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ORIGINAL PAPER

# Morphometrics, pelage variations and reproduction of the little studied Saharan striped polecat (*Poecilictis libyca*)

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**Abstract**
Understanding a species' biology and natural history is essential for uncovering its survival adaptations and guiding conservation efforts. However, research on the morphometrics, ontogeny, reproduction, and coat pattern variations of the Saharan striped polecat (*Poecilictis libyca*) remains limited. To address this gap, we studied 35 individuals from the Metbasta population in Tunisia, where habitat disturbance is characterized by tillage effects and grazing. We found low sexual dimorphism with higher values for males in 37.5% of measured traits ($N=24$), with the most pronounced differences in upper and lower canine lengths, body weight, and front foot size. Additionally, we recorded a slight degree of sexual dimorphism in the neck circumference and the distances between both upper and lower canines. The overall sex ratio was balanced, suggesting no effect of habitat disturbance. Furthermore, our study re-described this species, notably by searching social media images from North Africa for a comprehensive understanding. The Saharan striped polecat exhibits variation in pelage markings and hair length, with a typical face mask and occasional variation in facial patterns. Moreover, reproductive timing varied geographically, with parturition in Tunisia occurring from March to May, later than in Egypt and West Africa. Females may attain sexual maturity within the first year and can give birth to litters ranging from 2 to 5 cubs, occasionally reaching up to 6. We suggest further studies be conducted on Saharan striped polecat's diet and on other populations situated in natural habitats to better understand the factors influencing sexual dimorphism in this species.

**Keywords** *Poecilictis libyca* · Sexual dimorphism · Disturbed habitat · Sex ratio · Morphological description · Parturition

## Introduction

The Mustelidae family includes a minimum of 63 species, such as weasels, polecats, minks, otters, martens, badgers, and their relatives (Do Linh San 2022a, b). This family is distributed across all continents except Antarctica and Australasia (though they have been introduced into New Zealand) (Wolsan 2013). They occupy a diverse range of habitats, from tropical rainforests to Arctic tundra, as well as environments spanning the Sahara, inland waterways, and coastal areas (Wolsan 2013). While species like the European badger (*Meles meles*), honey badger (*Mellivora capensis*), Eurasian otter (*Lutra lutra*), and least weasel (*Mustela nivalis*) have been well or even extensively studied (e.g., Do Linh San 2006; Vanderhaar and Ten Hwang 2003; Sheffield and King 1994; Hung and Law 2016), others remain largely overlooked. This is especially true of African mustelids, particularly those in the Ictonychinae subfamily, which includes four species. Among these, the zorilla or striped polecat (*Ictonyx striatus*), is the most widespread, inhabiting the southern half of Africa and extending into sub-Saharan regions (Stuart et al. 2015). In North Africa, the zorilla is replaced by the Saharan striped polecat (Ahmim and Do Linh San 2015), often considered a congeneric

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species (*Ictonyx libycus*). These two species can coexist sympatrically across the Sahel belt (Stuart and Stuart, pers. comm.). However, recent molecular studies revealed that they diverged over 4.8–4.5 million years ago, supporting the reclassification of the Saharan striped polecat as *Poecilictis libyca* (Sato et al. 2012; Hayder et al. submitted a).

Although the Saharan striped polecat is widely distributed in North Africa, from Morocco and Senegal in the west to Egypt and Eritrea in the east (Ahmim and Do Linh San 2015), this desert-dwelling species remains poorly studied (Hayder et al. 2025). A few authors have provided descriptions of the species and noted differences in size between populations (Thomas and Hinton 1920; Osborn and Helmy 1980; Niethammer 1987), but their studies often involved a small number of specimens. In contrast, its counterpart, *Ictonyx striatus*, has been better described and exhibits phenotypic diversity in facial patterns, pelage coloration, and markings (Kingdon 1977). Like *I. striatus*, *P. libyca* has a generally elongated body, but it is still unclear whether this species shows intraspecific variation in pelage coloration, which remains a topic for further investigation.

Law et al. (2019) observed an evolutionary trend towards elongated bodies in the Mustelidae family. Some authors (e.g., Baskin 1998; Koepfli et al. 2008) propose that the small and elongated body shape of mustelids enhances their ability to navigate and exploit burrows and confined spaces for prey capture (Brown et al. 1972; Gliwicz 1988; King 1989). Furthermore, mammalian response to competitive pressures often involves morphological diversification, particularly in body size, cranial, and dental characteristics (Dayan et al. 1989; Brown 1995; McDonald 2002). Such diversification may also lead to morphometric differences between sexes, potentially reducing intraspecific competition for food. This phenomenon has been observed in other mustelids (Brown and Lasiewski 1972; Dayan et al. 1989) and warrants further investigation into the morphometric measurements of the Saharan striped polecat.

Sexual size dimorphism is common in many mammals, with significant variations observed in body mass and length in the Mustelidae (Sheng 1987; Abramov and Puzachenko 2009; Suzuki et al. 2013). Studies on various animal taxa have shown that the degree of sexual dimorphism in body mass may be influenced by food availability during growth, with body size dimorphism often exceeding that of teeth and jaws (Sumner et al. 1999; Hayder and Nasri-Ammar 2020). This phenomenon is evident in mustelids in general (King and Powell 2007; Melero et al. 2012) and may account for the absence or low levels of dimorphism in populations situated in disturbed habitats. Based on the suggestion by Ralls and Harvey (1985), low food availability can negatively impact male growth, preventing them from reaching their full size. In disturbed habitats (e.g., tillage and grazing), where prey abundance is generally reduced (Sterner et al. 2003; Müller et al. 2022), this limited food supply may further hinder growth. In Saharan striped polecats, although comparisons between sexes were made by Thomas and Hinton (1920), Flower (1932), Osborn and Helmy (1980), and Niethammer (1987), the sample sizes were very small, resulting in limited data on morphological traits and insufficient evidence to assess sexual dimorphism. Furthermore, data on the ontogeny and reproduction of the Saharan striped polecat are almost entirely lacking, presenting a major gap in our understanding of this species' biology (Stuart and Stuart 2013).

In this study, we examined *P. libyca* in a habitat characterized by significant disturbance, including fragmented landscapes and altered environmental conditions. We explore three key questions: (1) Will sexual dimorphism be influenced by the disturbed habitats? (2) Will the parturition period differ from that recorded in West Africa, and could litter size be larger than what has been observed in other countries? (3) Will there be variation in facial patterns, similar to what has been observed in the zorilla, along with differences in pelage coloration, markings, and hair length?

