BODY CONDITION CHANGES OF MINIOPTERUS SCHREIBERSII IN AUTUMN AND WINTER

J. SERRA-COBO*, M. LÓPEZ-ROIG**, T. MARQUÈS-BONET** & J.P. MARTÍNEZ-RICA*

RÉSUMÉ


La condition corporelle de M. schreibersii change significativement d’octobre à mars. Les chauves-souris du nord-est de l’Espagne accumulent des réserves d’octobre à la mi-novembre. Pendant l’automne, leur masse corporelle s’accroît de 31,5 % en 29 jours seulement, tandis qu’elle décroît de 23 % en à peu près quatre mois durant l’hiver. Nous avons prouvé l’existence d’une variabilité interannuelle de la condition corporelle des M. schreibersii au début et à la fin de l’hibernation (février) ainsi qu’à la mi-mars. Nous avons observé que l’hibernation de cette espèce ne constitue pas une période de torpeur continue. Quand la température du refuge d’hibernation est inférieure à 5 °C, les chauves-souris se réveillent et changent de place à l’intérieur du site hivernal ou bien elles changent de refuge. Les réveils peuvent être la cause d’importantes pertes de réserves pendant l’hiver. Les données obtenues devraient contribuer à mieux organiser la protection des refuges d’automne et des sites d’hivernage favorables à la sauvegarde des espèces cavernicoles menacées.

SUMMARY

To prepare for hibernation, bats rapidly deposit large amounts of adipose tissue in early autumn that will be needed to sustain them during the dormancy period. The store of a small amount of body fat in autumn or high mass loss during winter can be critical. This study aims to investigate the autumn and winter body condition changes in 1998-99 of M. schreibersii and its interannual variability.

We have studied bats from four Spanish shelters. Bats were weighed, sexed and their forearms measured. The samples were analysed by using calculation of residuals, one-way
ANOVA and Scheffé test. Interannual variability has been analysed by comparing the data obtained during winter 1998-99 to data obtained during winters 1984-85 and 1985-86. Body condition of *M. schreibersii* change significantly from October to March. *M. schreibersii* from NE Spain store reserves from October to mid-November. Bats increased their body mass of 31.5% in just 29 days during autumn 1998, whereas they lost 23% of prehibernation body mass in 4 months approximately.

We have proved the existence of interannual variability in *M. schreibersii* body condition at the beginning and at the end of hibernation (February), and we have also proved variability in mid-March. We have observed that hibernation in *M. schreibersii* is not a period of continuous torpidity. When hibernacula temperature was lower than 5°C bats woke up and changed places inside the winter quarter or they even changed shelters. Arousals in winter can be one of the cause of the large loss of body condition rate during winter. The information obtained must contribute to a better protection of autumn shelters used to prepare hibernation and caves used as hibernacula for the recovery of endangered cavernicolous species.

**INTRODUCTION**

Hibernation of insectivorous bats from temperate regions is an energy-saving mechanism to facilitate survival when low ambient temperature reduce food resources necessary to meet thermoregulatory demands (Webb et al., 1996; Johnson et al., 1998). Low body temperatures of bats are associated with low rates of energy expenditure, and are essential to survive for many months on limited stores of energy (French, 1985; Geiser, 1988; Speakman & Racey, 1989; Hosken & Withers, 1997). To prepare for hibernation, bats rapidly deposit large amounts of adipose tissue in early autumn that will be needed to sustain them during the dormancy period (Brosset, 1966; Ewing et al., 1970; LaVal & LaVal, 1980; Funakoshi & Uchida, 1975, 1982). Autumnal store of reserves, hibernation, and the first weeks after hibernation are very important for the survival of the bats. Store of a small amount of body fat in autumn or high mass loss during winter can be critical. In this sense, Speakman & Racey (1989) suggest that bats entering hibernation with large energy stores are more likely to survive than those with smaller stores.

*Miniopterus schreibersii* is a migratory bat which moves between summer roosts, commonly located in areas rich in food resources, and winter quarters, whose main features are high relative humidity and rather low and constant temperatures. Between these two kinds of localities the species stops in equinoctial spring and autumn shelters. *M. schreibersii* have specific roost requirements at hibernation that are only met at a few caves within their geographic range (Serra-Cobo et al., 1998).

This study aims to investigate the autumn and winter body condition changes of *M. schreibersii* and its interannual variability. The information obtained must contribute to a better protection of autumn shelters used to prepare hibernation and caves used as hibernacula for the recovery of endangered cavernicolous species.

