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Morphometric Variation of Six Subspecies of Striped Field Mouse, *Apodemus agrarius* Pallas (Mammalia, Rodentia), from China and Korea

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Four external and 27 cranial characters of striped field mice (*Apodemus agrarius*) from 16 regions in China and Korea, representing six subspecies, were analyzed by multivariate methods. Three subgroups were recognized: the large-size form from Cheju island, Korea (subspecies *chejuensis*), the middle-size form from the Korean peninsula (subspecies *coreae*), and the small-size form from China (subspecies *manchuricus, pallidior, ningpoensis, insulaemus*). It was confirmed that four subspecies of striped field mouse from China can be classified into subspecies *ningpoensis*, as noted by Corbet (1978), and that subspecies *coreae* and *chejuensis* are distinct subspecies, as stated by Jones and Johnson (1965). In the future, morphometric analyses with striped field mice from Europe and Russia will be necessary to confirm subspecies classification of *A. agrarius agrarius*.

The genus *Apodemus*, composed of 11 species, is confined to the Palaearctic Region: striped field mice, *A. agrarius* Pallas 1771, inhabit from Germany through China to Korea (Corbet and Hill, 1986). Corbet (1978) noted that most subspecies of *A. agrarius* were designated by the differences in pelage colour or body size, and summarized 24 nominal subspecies into three subspecies (*agrarius*, a western subspecies including 12 named subspecies; *ningpoensis*, an eastern subspecies including *manchuricus, pallidior, insulaemus* in China, *coreae and chejuensis* in Korea, and three other named subspecies; *chevrieri*, a southern Chinese subspecies including one named subspecies). From the analyses of penile bones, papilla lingulis, and serum proteins of striped field mouse, Wang (1985) concluded that subspecies *chevrieri* is a distinct species. The subspecies classification of *A. agrarius*, however, is still in confusion, as noted by Kobayashi (1985).

In the morphometric analyses with eight subspecies of striped field mouse from Asia, including 48 samples of the four known subspecies in China (Koh, 1991), four major subgroups were revealed: 1) *chejuensis*, 2) *chevrieri*, 3) *coreae*, 4) five other subspecies including *manchuricus, pallidior, ningpoensis, insulaemus, and agrarius*. In the analyses with mtDNA fragment patterns of the two subspecies of *A. agrarius* in Korea, subspecies *chejuensis* appeared to be distinct from subspecies *coreae* (Koh and Yoo, 1992). Moreover, mtDNA genotypes of *A. agrarius pallidior*, based on restriction fragments, seemed to be different from that of *A. agrarius coreae* (Wang and Koh, 1996).

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 the infraspecific level.

The objective of this paper is to analyze morphometric characters of six subspecies of *Apodemus agrarius* from China and Korea, including 196 samples of four subspecies from ten regions of China, in order to determine their subspecific status.

Materials and Methods

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 418 samples of young and middle-aged adults of *A. agrarius* from 16 regions in China and Korea, representing six subspecies, were analyzed as shown in Table 1 and Fig. 1.

Four external and 27 cranial characters were measured (for details see Koh, 1983) and samples 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 the SPSS/pc+ program. Discriminant and cluster analyses were also performed by subpro-

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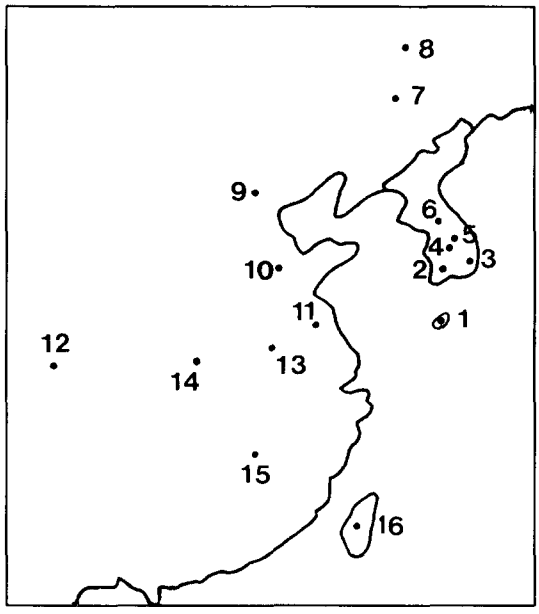

Fig. 1. A map showing 16 OTUs of samples in six subspecies of *Apodemus agrarius* from China and Korea. The subspecies name, locality, and number of samples in each OTU are given in Table 1.

grams DISCRIMINANT and CLUSTER of SPSS/pc+, respectively. Principal component analysis was carried out using subprograms EIGEN and PROJ of the NTSYS/pc program. Minimum spanning tree was also produced by subprogram MST of NTSYS/pc.