## Materials and methods

### Study area

Our study was conducted in an agricultural habitat (Metbasta site) situated in the center of Tunisia in an upper arid climate zone. The average annual temperatures range from 6 to 17 °C in winter and 25–42 °C in summer. Roughly, the average annual rainfall is 26 mm (ranging from 6.7 to 49.2 mm) and the driest months are July and August (Hayder et al. 2025). The study area is significantly impacted by human activities, including agricultural practices such as tillage, grazing, and poaching, all of which contribute to habitat destruction, direct killing and restrict the availability of suitable habitats for Saharan striped polecat.

## Methods

We captured 35 unique Saharan striped polecats using hand netting at night from November 2019 to December 2021 (Hayder et al. submitted b). Polecats were chemically immobilized by intramuscular injection of a mixture of ketamine hydrochloride (Virbac, France) and medetomidine (Orion Pharma, France) (Hayder et al. submitted b). During the sedation of the animals, we collected information on body mass, sex, and selected morphometric variables (Table 1), guided by studies conducted on other musteloids (Abramov

**Table 1** Descriptive statistics (mean ± SD) for 24 morphometric measurements (mass in g and the remaining variables in cm) and sexual dimorphism index (SDi (%)) of male and female saharan striped Polecat captured in Metbasta, Kairouan, center of Tunisia, during 2019–2021. Statistically significant intersexual differences are indicated in bold

| Variables | Males ($n=19$) | Females ($n=16$) | Wilcoxon-test | SDi (%) |
|---|---|---|---|---|
| Body length[a] | 26.33 ± 1.44 (19) | 25.65 ± 1.34 (16) | $W=268$; $P=0.124$ | 2.65 |
| Tail length | 14.53 ± 1.1 (19) | 14.39 ± 1.2 (15) | $W=211$; $P=0.5021$ | 0.97 |
| Tail length with hair tip | 19.03 ± 1.6 (19) | 18.46 ± 1.37 (16) | $W=249.5$; $P=0.2913$ | 3.09 |
| Body mass | 312 ± 49 (19) | 265 ± 33 (16) | $W=332.5$; **$P=0.001228$** | 17.55 |
| Neck circumference | 10.82 ± 0.73 (19) | 10.11 ± 0.7 (15) | $W=295.5$; **$P=0.001544$** | 7.02 |
| Height of left ear | 1.9 ± 0.2 (18) | 1.9 ± 0.18 (16) | $W=186$; $P=0.7199$ | 0.00 |
| Max. pad width[b] | 1.47 ± 0.06 (19) | 1.51 ± 0.23 (16) | $W=246.5$; $P=0.311$ | -2.65 |
| Max. pad length[b] | 1.54 ± 0.14 (19) | 1.5 ± 0.15 (16) | $W=237$; $P=0.3046$ | 2.67 |
| Front foot length[b] | 2.42 ± 0.17 (18) | 2.18 ± 0.2 (16) | $W=324.5$; **$P=0.0006549$** | 11.01 |
| Max. length claw[b] | 0.86 ± 0.14 (17) | 0.79 ± 0.08 (16) | $W=239.5$; $P=0.1574$ | 8.86 |
| Max. pad width[c] | 1.28 ± 0.15 (18) | 1.21 ± 0.08 (16) | $W=246.5$; $P=0.1889$ | 5.79 |
| Max. pad length[c] | 1.53 ± 0.16 (18) | 1.53 ± 0.16 (16) | $W=209.5$; $P=0.7918$ | 0.00 |
| Hindfoot length[c] | 3.12 ± 0.25 (19) | 3.08 ± 0.26 (16) | $W=245$; $P=0.3466$ | 1.30 |
| Max. claw length[c] | 0.51 ± 0.11 (18) | 0.49 ± 0.08 (16) | $W=220.5$; $P=0.5618$ | 4.08 |
| Min. distance between lower canines | 0.69 ± 0.17 (17) | 0.68 ± 0.04 (12) | $W=199$; $P=$**0.04937** | 1.47 |
| Max. distance between lower canines | 0.81 ± 0.09 (16) | 0.77 ± 0.05 (13) | $W=235.5$; **$P=0.0029$** | 5.19 |
| Lower canine length | 0.49 ± 0.02 (7) | 0.4 ± 0.06 (8) | $W=70$; **$P=0.005479$** | 22.50 |
| Max. width lower canine | 0.27 ± 0.04 (16) | 0.25 ± 0.06 (12) | $W=162$; $P=0.2711$ | 8.00 |
| Min. width lower canine | 0.16 ± 0.21 (16) | 0.17 ± 0.25 (11) | $W=138.5$; $P=0.3782$ | -5.88 |
| Min. distance between upper canines | 1.07 ± 0.11 (17) | 0.99 ± 0.03 (13) | $W=240$; **$P=0.0005245$** | 8.08 |
| Max. distance between upper canines | 0.93 ± 0.07 (16) | 0.9 ± 0.04 (13) | $W=208$; **$P=0.03693$** | 3.33 |
| Upper canine length | 0.56 ± 0.06 (9) | 0.47 ± 0.04 (7) | $W=97.5$; **$P=0.001584$** | 19.15 |
| Max. width upper canine | 0.28 ± 0.03 (16) | 0.28 ± 0.03 (12) | $W=156$; $P=0.3084$ | 0.00 |
| Min. width upper canine | 0.2 ± 0.23 (16) | 0.15 ± 0.12 (10) | $W=111$; $P=0.7491$ | 33.33 |

[a]Body length refers to head-and-body length

[b]Mesurements of left front foot

[c]Mesurements of left hind foot

et al. 2016; Luengos Vidal et al. 2016). Body mass was measured to the nearest 2 g using a 1 kg Pesola spring balance (Pesola AG, Baar, Switzerland), tared to zero with an empty drawstring cotton bag. Body length, tail length (with and without hair tip), and neck circumference were measured to the nearest 1 mm with a 1 m tape measure, and all other dimensions with a 15 cm vernier caliper (± 0.1 mm).

