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Author(s)	Ohdachi, S. D.; Abe, H.; Oh, H. S.; Han, S. H.
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Original investigation

Morphological relationships among populations in the <u>Sorex caecutiens/shinto</u> group (Eulipotyphla, Soricidae) in East Asia, with a description of a new subspecies from Cheju Island, Korea

By S. D. OHDACHI, H. ABE, H. S. OH and S. H. HAN

Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan; Department of Science Education, Cheju National University, Jeju, Republic of Korea; Asiatic Black Bear Management Team, National Parks Authority, Republic of Korea

Abstract

We investigated the morphological relationships among 8 populations of <u>Sorex</u> <u>caecutiens/shinto</u> group in East Asia using 11 cranial and dental characters and four external characters. Univariate and multivariate analyses of these characters failed to distinguish <u>S. caecutiens</u> and <u>S. shinto</u>. Morphological characters were, in fact, continuous between populations. <u>Sorex shinto</u> from Honshu was similar to <u>S.</u> <u>caecutiens</u> from the Korean peninsula and Primorye in skull dimensions and to <u>S.</u> <u>caecutiens</u> from Hokkaido-Sakhalin in external dimensions. <u>Sorex caecutiens</u> from Cheju Island is morphologically similar to <u>S. shinto</u> from Sado and Shikoku islands. These three insular populations were characterized by having large body size. <u>Sorex</u> <u>caecutiens</u> from Cheju was the largest of the <u>S. caecutiens/shinto</u> group in East Asia. This shrew from Cheju was classified definitively as <u>S. caecutiens</u> on DNA data but has a unique morphology among <u>S. caecutiens</u> populations in East Asia. We therefore regard this <u>Sorex</u> shrew on Cheju Island as a new subspecies of <u>S.</u> <u>caecutiens</u> and designate it <u>S. c. hallamontanus</u> ABE et OH.

Key words: Sorex caecutiens hallamontanus, Cheju, Korea, geographic variation

Introduction

Sorex caecutiens LAXMANN, 1788 and S. shinto THOMAS, 1905 are closely related and form the monophyletic Sorex caecutiens/shinto group (OHDACHI et al. 1997, 2001). The taxonomic position assigned to populations of this group has changed repeatedly since the initial description of S. shinto (THOMAS 1907) from Honshu, Japan. And the taxonomic status of local populations in the Japanese Islands and their vicinity has varied greatly among researchers (DOKUCHAEV et al. 2000). A major cause for the taxonomic debates around the <u>S. caecutiens/shinto</u> group is the difficulty of interpretating the morphological relationships among populations (DOKUCHAEV et al. 1999; HUTTERER and ZAITSEV 2004). It is now widely accepted, however, that S. <u>caecutiens</u> and <u>S</u>. <u>shinto</u> are two separate, though closely related, species, on the basis of genetic investigations of Sorex phylogeny (GEORGE 1988; OHDACHI et al. 1997; FUMAGALLI et al. 1999; NAITOH et al. 2005). In addition, DNA analyses indicate that S. caecutiens occurs on the Eurasian Continent, Sakhalin, Hokkaido, and neighboring small islands whereas S. shinto is distributed in Honshu, Shikoku, and Sado in the southern parts of the Japanese Islands (Fig. 1) (OHDACHI et al. 2001, 2003; NAITOH et al 2005). Furthermore, specimens from Cheju island are clearly assignable to <u>S. caecutiens</u> according to mitochondrial DNA, cytochrome <u>b</u> (mtDNA cytb) (OHDACHI et al. 2003, 2005), and nuclear ribosomal RNA (NAITOH et al. 2005). However, this assignment has not yet been formally described by any conventional protocol

After we obtained phylogenetic information of the <u>S. caecutiens/shinto</u> group, we investigated the morphological relationships among populations and species of the <u>S. caecutiens/shinto</u> group, especially in East Asia, to assess morphological variation among them. DOKUCHAEV et al. (1999) studied morphological variation among all subspecies (ssp. <u>shinto</u>, <u>shikokensis</u>, and <u>sadonis</u>) of <u>S. shinto</u>, and <u>S. caecutiens</u> in Hokkaido and found that there was a significant difference between the two species. However, they did not analyse <u>S. caecutiens</u> samples from Sakhalin, mainland Eurasia, the Korean peninsula, and Cheju Island.

