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Original investigation

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

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Abstract

We investigated the morphological relationships among 8 populations of Sorex caecutiens/shinto group in East Asia using 11 cranial and dental characters and four external characters. Univariate and multivariate analyses of these characters failed to distinguish S. caecutiens and S. shinto. Morphological characters were, in fact, continuous between populations. Sorex shinto from Honshu was similar to S. caecutiens from the Korean peninsula and Primorye in skull dimensions and to S. caecutiens from Hokkaido-Sakhalin in external dimensions. Sorex caecutiens from Cheju Island is morphologically similar to S. shinto from Sado and Shikoku islands. These three insular populations were characterized by having large body size. Sorex caecutiens from Cheju was the largest of the S. caecutiens/shinto group in East Asia. This shrew from Cheju was classified definitively as S. caecutiens on DNA data but has a unique morphology among S. caecutiens populations in East Asia. We therefore regard this Sorex shrew on Cheju Island as a new subspecies of S. caecutiens and designate it S. c. hallamontanus 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 S. caecutiens/shinto 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. caecutiens and S. shinto 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 S. caecutiens according to mitochondrial DNA, cytochrome b (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 S. caecutiens/shinto group, we investigated the morphological relationships among populations and species of the S. caecutiens/shinto group, especially in East Asia, to assess morphological variation among them. DOKUCHAEV et al. (1999) studied morphological variation among all subspecies (ssp. shinto, shikokensis, and sadonis) of S. shinto, and S. caecutiens in Hokkaido and found that there was a significant difference between the two species. However, they did not analyse S. caecutiens 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 S. shinto from Honshu, Shikoku, and Sado and of S. caecutiens 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 Sorex 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 S. caecutiens, and 37 individuals from Honshu, two from Sado, and eight from Shikoku for S. shinto (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 S. shinto shikokensis (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 S. caecutiens/shinto 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 S. caecutiens from Cheju Island tended to be significantly larger among all shrew populations examined (Tab. 2). Sorex caecutiens from the Korean peninsula and Primorye, and S. shinto in Honshu, tended to be smaller than the other populations of the S. caecutiens/shinto group. Except for

S. caecutiens in Cheju, there are no clear differences in cranial size between S. caecutiens and S. shinto at the species level (Tab. 2). Sorex shinto 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 S. caecutiens from Cheju was significantly narrower than in individuals from other populations of S. caecutiens and was not significantly different from individuals in any populations of S. shinto (Tab. 2). Sorex shinto from all localities, and S. caecutiens 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 S. caecutiens from the Korean peninsula had relative basal width of Pm^4 mesostyle values less than 58.9%.

Within S. caecutiens, 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 S. caecutiens except for population on Cheju Island (Spearman rank correlation, P = 0.0002). This showeda 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 S. caecutiens.

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 Pm^4 mesostyle showed a minor negative value (Tab. 3). For PC2, cranial characters indicated both positive and negative eigenvectors, and the relative basal width of Pm^4 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 S. caecutiens and S. shinto 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 S. shinto in Honshu, S. shinto in Shikoku and Sado, to S. caecutiens in Cheju (Fig. 4-A). Populations of S. caecutiens in Sakhalin and Hokkaido tended to have large PC2 values. In addition, PC2 values changed continuously in ascending order from S. shinto in Honshu, S. caecutiens in Korea, S. caecutiens in Primorye, S. caecutiens in Hokkaido, to S. caecutiens 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).

Sorex caecutiens 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 S. caecutiens and S. shinto in the two-dimensional scattergram of PC1 and PC2 (Fig. 4-B). Sorex caecutiens in Primorye tended to have small PC1 values with small PC2 values whereas S. caecutiens 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, S. shinto in Honshu tended to have large PC2 values and S. caecutiens 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 S. shinto from Sado and Sikoku islands and S. caecutiens from Cheju Island (Fig. 5-A). Sorex caecutiens from Hokkaido and Sakhalin formed one cluster, as did S. caecutiens from the Korean peninsula and Primorye. Sorex shinto from Honshu was closest to the Korea and Primorye clusters (Fig. 5-A).

Based on four external characters, S. shinto from Shikoku and Sado and S. caecutiens from Cheju formed a cluster (Fig. 5-B). As in the cluster analysis of cranial and dental characters, S. caecutiens from Hokkaido and Sakhalin and those from the Korean peninsula and Primorye formed distinct clusters (Fig. 5-B). Unlike the cranial and dental analysis, S. shinto from Honshu was more closely related to the cluster of S. caecutiens from Hokkaido and Sakhalin.