The individual variation in facial patterns, pelage diversity, and hair length was examined in 165 individuals: 35 from the Metbasta area, 24 collected by FH (pers. obs. 2018) from various regions in Tunisia during a one-year survey (Hayder et al. 2025), 37 sourced from Google images (Tunisia: 2, Algeria: 3, Libya: 1, Moroco: 7, Western Sahara: 1, Niger: 1, Nigeria: 1, various zoos in Europe: 8, and unknown locations: 13), 27 from Youtube (Tunisia: 2, Algeria: 17, Libya: 1, Moroco: 3, Mauritania: 1, Egypt: 3), and 42 obtained from Facebook (Tunisia: 24, Algeria: 12, Libya: 4, Moroco: 2). Additionally, data on reproduction dates and litter size per female were gathered through a questionnaire survey of 12 poachers conducted during a 2018 survey across Tunisia (Hayder et al. 2025) and supplemented by FH's direct observations. We further enhanced FH's observations with published data to provide a more comprehensive understanding of the species' reproductive biology.

## Data analysis

We utilized the non-parametric Wilcoxon test ($\alpha=0.05$) to compare the morphometric measurements and body masses between male and female Saharan striped polecats. Moreover, to further evaluate sexual dimorphism, a sexual dimorphism index (SDi) was calculated for each variable, expressed as 100 × ([mean males/mean females] − 1) (Rodríguez-Refojos and Zuberogoitia 2009; Luengos Vidal et al. 2016).

The $\chi^2$ goodness-of-fit test was employed to scrutinize the sex ratio within the population and investigate whether it deviates from the null expectation of a 1:1 ratio. Simple linear regression was applied to ascertain the relationship between body length and mass, as well as body length and tail length, followed by the Pearson test to examine

correlations. These analyses were conducted using R software, version 3.5.2 (R Core Team 2020).

## Results

### Morphometric measurements and morphological description

Only 37.5% of morphometric measurements exhibited significant size skewness between sexes (Table 1). Notably, lower canine length, upper canine length, and body mass demonstrated the highest values of sexual dimorphism in favour of males (22.5%, 19.14% and 17.55%, respectively; Table 1). In terms of body length, *P. libyca* lacked sexual size dimorphism, although males were heavier than females. Males had a body mass of 270–390 g and a body length of 23–29 cm, while females weighed from 240 to 300 g and measured 23.5–29 cm. The tail is long, measuring 14.47 ± 1.13 cm, which represents slightly more than half of the total body length (55.63%).

The head is black with short ears measuring 1.90 ± 0.19 cm. Each foot has five digits, and the front digits have long, curved, and strong claws with beveled tips measuring approximately 0.83 ± 0.12 cm, up to 1.1 mm along the curve (Fig. 1a). The hind feet claws are on average 0.50 ± 0.10 cm and less curved (Fig. 1c).

### Relationship between body length and body mass/tail length

The relationship between body length (BL) and body mass (BM), as well as between body length (BL) and tail length (TL), is depicted by two linear regression lines (Fig. 2). Pearson tests confirmed the positive correlations observed between body length and body mass ($R^2 = 0.4892359$, $p < 0.00117$), and body length and tail length ($R^2 = 0.3896338$, $p < 0.01421$).

### Facial mask and coat pattern variations

The Saharan striped polecat has a small, elongated body with a coat that is either black-and-white-striped and shaggy (Fig. 4b to g) or, more rarely, short-haired (Fig. 4a), along with short limbs. The head is black with short ears (white on the tips in a few individuals), a short muzzle, and a distinctive white band encircling the head, passing between the eyes and ears, creating a standard facial pattern (Fig. 3a). Facial pattern diversity is rare, with only one instance (among 165 individuals) of differing facial pattern observed in one photograph obtained from a poacher in Douz, Tunisia (Fig. 3b). Additionally, another cub found in Oued Souf, Algeria, nearly lacked a facial mask, had a pink nose (Fig. 3c) and displayed a distinct pelage coloration (see below).

The back and flanks are mostly buff to white (Fig. 4a and g). A black longitudinal stripe begins at the skull, then subdivides into three from the end of the neck, with the middle branch further dividing into two additional stripes, forming an oval shape in the middle of the back, all of which merge on the rump (Fig. 4a). Variations can occur, and the pelage may appear spotted, while white long hairs may conceal stripes in the case of the shaggy pelage (Fig. 4d and f). The black stripes are produced by relatively short black underhairs, while the white stripes are formed by long, all-white guard hairs, though the stripes are clear in the short pelage (Fig. 4a), with variations in the striped coat. The throat, belly, and legs are black to brownish (Fig. 4h), with haired palms and soles (Fig. 1b and c). The tail is long, bushy, and black and white, with long, bicolored guard hairs, while the tip and underside of the tail are darker (Fig. 4h). The female has two pairs of inguinal nipples (Fig. 5b), contrary to what was reported—one abdominal and one inguinal pair—by Stuart and Stuart (2013). Both sexes possess anal glands that produce a noxious fluid (Fig. 5a, b). Additionally, we recorded a case of a cub with a predominantly white coat pattern and a light black to brownish coloration (Fig. 4i).