The aim of this study therefore was to investigate morphological variation among samples of <u>S. shinto</u> from Honshu, Shikoku, and Sado and of <u>S. caecutiens</u> from Hokkaido, Sakhalin, Primorye, the Korean peninsula, and Cheju. We compared the morphological relationships with the phylogenetic groups reported in earlier molecular investigations. In addition, we name the <u>Sorex</u> population from Cheju Island by a traditional protocol based on morphology.

Material and methods

We examined six individuals from southern Sakhalin, 36 from Hokkaido, 13 from Primorye (Ussuri region), seven from the southern Korean peninsula, 11 from Cheju Island for <u>S. caecutiens</u>, and 37 individuals from Honshu, two from Sado, and eight from Shikoku for <u>S. shinto</u> (Fig. 1, Tab. 1). Of the 11 specimens from Cheju, the first six specimens were captured from elevated sites on Mt. Halla (elevation 1,100-1,300 m) between 15th and 17th August 1994 (by HSO). The other five were collected from nearby sites in 1999 (by SDO & colleagues). Specimens were young-of-the year, with one exception, to control for morphological differences

between young (immature) and adult (overwintered) shrews. The exception was one specimen from Shikoku that had overwintered and is the type specimen of <u>S. shinto</u> <u>shikokensis</u> (specimen code, HA1212 = NHM13311). In general, the body size of young soricine shrews shows little age difference until just before sexual maturity. Data from both sexes were pooled because a preliminary investigation showed no significant sexual differences in cranial and external dimensions for young-of-the year in the <u>S. caecutiens/shinto</u> group.

Four external (e.g., ABE et al. 1994) and 11 cranial and dental dimensions (Fig. 2) were measured and recorded. The external measures were body mass (measured to the nearest 0.1 g), head and body length (total length minus tail length, both measured to the nearest 0.5 mm), and hind foot length (to the nearest 0.1 mm). Cranial characters were measured using digital vernier calipers to the nearest 0.01 mm. The dental traits were measured by use of an ocular micrometer mounted in a binocular microscope.

Multivariate principal component analysis (PCA) and cluster analysis using external, cranial, and dental characters were carried out using JMP V. 5.0.1J (SAS Institute Inc.).

Results

Cranial and dental characters and PCA

Cranial characters of <u>S. caecutiens</u> from Cheju Island tended to be significantly larger among all shrew populations examined (Tab. 2). <u>Sorex</u> <u>caecutiens</u> from the Korean peninsula and Primorye, and <u>S. shinto</u> in Honshu, tended to be smaller than the other populations of the <u>S. caecutiens/shinto</u> group. Except for

<u>S. caecutiens</u> in Cheju, there are no clear differences in cranial size between <u>S.</u> <u>caecutiens</u> and <u>S. shinto</u> at the species level (Tab. 2). <u>Sorex shinto</u> from Sado and Shikoku have large skulls although sample sizes were small (this finding was supported in a preliminary investigation with more samples including adult individuals).

Relative basal width of Pm^4 mesostyle of <u>S. caecutiens</u> from Cheju was significantly narrower than in individuals from other populations of <u>S. caecutiens</u> and was not significantly different from individuals in any populations of <u>S. shinto</u> (Tab. 2). <u>Sorex shinto</u> from all localities, and <u>S. caecutiens</u> in Hokkaido, Sakhalin, and Primorye, were completely separated from each other by the relative basal width of Pm^4 mesostyle of 58.9% (Fig. 3). However, some samples of <u>S. caecutiens</u> from the Korean peninsula had relative basal width of Pm^4 mesostyle values less than 58.9%.

Within <u>S. caecutiens</u>, the relative basal width of Pm^4 mesostyle showed a continuous cline from the narrowest in Cheju individuals to widest in Hokkaido and Sakhalin individuals. Individuals from the Korean peninsula and Primorye populations were intermediate (Fig. 3). In addition, there was a positive correlation between the greatest skull length and relative basal width of Pm^4 mesostyle in <u>S. caecutiens</u> except for population on Cheju Island (Spearman rank correlation, P = 0.0002). This showed clinal change from individuals on the Korean peninsula, via Primorye and Hokkaido, to Sakhalin (Fig. 3). However, Cheju individuals did not fit this cline because of their unexpectedly large skulls (Fig. 3). Thus, the shrews from Cheju Island were morphometrically unique because of the the relationship

between greatest skull length and relative basal width of Pm^4 mesostyle within <u>S</u>. <u>caecutiens</u>.

