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External and Cranial Characteristics of *Mustela sibirica quelpartis* on Jeju Island

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ABSTRACT

This study investigates the morphological and skull characteristics of the Siberian weasel *Mustela sibirica quelpartis* from the Jeju Island, South Korea. A total of 26 roadkill specimens (22 males and 4 females) were collected from October 2012 to April 2016. All collected specimens were examined for morphological characteristics, but only 19 specimens (16 males and 3 females) were in a good enough condition to process for skull measurements. This study showed no significant differences in ear length between male and female ($p > 0.05$), and significant differences were found in head-body length, tail length (TL), and hind-food length ($p < 0.05$). Both the male and female of *M. s. quelpartis* were larger in its external characteristics except for TL than *M. s. coreanus* living in the mainland of South Korea. *M. s. quelpartis* males have a smaller skull size than their female counterparts. In general, both male and female *M. s. quelpartis* showed external characteristics in line with the Island Rule. The findings of this study are important in order to shed more light on the evolutionary mechanism of small mammals living on the Jeju Island.

Keywords: Jeju Island, *M. s. quelpartis*, external characteristics, skull characteristics, island rule

INTRODUCTION

The Siberian weasel *Mustela sibirica* is a small Mustelidae with natural populations extending from west of the Ural Mountains in Siberia to the Far East and southwards to Taiwan and the Himalayas (Abramov et al., 2016). They live sympatrically with a number of mustelids, including ferret-badgers, martens, otters, and stoats (Mustelidae). The small and elongated body of *M. sibirica* set them apart from other mustelids (Heptner et al., 2001; Larivière and Jennings, 2009). The presence of a black mask on its face that surrounds its eyes and a white snout and chin separate *M. sibirica* from other sympatric mustelines in its native range in Asia (Law, 2018). *M. sibirica* inhabiting in Korea are classified into three subspecies (*M. s. coreanus*, *M. s. manchurica*, and *M. s. quelpartis*) (Yoon, 1992; Abramov, 2005). Among them, *M. s. manchurica*, also known as "Manchurian Weasel" or "North Weasel" is widespread in the north of central Korea. In contrast, *M. s. coreanus* is endemic to the Korean Peninsula and to Tsushima, Japan called South Weasel (Koh, 1992; Yoon, 1992; Sasaki and Ono, 1994), while *M. s. quelpartis* is endemic only to Jeju Island (formerly Quelpart Island), Japan (Abramov, 2005; Han, 2013).

Mustela s. quelpartis was first reported by Thomas (1906) and once called *Lutreola quelpartis* to distinguish it from Weasel in the Korean Peninsula (Thomas, 1908). According to a previous study, *M. s. quelpartis* was not very different from other Korean Weasels in terms of external morphology. However, its body color was slightly different (Won, 1968). Male *M. s. quelpartis* had shorter heads, bodies, and tails than male *M. s. coreanus*, while females showed the opposite features (Yoon et al., 2004). However, this study had limitations in revealing the comparative anatomical features of *M. s. quelpartis* due to limited sampling, which were attributed to the characteristics of the outdoor study. Hence, our study provide fundamental materials for classification ecology by illuminating the external morphological and cranial features of *M. s. quelpartis* in Jeju Island.

MATERIALS AND METHODS

Sampling

Road killed and/or naturally dead *M. s. quelpartis* specimens

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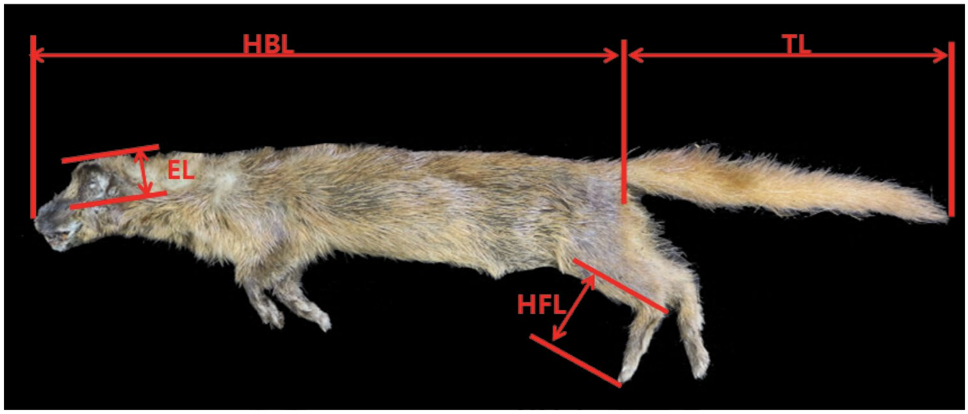

Fig. 1. Measurement of external body characters. HBL, head-body length; TL, tail length; EL, ear length; HFL, hind-foot length.

