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Observations on the captive behavior of the rare Patagonian opossum *Lestodelphys halli* (Thomas, 1921) (Marsupialia, Didelphimorphia, Didelphidae)

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Abstract

We describe the behavior in captivity of the rare Patagonian opossum (*Lestodelphys halli*) from five individuals captured at three localities, which were kept alive in glass terraria for different periods of time (between 2.5–3.5 months). During our observations we found that *L. halli* can climb and jump well, has a prehensile tail-tip which can hold the body suspended for several seconds, powerful grasping hind feet and the ability to dig. Feeding preferences of meat (mainly raw) and live animals (i.e., mice, lizards and beetles) over vegetables or fruit was observed. We document the first records of torpor/hibernation for the species, its locomotion and exploration patterns and feeding postures. Resting/sleeping in *L. halli* is done with the body curled along a vertical axis and its head placed against the chest and between the hind legs, a posture different from previously reported American marsupials. Stereotyped behavior patterns (e.g., grooming) were observed and compared with other studied species, providing comparative information for further studies on New World marsupials.

Keywords: feeding preferences; locomotion; New World marsupials; torpor/hibernation.

Introduction

The behavior of New World marsupials is poorly known and is limited to a few well studied species (e.g., *Didelphis virginiana*, McManus 1970; *Monodelphis domestica* and *Didelphis albiventris*, Streilein 1982; *Monodelphis dimidiata*, González and Claramunt 2000). Anecdotal information is also available for some of the 109 recognized species (Voss and Jansa 2009) scattered through different types of bibliographic accounts (Bruch 1917, McManus 1970) but many of the species that inhabit extreme environments which would be of interest remain unsurveyed. For example, caenolestids, which live at high altitudes and species such as *Thylamys pallidior,* which lives in a gradient from sea level to 4500 m and throughout a north-south range of more than 3500 km. Comparative studies between supraspecific taxa are also lacking, which would be important to form hypotheses about marsupial adaptations to different environments and would shed some light on how these behavior patterns have evolved (McManus 1970, Martin and Bateson 1993, González and Claramunt 2000).

The Patagonian opossum *Lestodelphys halli* is the southernmost living marsupial and is endemic to Argentina (Martin et al. 2008). The species is distributed from northern Mendoza Province and south to central-southern Santa Cruz Province (Martin et al. 2008) with a clear predominance in the extreme xeric and cold environments of Patagonia (León et al. 1998). Although aspects of the natural history of *L. halli* have been studied in some detail, for example, geographic distribution at a regional scale (Martin 2003, 2005, 2008, Udrizar Sauthier et al. 2007), little is known of its ecology and adaptations such as caudal fat storage, hibernation, resting postures etc. *L. halli* represents an interesting case study due to its distribution and the physiologically challenging environment it inhabits, which is in contrast to the majority of small (<150 g) New World marsupials.

The main objective of this contribution is to describe how the captive behavior of *Lestodelphys halli* compares to other previously studied marsupials. We follow the approach of Martin and Bateson (1993) by describing the observed behavior mostly in its structure, that is the subjects' posture and movements and leaving the consequences of the behavior for a few particular actions such as tail grasping.

Despite the general lack of information regarding the behavior of *Lestodelphys halli*, a few assumptions and their associated comments have been made about the species' ecology that we set to test with our observations: (1) climbing ability with/without the aid of its tail (2) digging ability and posture (3) feeding preferences for animals instead of vegetable/fruit matter and (4) torpor and/or hibernation capacity. Apart from these issues, we aimed to describe and compare several stereotyped behavior patterns observed in other marsupials: (1) locomotion (2) feeding posture (3) resting/sleeping posture and (4) grooming (Thomas 1929, McManus 1970, Marshall 1977, Birney et al. 1996, González and Claramunt 2000, Martin 2005). Due to the paucity of information about this peculiar marsupial we also describe several traits for which the observed patterns should be

investigated through studies of other marsupials, for example agonistic behavior and nest building.