Discussion

DOKUCHAEV et al. (1999) demonstrated that S. caecutiens from Hokkaido and S. shinto 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 S. caecutiens in Hokkaido and S. shinto. The former had higher values of relative basal width of Pm^4 mesostyle and the latter had lower values. We also showed that S. caecutiens from Hokkaido and S. shinto were completely separated at the 58.9% level of relative basal width of Pm^4 mesostyle. However, we demonstrated that relative basal width of Pm^4 mesostyle could not completely distinguish between S. caecutiens and S. shinto. This was because the values for all individuals of S. caecutiens from Cheju and some from the Korean peninsula were below the criterial value of 58.9%, although the values showed a clinal change within S. caecutiens.

Both principal component analyses and cluster analyses demonstrated that S. caecutiens and S. shinto are morphologically indistinguishable. Morphological differences are continuous among the eight populations of the S. caecutiens/shinto 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 S. caecutiens from the Eurasian continent and Sakhalin, whereas there is little genetic differentiation among these populations based on mtDNA cytb 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 S. caecutiens is faster than their genetic change.

Sorex caecutiens on Cheju Island has the largest body size among shrews of the S. caecutiens/shinto group in East Asia. Not only S. caecutiens on Cheju Island, but also S. shinto from Shikoku and Sado islands had large body size. These three islands are small and isolated. Additionally, S. caecutiens 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 S. caecutiens/shinto group is 42 and diploid number of chromosomal arms (NF) 70 (or 68) (ZIMA et al. 1998). Sorex caecutiens from Cheju also shows the same numbers (2n, NF) as in the other populations of the S. caecutiens/shinto group (OSHIDA et al. 2005). However, the banding pattern of chromosomes in S. caecutiens from Cheju is similar to that of S. shinto rather than to that of S. caecutiens from Hokkaido and, probably, that of S. caecutiens from the Eurasian Continent (OSHIDA et al. 2005). Thus, as with the morphological analyses, it is difficult to separate S. caecutiens from S. shinto on the basis of conventional karyological analyses.

Based on mtDNA cytb 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 S. caecutiens. However, in the present morphological analyses, S. caecutiens from Cheju not only was morphologically more like S. shinto from Shikoku and Sado islands, based on their large body (skull) size, and its morphological status was unique among populations of S. caecutiens in East Asia. Thus, we give a new subspecies rank to S. caecutiens 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 (N33º 20.628', E126º 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 S. caecutiens with very small values (range, 54.0-56.7%) in relative basal width of Pm^4 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 S. caecutiens and those of S. shinto (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 S. shinto, i.e. S. s. sadonis 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 S. c. hallamontanus than S. s. sadonis. Furthermore, S. c. hallamontanus occurs only on Cheju Island whereas S. s. sadonis occurs 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 S. shinto.

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 Sorex caecutiens/shinto 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 Sorex caecutiens/shinto-Gruppe untersucht. Gemäss univariaten und multivariaten Analysen dieser Merkmale sind S. caecutiens und S. shinto morphologisch nicht unterscheidbar. Die morphologischen Unterschiede zwischen den Populationen der Sorex caecutiens/shinto-Gruppe gehen vielmehr progressiv ineinander über. Ähnlichkeiten bestehen zwischen Sorex shinto von Honshu und S. caecutiens von

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

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Figure legend

Fig. 1. Study area and distribution of Sorex caecutiens (shaded areas) and S. shinto (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. Plots 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 Sorex caecutiens and S. shinto from 8 localities in East Asia.

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Fig. 5. Cluster analyses based on 11 cranial and dental characters (A) and four external characters (B) in Sorex caecutiens and S. shinto from 8 localities in East Asia. Ward method was applied using average values in each locality. Sc, S. caecutiens; Ss, S. shinto.

Fig. 6. Cranium and right mandible of Sorex caecutiens hallamontanus, 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.