Principal component analysis (PCA) based on 11 cranial and dental characters showed that the combined contribution of the first and second principal components (PCs) was 76.2% (Tab. 3). Thus, PC1 and PC2 explained a large part of the morphological variation among the populations. For PC1, all cranial characters had positive eigenvectors but relative basal width of Pm⁴ mesostyle showed a minor negative value (Tab. 3). For PC2, cranial characters indicated both positive and negative eigenvectors, and the relative basal width of Pm⁴ mesostyle and upper unicupsid row length showed large positive eigenvectors. Thus, as in the general trend, PC1 represents mainly size whereas PC2 axis represents predominantly shape.

There was no clear demarcation between <u>S. caecutiens</u> and <u>S. shinto</u> in the two-dimensional scattergram of PC1 and PC2 (Fig. 4-A). Shrews in Cheju were located in an area of large PC1 and small PC2 values. Along the PC1 axis, there was a ascending cline from <u>S. shinto</u> in Honshu, <u>S. shinto</u> in Shikoku and Sado, to <u>S. caecutiens</u> in Cheju (Fig. 4-A). Populations of <u>S. caecutiens</u> in Sakhalin and Hokkaido tended to have large PC2 values. In addition, PC2 values changed continuously in ascending order from <u>S. shinto</u> in Honshu, <u>S. caecutiens</u> in Sakhalin.

External characters and PCA

Shrews from smaller islands, such as Cheju, Sado and Shikoku, tended to have greater body mass and head and body length, regardless of species (Tab. 4).

<u>Sorex caecutiens</u> from Primorye tended to have smaller external characters, especially tail length.

The combined contribution of PC1 and PC2 was 72.5% in PCA based on four external characters (Tab. 5), and PC1 and PC2 can explain a large part of the morphological variations. All of the eigenvectors of the four traits were positive for PC1 (Tab. 5). For PC2, body mass and head and body length showed negative eigenvectors and tail length had a large positive eigenvector. Thus, PC1 represents a size dimension and PC2 a shape dimension. A shrew with larger value of PC2 is inferred to have a longer tail relative to body mass and length.

There was no clear demarcation between <u>S. caecutiens</u> and <u>S. shinto</u> in the two-dimensional scattergram of PC1 and PC2 (Fig. 4-B). <u>Sorex caecutiens</u> in Primorye tended to have small PC1 values with small PC2 values whereas <u>S. caecutiens</u> in Cheju tended to have large PC1 values with small PC2 values. Shrews from the other populations had intermediate PC1 values with no clear demarcation among them. However, <u>S. shinto</u> in Honshu tended to have large PC2 values and <u>S. caecutiens</u> from the Korean peninsula small PC2 values (Fig. 4-B).

Cluster analysis

Cluster analysis based on 11 cranial and dental characters showed the morphological similarity between <u>S. shinto</u> from Sado and Sikoku islands and <u>S.</u> <u>caecutiens</u> from Cheju Island (Fig. 5-A). <u>Sorex caecutiens</u> from Hokkaido and Sakhalin formed one cluster, as did <u>S. caecutiens</u> from the Korean peninsula and Primorye. <u>Sorex shinto</u> from Honshu was closest to the Korea and Primorye clusters (Fig. 5-A). Based on four external characters, <u>S. shinto</u> from Shikoku and Sado and <u>S. caecutiens</u> from Cheju formed a cluster (Fig. 5-B). As in the cluster analysis of cranial and dental characters, <u>S. caecutiens</u> from Hokkaido and Sakhalin and those from the Korean peninsula and Primorye formed distinct clusters (Fig. 5-B). Unlike the cranial and dental analysis, <u>S. shinto</u> from Honshu was more closely related to the cluster of <u>S. caecutiens</u> from Hokkaido and Sakhalin.