**Fig. 1** **a**, **b** Front foot of *Poecilictis libyca*. **c** Hind foot of *Poecilictis libyca*

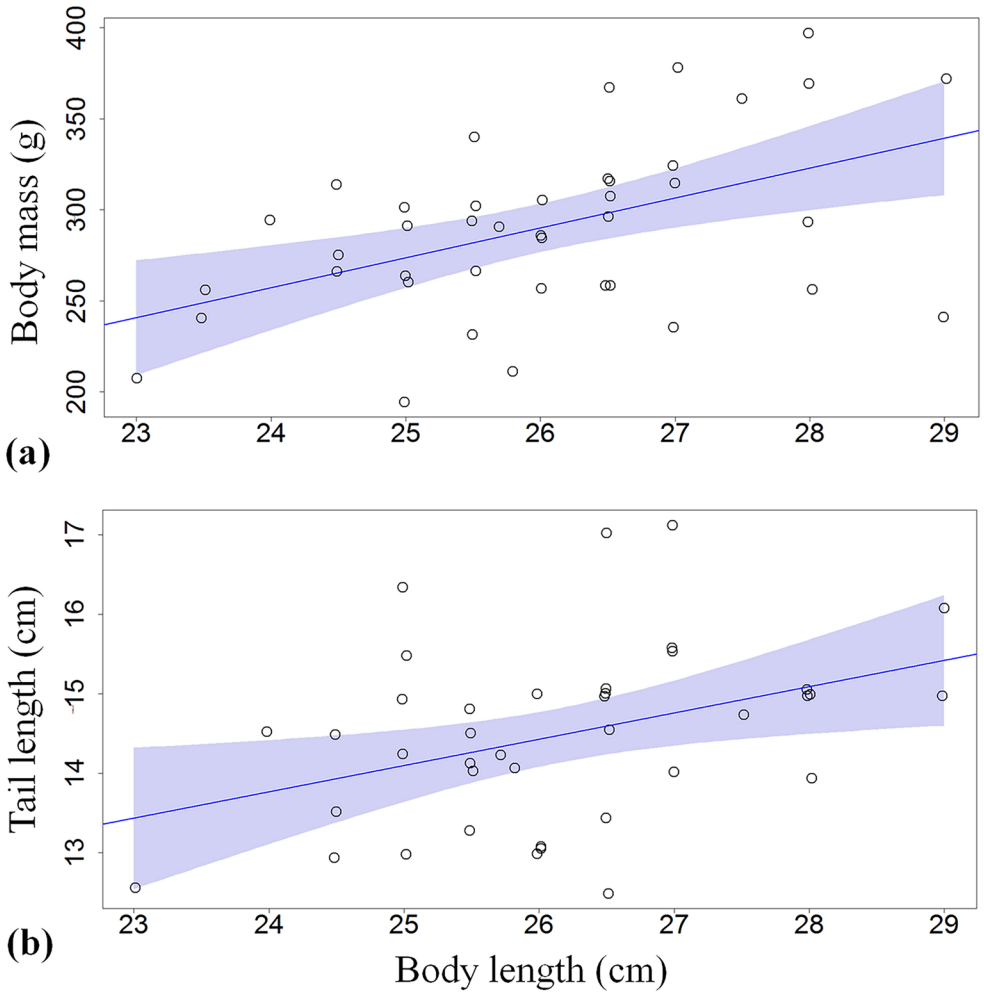



**Fig. 2** **a** Relation between body length and body mass of *Poecilictis libyca*: BM = 16.445 BL – 137.532. **b** Relation between body length and tail length: TL = 5.8110 + 0.3313 BL




**Fig. 3** **a** Ordinary face mask of *Poecilictis libyca*. **b**, **c** Variations in facial patterns. See text for details

## Sex ratio

Throughout the fieldwork period, a total of 19 males and 16 females was captured. The overall sex ratio of the Metbasta population (1.19) slightly favoured males. However, a $\chi^2$ test indicated no statistically significant difference from an even sex ratio ($\chi^2 = 0.025714$; df = 1; $p = 0.6121$).

## Reproduction and ontogeny

The reproductive behaviour of *P. libyca* remains poorly understood. In Tunisia, we made five observations. Two were made in the Sahara, where a female with a cub aged about 4–5 weeks was observed in mid-June 2018 (Fig. 6b), and another female was seen on 24 May 2018 with 6 cubs, likely born in early April. The remaining three observations were in Metbasta, with one female seen with 3 cubs on 20 March 2020 (Fig. 6a), another with 4 cubs on 30 May 2021,




**Fig. 4** Variation in pelage coloration, markings and hair length (photos ©: photo **f** was taken by the Tunisian General Directorate of Forestry in the South of Tunisia in 2016 and published by El Farhati and Nouira (2022)); photo **i** was taken by a person from El Oued, Algeria, who prefers to remain anonymous)

and the third with 2 cubs on 3 September 2021; all three females gave birth in March, suggesting that the peak parturition period occurs in mid-March. The duration of copulation is still unknown. *Poecilictis libyca* likely has a gestation period of approximately 37 days or slightly less (Petter 1959). Questionnaire surveys with poachers confirmed that parturition occurs from March to May, with litter sizes ranging between 2 and 5 cubs, although up to 6 cubs have been observed (FH, pers. obs. 2018).

Before giving birth, females line the den with grass, which they bite or shred into finer, softer pieces to create a comfortable bedding, and may use fabrics or small pieces

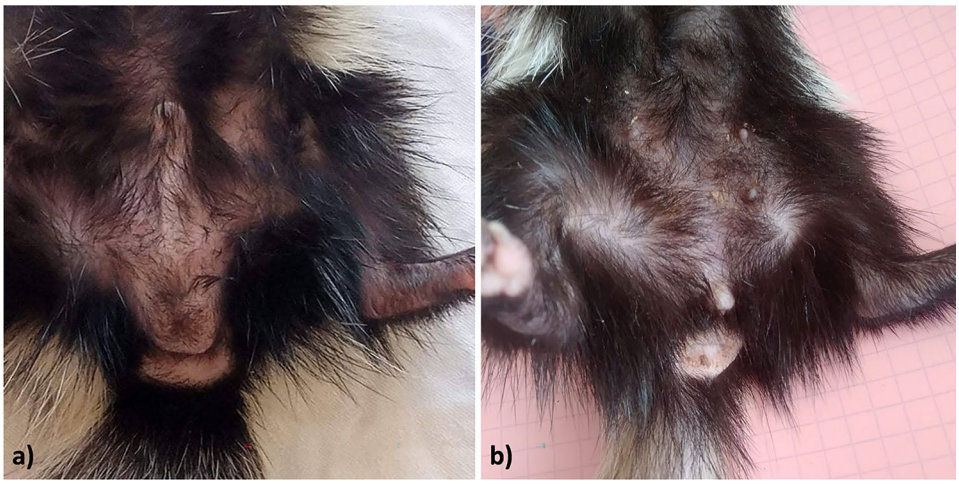



**Fig. 5** **a** Male genital organs of *Poecilictis libyca*. **b** Female genital organ and two pairs of inguinal nipples