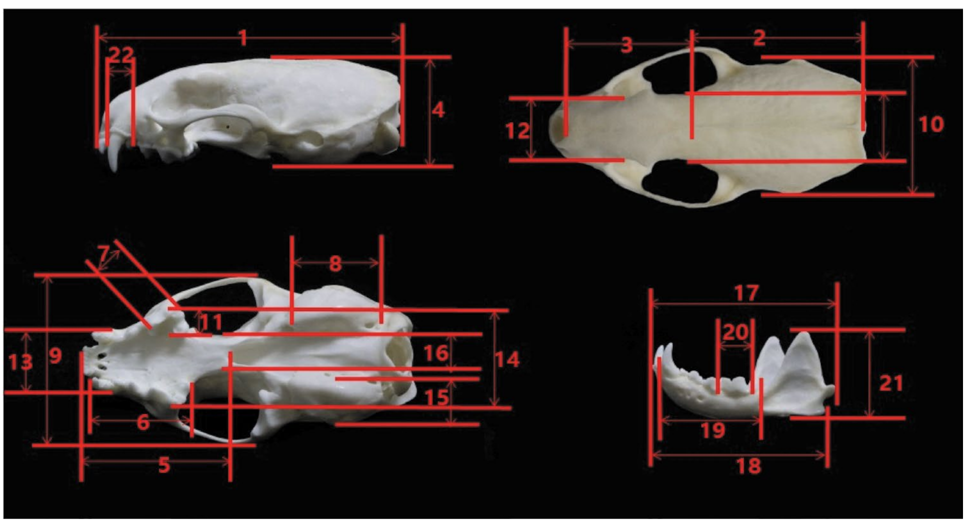

Fig. 2. Measurement of skull characters. 1, condylobasal length, CL; 2, neurocranium length, NL; 3, viscerocranium length, VL; 4, braincase height, BH; 5, palatal length, PL; 6, maxillary tooth-row, MTR; 7, length of upper carnassial teeth P4, LUC; 8, length of the auditory bullae, LAB; 9, zygomatic breadth, ZB; 10, mastoid width of skull, MW; 11, upper molar M1 length, UML; 12, Interorbital width, IOB; 13, breadth at the canine alveoli, BCA; 14, greatest palatal breadth, GPB; 15, width of the auditory bullae, WAB; 16, minimal palatal breadth, MPB; 17, total length of the mandible, TLM; 18, length between the angular process and infradentale, AI; 19, mandibular tooth-row length, MTL; 20, length of lower carnassial tooth m1, LLC; 21, vertical height of mandible, VHM; 22, width of the cranial, WC.

collected from October 2012 to April 2016 were used to measure the external morphology and cranial characteristics. The collected species whose cranium or appearance was damaged were excluded from the analysis. In total, 26 specimens (22 males and 4 females) were used for morphological analysis and only 19 specimens (16 males and 3 females) were used for cranial analysis. Comparison with *M. s. coreanus* was done using the characteristics reported by Han (2013).

Morphological appearance measurement and statistical analysis

For the external appearance, five factors were measured (Fig. 1): body weight (BW), head-body length (HBL), tail length (TL), ear length (EL), and hind-foot length (HFL). The external morphological features of the male and female *M. s. quelpartis* specimens were analyzed using the Mann-Whitney U test (IBM SPSS Statistics ver. 22, IBM Corp., Armonk, NY, USA).

Measurement of cranial morphological feature

The measurement of cranial morphological features was conducted according to the reports of Abramov (2000, 2005) and Han (2013). Measurements were made for the condylobasal length (CL), neurocranium length, viscerocranium length, braincase height, palatal length, maxillary tooth-row, the length of the upper carnassial teeth P4, the length of the auditory bullae, zygomatic breadth (ZB), mastoid width of the skull (MW), upper molar M1 length, interorbital width, breadth at the canine alveoli, greatest palatal breadth (GPB), the width of the auditory bullae (WAB), minimal palatal breadth (MPB), the total length of the mandible (TLM), the length between the angular process and infradentale, mandibular tooth-row length (MTL), the length of the lower carnassial tooth m1, the vertical height of the mandible (VHM), and the width of the cranium (Fig. 2).