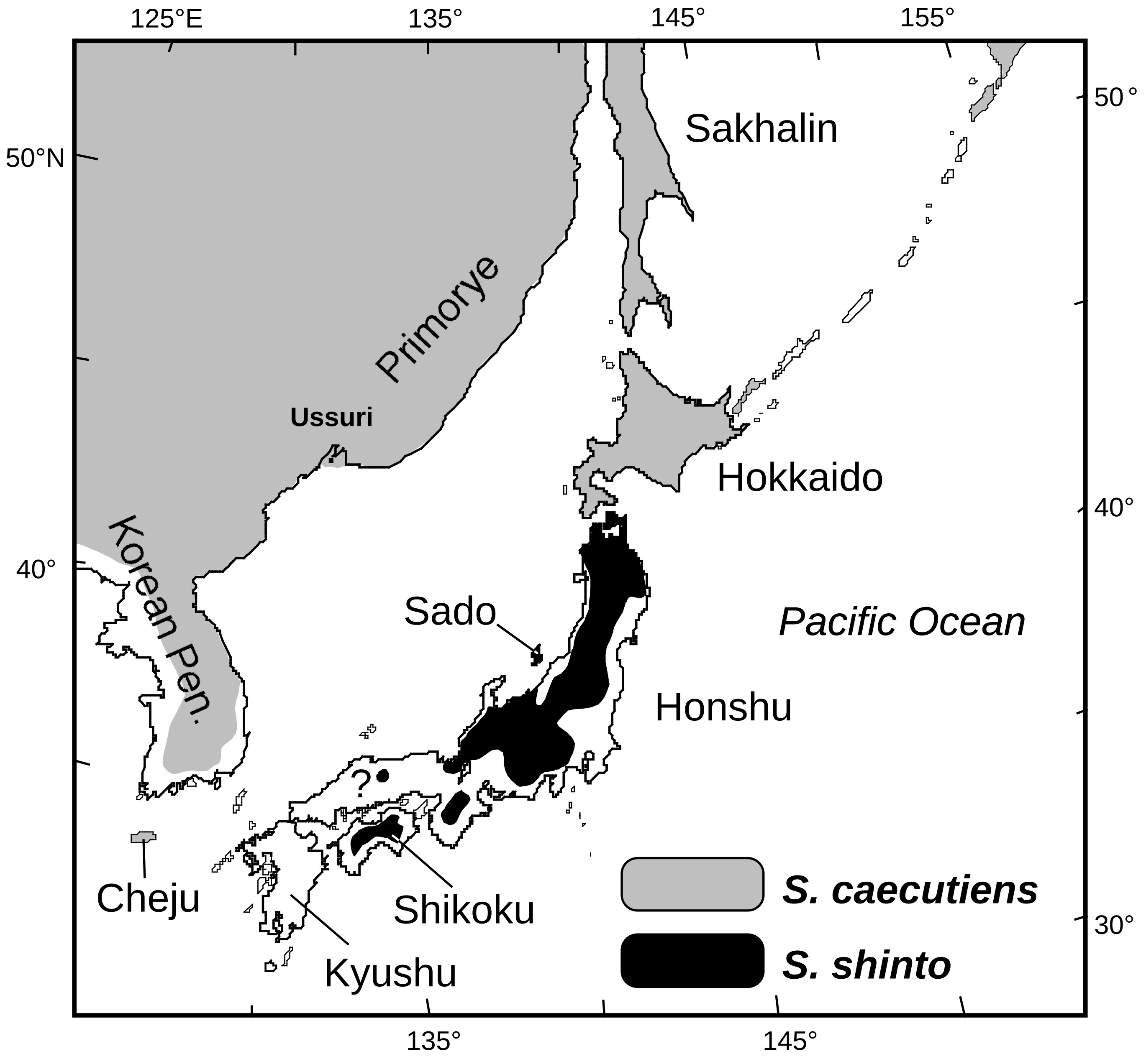
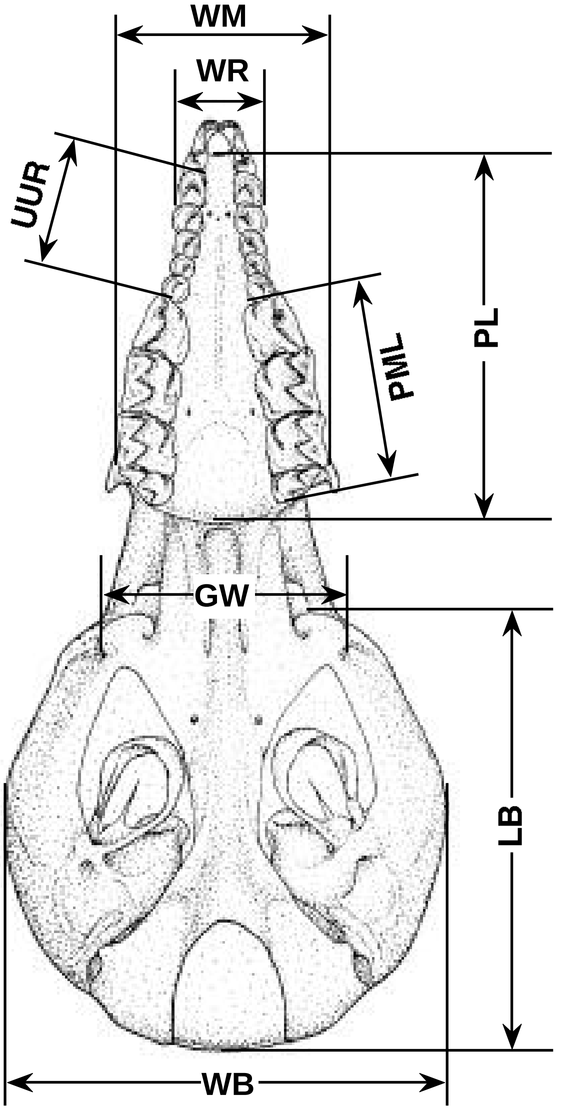
