary moult quite prior to the autumn migration and thus migrate with fresh primaries (Ginn & Melville 1983). Longer wings of adult birds compared to juveniles are known from several species (Alatalo *et al.* 1984). In autumn migrating Bluethroats the mean difference among males is 0.5 mm whereas no difference is found among females (Ellegren 1991). Since growth of the avian body is thought to cease after the early juvenile period, longer wings of adults are probably not linked to a corresponding difference in body size. We may thus expect small differences in body mass when individuals from different age groups (in this case probably only topical for males), having equal wing lengths, are compared. An indication of what differences are to be expected can be given by noting that the mean body mass increase per mm wing length in Bluethroats is 0.19 g (Ellegren 1989). With an average wing length difference of 0.5 mm between juvenile and adult males, juveniles would thus be in the magnitude of 0.1 g heavier than adults. However, since the opposite situation was found in the present study, age-related wing lengths cannot explain the observed pattern.

What is the significance of the observed situation for flight range estimates in Bluethroats? Referring to males separately, a discrepancy of about 0.15 g between the fat-free body mass of adults and juveniles implies that for an individual which total body mass is 17 g and which fat-free body mass is estimated to be 15.3 g (see Ellegren 1989), the esti-

mated fat content may be in the order of 10.0-10.9% depending on age. Corresponding values for a bird weighing 20 g would be 23.5-24.2% fat, i.e. the relative importance of age would diminish as the fat content increases. Transforming the fat contents to flight ranges according to Pennycuik (1975), we end up with distances of 631 vs. 697 km and 1802 vs. 1864 km. For most applications this variation may be considered as having minor importance.

To summarize, this study has indicated a small age-related difference in the fat-free body mass of migrating male Bluethroats, but has failed to detect other age- or sex-related differences. Those earlier studies that have documented clear differences due to age have all considered larger non-passerine birds (Evans & Smith 1975, Slagsvold 1982, Davidson 1983, Perdeck 1985). Possibly, corresponding and general age-related differences among small Passerines may well be below a level measurable with available techniques. Given other sources of errors in using constant values of the fat-free body mass for rough estimates of fat contents and flight ranges in small migrating birds (Moreau & Dolp 1970, Davidson 1984, Karlsson *et al.* 1988, Castro & Myers 1990, Piersma 1990, Piersma & Brederode 1990), present data suggest that age and sex may not constitute primary concerns.

## ACKNOWLEDGEMENTS

My thanks are due to Kjell Wallin for assistance with the field work and to an anonymous referee and Anders Hedenström for comments on the manuscript.

## REFERENCES

- Alatalo, R.V., L. Gustavsson, A. Lundberg 1984. Why do young passerine birds have shorter wing than older birds? *Ibis* 126:410-415.
- Baggot, G.K. 1986. The fat contents and flight ranges of four warbler species on migration in North Wales. *Ring. & Migr.* 7:25-36.
- Bairlein, F. 1987. The migratory strategy of the Garden Warbler: a survey of field and laboratory data. *Ring. & Migr.* 8:59-72.
- Baldassarre, G.A., R.J. Whyte & E.G. Bolen, 1980. Use of ultrasonic sound to estimate body fat depots in the mallard. *Prairie Nat.* 12:79-86.
- Biebach, H., W. Friedrich & G. Heine 1986. Interaction of bodymass, fat, foraging and stopover period in trans-sahara migrating passerine birds. *Oecologia (Berl.)* 69:370-379.
- Castro, G.G. & J.P. Myers 1990. Validity of predictive equations for total body fat in Sanderlings from different nonbreeding areas. *Condor* 92:205-209.
- Castro, G., B.A. Wunder & F.L. Knopf 1990. Total body electrical conductivity (TOBEC) to estimate total body fat of free-living birds. *Condor* 92:496-499.
- Connell, C.E., E.P. Odum & H. Kale 1960. The fat-free weights of birds. *Auk* 77:1-9.
- Davidson, N.C. 1983. Formulae for estimating the lean weight and fat reserves of live shorebirds. *Ring. & Migr.* 4:159-166.
- Davidson, N.C. 1984. How valid are flight range estimates for waders. *Ring. & Migr.* 5:49-64.
- Ellegren, H. 1989. Weight and wing length as indicator parameters for accumulated fat levels in migrating birds - a methodological study of autumn migrating Bluethroats. *Vår Fågelvärld* 48:75-85 (in Swedish with English summary).
- Ellegren, H. 1990a. Timing of autumn migration in Bluethroats *Luscinia s. svecica* depends on timing of breeding. *Ornis Fenn.* 67:1-5.
- Ellegren, H. 1990b. Autumn migration speed in Scandinavian Bluethroats *Luscinia s. svecica*. *Ring. & Migr.* 11:121-131.
- Ellegren, H. 1991. Stopover ecology of autumn migrating Bluethroats *Luscinia s. svecica* in relation to age and sex. *Ornis Scand.* 22:340-348.
- Ellegren, H. & R. Staav 1990a. Moulting migration in the Bluethroat *Luscinia s. svecica*. *Vår Fågelvärld* 49:80-86 (in Swedish with English summary).
- Ellegren, H. & R. Staav 1990b. The migration of the Bluethroat, *Luscinia s. svecica*, a recovery analysis of birds ringed in Sweden and Finland. *Vår Fågelvärld* 49:323-336 (in Swedish with English summary).
- Ellegren, H. & K. Wallin 1991. Autumn migrating Bluethroats *Luscinia s. svecica* orient in an east-south-easterly direction at Gävle, East Sweden. *Ornis Svecica* 1:47-50.
- Evans, P.R. & P.C. Smith 1975. Studies of shorebirds at Lindisfarne, Northumberland. 2. Fat and pectoral muscles as indicators of body composition in the Bar-tailed Godwit. *Wildfowl* 26:37-46.
- Ginn, H.B. & D.S. Melville 1983. Moulting in birds. *BTO Guide No 19*, British Trust for Ornithology, Tring.
- Hedenström, A. & J. Pettersson 1986. Differences in fat deposits and wing pointedness between male and female Willow Warblers caught on spring migration at Ottenby, SE Sweden. *Ornis Scand.* 17:182-185.