Materials and methods

Five individuals of *Lestodelphys halli* were captured in three localities of Chubut Province, Argentina: two from Campo Netchovitch, Fofo Cahuel (42°19′42″S; 70°33′40″W), one from Nahuel Pan (42°58′21″S; 71°09′10″W) and two from Pico Salamanca (45°24′32″S; 67°24′58″W). Individuals were kept in glass terraria of 100×50×30 cm space for variable periods of time (one for 2.5 months, two for 3 months and two for 3.5 months) and with two kinds of substrates: wood shavings and a mixture of sand and humus from the species' natural habitat. Animals were kept separate, with small cardboard boxes to use for shelter. Photoperiod of each terrarium resembled the seasons natural conditions, that is for individuals in spring and fall; 14–10 h of day/night; summer 17–7 h of day/night, respectively. Temperature was kept constant at 20–22°C except for torpor experiments (see below). Each terrarium was cleaned and the substrate replaced every 7–10 days. While this was done, animals were kept in tomahawk-type traps of 20×25×45 cm. These traps were placed vertically and climbing behavior was filmed with digital and analog cameras to evaluate the grasping ability of both hands and feet, and to observe if the tail aided grasping or balance. When individuals were placed back in the terraria with clean substrate any digging behavior was recorded. Special attention during this behavior was focused on the position and action of fore and hind limbs in addition to body posture and tail position. Materials (e.g., cotton, thread, grasses) were also provided to observe if the animals used them for nest building or other activities.

Only a few observations have been made on the feeding preferences of *Lestodelphys halli* (Birney et al. 1996) and much speculation remains on whether the species is fully carnivorous, carnivorous/insectivorous (Pearson 1995) or as omnivorous and/or opportunistic as the rest of the small opossums (Astúa de Moraes et al. 2003). Experimental qualitative observations on feeding preferences were conducted using a variety of live prey items, animal and vegetable matter, fruits and other available items which included live rodents (*Abrothrix olivaceus*, *Eligmodontia typus*), lizards (*Liolaemus* spp.), beetles (Insecta, Coleoptera, Tenebrionidae), raw meat (beef, chicken, dove [*Zenaida auriculata*]), chicken eggs (both raw and boiled), dog pellets, pate, jam, salami, apples, grapes, bananas, carrots, tomatoes and crackers. Several items of different origins were made available at any one time while we observed which the animals chose. Feeding posture was documented and compared with other New World marsupial species such as *Monodelphis dimidiata* (González and Claramunt 2000) and *Monodelphis domestica* (Streilen 1982).

The Patagonian opossum lives in an extreme and highly seasonal climate where it goes through fluctuating food supplies and has to cope with high levels of heat loss. A strategy for marsupials living in similar environmental conditions is to enter torpor and/or hibernation (Morton 1980, Geiser 1994), a condition that has not been described, but is thought to occur, in *L. halli* (Martin 2008). We evaluated the occurrence of torpor and/or hibernation through direct observation by reducing the amount of food provided for periods of 2–4 days and by lowering ambient temperature from approximately 20°C to approximately 12°C. In all cases, this procedure was done after individuals were abundantly fed and their tails were incrassated. When animals enter torpor, energy expenditure is reduced to a fraction of that in active animals and food restriction/withdrawal is widely employed for torpor induction in the laboratory (Geiser and Mzilikazi 2011). As this is what appears to happen in their natural habitat, a brief period of food withdrawal along with seasonal or daily temperature fluctuations, as in our study, will be something the animal experiences in the wild and therefore will not cause stress.

Locomotion was studied with the aid of digital and analog cameras, which were used to record the movement of animals both in horizontal substrates and while climbing, following the terminology and procedures of Inuzuka (1996).

All the behavior(s) we report herein were documented opportunistically at irregular intervals both by day and night (9–11 am, 3–6 pm, 9–11 pm, 12.30–2 am and occasionally from 4–6 am) and with the aid of photographic/video cameras. Comparisons were then made with the information presented by McManus (1970), Streilein (1982), González and Claramunt (2000) and literature therein.