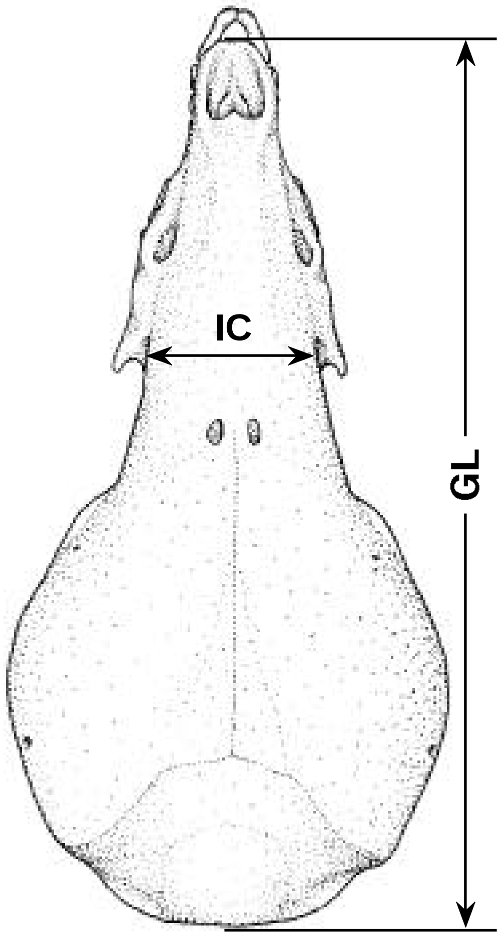
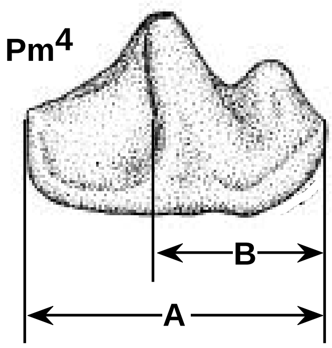