- Karlsson, L., K. Persson, J. Pettersson & G. Walinder 1988. Fat-weight relationships and migratory strategies in the Robin *Erithacus rubecula* at two stop-over sites in south Sweden. *Ring. & Migr.* 9:160-168.
- Krementz, D.G. & G.W. Pendleton 1990. Fat scoring: sources of variation. *Condor* 92:500-507.
- Lindström, Å. 1990. Stopover ecology of migrating birds. PhD thesis, Department of Ecology, Lund University.
- Lindström, Å., S. Bensch & D. Hasselquist 1985. Autumn migration strategy of young Bluethroats, *Luscinia svecica*. *Vår Fågelvärld* 44:187-206 (in Swedish with English summary).
- Lindström, Å., D. Hasselquist, S. Bensch & M. Grahm 1990. Asymmetric contests over resources for survival and migration: a field experiment with blue-throats. *Anim. Behav.* 40:453-461.
- Odum, E.P. & C.E. Connell 1956. Lipid levels in migrating birds. *Science* 123:892-894.
- Mascher, J.W. & V. Marström 1976. Measures, weights, and lipid levels in migrating Dunlins *Calidris a. alpina* L. at the Ottenby Bird Observatory, South Sweden. *Ornis Scand.* 7:49-59.
- McCabe, T.T. 1943. An aspect of the collector's technique. *Auk* 60:550-558.
- Moreau, R.E. & R.M. Dolp 1970. Fat, water, weights and wing-lengths of autumn migrants in transit on the northwest coast of Egypt. *Ibis* 112:209-228.
- Pennycuik, C.J. 1975. Mechanics of flight. In: Farner, D.S. & J.R. King (eds). *Avian Biology*, Vol V:1-75. Academic Press, London and New York.
- Perdeck, A.C. 1985. Methods of predicting fat reserves in the Coot. *Ardea* 73:139-146.
- Pettersson, J. 1983. Age determinations of Passerines and Waders. Special Report from Ottenby Bird Observatory No. 1, Degerhamn.
- Pettersson, J. & D. Hasselquist 1985. Fat deposition and migration capacity of robins *Erithacus rubecula* and goldcrests *Regulus regulus* at Ottenby, Sweden. *Ring. & Migr.* 6:66-76.
- Piersma, T. 1990. Pre-migratory "fattening" usually involves more than the deposition of fat alone. *Ring. & Migr.* 11:113-115.
- Piersma, T. & N.E. van Brederode 1990. The estimation of fat reserves in coastal waders before their departure from north-west Africa in spring. *Ardea* 78: 221-236.
- Rogers Jr, D.T. & E.P. Odum 1964. Effect of age, sex, and level of fat deposition on major body components in some wood warblers. *Auk* 81:505-513.
- Slagsvold, T. 1982. Criteria for estimating the condition of birds - relationship between fat content and body size dimensions in the Hooded Crow *Corvus corone cornix*. *Ornis Scand.* 13:141-144.
- Sokal, R.R. & F.J. Rohlf 1981. *Biometry*. W.H. Freeman & Co., San Fransisco.
- Svensson, L. 1984. *Identification Guide to European Passerines*. Stockholm.
- Walsberg, G.E. 1988. Evaluation of a non-destructive method for determining fat stores in small birds and mammals. *Physiol. Zool.* 61:153-159.

## SAMENVATTING

Voor het schatten van het vetreserves van trekkende vogels worden grootte-afhankelijke constanten gebruikt. Een vereiste voor de nauwkeurigheid van deze methode is dat het vetvrije lichaamsgewicht niet te sterk afhankelijk is van geslacht en leeftijd van de dieren. Om deze afhankelijkheid te onderzoeken werden 1407 Blauwborstjes gevangen tijdens de herfsttrek nabij de kust van midden Zweden. De hoeveelheid onderhuids vet werd geschat (score 0 tot 6), de vleugellengte gemeten en de leeftijd en het geslacht zorgvuldig vastgesteld. De relaties tussen deze componenten werden statistisch getoetst (Tabel 1).

Bij mannetjes werd een gering maar aantoonbaar effect op het gewicht gevonden van de leeftijd (volwassenen 0,16 g zwaarder), terwijl er verder geen effecten waren van leeftijd en geslacht op het gewicht. Het gevonden effect heeft nauwelijks invloed op de afstand die kan worden gevlogen. De auteur suggereert tenslotte dat, in tegenstelling tot wat bij grotere niet-zangvogels gevonden is, het vetvrije gewicht van kleine zangvogels in het algemeen nauwelijks wordt beïnvloed door geslacht en leeftijd. Het onderzoek naar de vetreserves in deze groep wordt dan sterk vereenvoudigd. -JvR/HdN