Results and discussion

Climbing

Vertical or lateral branch movement has not been recorded for *Lestodelphys halli* and some authors mention that this species is strictly terrestrial and without prehensile tail (Marshall 1977, Voss and Jansa 2003). When introduced into metal cages we were able to observe the ability of *L. halli* to climb using its anterior and posterior limbs and also the tail, which has a prehensile tip strong enough to hold the animal hanging for at least 5–7 s. The opposable hallux allows the animal to rotate without losing grip even when hanging from a cage side. We also recorded the ability to make vertical and diagonal jumps using its hind limbs, with a distance jumped of approximately 30 cm. Similar behavior has been observed in other predominantly terrestrial species such as *Monodelphis dimidiata*, with a capacity to jump a distance that is equal to the animals size, both vertically and horizontally (González and Claramunt 2000).

Digging

This activity was the first behavior observed when animals were introduced in the terraria (for the first time or after cleaning), particularly in sandy soils (Figure 1J). The digging behavior was registered in the same way every time, which was done by extending the body, setting the hind feet firmly into the substrate and opening them up as much as possible

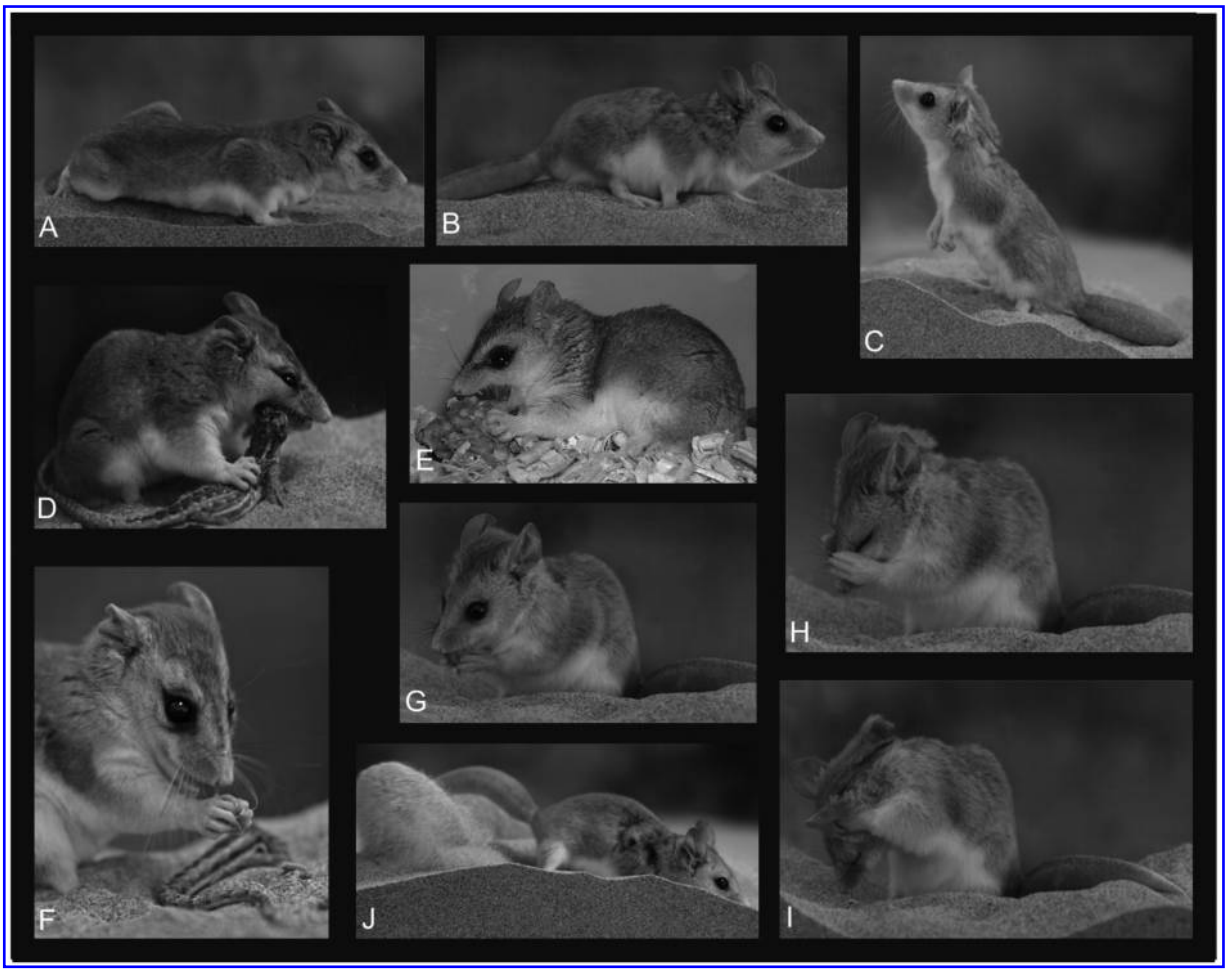

Figure 1 The Patagonian opossum, *Lestodelphys halli*, in different postures and behavior activities. (A–B) Locomotion, note the alternate position of the anterior/posterior limbs on the right side. (C) Alert attitude ''sniffing'' the air. (D) Ingesting prey (a lizard). (E) Holding food with both hands in a non-erect posture. (F) Grooming after feeding. (G–I) Grooming of forelimbs and head. (J) Excavating in fine sediment. Photos: Darío Podestá (except E, photo from senior author).

and forelimbs were used alternately to dig. On each digging bout, sediments were ''thrown'' backwards always passing between the open hind limbs (Figure 1J). In all observations, the tail remained directed backwards, erected or partially curved. When the substrate inside the terraria had wood shavings, *Lestodelphys halli* opened its way through with the muzzle and only on occasion used its fore limbs to dig.

Feeding preferences

When food was provided *Lestodelphys halli* showed a clear preference for items of animal origin, particularly raw meat instead of any vegetable matter. Even though the stomach content of a few animals analyzed had beetles as the most conspicuous element (Martin 2008), individuals preferred raw meat when these items were given together. We did not observe a preference for raw eggs over other items (as proposed by