Fig 1. Ohdachi et al.







GL = greatest length of skull
PL = palatal length
WB = width of braincase
LB = length of braincase
WM = width across molars
IC = interorbital constriction
WR = width of rostrum
UUR = upper unicuspid row length
PML = length between Pm^4 and M^3
GW = width across glenoids
RPM = relative basal width of Pm^4 mesostyle

Fig. 2. Ohdachi et al.

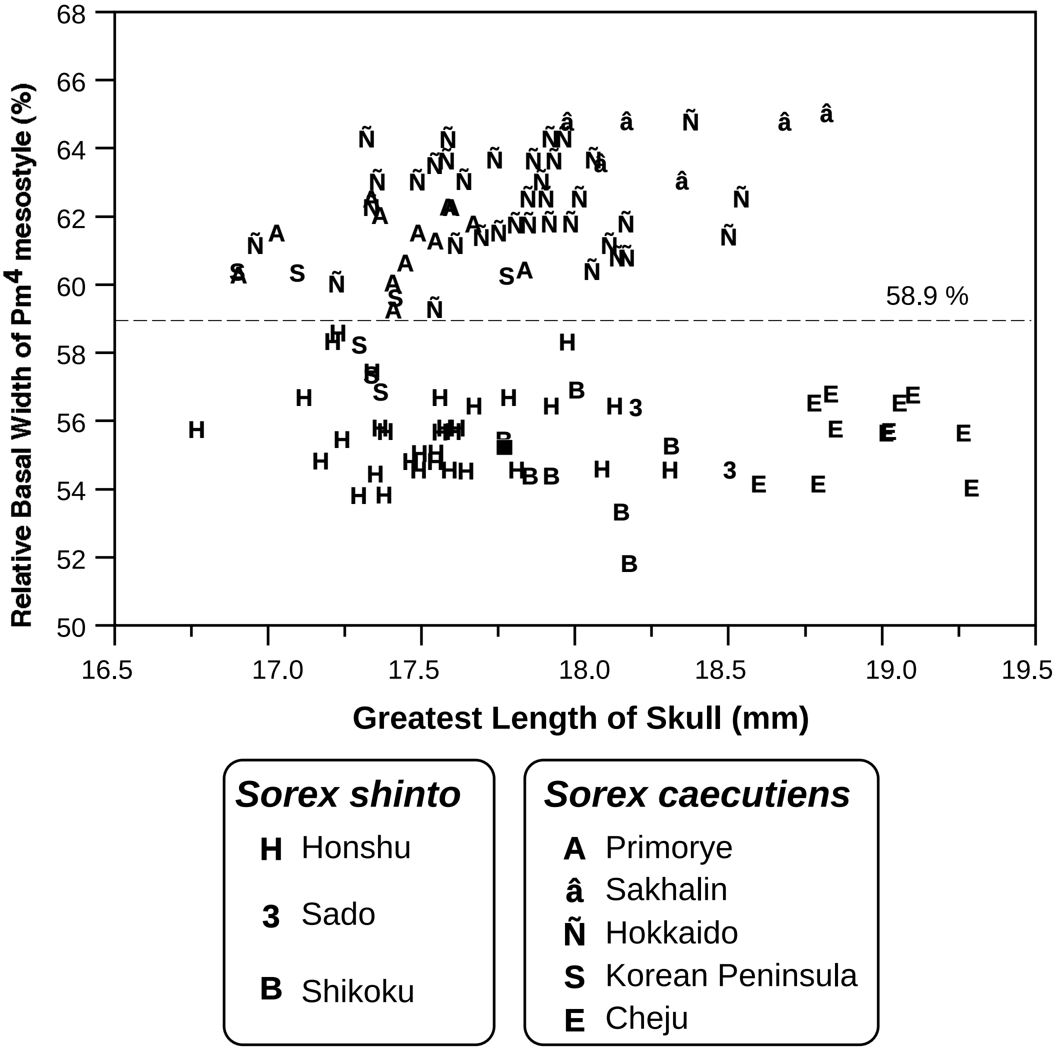


Fig. 3. Ohdachi et al.