Results

Two dimensional plottings from discriminant analysis with 16 OTUs in six subspecies of *Apodemus agrarius* are shown in Fig. 2 (numerals indicate centroids of OTUs and minimum spanning tree is superimposed on the plots). Functions I, II, and III represented 56, 29, and 15 percent of the variance, respectively (100 percent in total). Three subgroups were revealed: the large-size form (OTU 1), the middle-size form (OTUs 2, 3, 4, 5, and 6), and small-size form (OTUs 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16).

Two dimensional configurations of 16 OTUs of *A. agrarius* by principal component analysis are shown in Fig. 3 (minimum spanning tree is superimposed on the plots). Factors I, II, and III represented 66, 12, and 5 percent of the variance, respectively (83 percent in total). Three subgroups were recognized, as revealed by discriminant analysis mentioned above. Sixteen OTUs of *A. agrarius* were also grouped by cluster analysis of average linkage with taxonomic distances, as shown in Fig. 4. Three subgroups mentioned above were also revealed.

In summary, three subgroups were recognized: the large-size form from Cheju island, Korea (subspecies *chejuensis*, OTU 1), the middle-size form from the Korean peninsula (subspecies *coreae*, OTUs 2, 3, 4, 5, and 6), and the small-size form from China (subspecies *manchuricus*, OTUs 7 and 8; subspecies *pallidior*, OTUs 9, 10, 11, and 12; subspecies *ningpoensis*, OTUs 13, 14, and 15; subspecies *insulaemus*, OTU 16).

Table 1. Specimens of six subspecies of striped field mouse, *Apodemus agrarius*, from China and Korea

Subspecies	Locality	No. of Samples	OTU
A.a. chejuensis	Cheju, Korea	45	1
A.a. coreae	Mt. Chiri, Korea	30	2
"	Mt. Palgong, Korea	13	3
"	Cheongju, Korea	89	4
"	Mt. Weolak, Korea	35	5
"	Yeonchon, Korea	10	6
A.a. manchuricus	Kirin, China	40	7
"	Heilung, China	17	8
A.a. pallidior	Hopeh, China	19	9
"	Sandong, China	29	10
"	N. Jiangsu, China	11	11
"	Sichuan, China	22	12
A.a. ningpoensis	Anhui, China	10	13
"	Hupeh, China	26	14
"	Kiangsi, China	14	15
A.a. insulaemus	Taipei, Taiwan	8	16
		418	

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 analysis ordinates two or more a priori defined groups as that there is minimum overlap and maximum separation among them (Thorpe, 1981), whereas PCA makes no assumption about the existence 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 appropriate. In this paper based on discriminant analysis (Fig. 2), PCA (Fig. 3), and cluster analysis (Fig. 4) with morphometric characters, three subgroups were recognized; the large-size form (OTU 1), the middle-size form (OTUs 2, 3, 4, 5, and 6), and the small-size form (OTUs 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16).

Thomas (1908) distinguished four subspecies of *Apodemus agrairus* in China and Korea mainly based on the dorsal stripe. Kobayashi (1985) noted that it is necessary to reexamine the subspecies classification of striped field mice, *Apodemus agrarius*, which is widely distributed in Eurasia. In China, five subspecies of *A. agrarius* are recognized (Xia, 1984): *agrarius* from Omin, Tacheong, and northern Xinjiang; *manchuricus from* northeastern China and