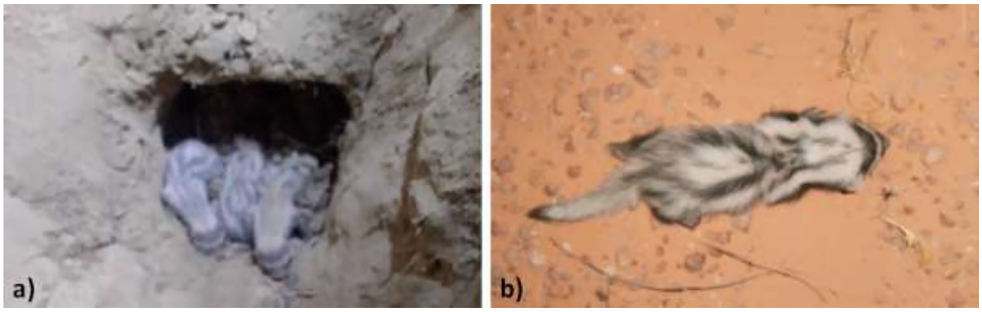



**Fig. 6** **a** Three cubs of *Poecilictis libyca* aged 2–3 weeks at Metbasta, Tunisia. **b** Cub aged 4–5 weeks at Zoggaba

of clothing (FH, pers. obs. 2020). Newborns are born blind and with very short hair (birth mass: 5 g) (Sitek 1996). Dark patterning develops at around 3 weeks, and the eyes open at approximately 3.5 weeks. Captive animals begin consuming solid food after 5 weeks, weigh around 250 g at 2 months, and are separated from their mother at 3 months (Sitek 1996). In the wild, young born in March leave their mother in September (FH, pers. obs. 2020–2022). Females reach sexual maturity in their first year (FH, pers. obs. 2020). Longevity in captivity can reach up to 6 years (Rosevear 1974; Haltenorth and Diller 1980; Weigl 2005).

## Discussion

Variations in the degree of sexual size dimorphism have been observed across the geographic distribution of animals, as noted for example for another small carnivoran species, the Siberian weasel (*Mustela sibirica*) (Sheng 1987; Abramov and Puzachenko 2009; Suzuki et al. 2013). Abramov and Puzachenko (2009) indeed noted a higher degree of sexual size dimorphism in the subspecies *M. s. manchurica* of the Far East compared to *M. s. sibirica* of western and central Siberia. Similarly, Sheng (1987) observed that populations in China's river plains near the Yangtze and Huai rivers tend to be larger and exhibit more sexual size dimorphism than conspecifics in Changbai Mountains forest habitats.

The Saharan striped polecat lacks pronounced sexual size dimorphism, although males are slightly heavier than females. This small mass difference makes it difficult to distinguish between the sexes by visual inspection. This absence of sexual dimorphism differs from typical patterns observed in mustelids (Carnivora, Mustelidae). According to Holmes and Powell (1994) and King and Powell (2007), three primary theories attempt to explain sexual dimorphism in Mustelidae: bioenergetics, sexual selection, and prey availability. Discriminant analyses based on our measurements reveal significant differences between the sexes, particularly in measurements related to canine size and neck circumference. These differences play a crucial role in morphological distinctions between males and females. These measurements, according to Radinsky (1981a, b), indicate stronger neck and jaw muscles linked to biting, with larger canines likely reflecting trophic selection (Gittleman and Van Valkenburgh 1997; Abramov et al. 2009).

Variations in prey type related to sex were observed among various mustelid species, such as the least weasel, Siberian weasel, stoat (*Mustela erminea*), and American mink (*Neogale vison*) (Erlinge 1975, 1979; Birks and Dunstone 1985; Abramov and Puzachenko 2009; Suzuki et al. 2013). Body mass dimorphism, biased towards males, may indicate their preference for larger prey species (Ireland 1990; Yamaguchi and Macdonald 2003; Abramov and Puzachenko 2009). In addition, energy expenditure and

sexual selection may contribute to body mass dimorphism (Sandell 1989; Thom et al. 2004).

Reig and Ruprecht (1989) and Rozhnov and Abramov (2006) suggest that the low sexual dimorphism observed in skull measurements may result from shared diets between males and females or limited food availability. In our study, the arid environment of the disturbed sites, affected by tillage and grazing, likely reduces the abundance of small prey (Sterner et al. 2003; Müller et al. 2022). Therefore, the overall minimal dimorphism observed across the 24 morphometric measurements in the Saharan striped polecat may be partially attributed to restricted food resources, although subtle functional differences between the sexes suggest that trophic specialization cannot be entirely ruled out.

Saharan striped polecats are known to dig burrows, which are used as resting sites during the day (Hayder et al. in prep. a). In a recent study, individuals were predicted to use between 30 and 35 burrows per season, which is a significant number (Hayder et al. in prep. a). This underscores the importance of forelimb morphology for survival, particularly in species with digging behaviour. Several studies (Lin et al. 2017; Siciliano-Martina et al. 2024) have demonstrated a relationship between forelimb morphology and soil substrate. In our study, we observed distinct sexual dimorphism, with males having larger front feet than females. This may explain the findings of Hayder et al. (in prep. b), where larger males used burrows in compact clay soil more frequently than predicted, while smaller males and females used them less often than predicted.

Our measurements revealed that the tail represents almost half of the total body length, with a positive correlation between body length and tail length. Mincer and Russo (2020) demonstrated that tail-length selection is associated with behaviours and environmental factors, with the tail acting as a blanket to provide an additional layer of insulation for thermoregulation (Harrison 1958; Muchlinski et al. 1979). Law et al. (2019) demonstrated that body elongation is prominent in weasels and polecats. Our data show a moderate correlation between body length and body mass in the Saharan striped polecat. This body shape, with increased surface area relative to body volume, results in higher thermal conductance, leading to faster heat loss (Brown et al. 1972; Iversen 1972; Williams 1983), which can be particularly problematic in cold environments. Although the tail may help reduce heat loss to some extent, its considerable length—especially compared to the much shorter tails of mustelids in colder climates (e.g., stoat (King 1983); least weasel (Sheffield and King 1994)—suggests that thermoregulation is unlikely its primary function. Instead, the tail may serve a more important defensive role, acting as a visual signal that enhances the effectiveness of the species' warning coloration and potent anal gland secretions in deterring predators (Sitek 1996).

Based on our observations and questionnaire surveys, we estimate that the parturition period for this species in Tunisia spans from March to May. This period aligns with observations in West Africa but occurs earlier there, from January to March (Rosevear 1974). Similarly, in Egypt, parturition has been recorded from January to March (Flower 1932). Notably, a case in Egypt also documented a female with advanced embryos in September (Hoogstraal 1958). These variations in reproductive timing may stem from differences in latitude (which affects day length and the onset of seasonal photoperiod changes), elevation, temperature, and trophic level (Brown et al. 2016; McNutt et al. 2019; Chmura et al. 2019). In some instances, litter loss may cause females to return to oestrus later in the year (Rowe-Rowe 1978). Furthermore, within the same population, some females give birth earlier or later than the main parturition period (Gibbs and Breisch 2001; Kharouba et al. 2014; Hayder 2016). Our study also revealed litter sizes ranging from 2 to 6 young, with one female observed reaching sexual maturity within the first year. However, it remains unclear whether this is typical for the population as a whole. This litter size is notably higher than previously observed by Petter (1959), Rosevear (1974), Dragesco-Joffé (1993), and Sitek (1996), who reported litter sizes typically ranging from 2 to 3 young for *P. libyca*. In comparison to other Ictonychinae species, such as *Ictonyx striatus* (1–3) and *Poecilogale albinucha* (1–3) (Rowe-Rowe 1978), the litter size of *P. libyca* appears to be comparatively larger, albeit smaller than that of *Vormela peregusna* (4–8) (Gorsuch and Larivière 2005).