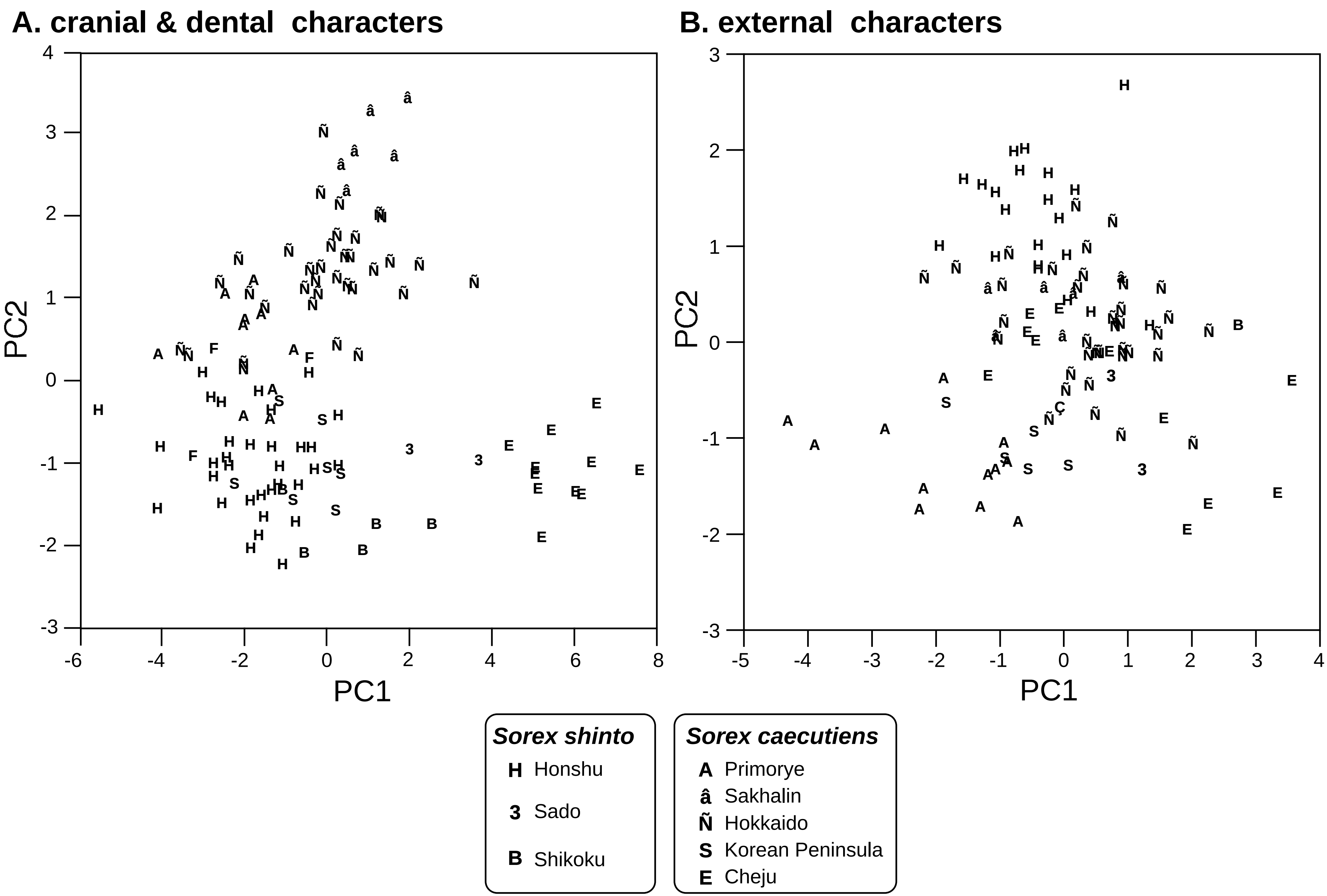


Fig. 4. Ohdachi et al.