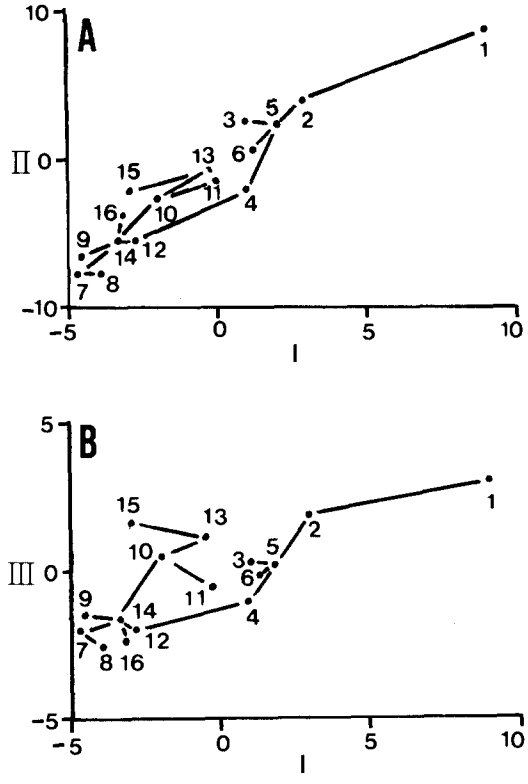

Fig. 2. Plotting of 16 OTUs in six subspecies of *Apodemus agrarius* from China and Korea by discriminant analysis. Numerals indicate the group centroid and minimum spanning tree is superimposed on the plots. A, OTUs ordinated with function I vs. function II. B, OTUs ordinated with function I vs. function III.

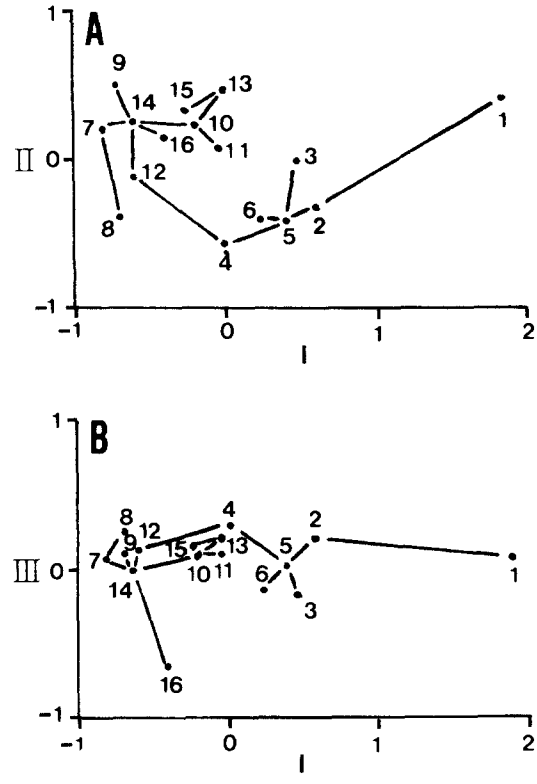

Fig. 3. Plotting of 16 OTUs in six subspecies of *Apodemus agrarius* from China and Korea by principal component analysis. Numerals indicate OTUs. Minimum spanning tree is superimposed on the projections. A, OTUs ordinated with factor I vs. factor II. B, OTUs ordinated with factor I vs. factor III.

eastern Inner Mongolia; *pallidior* from northern China, eastern part of northwestern China, Sichuan, and northern Jiangsu; *ningpoensis* from middle and lower part of Yangtze Valley, Guizhou, and northern Fujian; *insulaemus* from Taiwan. Zhao and Lu (1986) analyzed biochemical characters of samples in two subspecies of striped field mice from Sandong, Jiangsu, and Anhui provinces and concluded that *A. agrarius pallidior* from Sandong is distinct from *A. agrarius ningpoensis* from Jiangsu and Anhui provinces. Based on the comparison of black dorsal stripe and colour of their dorsal hair, Liu et al. (1991) noted that subspecies *pallidior* from northern part of its distribution is the synonym of *manchuricus* and that subspecies *pallidior* from southern part of its distribution is the synonym of *ningpoensis*. Corbet (1978) summarized subspecies *manchuricus*, *pallidior*, *ningpoensis*, *insulaemus*, and three other named subspecies of *A. agrarius* in China into a eastern subspecies *ningpoensis*, and Koh (1991) stated that the small-size form is composed of five subspecies (*manchuricus*, *pallidior*, *ningpoensis*, *insulaemus*, and *agrarius*) in their morphological characters. In this paper with morphometric analyses (see Figs. 2, 3, and 4), the small-size form is composed of OTUs 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16 (subspecies *manchuricus*, *pallidior*, *ningpoensis*, and *insulaemus* in China), indicating that four subspecies of striped field mice from China can be summarized into subspecies *ningpoensis*, as noted by Corbet (1978).