The external features and skull size were measured using digital calipers (CD-15CPX; Mitutoyo Co., Japan), and the BW was obtained using an electric balance (MW2-3000N; Cas, Korea).

RESULTS AND DISCUSSION

External morphological features

Table 1 presents the external morphological measurements of male and female *M. s. quelpartis* specimens. The males had higher BW, longer HBL, TL, EL, and HFL compared to that of females. Except EL, the HBL, TL, and HFL showed significant difference ($p<0.05$). The HBL of the males was 348.99±22.51 mm, which was 27.3 mm longer than that of the females (321.69±24.96 mm). The TL (181.97±16.35 mm), EL (24.07±4.08 mm), and HFL (58.42±3.62 mm) of the males were 20.51 mm, 1.46 mm, and 2.69 mm longer, respectively, compared to those of the females. In Stoats and weasels, male having larger body size compared to female have the chance of successful mating (Yom-Tov et al., 2010). The same was observed for Eastern grey kangaroos (*Macropus giganteus*), as male having larger body size improved reproductive success (Miller et al., 2010). These results are attributed to the acquired characteristic where larger sized male are usually observed in animals having polygynous breeding system (Erlinge, 1979; King, 1989; Sandell, 1989; Yom-Tov et al., 2010).

Morphological characteristics comparision between *M. s. quelpartis* and *M. s. coreanus* showed that, male of *M. s. quelpartis* have longer HBL, EL, and HFL but smaller BW and TL (Table 2). Similarly, female *M. s. quelpartis* have longer HBL, EL, and HFL, but have smaller TL compared to *M. s. coreanus* (Tables 2, 3).

Among land mammals, the roe deer (*Capreolus pygargus*) living in Jeju Island were comparatively smaller compared to those living in mainland Korean (Koh et al., 2000; Yoon et al., 2003; Kim et al., 2015). Likewise, big mammals tended to become smaller and vice versa for adjusting to the island environment (Maldonado et al., 2004; Meiri et al., 2004).

This study result was similar to that of Yoon et al. (2004), in which the HBL of *M. s. quelpartis* was larger than those of

Table 1. Comparison of external body characters of *Mustela sibirica quelpartis* between males and females

Character	*M. s. quelpartis* ♂			*M. s. quelpartis* ♀			p-value
	No.	Range (mm)	Mean±SD (mm)	No.	Range (mm)	Mean±SD (mm)	
BW	22	254.30–833.20	523.29±163.45	4	248.70–400.00	325.27±75.15	–
HBL	21	301.98–389.50	348.99±22.51	4	293.82–342.00	321.69±24.96	0.020*
TL	22	145.00–211.50	181.97±16.35	4	151.98–175.39	161.46±12.32	0.007*
EL	22	15.55–29.75	24.07±4.08	4	20.09–24.12	22.61±2.20	0.892
HFL	22	48.75–67.09	58.42±3.62	4	54.15–56.60	55.73±1.37	0.039*

BW, body weight; HBL, head-body length; TL, tail length; EL, ear length; HFL, hind-foot length.
*$p<0.05$.

Table 2. Comparison of external body characters of males between *Mustela sibirica quelpartis* and *M. s. coreanus*

Character	*M. s. quelpartis*			*M. s. coreanus* (Han, 2013)		
	No.	Range (mm)	Mean±SD (mm)	No.	Range (mm)	Mean±SD (mm)
BW	22	254.30–833.20	523.29±163.45	–	–	–
HBL	21	301.98–389.50	348.99±22.51	13	278–325	297.3±16.1
TL	22	145.00–211.50	181.97±16.35	13	166–208	187.5±13
EL	22	15.55–29.75	24.07±4.08	13	17–22	19.3±1.9
HFL	22	48.75–67.09	58.42±3.62	13	49–64	57.3±4.6

BW, body weight; HBL, head-body length; TL, tail length; EL, ear length; HFL, hind-foot length.

Table 3. Comparison of external body characters of females between *Mustela sibirica quelpartis* and *M. s. coreanus*

Character	*M. s. quelpartis*			*M. s. coreanus* (Han, 2013)		
	No.	Range (mm)	Mean±SD (mm)	No.	Range (mm)	Mean±SD (mm)
BW	4	248.70–400.00	325.27±75.15	–	–	–
HBL	4	293.82–342.00	321.69±24.96	3	260–282	270.3±11.1
TL	4	151.98–175.39	161.46±12.32	3	170–188	177.7±9.3
EL	4	20.09–24.12	22.61±2.20	3	16–18	17±1
HFL	4	54.15–56.60	55.73±1.37	3	39–47	42.7±4

BW, body weight; HBL, head-body length; TL, tail length; EL, ear length; HFL, hind-foot length.