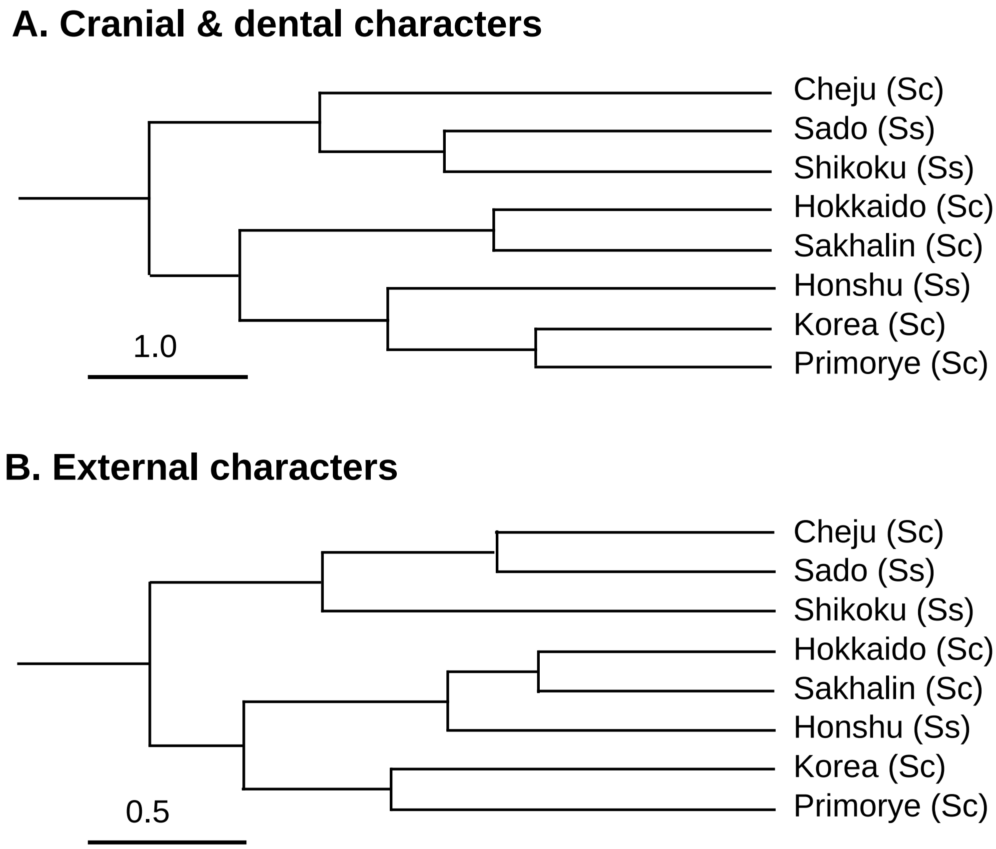


Fig. 5. Ohdachi et al.

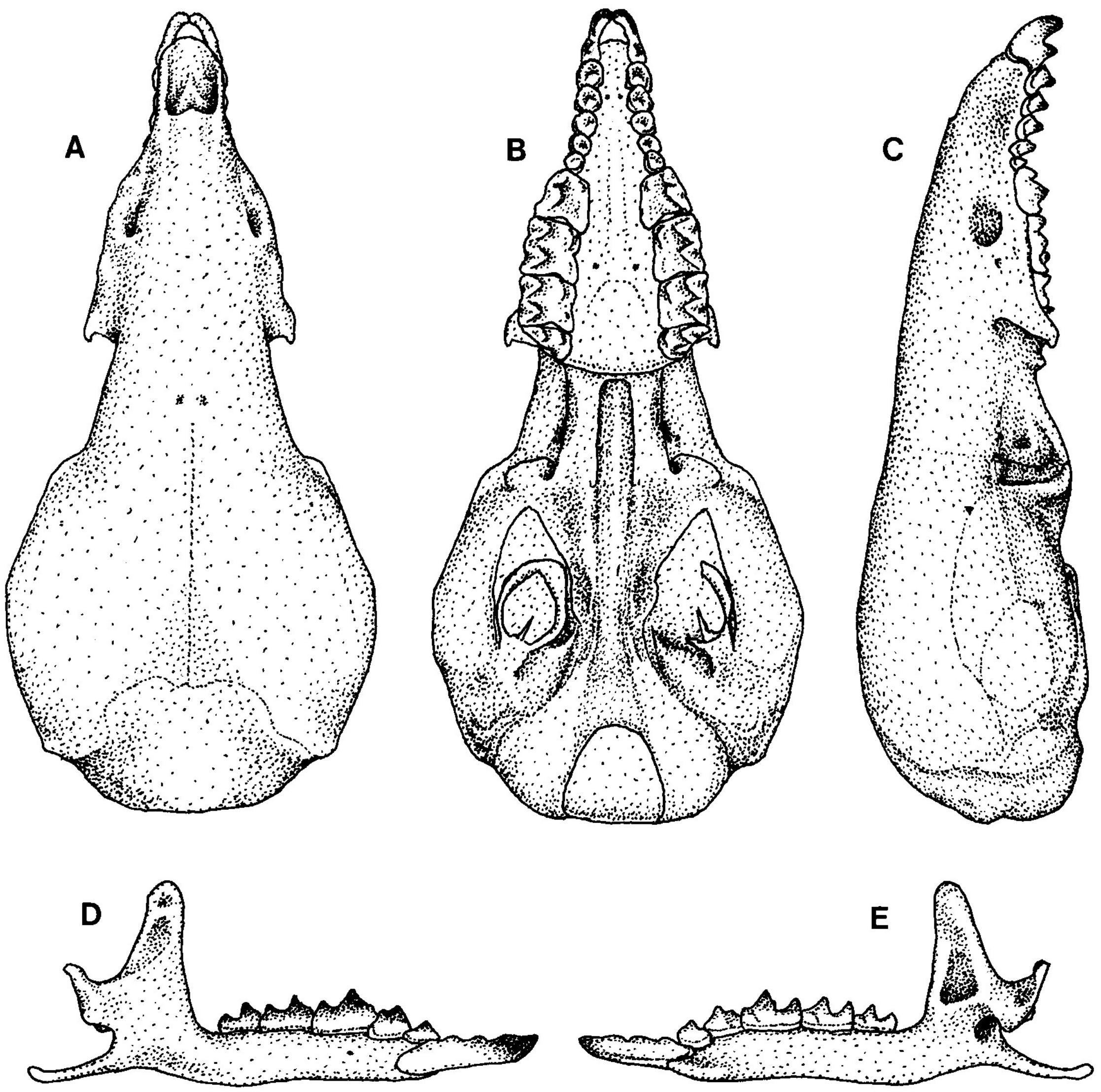


Fig. 6. Ohdachi et al.