High mortality linked to dispersal may skew sex ratios by reducing survival in the dispersing sex and thereby favouring philopatric sexes (Banks et al. 2005; Dale 2001). Competition for food resources can also influence sex ratios, although in our study a balanced sex ratio was recorded. We observed considerable variation in the breadth of dorsal striping and hair length, reporting three types of hair lengths: long, mid-length, and short. However, variations in facial patterns were rare compared to other species such as *I. striatus* (Stuart and Stuart 2013) and North American hog-nosed skunks (*Conepatus leuconotus*) (Ferguson et al. 2022). Additionally, we encountered a specimen with a different colour, and completely different dorsal stripes and facial pattern.

In conclusion, our findings reveal unique aspects of the Saharan striped polecat's biology, including the absence of sexual size dimorphism in body length, the presence of body mass dimorphism favouring males, and a significant correlation between body and tail length. We also observed sexual differences in measurements related to canine size and neck circumference. Additionally, we documented

variations in reproductive timing and litter sizes that exceed previous records for the species. The study highlights diversity in coat characteristics, showing significant variations in dorsal striping, coloration, and hair length, with short hair and variations in facial patterns being relatively rare.

These insights substantially enhance our understanding of *P. libyca* and lay a foundation for future research on small carnivorans in arid environments. Our conclusions were informed by studies of other species, and we recommend further research on the forelimb morphology of *P. libyca* and *I. striatus* to better understand the relationship between forelimb structure and the types of substrates these species inhabit. Additionally, studying the diet of the Saharan striped polecat is crucial to determine whether the observed dimorphism in canine length, body mass, and forelimb structure is related to dietary niche segregation (Law 2019) or to territoriality and female defence during the mating season, as observed in the striped hog-nosed skunk (*Conepatus amazonicus*) (Machado et al. 2024). We also recommend a more detailed study on the effects of food abundance on sexual dimorphism and growth in the species.

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**Author contributions** FH and EDLS conceived the idea and designed the study. FH conducted the field work, analysed the data, and wrote and revised the paper. EDLS and ZJKM supervised the study and wrote and revised the paper.

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## Declarations

**Ethical approval** This study obtained all necessary permits from the Ministry of Agriculture, Hydraulic Resources, and Fisheries of the Tunisian Republic, and ethical approval from the University of Fort Hare's Animal Research Ethics Committee (clearance number DOL011SHAY01/19/A).

**Conflict of interest** We declare no competing interests.

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## References

Abramov AV, Puzachenko AY (2009) Spatial variation of sexual dimorphism in the Siberian weasel *Mustela sibirica* (Mustelidae, Carnivora). Russ J Theriol 8:17–28

Abramov AV, Puzachenko AY, WIIG Ø (2009) Cranial variation in the European badger *Meles meles* (Carnivora, Mustelidae) in Scandinavia. Zool J Linn 157:433–450

Abramov AV, Puzachenko AY, Tumanov IL (2016) Morphological differentiation of the skull in two closely-related mustelid species (Carnivora: Mustelidae). Zool Stud 55:1

Ahmim M, Do Linh San E (2015) *Ictonyx libycus*. The IUCN Red List of Threatened Species 2015: e.T41645A45212347. Retrieved from: https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T41645A45212347.en

Banks SC, Finlayson GR, Lawson SJ, Lindenmayer DB, Paetkau D, Ward SJ, Taylor AC (2005) The effects of habitat fragmentation due to forestry plantation establishment on the demography and genetic variation of a marsupial carnivore, *Antechinus agilis*. Biol Conserv 122:581–597

Baskin JA (1998) Mustelidae. In: Janis CM, Scott KM, Jacobs LL (eds) Evolution of tertiary mammals of North America: terrestrial carnivores, ungulates, and ungulatelike mammals. Cambridge University, Cambridge, pp 152–173

Birks JDS, Dunstone N (1985) Sex-related differences in the diet of the Mink *Mustela vison*. Ecography 8:245–252

Brown JH (ed) (1995) Macroecology. University of Chicago Press, Chicago

Brown JH, Lasiewski RC (1972) Metabolism of weasels: the cost of being long and thin. Ecol 53:939–943

Brown CJ, O'Connor MI, Poloczanska ES, Schoeman DS, Buckley LB, Burrows MT, Duarte CM, Halpern BS, Pandolfi JM, Parmesan C, Richardson AJ (2016) Ecological and methodological drivers of species' distribution and phenology responses to climate change. Glob Change Biol 22:1548–1560

Chmura HE, Kharouba HM, Ashander J, Ehlman SM, Rivest EB, Yang LH (2019) The mechanisms of phenology: the patterns and processes of phenological shifts. Ecol Monogr 89:e01337

Dale S (2001) Female-biased dispersal, low female recruitment, unpaired males, and the extinction of small and isolated bird populations. Oikos 92:344–356

Dayan T, Simberloff D, Tchernov E, Yom-Tov Y (1989) Inter-and intraspecific character displacement in Mustelids. Ecol 70:1526–1539

Do Linh San E (2022a) The world's small carnivores: species list and selected attributes. In: Do Linh San E, Sato JJ, Belant JJ, Somers MJ (eds) Small carnivores: evolution, ecology, behaviour, and conservation. Wiley–Blackwell, Oxford, pp 539–557

Do Linh San E (2022b) The world's small carnivores: contentious taxonomic cases. In: Do Linh San E, Sato JJ, Belant JJ, Somers MJ (eds) Small carnivores: evolution, ecology, behaviour, and conservation. Wiley–Blackwell, Oxford, pp 559–579

Do Linh San E (2006) [The Eurasian badger: description, behavior, social life, protection, observation]. Delachaux et Niestlé, Paris (In French)

Dragesco-Joffé A (ed) (1993) La Vie Sauvage au Sahara. Delachaux et Niestlé, Lausanne, Switzerland, pp 441–442