Discussion

DOKUCHAEV et al. (1999) demonstrated that <u>S. caecutiens</u> from Hokkaido and <u>S. shinto</u> could be distinguished from each other based on cranial and dental characters. Relative basal width of the mesostyle of the upper fourth premolar was the most effective indicator to distinguish between <u>S. caecutiens</u> in Hokkaido and <u>S. shinto</u>. The former had higher values of relative basal width of Pm⁴ mesostyle and the latter had lower values. We also showed that <u>S. caecutiens</u> from Hokkaido and <u>S. shinto</u> were completely separated at the 58.9% level of relative basal width of Pm⁴ mesostyle. However, we demonstrated that relative basal width of Pm⁴ mesostyle could not completely distinguish between <u>S. caecutiens</u> and <u>S. shinto</u>. This <u>was</u> because the values for all individuals of <u>S. caecutiens</u> from Cheju and some from the Korean peninsula were below the criterial value of 58.9%, although the values showed a clinal change within <u>S. caecutiens</u>.

Both principal component analyses and cluster analyses demonstrated that <u>S. caecutiens</u> and <u>S. shinto</u> are morphologically indistinguishable. Morphological differences are continuous among the eight populations of the <u>S. caecutiens/shinto</u>

group in East Asia, but the cline is not always in concordance with geographical gradients such as latitude. Thus, morphological relationships among the eight populations were so complex that S. caecutiens and S. shinto could not be separated completely from each other. Because of the difficulty in interpretation of morphological data for these two species, several opinions as to the taxonomic status of the S. caecutiens/shinto group had been proposed (see introduction of DOKUCHAEV et al. 1999) before genetic investigations clarified the phylogenetical relationships between S. caecutiens and S. shinto. (GEORGE 1988; OHDACHI et al. 1997; FUMAGALLI et al. 1999; NAITOH et al. 2005; OHDACHI 2005). Our study also shows the difficulty of using morphometrics to distinguish S. caecutiens and S. shinto. DOLGOV (1985) reported a clinal change in cranial size for S. caecutiens within the former U.S.S.R. and demonstrated that there was a great deal of morphological variation. To fully understand the morphological relationships between S. caecutiens and S. shinto, we need to examine samples of S. caecutiens from throughout its distribution from the northern Kuril Islands and the Chukot peninsula, Central Siberia, to Fennoscandia.

It is worth noting that morphological variation based on skull and external measures is great among populations of <u>S. caecutiens</u> from the Eurasian continent and Sakhalin, whereas there is little genetic differentiation among these populations based on mtDNA <u>cytb</u> sequences (OHDACHI et al. 2001, 2003; OHDACHI 2005) and restriction fragment length polymorphism (RFLP) of the nuclear ribosomal RNA (NAITOH et al. 2005). This may imply that morphological change among populations of <u>S. caecutiens</u> is faster than their genetic change.

Sorex caecutiens on Cheju Island has the largest body size among shrews of the <u>S. caecutiens/shinto</u> group in East Asia. Not only <u>S. caecutiens</u> on Cheju Island, but also <u>S. shinto</u> from Shikoku and Sado islands had large body size. These three islands are small and isolated. Additionally, <u>S. caecutiens</u> from two small islands in the northern Kuril Islands also showed larger body size than their mainland counterparts from the nearby Kamchatka Peninsula (VORONOV 1974; OKHOTINA 1993). In general, individuals of insular populations of small mammal species tend to have larger bodies than their mainland counterpart (e.g., FOSTER 1964; LOMOLINO 1985; DAMUTH 1993). This phenomenon is called the "island rule". Thus, morphological similarity among the three shrew populations from small offshore islands in the present study may be the result of convergence related to their insular habitats.

The diploid chromosome number (2n) of the <u>S. caecutiens/shinto</u> group is 42 and diploid number of chromosomal arms (NF) 70 (or 68) (ZIMA et al. 1998). <u>Sorex caecutiens</u> from Cheju also shows the same numbers (2n, NF) as in the other populations of the <u>S. caecutiens/shinto</u> group (OSHIDA et al. 2005). However, the banding pattern of chromosomes in <u>S. caecutiens</u> from Cheju is similar to that of <u>S. shinto</u> rather than to that of <u>S. caecutiens</u> from Hokkaido and, probably, that of <u>S. caecutiens</u> from the Eurasian Continent (OSHIDA et al. 2005). Thus, as with the morphological analyses, it is difficult to separate <u>S. caecutiens</u> from <u>S. shinto</u> on the basis of conventional karyological analyses.

