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Morphometric Variation in Three Subspecies of Korean Field Mice, *Apodemus peninsulae* Thomas (Mammalia, Rodentia), in China and Korea

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ABSTRACT

Four external and 27 cranial characters of Korean field mice (*Apodemus peninsulae*) from nine regions in China and Korea, representing three subspecies, were analyzed by multivariate methods. Four size-forms were recognized; a largest-size form from Mt. Weolak and Yeoncheon in Korea (= subspecies *peninsulae*) and Kirin and Heilung in China (= subspecies *praetor*), a large-size form from Inner Mongolia in China (= subspecies *praetor*) and Sanxi and Sandong in China (= subspecies *sowerbyi*), a middle-size form from Beijing in China (= subspecies *sowerbyi*), and a small-size form from Xinjiang in China (= subspecies *sowerbyi*). Although Corbet (1978) recognized only two subspecies in *A. peninsulae,* subspecies *peninsulae* and *sowerbyi,* within its distributional range in the continent of Asia, it was revealed in this study with morphometric characters that *A. peninsulae* could not be classified simply into two subspecies, because subspecies *praetor* and subspecies *sowerbyi* formed the large-size form and because subspecies *sowerbyi* was so diverse in its morphology as to be composed of three size-forms. Further analyses with the samples from other regions of China and Russia seem to be necessary to clarify the taxonomy of *A. peninsulae.*

Key words: Systematics, morphometry, *Apodemus peninsulae*, China and Korea

INTRODUCTION

The genus *Apodemus*, composed of 14 species, is confined to the Palaearctic and northern part of

the Oriental regions (Corbet and Hill, 1991). Six species, *A. agrarius, A. chevrieri, A. draco, A. latronum, A. sylvaticus*, and *A. peninsulae*, inhabit in China and two species, *A. agrarius* and *A. peninsulae*, are distributed in Korea. In morphometric analyses with eight subspecies of striped field mice, *A. agrarius*, in Asia (Koh, 1991), it is confirmed that one subspecies (*A. agrarius chevrieri*) from southern China is a species, *A. chevrieri*, and another subspecies (*A. agrarius chejuensis*) from Cheju island in Korea is also a distinct species, *A. chejuensis*.

Korean field mice, *A. peninsulae* Thomas 1906, are distributed over much of Siberia, China, Manchuria, Korea, and Hokkaido (Corbet and Hill, 1991), and the type locality of *A. peninsulae* is Mungyong, 110 miles southeast of Seoul, Korea (Jones, 1956). *A. peninsulae* was considered as a subspecies of *A. speciosus* (Thomas, 1906; Vinogradov and Argiropulo, 1941; Tate, 1947; Woon, 1967), but Vorontsov *et al.* (1977) claimed on the basis of karyological and morphological analyses with samples of boreal regions of East Asia that all the eastern Asian forms of *A. speciosus* should be transferred to the species, *A. peninsulae*.

Corbet (1978) summarized eight subspecies (*peninsulae, major, majusculus, praetor, rufulus, tscherga, sowerbyi*, and *giliacus*) of *A. peninsulae* into three subspecies (*peninsulae* including *praetor* and other four subspecies, *sowerbyi*, and *giliacus*). In *A. peninsulae*, three subspecies (*praetor, sowerbyi*, and *qinghaiensis*) were recognized in China (Xia, 1985). In chromosomal and morphometric analyses it is confirmed that the Korean field mice from Korea are not *A. speciosus peninsulae*, but *A. peninsulae peninsulae* (Koh, 1986). Morphometric analyses with 79 samples of five subspecies of *A. peninsulae* from eastern Asia, it is confirmed that two subspecies of *A. peninsulae, peninsulae* and *sowerbyi*, can be recognized in the continent of Asia (Koh and Lee, 1994). Therefore, the taxonomy of *A. peninsulae* is still in doubt, as noted by Xia (1985).