El-Farhati H, Nouira S (2022) New records of the Libyan striped weasel *Ictonyx libycus* in Tunisia. Afr J Ecol 60:1257–1261

Erlinge S (1975) Feeding habits of the weasel *Mustela nivalis* in relation to prey abundance. Oikos 26:378–384
Erlinge S (1979) Adaptive significance of sexual dimorphism in weasels. Oikos 33:233–245
Ferguson AW, Strauss RE, Dowler RC (2022) Beyond black and white: addressing colour variation in the context of local environmental conditions for the aposematic North American hog-nosed skunk. In: Do Linh San E, Sato JJ, Belant JL, Somers MJ (eds) Small carnivores: evolution, ecology, behaviour, and conservation. Wiley-Blackwell, Oxford, pp 107–130
Flower SS (1932) Notes on the recent mammals of Egypt, with a list of the species recorded from that Kingdom. Proc Zool Soc Lond 102:369–450
Gibbs JP, Breisch AR (2001) Climate warming and calling phenology of frogs near Ithaca, new York, 1900–1999. Conserv Biol 15:1175–1178
Gittleman JL, Valkenburgh BV (1997) Sexual dimorphism in the canines and skulls of carnivores: effects of size, phylogency, and behavioural ecology. J Zool 242:97–117
Gliwicz J (1988) Sexual dimorphism in small Mustelids: body diameter limitation. Oikos 53:411–414
Gorsuch WA, Larivière S (2005) *Vormela peregusna*. Mamm Species 2005:1–5
Gray A, Brito JC, Edwards CW, Figueiró HV, Koepfli KP (2022) First complete mitochondrial genome of the Saharan striped polecat (*Ictonyx libycus*). Mitochondr DNA Part B 7:1957–1960
Haltenorth T, Diller H (eds) (1980) A field guide to the mammals of Africa including Madagascar. Collins, London, p 400
Harrison GA (1958) The adaptability of mice to high environmental temperatures. J Exp Biol 35:892–901
Hayder F (2016) [Characterization of the life cycle of *Hemilepistus reaumurii* in the Gabès region]. MSc thesis, University of Tunis El Manar (In French)
Hayder F, Madikiza ZJK, Do Linh San E (2025) Distribution, threats, population trends and ecology of the Saharan striped polecat (*Poecilictis libyca*) in Tunisia: a questionnaire and field-based survey. J Mammal. https://doi.org/10.1093/jmammal/gyaf043
Hayder F, Wolsan M, Madikiza ZJK, Sato JJ, Do Linh San E (submitted a) A review and recommendations pertaining to the nomenclature of the Saharan striped polecat *Poecilictis libyca* (Thomas and Hinton, 1833). Afr J Wildl Res
Hayder F, Madikiza ZJK, Do Linh San E (submitted b) An evaluation of techniques used for the capture, immobilization and radio-tracking of saharan striped Polecat (*Poecilictis libyca*), and recommendations for field biologists. Wildl Soc Bull
Hayder F, Madikiza ZJK, Do Linh San E (in prep. a) Burrow and habitat use by saharan striped Polecat (*Poecilictis libyca*) in an agricultural area of central Tunisia
Hayder F, Madikiza ZJK, Do Linh San E (in prep. b) Effects of weather conditions, moonlight and human presence on the activity of Saharan striped polecat (*Poecilictis libyca*) in a cropland environment
Hayder F, Nasri-Ammar K (2020) Effects of habitat fragmentation on the sub-social desert terrestrial isopod *Hemilepistus reaumurii*. J Arid Environ 178:104173
Holmes T, Powell RA (1994) Morphology, ecology and the evolution of sexual dimorphism in North American *Martes*. In: Buskirk SW, Harestad AS, Raphael MG, Powell RA (eds) Martens, sables and fishers biology and conservation. Ithaca, New York, pp 72–84
Hoogstraal H (1958) Notes on African *Haemaphysalis* ticks. IV. Description of Egyptian populations of the yellow dog-tick, *H. leachii leachii* (Audouin, 1827) (Ixodoidea, Ixodidae). J Parasitol 44:548–558
Hung N, Law CJ (2016) *Lutra lutra* (Carnivora: Mustelidae). Mamm Species 48:109–122
Ireland MC (ed) (1990) The behaviour and ecology of the American mink *Mustela vison* (Schreber) in a coastal habitat. Doctoral dissertation, Durham University
Iversen JA (1972) Basal energy metabolism of Mustelids. J Comp Physiol 81:341–344
Kharouba HM, Paquette SR, Kerr JT, Vellend M (2014) Predicting the sensitivity of butterfly phenology to temperature over the past century. Glob Change Biol 20:504–514
King CM (1983) *Mustela erminea*. Mamm Species 195:1–8
King CM (1989) The advantages and disadvantages of small size to weasels, *Mustela* species. In: Gittleman JL (ed) Carnivore behavior, ecology, and evolution. Cornell University Press, Ithaca, pp 302–334
King CM, Powell RA (eds) (2007) The natural history of weasels and stouts: ecology, behavior and management, 2nd edn. Oxford University Press, New York
Kingdon J (ed) (1977) East African mammals: an atlas of evolution in Africa, vol IIIA. Carnivores. Academic Press, London, p 476
Koepfli KP, Deere KA, Slater GJ, Begg C, Begg K, Grassman L, Lucherini M, Veron G, Wayne RK (2008) Multigene phylogeny of the Mustelidae: resolving relationships, tempo and biogeographic history of a mammalian adaptive radiation. BMC Biol 6:1–22
Law CJ (2019) Solitary meat-eaters: solitary, carnivorous carnivorans exhibit the highest degree of sexual size dimorphism. Sci Rep 9:15344
Law CJ, Slater GJ, Mehta RS (2019) Shared extremes by ectotherms and endotherms: body elongation in Mustelids is associated with small size and reduced limbs. Evol 73:735–749
Lin YF, Chappuis A, Rice S, Dumont ER (2017) The effects of soil compactness on the burrowing performance of sympatric Eastern and hairy-tailed moles. J Zool 301:310–319
Luengos Vidal EM, Castillo DF, Caruso NC, Casanave EB, Lucherini M (2016) Field capture, chemical immobilization, and morphometrics of a little-studied South American carnivore, the lesser Grison. Wildl Soc Bull 40:400–405
Machado GA, Azevedo FC, Freitas-Junior MC et al (2024) Size does not matter: natural history and sexual dimorphism of the striped hog-nosed skunk (*Conepatus amazonicus*) in central Brazil. Mamm Res 69:257–270
McDonald RA (2002) Resource partitioning among British and Irish Mustelids. J Anim Ecol 71:185–200
McNutt JW, Groom R, Woodroffe R (2019) Ambient temperature provides an adaptive explanation for seasonal reproduction in a tropical mammal. J Zool 309:153–160
Melero Y, Santulli G, Gómez A, Gosàlbez J, Rodriguez-Refojos C, Palazón S (2012) Morphological variation of introduced species: the case of American Mink (*Neovison vison*) in Spain. Mamm Biol 77:345–350
Mincer ST, Russo GA (2020) Substrate use drives the macroevolution of mammalian tail length diversity. Proc Royal Soc B 287:20192885
Muchlinski AE, Shump KA (1979) The sciurid tail: a possible thermoregulatory mechanism. J Mammal 60:652–654
Müller P, Neuhoff D, Nabel M, Schiffers K, Döring TF (2022) Tillage effects on ground beetles in temperate climates: a review. Agron Sustain Dev 42:65
Niethammer J (1987) Das Streifenwiesel (*Poecilictis libyca*) im Sudan und seine Gesamtverbreitung. Bonn Zool Beitr 38:173–182
Osborn DJ, Helmy I (eds) (1980) The contemporary land mammals of Egypt (including Sinai). Field Museum of Natural History, Chicago, IL, USA
Petter F (1959) Reproduction En captivité du Zorille du Sahara *Poecilictis libyca*. Mammalia 23:378–380
Radinsky LB (1981a) Evolution of skull shape in carnivores: 1. Representative modern carnivores. Biol J Linn Soc 15:3–388