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

<u>Sorex</u> <u>caecutiens</u>

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

<u>Sorex</u> <u>shinto</u>

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, SO96misc-22, SO97misc-17, SO97misc-19, SO99misc14; (Shizuoka 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 / Location	GL	PL	WB	LB	WM
Sakhalin (Sc)	18.35(0.12), 6	7.56(0.06),6b	9.16(0.07),6a	8.43(0.08),6b	4.07(0.04),6c
Hokkaido (Sc)	17.82(0.05),36	7.40(0.02),36	8.87(0.03),36	8.23(0.03),36b	4.13(0.02),36c
Primorye (Sc)	17.43(0.08),13	7.11(0.04),13	8.75(0.05),13	8.17(0.05)13b	4.03(0.03),13c
Korean Pen. (	17.31(0.12),7d	7.26(0.05),7c	8.73(0.07),7c	8.16(0.07),7b	4.29(0.04),7b
Cheju (Sc)	18.96(0.09),11	8.06(0.04),11	9.06(0.05),11	8.82(0.06),11a	4.62(0.03),11a
Honshu (Ss)	17.54(0.05),33	7.25(0.03),33	8.58(0.03), 3	8.21(0.03),33b	4.07(0.02),33c
Sado (Ss)	18.35(0.22), 2	7.67(0.10),2b	8.99(0.13),2a	8.53(0.13),2ab	4.47(0.07),2ab
Shikoku (Ss)	18.0(0.11), 8b	7.42(0.05),8b	8.74(0.07),7c	8.37(0.06),8b	4.37(0.04),8b

continued

	IC	WR	UUR	PML	GW	RPM (%)
[Sakhalin (Sc)]	3.39(0.05),6b	1.70(0.03),6cd	1.70(0.04),6a	2.87(0.07),6b	4.27(0.07),6bc	64.32(0.84),6a
[Hokkaido (Sc)]	3.38(0.02),36	1.75(0.01),36b	1.75(0.07),36	2.72(0.08),36	4.24(0.08),36b	62.37(1.35),36b
[Primorye (Sc)]	3.31(0.03),13	1.76(0.02),13b	1.76(0.06),13	2.53(0.07),13	4.11(0.08),13c	61.21(1.01),13b
[Korean Pen.]	3.43(0.04),7b	1.81(0.02),7ab	1.81(0.02),7d	2.47(0.04),7b	4.29(0.10),7bc	59.01(1.49),7c
[Cheju (Sc)]	3.66(0.03),11	1.90(0.02),11a	1.90(0.05),11	2.68(0.06),11	4.70(0.08),11a	55.55(1.05),11d
[Honshu (Ss)]	3.38(0.02),33	1.65(0.01),33d	1.65(0.06),33	2.56(0.07),33	4.19(0.09),33d	55.56(1.27),33d
[Sado (Ss)]	3.57(0.08),2a	1.86(0.04),2ab	1.86(0.00),2b	2.65(0.07),2b	4.42(0.11),2ab	55.45(1.34),2d
[Shikoku (Ss)]	3.56(0.04),8a	1.74(0.02),8bc	1.74(0.09),8c	2.50(0.07),6b	4.37(0.06),6b	54.56(1.55),8d

Table 3. Principal component analysis based on 11 cranial 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.

	PC1	PC2	PC3
Eigen value	6.438	1.941	0.884
Accumulative contribution (%)	58.5	76.2	84.2
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
WM	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

削除:

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*.

Location \ Trait	Body mass	Head and body length	Tail length	Hind foot 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), 3	46.9 (1.84), 36b	12.32 (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	12.45 (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	12.0 (0.00), 2bcde
Shikoku (Ss)	6.00 (−), 1abc	65.0 (1.41), 2a	47.8 (0.35), 2ab	13.25 (0.35), 2a