Based on mtDNA <u>cytb</u> gene sequences (OHDACHI et al. 2003; OHDACHI 2005) and RFLP of nuclear ribosomal RNA gene spacer region (NAITOH et al. 2005), it is known that shrews from Cheju Island are members of the

species <u>S. caecutiens</u>. However, in the present morphological analyses, <u>S. caecutiens</u> from Cheju not only was morphologically more like <u>S. shinto</u> from Shikoku and Sado islands, based on their large body (skull) size, and its morphological status was unique among populations of <u>S. caecutiens</u> in East Asia. Thus, we give a new subspecies rank to <u>S. caecutiens</u> on Cheju Island in the next section.

Description of a new subspecies from Cheju Island

Sorex caecutiens hallamontanus ABE et OH, ssp. nov.

Holotype: subadult male, skin and skull, collected at an altitude of 1000 m (N33° 20.628', E126° 27.493') of Mt. Halla, Cheju Island, Republic of Korea by S. D. OHDACHI on 13th October 1999. The collector's number is SO-99/10/13-3 (Fig. 6). The holotype is preserved in Institute of Low Temperature Science, Hokkaido University, Japan.

Measurements of holotype (in mm except for body mass): Head and body 71, tail 47, hind foot (without claw) 12.7, ear 7, body mass 7.9 g, greatest length of skull 19.10, palatal length 8.32, width of braincase 9.10, length of braincase 8.81, width across molars 4.62, least interorbital constriction 3.67, width of rostrum 1.92, length of upper unicuspid row 2.80, length between Pm^4 and M^3 4.74, width across glenoids 5.22, relative basal width of Pm^4 mesostyle 56.7%, and length of mandible (see ABE 1967 for definition of this measurement) 9.74.

Diagnosis: A large-sized <u>S. caecutiens</u> with very small values (range, 54.0-56.7%) in relative basal width of Pm⁴ mesostyle, long upper unicuspid row, slender braincase, and broad palatal portion at molar rows (see Tab. 2 for means and

standard deviations of those characters). Skull larger than any of the northeastern Asiatic continental, Hokkaido, and Sakhalin populations of <u>S. caecutiens</u> and those of <u>S. shinto</u> (95% lower and upper limits of the greatest length of skull are 18.78 and 19.15 mm, respectively).

Description: Size moderately large (Tabs. 1 and 3). Ears as usual. Tail longer than those of the Korean peninsula and Ussuri populations, but shorter than those of Hokkaido and Sakhalin populations. Hind foot larger than those in the Korean peninsula, Ussuri, and Sakhalin populations, but close to that in Hokkaido population. Summer pelage of subadult, back light bister, paler than other local forms, underparts light drab. The demarcation along sides not conspicuous. Tail bicolored, concolor with back above, light drab below. Back of feet light brown.

Skull very large, robust but rather slender. Facial portion massive. Posterior margin of nare extends to the middle or posterior end of 4th unicuspid. Mandible large and massive. The overall shape similar to that of the largest local form of <u>S</u>. <u>shinto</u>, i.e. <u>S</u>. <u>s. sadonis</u> on Sado Island. However, as indicated in the previous sections, it is quite difficult to distinguish these two shrews based only on morphometry although skull is a little more slender in <u>S</u>. <u>c</u>. <u>hallamontanus</u> than <u>S</u>. <u>s. sadonis</u>. <u>Furthermore, S</u>. <u>c</u>. <u>hallamontanus</u> occurs only on Cheju Island whereas <u>S</u>. <u>s. sadonis</u> occurs on Sado Island.

Tooth pigmentation as usual. When viewed from side, size of unicuspid gradually diminishing from 1st to 4th, 5th much smaller than 4th (Fig. 6). Relative basal width of Pm^4 mesostyle small, i.e. smaller than that of the Korean peninsula population, but equal to that of <u>S. shinto</u>.

Etymology: The subspecific name is derived from the type locality, Mt. Halla which is the central mountain (alt. 1950 m) of Cheju Island.

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Zusammenfassung

Morphologische Beziehungen zwischen Populationen der <u>Sorex caecutiens/shinto</u> Gruppe (Eulipotyphla, Sorididae) in Ostasien mit einer Beschreibung einer neuen Unterart von der Cheju Insel, Korea.