**MATERIAL AND METHODS**

**LOCALITIES STUDIED**

We have studied *M. schreibersii* from Daví winter quarter and from the equinoctial localities in Esquerrà and Castellsapera potholes and Castanya mines.
All the localities studied are located in north-east Spain, in the province of Barcelona (Serra-Cobo et al., 1998). Daví is a 65 m deep pothole which shelters from 600 to 9000 bats every winter. The population of *M. schreibersii* from Daví usually hibernates from the end of December to mid-February (Serra-Cobo, 1989). *M. schreibersii* hibernates in crevices and small rooms located in the lower part of the pothole. Studies on migratory movements have proved that most of the bats from Daví come from Esquerrà, Castellsapera, and Castanya equinoctial shelters. The colonies from these three shelters are closely related to the hibernation colony from Daví. The bats from Esquerrà, Castellsapera, and Castanya migrate every year to Daví towards the end of autumn. At the beginning of spring, the bats from Daví go back to the equinoctial shelters only to migrate again, by the end of spring, to summer shelters in the Spanish north-east coast (Catalunya) and to south-east France (Languedoc-Roussillon) (Serra-Cobo et al., 1998).

**MEASUREMENTS PROCEDURES**

In order not to disturb bat colony (Speakman et al., 1991), we carried out, at the most, three samplings per hibernation period (December-February). The rest of samplings were performed in October, November, and March in order to determine the changes in body condition during autumn and once hibernation was over. Carbide lamps were not used in hibernacula visits in order not to increase hibernacula temperature. Bats from Daví were captured by hand at random and kept in perspiratory bags. Afterwards, they were weighed, sexed and their forearms measured. To prevent disturbing the hibernation colony and the consequent premature use of hibernal fat reserves, the capture of bats was done very quickly and the measurements were taken outside the hibernation place, though inside the pothole. Once weighed and measured (a few minutes after capture) *M. schreibersii* were brought back to the same place where they had been found. Bats from Esquerrà and Castellsapera shelters were captured by using nets when they were coming out of the roost at dusk. In Castanya mines they were captured with the help of a fishing rod. The bats captured during the winters of 1984-85 and 1985-86 were not only measured and weighed, but also banded. Not any bat suffered harm through the measurement process.

**BODY CONDITION CHANGES IN AUTUMN-WINTER**

We obtained seven samples to study body condition variability during autumn-winter 1998-99 (one of them in Esquerrà, two in Castellsapera, and four in Daví: three of them during hibernation and one during post-hibernation). Body mass was adjusted by calculation of the cubic roots followed by performing log-log regression with forearm length. The residuals of the regressions were subjected to one-way ANOVA for determining possible differences. Scheffé test was used to perform multiple comparisons among the different samples. Residuals give us an estimation of the physical condition of bats by taking into account body mass and forearm length, the latter providing an approximate idea of the bat size. In addition to residuals calculation and to be able to compare our results with those of other authors, body mass variability without regressions with forearm was also determined.

**INTERANNUAL BODY CONDITION VARIABILITY**

Interannual variability of winter body condition has been analysed by comparing the data obtained during winter 1998-99 to data obtained by Serra-
Cobo (unpublished data) during winters 1984-85 and 1985-86. We have analysed one sample at the beginning of hibernation (December) and at the end of it (February), and another one around mid-March for each of the three winters studied. The samples were analysed by using calculation of residuals, one-way ANOVA and Scheffé test. Body mass variability without correlation with forearm was also estimated. Body mass of bats captured twice in contiguous years has acted as a control in the study of interannual body mass variability carried out from random samples. Body mass of individuals captured twice in contiguous years have been compared by using Student-test for paired samples. Body conditions of males and females were compared to learn about differences between both sexes.

TEMPERATURES ANALYSES

We analysed daily hibernacula mean ambient temperatures of Daví pothole and of external ambient temperatures. Hibernacula temperatures were recorded by data logger from December 12th 1998 until February 27th 1999. External temperatures of October-March period in 1984-85, 1985-86 and 1998-99 were obtained from the nearby weather station in Caldes de Montbui. Hibernacula and external temperatures were correlated to know whether the hibernacula temperature variations followed external temperature changes. Interannual external temperatures variability was analysed by comparing daily mean temperatures of the same months in different years by using one-way ANOVA and Scheffé test.

