Changes in body mass of postweaning juveniles of the edible dormouse, *Glis glis* (L.), in captivity

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Abstract: Edible dormice have to accumulate an adequate amount of body fat before hibernation. Because young dormice are born late in the season, they have a relatively short time for prehibernation fattening. The aim of our study was a) to determine what body mass juveniles reach prior to hibernation, and b) to examine patterns of mass gain in juvenile dormice with unlimited food supply. Dormice were kept in outdoor cages, fitted with wooden boxes and with the floor covered with soil suitable for hibernation. They were provided with water and fed ad libitum. They were weighed every 5–8 days. Of 34 juveniles (17 males and 17 females; 26 born in captivity and 8 caught in the wild), 22 began hibernation in underground cavities. The mean body mass of juveniles prior to hibernation was 89.7 ± 14.8 g. The mean daily mass gain was 0.82 g. The range of mass change varied from –4.00 to 5.71 g/day. Wild-caught juveniles most quickly gained mass during the first week in captivity with a mean rate of 4.54 g/day. We found that prior to hibernation body mass of juvenile dormice was lower than it was expected according to the literature. We show that fluctuations of body mass can be high, even in a short period of time.

Key words: Mass gain, mass loss, unexpected changes, prehibernation

Winter is an unfavourable season for many organisms because of food shortages and severe weather conditions. To survive this difficult time of year, numerous strategies have evolved among animal species, with one of the most peculiar being hibernation (Feldhamer et al., 1999). Hibernation is a prolonged state of energy-saving dormancy characterised by reduced metabolic rate, reduced body temperature, in some cases falling to near ambient temperature, and reduced heart rate and breathing (Wilz and Heldmaier, 2000). During this inactive period, facultative hibernators rely first on food supplies they manage to store and use physiological hibernation only as necessary, whereas obligate hibernators, which do not eat, depend instead on fat reserves accumulated prior to hibernation (Humphries et al., 2003; Dark, 2005). Thus greater body mass and larger fat reserves increase the probability of the animal's survival (Murie and Boag, 1984; Schorr et al., 2009). To gain mass in the form of fat reserves animals consume large amounts of food, and therefore changes in body mass before hibernation can be quite significant (Dark, 2005). Obtaining sufficient fat stores can be especially difficult for late-born juveniles (Lenihan and Van Vuren, 1996; Monclús et al., 2014) due to the reduced

foraging period before winter. Effective mass gain is crucial for them because heavier juveniles are more likely to survive hibernation (Armitage et al., 1976; Lenihan and Van Vuren, 1996; Ruf and Arnold, 2000). Edible dormice, *Glis glis*, belong to a group of heterothermic mammals that hibernate (Vietinghoff-Riesch, 1960; Storch, 1978). In Poland, edible dormice hibernate from September/October to May/June (Jurczyszyn, 2011). During hibernation, dormice may lose up to one third of their body mass (Kryštufek, 2010). Therefore, the chance of surviving winter likely depends on fat reserves that dormice manage to accumulate in autumn (Vietinghoff-Riesch, 1960). In the northern part of their range (including Germany, Poland, Lithuania, Latvia, Belarus, and Russia), females produce one litter per year in August (Kryštufek, 2010; Juškaitis et al., 2015). After circa 30 days, usually in September, juveniles leave the nest and become independent. Thus, young dormice have a relatively short time for prehibernation fat accumulation before the first frost, which prevents access to arboreal food.

The aim of our study was a) to determine peak body mass of juveniles prior to hibernation, and b) to examine patterns of mass gain in young dormice with an unlimited food supply.

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Our study was carried out in autumn 2013 at the Ecological Station of Adam Mickiewicz University in Poznań, which is located in the village of Jeziory (52°15′54″N, 16°48′04″E). Dormice were kept in 7 outdoor cages (2 × 2 × 2 m) made of steel mesh sides with concrete slabs at the bottom of each cage. To create suitable conditions for hibernation, similar to natural ones, the floor of each cage was covered with a 50–60 cm layer of soil (Jurczyszyn, 2007). Dormice were provided with wooden boxes as shelters (size of base: 180 mm by 180 mm, diameter of the entrance about 50 mm) and branches for climbing. They were provided with water and fed ad libitum with shelled sunflower seeds, shelled hazelnuts, apples, grapes, pears, carrots, peaches, nectarines, plums, and raisins.