The methods of numerical taxonomy based on equal weighting and overall similarity seemed inapplicable in defining higher categories above the species level (Farris, 1966). On the other hand, Flake and Turner (1968) stated that the numerical approach offers potential for the resolution of taxonomic problems for populations at infraspecific level.

The objective of this paper is to analyze morphometric characters of 219 samples of *A. peninsulae* from nine regions in China and Korea, representing three subspecies (*peninsulae, praetor*, and *sowerbyi*), in order to determine their subspecific status in *A. peninsulae*.

MATERIALS AND METHODS

Materials

Sexual variation was not significant, but age variation was evident with rather slower rate of growth among three age classes of adults in *A. agrarius* (Koh, 1983). Juveniles, subadults, and old adults were not used, and 219 samples of young and middle-aged adults of *A. peninsulae* from nine regions in China and Korea, representing three subspecies, were analyzed as shown in Table 1 and Fig. 1.

Multivariate Analyses

Four external and 27 cranial characters were measured (for details see Koh, 1983) and samples

Table 1. Subspecies name, region, and number of samples in three subspecies of *Apodemus peninsulae* from China and Korea, used for morphometric analyses.

Subspecies	Region	No. of sample	OTU
peninsulae	Mt. Weolak, Korea	31	1
	Yeoncheon, Korea	9	2
praetor	Kirin, China	28	3
	Heilung, China	69	4
	Inner Mongolia, China	16	5
sowerbyi	Xinjiang, China	31	6
	Sansi, China	16	7
	Beijing, China	10	8
	Sandong, China	9	9
		219	

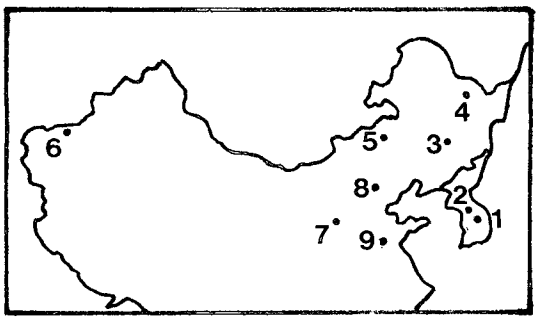

Fig. 1. A map showing nine regions (OTUs) of samples in three subspecies of *Apodemus peninsulae* from China and Korea. The subspecies name and number of samples in each OTU are given in Table 1.

from several localities in the same province were grouped as Operational Taxonomic Units, OTUs (see Table 1). Sample statistics such as mean and standard deviation were calculated by subprogram DESCRIPTIVE of SPSS/pc+ program. Discriminant and cluster analyses were also performed by subprograms DISCRIMINANT and CLUSTER of SPSS/pc+, respectively. Principal component analysis was carried out usingsubprograms EIGEN and PROJ of NTSYS/pc program. Minimum spanning tree was also produced by subprogram MST of NTSYS/pc.

RESULTS

Two dimensional plottings from discriminant analysis with nine OTUs in three subspecies of *A. peninsulae* are shown in Fig. 2 (numerals indicate centroids of OTUs and minimum spanning tree is superimposed on the plots with minimum distance shown). Functions I, II, and III represented 45, 33, and 9 per cent of the variance, respectively (87 per cent in total). Four size-forms were revealed; a largest-size form (OTUs 1, 2, 3, and 4), a large-size form (OTUs 5, 7, and 9), a middle-size form