RESULTS

BODY CONDITION CHANGES IN AUTUMN-WINTER

The body condition of *M. schreibersii* has changed significantly (*F* (6.313) = 105.69, *p* < 0.001) from October to March (Fig. 1, Table I). We have observed a relatively quick autumnal gain (October-November) and a subsequent slower winter loss (Table II). *M. schreibersii* increased its body mass 3.81 g (31.5%) in just 29 days during autumn 1998, whereas it lost 3.73 g (23% of prehibernation body mass) in 4 months, approximately. *M. schreibersii* had better body condition at the end of hibernation (February 13th) than at the beginning of the reserves store (October 16th). However, their body condition decreased during post-hibernation to the extent that there were no differences with the one they showed in mid-October (Fig. 1, Table I).

INTERANNUAL BODY CONDITION VARIABILITY

We have proved the existence of interannual variability in *M. schreibersii* body condition both at the beginning (*F* (2.276) = 131.24, *p* < 0.001) and at the end of hibernation (February) (*F* (2.224) = 7.42, *p* < 0.001) and also in mid-March (*F* (2.190) = 160.92, *p* < 0.001). Bats showed better body condition in December 1984 (Scheffé test, *p* < 0.001) than at the beginning of winters 1985-86 and 1998-99, and it was also better in mid-March 1985 (Scheffé test, *p* < 0.001) as
Variation in body condition

Figure 1. — Body condition changes of *M. schreibersii* in autumn-winter 1998-99.

**TABLE I**

*Table I: Body condition changes of Miniopterus schreibersii in autumn-winter 1998-99 (Scheffé-test).*

<table>
<thead>
<tr>
<th></th>
<th>Castellsapera</th>
<th>Daví</th>
<th>Daví</th>
<th>Daví</th>
<th>Daví</th>
<th>Daví</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castellsapera</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>n.s.</td>
</tr>
<tr>
<td>16-X-98</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>n.s.</td>
</tr>
<tr>
<td>Castellsapera</td>
<td>**</td>
<td>*</td>
<td>n.s.</td>
<td>n.s.</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>25-X-98</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>15-XI-98</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Daví</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>2-I-99</td>
<td>n.s.</td>
<td>**</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-I-99</td>
<td>n.s.</td>
<td>**</td>
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<tr>
<td>13-II-99</td>
<td>n.s.</td>
<td>**</td>
<td></td>
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</tr>
</tbody>
</table>

* p < 0.05, ** p < 0.001, n.s. no significative.

compared to the body condition they showed in March 1986 and 1999 (Fig. 2). At the end of hibernation significant differences were only found between 1985 and 1986 (Scheffé test, *p* < 0.01), showing better body condition in the bats captured in 1985. No differences were found between male and female body conditions (*F*(1, 577) = 0.00, *p* < 0.9).

The daily loss of body mass during the hibernation period of 1984-85 was relatively higher than in 1985-86 and 1998-99 (Fig. 2, Table II). The body mass of
### Table II

*Body condition changes of Miniopterus schreibersii in autumn and winter.*

<table>
<thead>
<tr>
<th>Date</th>
<th>Winter random samples</th>
<th>Capture/recapture samples of banded bats</th>
<th>Autumn random samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Body mass (g) mean ± S.D.</td>
<td>n</td>
<td>Daily lost (g/day)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>A 15-XII-84</td>
<td>17.10 ± 0.82</td>
<td>99</td>
<td>0.05(1)</td>
</tr>
<tr>
<td>B 10-II-85</td>
<td>14.00 ± 1.03</td>
<td>138</td>
<td>0.01(2)</td>
</tr>
<tr>
<td>C 23-III-85</td>
<td>13.61 ± 0.89</td>
<td>85</td>
<td>0.03(1)</td>
</tr>
<tr>
<td>A 21-XII-85</td>
<td>14.99 ± 1.17</td>
<td>131</td>
<td>0.03(2)</td>
</tr>
<tr>
<td>B 16-II-86</td>
<td>13.31 ± 0.97</td>
<td>62</td>
<td>0.03(1)</td>
</tr>
<tr>
<td>C 23-III-86</td>
<td>12.46 ± 0.68</td>
<td>64</td>
<td>0.03(2)</td>
</tr>
<tr>
<td>A 2-I-99</td>
<td>14.89 ± 1.17</td>
<td>50</td>
<td>15-XII-84</td>
</tr>
<tr>
<td>B 13-II-99</td>
<td>13.43 ± 0.69</td>
<td>27</td>
<td>14.34 ± 0.74</td>
</tr>
<tr>
<td>C 20-III-99</td>
<td>12.19 ± 0.79</td>
<td>41</td>
<td>13.69 ± 0.74</td>
</tr>
</tbody>
</table>

(1) During the hibernation period (from A to B). (2) During the post-hibernation period (from B to C). (3) During the first period (from A to B). (4) During the second period (from B to C).