We examined 34 young dormice (17 females and 17 males), consisting of 26 captive-born individuals from 6 groups of siblings and 1 group of 8 unrelated, wild-caught dormice, which came from Central Roztocze in south-eastern Poland. The exact dates of birth of the captive-born dormice were known, but the ages of the wild-caught animals could only be estimated (according to colour of fur, length of hair on tail, eruption of third molar teeth). For the purpose of subsequent identification, each animal was individually marked with an ear tattoo. Body mass measurements of juveniles began on 16 September and were completed on 6 November, although weighing of later born individuals started later. The study was completed when most individuals (22) started to hibernate. The dormice were weighed to the nearest 1 g using a spring balance (Pesola, Baar, Switzerland) every 5–8 days at the same time of day (between 1000 and 1400).

We assumed that body mass is an appropriate measure to achieve our objectives. As it was found in adult edible dormice by Schaefer et al. (1976), and in juvenile garden dormice, *Eliomys quercinus*, by Stumpfel et al. (2017), body mass increase is a function of fattening in autumn.

Statistical analyses were performed using Statistica 12 for Windows. The study was approved by the local ethical commission (No 47/2013) and the General Directorate for Environmental Protection (DOP-OZ.6401.05.6.2013.mk).

At the beginning of the study, edible dormice from various litters were of different ages and so the initial body mass differed between groups of siblings (Table 1). Mean mass of edible dormice from the oldest group of captive-born siblings (kept in cage A4) at the first measurement was 80.5 g on 16 September and from the youngest group (cage A3) was only 43.5 g on 4 October. The wild-caught dormice (cage A2) were most diverse in terms of body mass. Mean initial body mass of wild-caught animals was 68.2 g, with a high standard deviation (±13.37).

There were no significant differences between the sexes in maximum mass [97.1 ± 19.1 g (n = 17) vs. 98.2 ± 19.3 g (n = 17) for females and males, respectively; t = −0.18, df = 32, P = 0.86].

By the end of the study 22 juveniles (about 65%) had entered hibernation, while the rest of the animals remained active. Mean body mass at the last weighing was 89.7 ± 14.8 g. The lightest juvenile entering hibernation weighed 70 g and the heaviest one weighed 124 g (Figure). There were no significant differences between prehibernation masses of males and females [92.0 ± 15.7 g (n = 11) vs. 87.5 ± 14.3 g (n = 11) for males and females, respectively; t = 0.71, df = 20, P = 0.49].

Juveniles gained mass at a mean rate of 0.82 ± 1.83 g/day. Nevertheless, the range of body mass changes varied from −4.00 to 5.71 g/day. The fastest rate of mass gain amounted to 4.88 ± 0.72 g/day (range 4.0–5.6) and was found in the first week of the study in one of the groups of siblings. The amount of mass gain was variable not only between individuals but also within individuals. Some animals born in captivity gained mass and another time lost mass between weighing sessions (Table 2). For example, female *F31* (initial mass 70 g) gained 28 g (40% of initial body mass) in 5 days, lost 4 g in 6 days and then

Table 1. Mean body mass (SD, min, max) of all sibling group and wild-caught (cage A2) edible dormice at the beginning of the study.

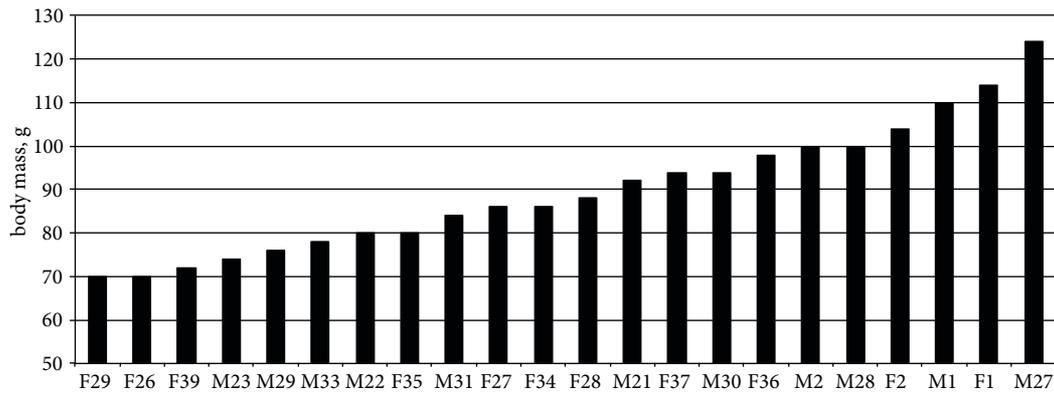| Group (no. of cage)	Body mass (g)				Age during the first weighing (days)
	n	x	Min	Max	
A3	8	43.5	41	47	33
A1	5	63.2	56	72	42
B4	4	67.0	64	72	48
A4	4	80.5	74	92	55
B3	5	74.8	70	78	55
A2	8	68.2	46	84	probably 6–8 weeks