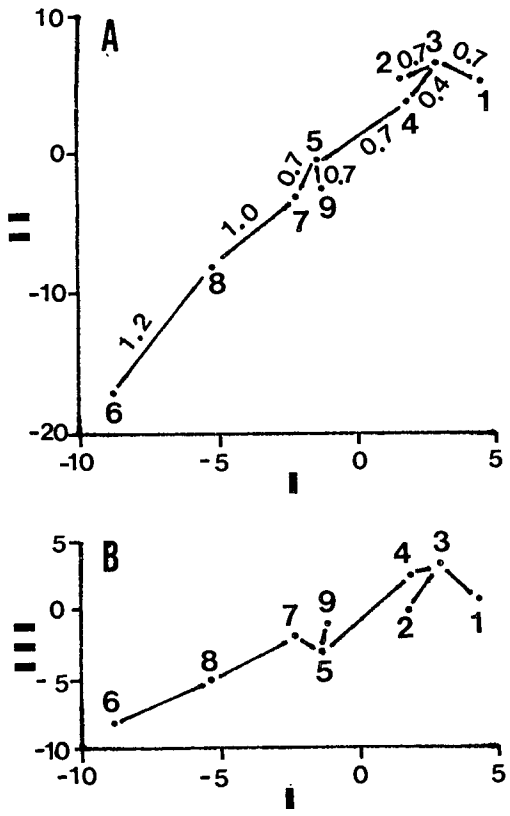

Fig. 2. Plottings of nine OTUs in three subspecies of *Apodemus peninsulae* from China and Korea by discriminant analysis with 219 samples. Numerals indicate the centroid of each OTU and minimum spanning tree is superimposed on the plots (minimum distance is also given). A, OTUs ordinated with function I vs. function II. B, OTUs ordinated with function I vs. function III.

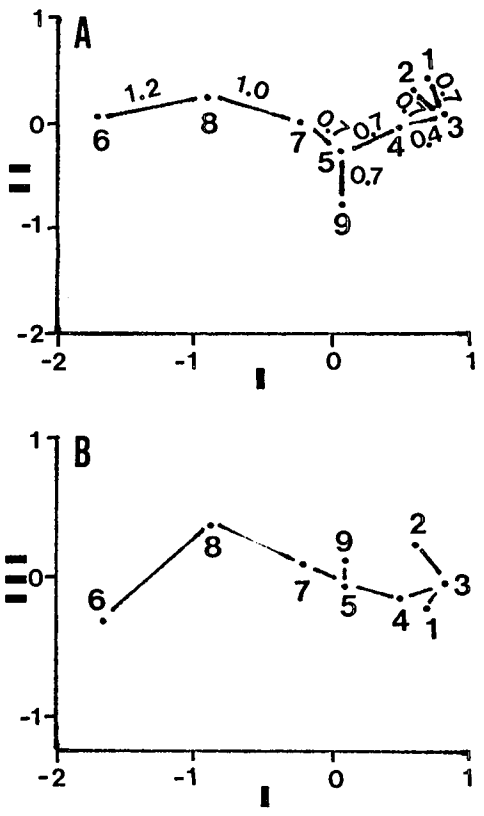

Fig. 3. Projections of nine OTUs in three subspecies of *Apodemus peninsulae* from China and Korea by principal component analysis. Numerals indicate each OTU. Minimum spanning tree is superimposed on the projections and minimum distance is also given. A, OTUs ordinated with factor I vs. factor II. B, OTUs ordinated with factor I vs. factor III.

(OTU 8), and a small-size form (OTU 6).

Two dimensional configurations of nine OTUs of *A. peninsulae* by principal component analysis are shown in Fig. 3 (minimum spanning tree is superimposed on the plots with minimum distance shown). Factors I, II, and III represented 70, 13, and 6 per cent of the variance, respectively (89 per cent in total). Four-size forms were recognized, as revealed by discriminant analysis mentioned above. Nine OTUs of A. peninsulae were also grouped by cluster analysis of average linkage with taxonomic distances, as shown in Fig. 4. Four subgroups mentioned above were also revealed.

In summary, four size-forms were recognized; a largest-size form from Mt. Weolak and Yeoncheon in Korea (OTUs 1 and 2, subspecies *peninsulae*) and Kirin and Heilung in China (OTUs 3 and 4, subspecies praetor), a large-size form from Inner Mongolia in China (OTU 5, subspecies *praetor*) and Sanxi and Sandong in China (OTU 7 and 9, subspecies *sowerbyi*), a middle-size form from Beijing in China (OTU 8, subspecies *sowerbyi*), a small-size form from Xinjiang in China (OTU 6, subspecies

sowerbyi).