Basierend auf 11 Schädel- und Zahnmerkmalen sowie vier Körpermerkmalen wurden die morphologischen Beziehungen zwischen 8 Populationen der <u>Sorex</u> <u>caecutiens/shinto</u>-Gruppe untersucht. Gemäss univariaten und multivariaten Analysen dieser Merkmale sind <u>S. caecutiens</u> und S. <u>shinto</u> morphologisch nicht unterscheidbar. Die morphologischen Unterschiede zwischen den Populationen der <u>Sorex caecutiens/shinto</u>-Gruppe gehen vielmehr progressiv ineinander über. Ähnlichkeiten bestehen zwischen <u>Sorex shinto</u> von Honshu und <u>S. caecutiens</u> von

der koreanischen Halbinsel und Primorye betreffend Schädelmasse und zu <u>S.</u> <u>caecutiens</u> von Hokkaido-Sakhalin betreffend Körpermasse. <u>Sorex caecutiens</u> von der Cheju Insel gleicht morphologisch S. <u>shinto</u> der Sado und Shikoku Inseln. Die drei Inselpopulationen sind durch ihre außerordentliche Körpergröße charakterisiert; <u>S. caecutiens</u> der Cheju Insel ist denn auch die größte Spitzmaus der <u>Sorex</u> <u>caecutiens/shinto</u>-Gruppe in Ostasien. Basierend auf Analysen von DNA-Sequenzen gehören die Spitzmäuse der Cheju Insel eindeutig zu <u>S. caecutiens</u>; sie weisen allerdings eine einzigartige Morphologie unter den ostasiatischen <u>S. caecutiens</u> auf. Aufgrund dieser Tatsache betrachten wir die <u>Sorex</u> der Cheju Insel als eine neue Unterart von <u>Sorex caecutiens</u> und benennen sie <u>S. c. hallamontanus</u> ABE et OH.

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Authors' addresses:

SATOSHI D. OHDACHI, Institute of Low Temperature Science, Hokkaido University, Sapporo 060-08191, Japan (e-mail: ohd@pop.lowtem.hokudai.ac.jp); HISASHI ABE, Katsuraoka 26-17, Otaru 047-0264, Japan; HONG-SHIK, OH, Department of Science Education, Cheju National University, 1, Ara-1 Dong, Jeju, 690-756, Republic of Korea; SANG-HOON, HAN, Asiatic Black Bear Management Team, National Parks Authority, 511-1 Whangjeon-ri, Masan-myeon, Jeolla-Namdo 542-853, Republic of Korea

Figure legend

- Fig. 1. Study area and distribution of <u>Sorex caecutiens (shaded areas)</u> and <u>S. shinto</u> (dark areas) in East Asia. ?, uncertain range.
- Fig. 2. Skull of Sorex showing cranial and dental characters used in analyses.
- Fig. 3. Relative basal width of Pm4 mesostyle (%) against greatest length of skull (in mm) of Sorex caecutiens and S. shinto from 8 localities in East Asia.
- Fig. 4. <u>Plots</u> of principal components 1 and 2 for a principal component analysis based on 11 cranial and dental characters (A) and a principal component analysis based on four external characters (B) in <u>Sorex caecutiens</u> and <u>S. shinto</u> from 8 localities in East Asia

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- Fig. 5. Cluster analyses based on 11 cranial <u>and dental characters</u> (A) and four external characters (B) in <u>Sorex caecutiens</u> and <u>S. shinto</u> from 8 localities in East Asia. Ward method was applied using average values in each locality. Sc, <u>S. caecutiens</u>; Ss, <u>S. shinto</u>.
- Fig. 6. Cranium and right mandible of <u>Sorex caecutiens hallamontanus</u>, ssp. nov.,
 Collection number, SO-99/10/13-3; age, subadult; sex, male. A, dorsal view; B, ventral view; C, D, lateral views; E, lingual side view.





RPM=B/Ax100



PL = palatal length WB = width of braincase LB = length of braincase WM = width across molars IC = interorbital constriction WR = width of rostrum UUR = upper unicupsid row length PML = length between Pm⁴ and M³ GW = width across glenoids RPM = relative basal width of Pm⁴ mesostyle





A. Cranial & dental characters



B. External characters



Fig. 5. Ohdachi et al.



 Table 1.
 Collection numbers and capture locations for specimens used.