Figure. Distribution of body mass of 22 edible dormouse juveniles at the last weighing before hibernation.

gained 32 g (34% of body mass) in 7 days. After an initial increase in mass, female *F31* during the following three periods lost 40 g. Twenty-one juveniles (about 62%) lost mass between successive measurements at least once.

During the week after arrival at the station, all wild-caught edible dormice quickly gained mass at a mean rate of 4.54 g/day (2.29 to 5.71 g/day). Male *M30* was particularly impressive as during the first week in captivity he gained 40 g, representing 62.5% of his initial body mass. In the following period (between 4 October and 12 October) the mean mass gain of wild-caught juveniles was lower (0.15 ± 3.13 g/day). Three dormice even decreased in mass and three others entered hibernation (Table 2). Before the next measurements on 19 and 26 October, dormouse mass had decreased (–1.33 ± 2.92 g/day and –1.86 ± 0.61 g/day, respectively) and another group of five animals began hibernation.

Morris and Morris (2010) found that prehibernation body mass of free-ranging dormice needs to exceed 110 g to enable them to survive winter. This corresponds to the data reported by Vietinghoff-Riesch (1960), who found that prehibernation body mass of juveniles ranged from 106 to 116 g. In contrast, we found that 86% of animals (19 out of 22 juveniles that entered hibernation) before hibernation had a body mass lower than 106 g, and, what is more, two of them were barely 70 g. Differences in minimal body mass allowing dormice to survive hibernation may result from regional variation between local populations. Maintaining low body temperature during hibernation, near to ambient temperature, generates energetic costs, which depend on climatic conditions. Therefore, edible dormice from different parts of their distribution range may present slightly different patterns of prehibernation mass gain and may vary in regard to minimal body fat reserves necessary to survive winter. We found mean body mass of juveniles before hibernation was 89.7 g, similar to the results reported by Bieber and Ruf (2004),

who estimated under laboratory conditions that at the end of the active season, but not directly before hibernation, juveniles from central Germany weighed on average 86.9 g. Still, there is a possibility that animals that remained active after the termination of our study gained mass and actually were heavier entering hibernation compared to the last weighing. Nevertheless, most dormice in Jeziory began hibernation with a lower body mass than expected based on the literature data, even though they were fed high quality food ad libitum. Given the substantial mass gain by all wild-caught dormice in the first week after arrival at the station, the food was adequate. Moreover, if juveniles suffered due to lack of adequate food, they would probably employ torpor to save energy (Geiser, 2008). Such an energy-saving mechanism, which promotes growth and fat accumulation in the prehibernation period, occurs in juveniles of the garden dormouse, a species related to the edible dormouse (Giroud et al., 2012, 2014). Intermittently fasted garden dormouse juveniles used torpor bouts more readily than those fed ad libitum. However, we never observed torpor in juvenile edible dormice before they began hibernation. We argue that the excess food caused the effect of "hibernation underweight" in the majority of young dormice. We think that such an excess of food in the surroundings might not encourage juveniles to accumulate fat, because the animals may expect that food would be available continuously. This idea is consistent with Bieber and Ruf (2004), according to whom the best strategy for juveniles of the edible dormouse is to shorten the hibernation season, instead of gaining extreme mass in autumn, and count on any food that would be available in spring.

The body mass of juvenile dormice was surprisingly variable. We expected a gradual increase in body mass as reported in other studies conducted in Germany (Vietinghoff-Riesch, 1960; Bieber and Ruf, 2004), Italy (Pilastro et al., 1994), Croatia (Margaletič et al., 2006),

Table 2. Changes in body mass of studied edible dormice between subsequent measurements.