Thomas 1921) but it should be noted that this might be an important resource in natural conditions. Rodent consumption, from approach (to the rodent) to killing was done in a similar manner to that described by Birney et al. (1996), a quick attack over the rodents neck that ended up with its almost immediate death, cleaning/washing before feeding and consumption of the head first complete with teeth. The rest of the body including guts was consumed in different moments separated by resting periods of 3–5 h. Two different patterns were observed when consuming the head of the rodents, one that started from the muzzle and including teeth and another where the incisors were used to ''peel off'' the skin around the upper-back skull exposing the braincase, which was then opened with the use of molars and premolars to reach the brain. After the brain was consumed the animal continued in a similar pattern as described above (i.e., consuming the head completely, then the rest of the body). This second pattern and the complete consumption of rodents except hind feet and tail was also observed in a specimen of *Lutreolina crassicaudata* (F. Goin, pers. comm.). It is interesting to note that in all cases the rodents consumed had a weight of near half that of the individuals of *L. halli* studied, a prey-predator ratio of 0.45–0.52.

Feeding animals daily increased their tail thickness from thin and dorso-ventrally flattened to the aspect of a carrot,

reaching a diameter of 25 mm in some individuals. Caudal fat storage is an adaptation present in some small mammals that live in extreme environments or those that live in places where food availability fluctuates drastically (Morton 1980). This adaptation is common in many small dasyurid marsupials that inhabit desert environments in central Australia and is present in some rodents, insectivores and lemurs (Morton 1980). It is also present in some new world marsupials such as *Dromiciops gliroides* and *Rhyncholestes raphanurus,* endemic to the temperate rainforests of southern Argentina and Chile and in species of the genus *Thylamys* (Morton 1980, Martin 2008). Even though information on the total amount of calories stored in the tail and the speed at which it is consumed or is metabolized remains unknown for Patagonian marsupials, we observed that tail thickness varied rapidly in *Lestodelphys halli*, indicating a high resource availability for consumption and a fast (in a matter of days) deposition. Our observations did not allow us to assert the duration of these reserves but they appear to agree at least preliminarily with what Hume (1999) mentioned for small dasyurids i.e., that caudal fat is mainly composed of short term resources.