Sorex caecutiens

Primorye Territory, Russia: (Ussuri region) HA5981, HA5982, HA5983, HA5984, HA5985, SO96/7/10-1, SO96/7/10-2, SO96/7/10-3, SO96/7/10-4, SO96/7/10-5, SO97/7/11-1, SO97/7/11-2, SO97/7/12-1

Sakhalin, Russia: (Trudovoe) SO94sak-4, SO94sak-5, SO94sak-6, SO94sak-7, SO94sak-8, SO94sak-9

Hokkaido, Japan: HA1013, HA1016, HA1061, HA1064, HA1065, HA1075, HA1077, HA1080, HA1086, HA1088, HA1094, HA1106, HA1108, HA1129, HA1130, HA1170, HA1177, HA1178, HA1179, HA1180, HA1181, HA1182, HA1183, HA1184, HA1185, HA1186, HA1187, HA1188, HA1190, HA1193, HA1194, HA1195, HA1196, HA1199, HA3578, HA4065

Korean Peninsula, Republic of Korea: (Mt. Chiri) HSH-7; (Mt. Odae) SO99/10/17-1, SO99/10/17-2, SO99/10/19-1, SO99/10/19-3, SO99/10/19-4, SO99/10/20-1; (Mt. Gaya) SO99misc-9, SO99misc-10

Cheju Island, Republic of Korea: (Mt. Halla) OHS-1, OHS-2, OHS-3, OHS-4, OHS-5, OHS-6, SO99/10/12-1, SO99/10/13-1, SO99/10/13-2, SO99/10/13-3, SO99/10/14-1

Sorex shinto

Honshu, Japan: (Nagano pref.) HA1174, HA1213, HA1215, HA1216, HA1217, HA 1244, HA1245, HA1246, HA5800, SO97misc-134, SO96misc-9, SO96misc-10, SO96misc-11, SO96misc-13, SO96misc- 14, SO96misc- 15, SO96misc -16, SO96misc-17, SO96misc-18, SO96misc-19, SO96misc-20, SO96misc-21, SO97misc-19, SO99misc14; (Shizuoka SO96misc-22. SO97misc-17, pref.) SO97misc-37, SO97misc-39, SO97misc-40, SO98misc-16; (Toyama pref.) SO96misc-57; (Yamagata pref.) SO97/8/2-1; (Iwate pref.) SO97/8/5-1, SO97/8/6-3, SO97/8/6-35;(Aomori Pref.) HA1226, SO98misc-1

Shikoku, Japan: (Ehime pref.) HA1209, HA1212, HA1238, HA1239, HA1242, HA1243; (Tokushima pref.) HA1228, HA1229

Sado Island, Japan: HA5961, HA5962

Depository Institutions: HA (Botanical Garden Museum, Hokkaido University,

Japan), SO (Institute of Low Temperature Science, Hokkaido University Japan),

SHH (SHH personal collection), OHS (Cheju University, Korea)

Table 2. Cranial and dental measurements (in mm) of *Sorex caecutiens* and *S. shinto* and comparison of the averages between localities in eastern Asia. Mean (SD), N. Letters after N indicate the result of Tukey-Kramer's HSD test. Localities which include the same letters do not have significantly different means (5%). Traits measured are shown in Fig. 2. Sc = S. caectutiens, Ss = S. shinto