Table 4. Comparison of skull characters of males between *Mustela sibirica quelpartis* and *M. s. coreanus*

Measurement[a]	*M. s. qualpartis* (n=16)		*M. s. coreanus* (n=13), (Han, 2013)	
	Range (mm)	Mean±SD (mm)	Range (mm)	Mean±SD (mm)
CL	55.30–65.34	61.72±1.89	60.82–63.84	62.64±1.01
NL	30.46–39.87	34.92±2.93	–	–
VL	27.51–36.02	31.25±2.43	–	–
BH	5.79–7.52	6.79±0.38	–	–
PL	24.05–29.76	27.29±1.38	–	–
MTR	15.12–18.72	17.61±0.85	–	–
LUC	5.29–6.80	6.21±0.42	–	–
LAB	15.72–19.00	17.57±0.74	–	–
ZB	28.83–35.52	32.51±1.78	30.40–34.54	32.67±1.38
MW	25.41–30.30	27.73±1.33	27.18–29.71	28.37±0.88
UML	10.48–14.08	12.45±0.92	–	–
IOB	12.98–10.28	12.06±0.67	–	–
BCA	17.69–20.16	18.67±0.73	–	–
GPB	9.89–8.41	9.28±0.46	–	–
WAB	4.39–5.49	4.97±0.31	6.27–7.28	6.55±0.29
MPB	19.97–24.37	22.45±1.05	21.30–23.72	22.61±0.64
TLM	30.50–38.05	34.38±1.83	34.58–37.75	36.36±0.98
AI	29.90–33.80	33.79±1.3	–	–
MTL	18.23–21.78	20.26±0.85	16.78–18.08	17.42±0.41
LLC	6.26–8.27	7.14±0.48	–	–
VHM	15.11–19.21	17.47±1.06	17.11–19.59	18.19±0.74
WC	4.23–5.52	4.8±0.4	–	–

CL, condylobasal length; NL, neurocranium length; VL, viscerocranium length; BH, viscerocranium length; PL, palatal length; MTR, maxillary tooth-row; LUC, the length of the upper carnassial teeth P4; LAB, the length of the auditory bullae; ZB, zygomatic breadth; MW, mastoid width of the skull; UML, upper molar M1 length; IOB, interorbital width; BCA, breadth at the canine alveoli; GPB, greatest palatal breadth; WAB, the width of the auditory bullae; MPB, minimal palatal breadth; TLM, the total length of the mandible; AI, the length between the angular process and infradentale; MTL, mandibular tooth-row length; LLC, the length of the lower carnassial tooth m1; VHM, the vertical height of the mandible; WC, the width of the cranium.
[a]Measurement are marked in Fig. 2.

M. s. coreanus. Furthermore, *M. s. quelpartis* showed longer EL and HFL than *M. s. coreanus*. The presence of larger and longer features in *M. s. quelpartis* is contrary to Bergmann's Rule, which states that homeothermic animals living in cold areas have larger bodies than those in warmer areas. On the contrary, the result is consistent with the Island Rule regarding the larger size of island animals than mainland animals. Similarly, Asian lesser white-toothed shrew (*Crocidura shantungensis*) and larger size Japanese rodent (*Apodemus speciosus*) of Jeju Island has a larger body size and skull characteristics compared to Korean peninsula group (Millien and Damuth, 2004; Kim et al., 2015).

This result seems to have arisen from the adaptation of *Mustela* to the special environment of Jeju Island just like other

Table 5. Comparison of skull characters of females between *Mustela sibirica quelpartis* and *M. s. coreanus*