DISCUSSION

Boyce (1969) noted that average linkage or UPGMA represents a distance matrix of random points better than either complete or single linkage. The relationships between close neighbors are frequently distorted in an ordination, especially one based on principal component analysis, PCA (Rohlf, 1970), and it is useful to superimpose minimum spanning tree on the plots by ordination methods (Kruskal, 1956). Discriminant ananlysis ordinates two or more a priori defined groups as that there is minimum overlap and maximum separation among them, whereas PCA makes no assumption about the existance of grouping among the OTUs (Clifford and Stephenson, 1975). Furthermore, Sneath and Sokal (1973) stated that there are no satisfactory methods for telling whether clustering or ordination is most appropriate. In this paper based on discriminant analysis (Fig. 2), PCA (Fig. 3) and cluster analysis (Fig. 4) with morphometric characters, it is concluded that samples of three subspecies of *Apodemus peninsulae* from nine OTUs in China and Korea are grouped into four-size forms; a largest-size form (OTUs 1, 2, 3, and 4), a large-size form from (OTUs 5, 7, and 9), a middle-size form (OTU 8), and a small-size form (OTU 6).

Miller (1914) stated that a new species from Kirin in China, *A. praetor* (= *A. peninsulae praetor*), is greater in its size than *A. speciosus peninsulae* (= *A. peninsulae peninsulae*). Corbet (1978) summarized five nominal subspecies including praetor into one subspecies *A. peninsulae peninsulae*. In the present analyses with three subspecies of *A. peninsulae* (Figs. 2, 3, and 4), it is revealed that *A. peninsulae peninsulae* (OTUs 1 and 2) and *A. peninsulae praetor* (OTUs 3 and 4) constitute the largest-size form, indicating that two subspecies are similar with each other, and it is confirmed that subspecies *praetor* is a synonym of subspecies *peninsulae*, as noted by Corbet (1978). Koh and Lee (1994) also found that subspecies *peninsulae* and *praetor* are similar with each other in their morphology.

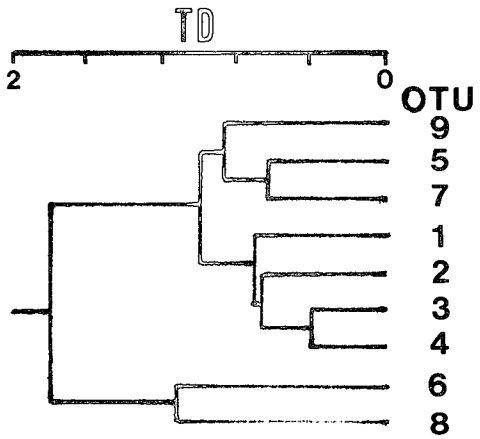

Fig. 4. Grouping of nine OTUs in three subspecies of *Apodemus peninsulae* from China and Korea by average linkage cluster analysis with taxonomic distances (TD).

Jones (1956) reported that *A. peninsulae* is distinct from *A. spesiosus* and he recognized a new subspecies, *A. peninsulae sowerbyi*, from central China, because it is smaller in its external and cranial characters than *A. peninsulae peninsulae* from Korea. However, he did not describe the exact distributional range of subspecies *sowerbyi*. Xia (1985) noted that distributional range of subspecies *A. peninsulae praetor* in China is three provinces of northeastern China and eastern Inner Mongolia and that of subspecies *sowerbyi* is northern China and eastern part of northwest China. In this paper with 219 samples of *A. peninsulae* in China and Korea (see Figs. 2, 3, and 4), the large-size form was composed of subspecies *praetor* (OTU 5) from Inner Mongolia and subspecies *sowerbyi* (OTUs 7 and 9) from Sanxi and Sandong, indicating that samples from Inner Mongolia might not be subspecies *praetor*, but subspecies *sowerbyi*.