Radinsky LB (1981b) Evolution of skull shape in carnivores: 2. Additional modern carnivores. Biol J Linn Soc 16:337–355
Ralls K, Harvey PH (1985) Geographic variation in size and sexual dimorphism of North American weasels. Biol J Linn Soc 25:119–167
Rappole JH, Warner DW (1980) Ecological aspects of migrant bird behavior in Veracruz, Mexico. In: Keast A, Morton ES (eds) Migrant birds in the neotropics: ecology, behavior, distribution, and conservation. Smithsonian Institution, Washington, D.C., pp 353–393
Reig S, Ruprecht AL (1989) Skull variability of *Martes martes* and *Martes foina* from Poland. Acta Theriol 34:595–624
Rodríguez-Refojos C, Zuberogoitia I (2009) Estudio biométrico preliminar del dimorfismo sexual en visones americanos *Neovison vison* (Schreber, 1777) de granja y salvajes en el norte de la Península Ibérica. Galemys 21:71–80
Rosevear DR (ed) (1974) The carnivores of West Africa. Trustees of the British museum. Natural History), London, p 548
Rowe-Rowe DT (1978) Reproduction and post-natal development of South African Mustelines (Carnivora: Mustelidae). Afr Zool 13:103–114
Rozhnov VV, Abramov AV (2006) Sexual dimorphism of marbled Polecat *Vormela peregusna* (Carnivora: Mustelidae). Biol Bull 33:144–148
Sandell M (1989) Ecological energetics, optimal body size and sexual size dimorphism: a model applied to the Stoat. *Mustela erminea* L Funct Ecol 3:315–324
Sato JJ, Wolsan M, Prevosti FJ, D'Elía G, Begg C, Begg K, Hosoda T, Campbell KL, Suzuki H (2012) Evolutionary and biogeographic history of weasel-like carnivorans (Musteloidea). Mol Phylogenet Evol 63:745–757
Sheffield SR, King CM (1994) *Mustela nivalis*. Mamm Species 454:1–10
Sheng H (1987) Sexual dimorphism and geographical variation in the body size of the yellow weasel (*Mustela sibirica*). Acta Zool Sin 7:92–95
Siciliano-Martina L, Guerra DA, Veech JA (2023) Forelimb morphology as an adaptation for burrowing in kangaroo rat species (genus *Dipodomys*) that inhabit different soil substrates. J Mammal 104:1377–1389
Sitek H (1996) Breeding of the Libyan striped weasel *Poecilictis libyca* at Poznan zoo, Poland. Small Carniv Conserv 13:8–9
Sterner RT, Petersen BE, Gaddis SE, Tope KL, Poss DJ (2003) Impacts of small mammals and birds on low-tillage, dryland crops. Crop Prot 22:595–602
Stuart C, Stuart T (2013) *Ictonyx striatus* Zorilla. In: Kingdon J, Hoffmann M (eds) Mammals of Africa. Volume V: carnivores, Pangolins, equids and rhinoceroses. Bloomsbury, London, pp 93–97
Stuart C, Stuart M, Do Linh San E (2015) *Ictonyx striatus*. The IUCN Red List of Threatened Species 2015: e.T41646A45212491. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T41646A45212491.en. Accessed on 18 September 2024
Sumner J, Moritz C, Shine R (1999) Shrinking forest shrinks skink: morphological change in response to rainforest fragmentation in the prickly forest skink (*Gnypetoscincus queenslandiae*). Biol Conserv 91:159–16
Suzuki S, Peng JJ, Chang SW, Chen YJ, WuY, Lin LK, Kimura J (2013) Insular variation of the craniodental morphology in the Siberian weasel *Mustela sibirica*. J Vet Med Sci 75:575–581
Thom MD, Harrington LA, Macdonald DW (2004) Why are American mink sexually dimorphic? A role for niche separation. Oikos 105:525–535
Thomas O, Hinton MA (1920) L.—On the group of African Zorils represented by *Ictonyx libyca*. Ann Mag Nat Hist 5:367–369
Vanderhaar JM, Ten Hwang Y (2003) *Mellivora capensis*. Mamm Species 721:1–8
Weigl R (ed) (2005) Longevity of mammals in captivity; from the living collections of the world. Kleine Senckenberg-Reihe, Germany
Williams TM (1983) Locomotion in the North American mink, a semi-aquatic mammal: I. Swimming energetics and body drag. J Exp Biol 103:155–168
Wolsan M (2013) Family Mustelidae: weasels, polecats, otters, ratel and allies. In: Kingdon J, Hoffmann M (eds) Mammals of Africa. Volume V: carnivores, pangolins, equids and rhinoceroses. Bloomsbury, London, pp 82–84

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