Measurement[a]	*M. s. qualpartis* (n=3)		*M. s. coreanus* (n=3), (Han, 2013)	
	Range (mm)	Mean±SD (mm)	Range (mm)	Mean±SD (mm)
CL	57.54–58.78	58.26±0.64	53.89–54.25	54.07±0.18
NL	20.22–30.78	25.31±5.29	–	–
VL	33.36–40.77	36.68±3.77	–	–
BH	4.54–4.92	4.79±0.22	–	–
PL	25.52–25.93	25.67±0.22	–	–
MTR	16.41–17.30	16.61±0.28	–	–
LUC	5.96–6.36	6.16±0.20	–	–
LAB	17.10–17.86	17.36±0.43	–	–
ZB	29.41–30.11	29.86±0.39	26.30–26.50	26.43±0.11
MW	24.61–26.02	25.48±0.76	23.10–24.00	23.54±0.45
UML	11.11–11.61	11.42±0.27	–	–
IOB	10.98–11.51	11.19±0.28	–	–
BCA	17.41–18.31	17.90±0.45	–	–
GPB	8.65–9.11	8.94±0.25	–	–
WAB	4.84–4.92	4.79±0.22	5.30–5.66	5.51±0.19
MPB	21.68–22.51	22.08±0.42	17.89–19.39	18.70±0.76
TLM	31.68–33.03	32.38±0.68	29.78–30.37	30.06±0.30
AI	30.88–31.91	31.32±0.53	–	–
MTL	18.76–20.25	19.49±0.75	14.34–15.06	14.75±0.37
LLC	6.61–6.88	6.78±0.15	–	–
VHM	15.80–16.38	16.17±0.32	13.88–15.07	14.39±0.61
WC	4.32–4.92	4.71±0.34	–	–

CL, condylobasal length; NL, neurocranium length; VL, viscerocranium length; BH, viscerocranium length; PL, palatal length; MTR, maxillary tooth-row; LUC, the length of the upper carnassial teeth P4; LAB, the length of the auditory bullae; ZB, zygomatic breadth; MW, mastoid width of the skull; UML, upper molar M1 length; IOB, interorbital width; BCA, breadth at the canine alveoli; GPB, greatest palatal breadth; WAB, the width of the auditory bullae; MPB, minimal palatal breadth; TLM, the total length of the mandible; AI, the length between the angular process and infradentale; MTL, mandibular tooth-row length; LLC, the length of the lower carnassial tooth m1; VHM, the vertical height of the mandible; WC, the width of the cranium.
[a]Measurement are marked in Fig. 2.

mammals (Lomolino, 1985; Meiri et al., 2004). Although the size was larger, the TL of *M. s. quelpartis* was still shorter than that of *M. s. coreanus*. Tail of mammals usually helps in maintaining balance during swimming, jumping and running (Hickman, 1979). However, *M. s. quelpartis* living in Jeju Island has few natural enemy, they did not have to maintain a large range of action, which might have resulted in its relatively short tail. Still, there has been no study revealing the association between TL and ecological differences in *M. s. quelpartis*, but the habitat characteristics of Jeju Island and the Korean mainland show significant differences. Therefore, a detailed study regarding the association between TL and ecological features is necessary.

Cranial morphological features

Table 4 presents a comparison of the cranial morphological characteristics of male *M. s. quelpartis* with those reported by Han (2013). We compared the following eight features suggested by Han (2013) in *M. s. coreanus* as: CL, ZB, MW, WAB, MPB, TLM, MTL, and VHM. Most features of *M. s. quelpartis* (CL, ZB, MW, WAB, MPB, TLM, and VHM) showed smaller values except MTL, which is consistent with previous study (Abramov, 2005; Han, 2013), showing smaller cranial features than those of *M. s. coreanus*.

Table 5 shows the measurements of the cranial features of female *M. s. quelpartis*. When compared to the eight features (CL, ZB, MW, WAB, MPB, TLM, MTL, and VHM) proposed by Han (2013), the results were contrary to the argument that *M. s. quelpartis* showed relatively smaller cranium size than *M. s. coreanus* for seven features, except for the WAB (Table 5). This requires confirmation by securing and examining more samples.

The trend for the cranium of *M. s. quelpartis* to be smaller than that of *M. s. coreanus* is interpreted differently according to the phenomenon that a population adapted to an island environment shows larger craniums and external sizes (Kim et al., 2015). The nest size and predetor can determine the maximum size of *Mustela* (Sandell, 1989; Yom-Tov et al., 2010).

The geology of Jeju Island is different from that seen in the interior of the Korean Peninsula because the geological layer is composed of volcanic pyroclastic rocks and granite because of volcanic activity (Ahn et al., 1995). Therefore, *M. s. quelpartis*, which mainly uses underground caves, is believed to have undergone a shrinkage with regards to the size of its head as an adaptation to the island. However, more detailed and diverse studies are required on the smaller skull size of the males on Jeju Island.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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