In Korea, Jones and Johnson (1965) reported four subspecies of *A. agrarius*: *manchuricus* in the extreme northern part, *pallescence* in the coastal lowlands of southern and southwestern Korea, *coreae* throughout the major portion of the peninsula, and *chejuensis* in Cheju island. They also noted that *A. agrarius chejuensis* is larger, both externally and cranially, than any other described subspecies of *A. agrairus* and is easily distingushed from the other known subspecies, although Corbet (1978) stated that the insular form from Cheju island (subspecies *chejuensis*) is rather large but is not very distinctive. In morphometric analyses, Koh (1986) concluded that *A. agrarius pallescence* is the synonym of *A. agrarius coreae*. Koh (1987 and 1989) stated that *A. agrarius chejuensis* (large-size form) is distinct from *A. agrarius coreae*. Moreover, *A. agrarius coreae* (middle-size form) is also different from other five subspecies (small-size form) from China and Turkey,

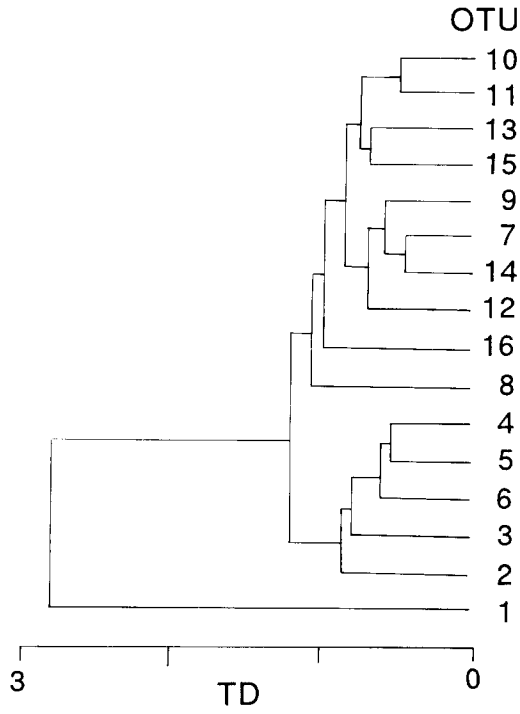

Fig. 4. Grouping of 16 OTUs in six subspecies of *Apodemus agrarius* from China and Korea by cluster analysis of average linkage with taxonomic distances (TD).

i.e. *manchuricus, pallidior, ningpoensis, insulaemus*, and *agrarius* (Koh, 1991). In these morphometric analyses (see Figs. 2, 3, and 4), large- and middle-size forms among three size-forms are subspecies *chejuensis* and *coreae*, respectively, and it is confirmed that subspecies *coreae* and *chejuensis* are distinct subspecies, as noted by Jones and Johnson (1965). Koh (1982, 1987) noted that the karyotype, i.e., diploid number of 48 (38 acrocentric autosomes, four pairs of small metacentric autosomes, large acrocentric X chromosome, and small acrocentric Y chromosome) of *A. agrarius coreae* and *A. agrarius chejuensis* is the same. Wang et al. (1993) reported that the karyotype of *Apodemus agrarius pallidior* is eight metacentric and 38 telocentric autosomes with large telocentric X and small telocentic Y chromosomes, indicating that in chromosomal karyotype, subspecies *pallidior* is identical with subspecies *coreae* and *chejuensis*.

However, in the analyses of mtDNA restriction fragment patterns with in the two subspecies of *Apodemus agrarius* from Korea, subspecies *chejuensis* differed from subspecies *coreae* (Koh and Yoo, 1992). In mtDNA analyses of two subspecies of *A. agrarius* from China and Korea, subspecies *pallidior* from China and *coreae* from Korea are different in their mtDNA genotypes with each other (Wang and Koh, 1996), indicating that these three subspecies are different in their mtDNA genotyes.

Developments in the areas of molecular, cyto-, and numerical taxonomy are enormous (Quicke, 1993) and there has been a conflict between molecular biologists and morphologists about the merits of their data (Ferguson, 1980). But modern molecular techniques have not yet pushed comparative morphology into the shadows (Patterson, 1987). It was advocated that a classification should be the product of all available characters distributed as widely and evenly as possible over the organisms studied (Mayr and Ashlock, 1991; Huelsenbeck et al., 1996).

Corbet (1978) stated that the western form (subspecies *agrarius*) and the eastern form (subspecies *ningpoensis*) in *A. agrarius* are not clearly differentiated. Koh (1991) also noted that subspecies *agrarius* is not different from those of subspecies *ningpoensis* in their morphometric characters, i.e. they were small-size form. In the future, morphometric analyses with striped field mice from Europe and Russia will be necessary especially to confirm subspecies classification of *Apodemus agrarius agrarius*.

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