Torpor and hibernation

Despite the fact that we did not have the appropriate equipment to satisfactorily measure this process, animals in captivity allowed us to observe the following: (1) when eventually deprived from food, *Lestodelphys halli* enters a torpid stage from which it spontaneously and actively awakes (2) when constantly (i.e., 2–4 days) deprived from food and with a decrease in ambient temperature, it enters a prolonged state of torpor from which it slowly awakes (3) the duration of daily torpor bouts lasted between 2–7 h and prolonged torpor lasted at least 4 days. We did not record any torpor or hibernation activity under normal food intake and conditions of ambient temperature. These data are consistent with measurements for torpor and hibernation reported for other marsupials (Geiser 2003, Bozinovic et al. 2004, 2005).

Locomotion and exploration

The locomotion of *Lestodelphys halli* is mostly plantigrade and symmetrical, with a slow and paced movement in the horizontal plane. The movement pattern is primarily diagonal (sensu Inuzuka 1996), in which limbs on each side of the body move forward alternately and not together (Figure 1A, B). This type of locomotion has been documented for small didelphids such as *Monodelphis domestica* (Pridmore 1992, Lammers and Biknevicius 2004), both on arboreal and ground substrates (Hildebrand 1995, Lemelin et al. 2003, Vieira 2006).

The exploratory behavior of *Lestodelphys halli* is similar to that observed in *Didelphis virginiana* (McManus 1970), *Didelphis albiventris, Monodelphis domestica* (Streilein 1982) and *Monodelphis dimidiata* (González and Claramunt 2000), in which the initial movements are slow, the head is kept erected at shoulder level and the muzzle is higher ''sniffing'' the air (Figure 1C). During exploration the tail is kept erect and directed backwards, individuals move slowly with short intervals to ''sniff'' and occasionally move backwards, ears are erect and moved to the sides of the head, particularly if any loud sound is heard.

Other observations

Feeding postures During feeding, *Lestodelphys halli* holds the food items with one or both hands (Figure 1D, E) but did not place its body in an erect posture, keeping the body horizontal to the substrate. Occasionally, the weight of its body was in its hind limbs and the vertebral column was curved and the forelimbs raised in what can be considered a semi-erect posture (Figure 1E). Although *L. halli* has the ability to manipulate objects as other marsupials have, forelimbs were only used to strongly hold food items tight, animals directed the mouth and muzzle to the food items and not the other way around. This contrasts with *Monodelphis* spp. and other American marsupials (e.g., *Marmosa robinsoni, Thylamys karimii, Thylamys fenestrae*), in which individuals adopt a semi-erect posture and manipulate food taking it to their mouths (Bruch 1917, Streilein 1982).

Resting/sleeping postures In the ''typical'' resting behavior documented for *Didelphis* spp. and *Monodelphis domestica* by Streilein (1982) and for *Thylamys fenestrae* by Bruch (1917), animals lie on their sides with their fore and hind limbs extending more or less from the body depending on environmental conditions, that is closer to the body when it is colder and extended when it is warmer. When thermal conditions become adverse (e.g., low temperatures or rain) they adopt a curled position in which the head is placed between the forelimbs and close to the body. On the contrary, *Lestodelphys halli* is curled antero-vertically when resting, with its head close to the venter and its tail surrounding the body on either side. This posture was also observed in resting individuals of *Dromiciops gliroides* (Martin 2008), even when thermal conditions were not adverse or extreme (temperatures remained at approximately 20°C).