The bats banded in 1984-85 and recaptured in 1985-86 confirm the existence of interannual body condition variability of *M. schreibersii* (Table II).

**Temperature analyses**

There is positive correlation ($r = 0.574, p < 0.001$) between hibernacula daily mean temperatures of Daví and external ambient temperatures (Fig. 3A). The minimum, maximum, and mean temperatures registered at the hibernation site are 3.5, 7.2 and 6.0 ± 0.78 °C, respectively. The hibernacula ambient temperature was
especially low during the first sixteen days of February. The comparison between the daily external mean ambient temperatures of the same months in different years (October-March period) shows the existence of significant differences (ANOVA, \( p < 0.01 \)) in all months except December (ANOVA, \( p > 0.1 \)). November 1984 and February 1985 were relatively milder, whereas January and March 1985 were significantly colder (Scheffé-test, \( p < 0.05 \)). The temperatures recorded in 1985-86 and 1998-99 during the October-March period are very similar. We only find significant differences in October temperatures (Scheffé-test, \( p < 0.05 \)), being October 1998 the coldest one (Fig. 3B).

**DISCUSSION**

Autumn is an important season for the populations of *M. schreibersii*, during which bats mate and store reserves to prepare hibernation. *M. schreibersii* from north-east Spain mate from mid-September to beginning of October (Serra-Cobo, 1989) and they store reserves from October to mid-November. The quantity of stored reserves during prehibernation can differ from year to year. In 1984 *M. schreibersii* from Daví pothole stored a large quantity of reserves and in December they showed a better body condition than at the beginning of hibernation of the two other years studied (Fig. 2). Several factors can influence interannual body condition variability of bats at the beginning of winter, such as food availability and ambient temperature inside and outside the shelter. In November we observed that high external temperatures, like those in 1984, favour the presence of insects (Williams, 1961). Taking into account the large reserves
stored and Speakman & Racey’s suggestions (Speakman & Racey, 1989),
M. schreibersii were more likely to survive during 1984-85 hibernation than
during the two other winters studied.

Our estimate of overwinter body mass loss in M. schreibersii of Daví pothole
(23 % of prehibernation body mass) is similar to the one obtained by Norton & van
der Merwe (1978) in Southafrikan M. schreibersii natalensis (21.3 %) and for
Dwyer (1964) in Australian M. schreibersii blepotis (22 %).

There exists interannual variability in the rate of body condition loss during
hibernation (Table II). The rate and total magnitude of energy expenditure during
hibernation are affected by several variables, such as roost microclimate, body
temperatures, duration of hibernation, arousal frequency, and frequency of human
visits (Johnson et al., 1998). We have observed that hibernation in M. schreibersii
is not a period of continuous torpidity, but it is characterized by intra and
inter-pothole movements. When hibernacula temperature was lower than 5 °C
M. schreibersii woke up and changed places inside Daví pothole or they even
changed shelters. The temperature at which European M. schreibersii populations
had been recorded torpid inside a hibernaculum ranged between 5 and 10 °C
(Balcells, 1964; Gaisler, 1970; Serra-Cobo, 1989). These arousals and winter
movements imply the utilization of a portion of hibernal fat reserves and body
condition loss (Speakman & Racey, 1989). The Daví hibernacula temperature
changes according to the external temperature (Fig. 3A). The largest loss of body
condition rate was observed between December 1984 and February 1985 (Fig. 2,
Table II). January 1985 was very cold. Arousals in January 1985 can be the cause
of the large loss of body condition rate.

At the end of winter (February-March) there is also variability in loss of body
condition rate of M. schreibersii. The largest loss was observed in 1999 (Fig. 2,
Table II). The low hibernacula temperatures at the beginning of February 1999
(Fig. 3A) woke up the bats. A 75 % of the colony of Daví pothole moved to
another shelter, only to go back to Daví in March with the consequent loss in body
condition.

Daví winter quarter and Esquerrà, Castellsapera, and Castanya equinocial
shelters are very important for the annual dynamics of the species and they shelter
M. schreibersii from a wide area of north-east Spain and south-east France
(Serra-Cobo et al., 1998). In recent years, the attention of a number of authors has
been concentrated on the protection of hibernating bat colonies (Speakman et al.,
1991, Johnson et al., 1998). This, of course, is important, but it is also important
to preserve autumn shelters, especially in years with cold autumns. That protection
is essential for the preservation of M. schreibersii.

ACKNOWLEDGEMENTS

We wish to thank the Nature Reserve Service of the Diputaciô de Barcelona and the Sant Llorenç
del Munt and Garraf Natural Parks for their help in the carrying out of this study.

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