No. of cage	No. of individual	Change in body mass (g)							
		21.09.	27.09.	04.10.	12.10.	19.10.	26.10.	31.10.	06.11.
A3	F38				11	6	-2	8	–4
	F39				14	12	8	–4	h
	M34				12	4	2	10	–2
	M35				14	2	6	6	0
	F40				14	10	moved to A5		
	M31				13	8	moved to A5		
	M32				9	4	moved to A5		
	M33				16	9	moved to A5		
A4	F1	–6	16	10	14	h			
	F2	10	6	14	h				
	M1	6	2	10	h				
	M2	–8	20	2	–6	4	10	h	
B3	F31	28	–4	32	–20	–12	–8	2	0
	F32	22	8	18	–26	–10	–4	6	–2
	F33	28	18	–16	–16	–10	0	2	6
	M25	20	2	16	–8	–12	–8	4	6
	M26	24	4	24	4	–16	–8	–2	–4
B4	F29	10	6	–14	h				
	F30	4	0	12	0	–12	4	2	–6
	M23	0	2	6	20	–18	h		
	M24	–2	8	–4	–6	–6	12	–2	–6
A5	F40						8	10	6
	M31						8	12	h
	M32						14	10	6
	M33						14	–4	h
A1	F26		2	10	20	–28	h		
	F27		2	6	4	6	h		
	F28		10	20	8	h			
	M21		–2	14	8	h			
	M22		6	18	h				
A2	F34			36	–32	h			
	F35			26	h				
	F36			16	22	14	h		
	F37			30	–6	h			
	M27			40	h				
	M28			32	h				
	M29			34	–8	–18	–10	h	
	M30			40	30	–24	–16	h	

A2 – juveniles caught in the wild
A5 – juveniles moved on 19 October from cage A3
h – juvenile entered hibernation

Turkey (Özkan, 2006), Austria (Lebl et al., 2010), and Britain (Morris and Morris, 2010). Indeed Morris and Morris (2010) found a considerable range of mass increase (between 0.31 and 2.87 g/day) in pups from preweaning and postweaning periods, but they suggested continuous increases. Özkan (2006) made a similar suggestion, namely that mass gain of juveniles older than 30 days was between 1.17 and 1.92 g/day. A continuous increase in body mass in juveniles after weaning was described also in other hibernating dormouse species, i.e. the mouse-tailed dormouse, *Myomimus roachi* (Buruldağ and Kurtonur, 2001), and the common dormouse, *Muscardinus avellanarius* (Juškaitis, 2008). This is different from our observations, which ranged from considerable mass growth (5.71 g/day) to substantial mass loss (4 g/day). Furthermore, in 66% of juveniles, we noted at least one episode of losing mass, and in some individuals body mass decreased between three consecutive weighings. Body mass fluctuation also occurred in some wild-caught juveniles (already during the second week in cages), which suggests that it is not exceptional to animals born in captivity. It is possible that if the same free-ranging juvenile dormice could be caught and weighed weekly, body mass fluctuation might be similar to those observed in our study. In hibernators, mass gain towards the end of the active season has costs and benefits. Body mass gain is necessary for surviving winter, but, at the same time, running speed is reduced due to prehibernation fat deposition (Trombulak, 1989; Feldhamer et al., 2003; Bieber et al., 2014). Free-ranging animals with decreased mobility are more vulnerable to predators. Arboreal species, such as *G. glis*, may suffer most from reduced agility, and we therefore argue that rapid and considerable mass loss in juveniles may just be a consequence of the preceding rapid body mass gain.

Wild-caught juveniles likely quickly gained mass in the first days of captivity because of access to unlimited food of high quality, but also probably because of reduced movement in the relatively small cages and stress. Dormice could behave like laboratory animals, in which the desire for food increases when experiencing negative emotional states (McMillan, 2013). Negative emotions may be a result of catching, moving juveniles to a new location, and then keeping them in a relatively small and confined area. If rapid mass gain was actually a symptom of stress, in most individuals it disappeared in the next and following weeks, when mass loss was more common.

Our results shed some light on patterns of mass gain in juvenile edible dormice during the prehibernation period, which is critical for survival. Fluctuations in body mass observed both in captive-born and wild-caught juveniles suggest that mechanisms regulating this process are more complicated than a simple relation food intake – body mass increase.

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