Grooming Previous works give accounts of more or less constant grooming in various species of American marsupials, some of them small sized and of similar habits than *Lestodelphys halli* as *Monodelphis dimidiata*, *Monodelphis domestica* and *Thylamys* spp. (Bruch 1917, Streilein 1982, González and Claramunt 2000). However, no work has even mentioned the grooming activities of *L. halli.* The species was not observed in constant grooming activity, this behavior was mostly registered before and after feeding (Figure 1F). On occasion, grooming was observed when the species came out of its refuge and previous to its ''night'' activities. The grooming followed the patterns described by González and Claramunt (2000) for *M. dimidiata,* the exception of the ''washing of the head'', in which *L. halli* was found to lick its hands and later pass them over its head instead of grabbing the tongue between them. On occasions *L. halli* was observed licking the dorsal surface and ventral surfaces of the hand, sticking its tongue between its fingers before ''combing'' its mystacial and superciliary or supraorbitarty

vibrissae (sensu Brown 1971). To clean the back and borders of ears, hands were licked as described above and ears were ''combed'' from back to front or from the outer edge towards the center of the head (Figure 1G, H, I). Posterior limbs were generally used for scratching instead of washing.

Intraspecific agonistic behavior In the terraria, animals presented both diurnal and nocturnal activities but peaks of daily activities were verified during the night. Immediately after sunset, we observed (and heard depending on the situation) activities in the terraria which included exploration, climbing, jumping and nest building (see below). These activities lasted for 2–3 h, ceased for another 2–4 h and started again before sunrise. In all individuals activities were therefore concentrated twice during the night, with a period of little or no activity between these peaks. During the day, animals would exit their nests to feed, drink water and display grooming or cleaning activities.

When two different individuals from different sexes were introduced in the same terraria no hostile behavior was observed between them and both of them slept together side by side. No hostile behavior between co-specifics were observed at any time. It is unknown if very old adults or animals in reproductive stages would react in the same way. Different levels of intra-sexual hostility have been observed and described for some small opossums such as *Monodelphis dimidiata* (González and Claramunt 2000) and *Thylamys pallidior* (D. Udrizar Sauthier, personal observation.).

When animals feel threatened a characteristic and very high pitched sound (similar to a ''cric...cric...cric'') is made, which is often accompanied by the constant opening of the mouth, a bipedal posture and with up-to-down movements of the hands. Apart from this, it is frequent to hear a snap which is done with its teeth (mainly molars) in diverse situations of threat, consistent with what has been described for dasyurids (e.g., *Sarcophilus harrisii*, Eisenberg et al. 1975).

From an alert or defensive position, individuals can adopt an aggressive behavior only when contact with a different subject is imminent, which is manifested by a bite in a similar way as described for *Thylamys fenestrae* by Bruch (1917). In his observations on the captive behavior of *T. fenestrae* Bruch (1917) described that when trying to pet his captive individual it would retire to its nest, wrinkle the skin on its forehead, make screeching sounds and try to bite off his fingers (''cuando intentaba tocarla, se retiraba a su nido, frunció la frente, soltando unos chillidos..., y trataba de morderme los dedos'').

Nest and gallery building in a marsupial? The construction of a nest with grasses in a spiral arrangement opened at the top was observed. Both male and female individuals constructed nests, which were built overnight when animals were placed in recently cleaned terraria. Nests were made with different kinds of materials that we provided including threads of different types, wool, grasses and cotton, the latter being the item most used by all individuals. In addition, subterranean galleries were made by three of the animals, which were supported interiorly by grasses. These galleries were of a diameter similar to the animal's body, with a small chamber in the end, in which animals spent most of the day. From this, we can infer that in its natural environment *Lestodelphys halli* builds its own poorly elaborated galleries under clumps of grass, shrubs or rocks where vegetable matter is used structurally and to build a nest. It is also possible that animals in the wild could recondition old rodent galleries of several species that are common throughout its distribution range (e.g., *Reithrodon auritus*, *Ctenomys* spp., *Microcavia australis*).

This work represents the first continuous observations on the captive behavior of various individuals of *Lestodelphys halli* and should be complemented with further studies. Although *L. halli* is a species that inhabits clearly distinct habitats from the rest of the American marsupials (with the exception of some species of *Thylamys* [Martin 2008]) and has some behavior patterns that are different than other small didelphids, its behavior corresponds to certain stereotypes that are shared with other New World marsupials (Bruch 1917, Streilein 1982, González and Claramunt 2000). Future work, apart from testing our findings, should concentrate on aspects still unknown of this small marsupial, especially about its reproduction, physiology and habitat use.

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