Jones (1956) noted that Beijing samples of *A. peninsulae sowerbyi* were somewhat similar with subspecies *praetor* in their pelage colour. In this paper with *A. peninsulae* from nine OTUs from China and Korea, the samples from Beijing (OTU 8) were the middle-size form, whereas samples from Sanxi and Sandong (OTUs 7 and 9) were the large-size form, indicating that Beijing samples are also somewhat distinct in their morphology from other samples of subspecies *sowerbyi*.

Jones (1956) also stated that the western limits of the geographic range of *A. peninsulae* are unknown, but Xia (1985) described that the distributional range of subspecies *sowerbyi* is northern China and eastern part of northwestern China. In the present paper, samples from Xinjiang (OTU 6) in northwestern China are the small-size form, indicating that Xinjiang samples are different in their morphology from other samples of *sowerbyi*.

Corbet (1978) summarized eight subspecies (*peninsulae, major, majusculus, praetor, rufulus, tscherga, sowerbyi*, and *giliacus*) of *A. peninsulae* into three subspecies (*peninsulae* including *praetor* and other four subspecies, *sowerbyi*, and *giliacus*). However, three subspecies (*praetor, sowerbyi*, and *qinghaiensis*) were recognized in *A. peninsulae* in China (Xia, 1985). Koh and Lee (1994) analyzed 79 samples of *A. peninsulae* from nine OTUs in eastern Asia and noted that subspecies *sowerbyi* is smaller than subspecies *peninsulae*, and that two subspecies (*peninsulae* and *sowerbyi*) can be recognized in the Asian continent. In this paper with 219 samples of *A. peninsulae* from nine OTUs from China and Korea, it is reconfirmed that subspecies *sowerbyi* is smaller than subspecies *peninsulae*, but they are so heterogenous as to be recognized into three size-forms, large-, middle-, and small-size forms, as mentioned above. Kobayashi (1985) also noted that "there still remains the important question that either Vorontsov's *peninsulae* is homologous with the Thomas's *peninsulae*, or he made a mistake in terms of the international naming code." Therefore, morphometric analyses with additional samples of *A. peninsulae* from China and Russia are necessary to solve the taxonomy of this species.

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중국과 한국에 서식하는 흰넓적다리붉은쥐, *Apodemus peninsulae* Thomas (포유강, 설치목), 3아종의 형태적 형질의 변이

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적 요

중국과 한국에 서식하는 흰넓적다리붉은쥐(*Apodemus peninsulae*) 3아종의 표본들의 4개 외부형질과 27개 두골형질들을 다변량통계 방법으로 분석하였다. 4개 형(form)으로 나뉘어졌는데, 한국의 월악산과 연천의 아종 *peninsulae*와 중국의 길림과 흑룡성의 아종 *praetor*는 가장 큰 형이며, 중국 내몽고의 아종 *praetor*와 중국 산서와 산동성의 아종 *sowerbyi*는 큰 형이고, 중국 북경의 아종 *sowerbyi*는 중간 형이며, 중국 신강성의 아종 *sowerbyi*는 작은 형이었다.

Corbet(1978)는 아시아 대륙내의 흰넓적다리붉은쥐의 분포범위에서는 2아종(*peninsulae* and *sowerbyi*)으로 분류된다고 하였지만, 형태적 형질을 이용한 본 연구에서 아종 *praetor*와 *peninsulae*가 큰 형이었고, 아종 *sowerbyi*는 3개의 형태로 나뉠 정도로 다양했으므로, 단지 2아종으로만 분류할 수가 없음이 밝혀졌다. 중국과 러시아의 다른 표본들을 포함한 계속되는 연구가 본 종의 확실한 분류의 완성을 위해서 필요하다.