	Trait	GL	PL	WB	LB	WM	
Locat	ion						
Sakha	lin (Sc)18.35(0.12),	67.56(0.06),6	5b9.16(0.07),6a	a8.43(0.08),6b	4.07(0.04),6c	
Hokka	ido (Sc)17.82(0.05),3	67.40(0.02),3	368.87(0.03),30	58.23(0.03),36	b4.13(0.02),36c	
Primc	orye (Sc)17.43(0.08),1	37.11(0.04),3	138.75(0.05),13	38.17(0.05)13b	4.03(0.03),13c	
Korea	n Pen.	(17.31(0.12),7	d7.26(0.05),	7c8.73(0.07),7c	c8.16(0.07),7b	4.29(0.04),7b	
Cheju	ı (Sc)	18.96(0.09),1	18.06(0.04),2	119.06(0.05),1	18.82(0.06),11	a4.62(0.03),11a	
Honsh	u (Ss)	17.54(0.05),3	37.25(0.03),3	338.58(0.03),	38.21(0.03),33	b4.07(0.02),33c	
Sado	(Ss)	18.35(0.22),	27.67(0.10),2	2b8.99(0.13),2a	a8.53(0.13),2a	b4.47(0.07),2ab	
Shikc	oku (Ss)	18.0(0.11), 8	k7.42(0.05),8	3b8.74(0.07),70	28.37(0.06),8b	4.37(0.04),8b	
continued							
	IC	WR	UUR	PML	GW	RPM (왕)	
2 20/			:1 00(0 04)				
3.39(0.05),6	(1.70(0.03), 60)	CI./U(U.U4),6	ba2.8/(0.07), 61	(0.07),60	C64.32(0.84),6a	
3.38	(0.02), 3	01.75(0.01),36	L1.75(0.07), 3	362.72(0.08), 36	54.24(0.08), 36	062.37(1.35),36	
3.31(3.42/	0.03),I	51.70(0.02), 13	LI./0(0.00),.	$L_{3} \ge 2.55(0.07), L_{3}$	54.11(0.00), 15	201.21(1.01), 13	
3.43	(0.04), 7	(0.02), 7a	(0.02),	112.47(0.04), 1	14.29(0.10),70	(1.49), 70	
3.00((0.03), 1	11.90(0.02),11 21.65(0.01),22	e1.90(0.05),	LIZ.68(0.06),I.	14.70(0.08), 11	d = 5.55(1.05), 11	
2.30((0,02),3	51.05(0.01),330	(1.05(0.00))	2.20(0.07), 33	54.19(0.09),33	$L_{22}, 20(1.27), 33$	
3.5/((0,00),20	$a \pm .00 (0.04), 2d$ a 1 7/(0 02) oh	(1.00(0.00)), 2	202.03(0.07),21 202.50(0.07) 61	24.42(0.11), 2d a $37(0.06) ch$	50.45(1.54),20 57 56(1 55) 07	
2.201	0.04/,00	a1./4(0.02),0D	(1, 1, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3,	562.50(0.07),01	do, (0.00), c. F.	J4.J0(1.JJ), 80	

Table 3. Principal component analysis based on 11
cranial <u>and dental characters in Sorex
caecutiens and S. shinto in East Asia. Values are
presented for axes 1 to 3. See Fig. 1 for
abbreviation of characters.</u>

	PC1	PC2	PC3
Eigen value	6.438	1.941	0.884
Accumulative	58.5	76.2	84.2
contribution (%)			
Eigenvector			
GL	0.357	0.095	-0.338
PL	0.358	0.048	-0.305
WB	0.280	0.356	0.202
LB	0.337	-0.057	-0.195
MM	0.343	-0.257	0.150
IC	0.279	-0.261	0.185
WR	0.300	-0.014	0.578
UUR	0.182	0.544	-0.348
PML	0.350	-0.161	-0.137
GW	0.331	0.047	0.262
RPM	-0.039	0.632	0.338

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Table 4. Extenal measurements (in mm) and body mass (in g) of Sorex caecutiens and S. shinto and comparison of the averages between localities in eastern Asia. Mean (SD), N. Letters after N indicate the result of Tukey-Kramer's HSD test. Localities which include the same letters do not have significantly different means (5%). Sc = S. caectutiens, Ss = S. shinto.

Trait Body mass	Head and	Tail	Hind
	body	length	foot
Location	length		length
Sakhalin (Sc) 4.95(0.29),6ab	60. 7 (2. 94) , 6a 48	. 4 (1. 59), 6ab 11	. 88 (0. 37) , 6cde
Hokkaido (Sc)5.19(0.71),36a	62.0(5.82), 346	. 9 (1. 84) , 36b 12	2. 32 (0. 33) , 36bc
Primorye (Sc)4.33(0.42),13b	59. 3 (6. 39) , 13 37	. 4 (2. 12) , 13e 11	. 48 (0. 39), 13e
Korean Pen. (4.96(0.45),5ab	63. 3 (3. 31) , 5a 41	.2(1.68),5d 11	. 68 (0. 16) , 5de
Cheju (Sc) 5.71(1.50),11a	64. 5 (5. 55) , 11 44	. 7 (2. 84) , 11c 12	2. 45 (0. 41), 11ab
Honshu (Ss) 4.32 (0.49), 2	60. 5 (3. 46) , 22 51	. 1 (2. 65) , 22a 11	. 95 (0. 39) , 22d
Sado (Ss) 6.05(0.78),2ab	66. 8 (0. 35) , 2a 46	. 3 (1. 77) , 2ab 12	2. 0 (0. 00) , 2bcde
Shikoku (Ss) 6.00(-),1abc	65.0(1.41), 2a 47	. 8 (0. 35) , 2ab 13	3. 25 (0. 35) , 2a