CRANIAL MORPHOLOGY OF SOUTH-URAL MOOSE

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ABSTRACT: Cranial morphology of moose populations in the South-Ural region of Russia were studied from collections taken from 1972-1985. Nine different skull measurements were examined for each time period for differences. Interorbital width, skull length, and skull width varied through time. More favorable ecological conditions in the 1960's than in the 1970's, caused larger dimensions. Comparison with eastern Siberia moose and other populations are made.

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Investigations of variability in cranial morphology related to development is important in population ecology. This variability determines adaptive capabilities of individuals and populations. Different developmental stages of each individual are influenced by environmental conditions. Genetic and ecological factors play important roles (Shwartz 1980).

Genetics influence morphology of individuals and populations in time. Analysis of the influence of ecological mechanisms in morphology of a population is reviewed by Shwartz (1969, 1980). Morphological peculiarities which distinguish populations through time in response to variations of ecological factors are influenced by complicated mechanisms.The epigenetic landscape model (Waddington 1957) proposes a system of alternative developmental strategies which was extended to population development (onthodemogenesis) by Vasilyev and Vasilyeva (1988). Developmental patterns founded on phenetic characteristics of individuals can be related to individual development (Vasilyev 1996). We propose to generalize onthodemogenesis for continuously distributed population characteristics by studying craniological morphology of South-Ural moose (*Alces alces*) over the 1972-1985 period.

METHODS

Craniological characteristics are widely used in systematics and ecological research because bone tissue does not vary annually due to environmental change. They reach their maximal sizes early. Dental development occurs in early stages of ontogenesis and does not change much with time and age. A series of >100 moose skulls from the Bashkirian reserve from 1972 to 1985 were available for study. The following skull dimensions were taken: (1) greatest skull length; (2)basal length; (3)condylobasal skull length; (4)greatest width; (5)breadth of skull; (6)tooth row length; (7)nasal bone length; (8)upper alveolar tooth row length; and (9) interorbital width (Heptner *et al.* 1961).

Age groups were selected according to tooth wear criteria (Sokolov 1959). Moose skulls grow rapidly the first 3 years of life, more slowly from ages 4-6, and minimally thereafter. We used male skulls since they were most abundant in the collections of animals >2years old. Chronological variability of 7 age groups was examined by amined by year of collection from 1972-1985 (Table 1).

We used discriminant and factor analyses (Yelkin 1990) and graph theory to detect differences. Sex and age differences were modeled using image recognition and automatic classification (Kazantev 1990).

RESULTS AND DISCUSSION

There were similar patterns in skull formation of moose born in different years. Analysis of absolute size change shows large variability in length measurements 1, 2, and 3 (Table 1), tooth row length (6), and interorbital width (9). All average skull dimensions increased monotonously from 1972-73 to 1978-79, for 3-6 year-olds. Animals born in the second half of the 1960's had slower rates of increase in skull dimensions than later. Moose >6 years old in the 1975-76 age group, born in the 1960's, had generally larger skull dimensions. Skull dimensions increased in all age groups and were largest in most dimensions in 3-6 year-olds collected in 1978-79. We conclude that ecological conditions for moose born and living at the beginning and mid-1970's were more favorable than in the 1960's. Moose 3-6 years old in 1981-1985 showed decreased average values for most dimensions, as well as an increase in interorbital width. The same pattern occurred for moose >6 years old collected in 1981-1985, animals born and living in the second half of the 1970's, and the beginning of the 1980's.

For each time-age sample, a correlation matrix was constructed. Then, based on the in-pair correlation coefficients, similarity graphs were built (Fig.1). The analysis showed a stable, strong correlation group of basic skull dimensions (1,2,3,6) and molar row length for every identifiable population of South-Ural moose by age, sex, and time.

These results have a practical meaning. We can reconstruct all skull dimensions from 1 or 2 dimensions using regression analysis. In the 1981-85 samples, 1 more cluster appears which includes skull breadth and interorbital width. This is probably a response to changing ecological conditions.

Multivariate morphometric analysis is often used in population and systematic

Table 1. Mean craniological dimensions of South-Ural moose males.

Year	1972-73	1975-76	1978-79	1981-85	1975-76	1978-79	1981-85
Age	3-6	3-6	3-6	3-6	7-10	7-10	7-10
Dimension[1]							
1	499	553	562	547	591	582	579
2	445	480	492	481	515	509	509
3	470	506	521	511	544	537	539
4	198	205	210	212	220	216	217
5	143	149	151	151	164	159	160
6	337	367	389	366	403	36	393
7	96	107	111	100	113	104	107
8	140	145	145	148	139	144	139
9	136	145	152	178	156	161	181

[1]**Note:** 1= skull length, 2=basal length, 3= condylobasal skull length, 4=greatest width, 5= breadth of skull, 6=incisive molar length, 7=nasal length, 8=length of upper alveolar toothrow, 9= interorbital width.

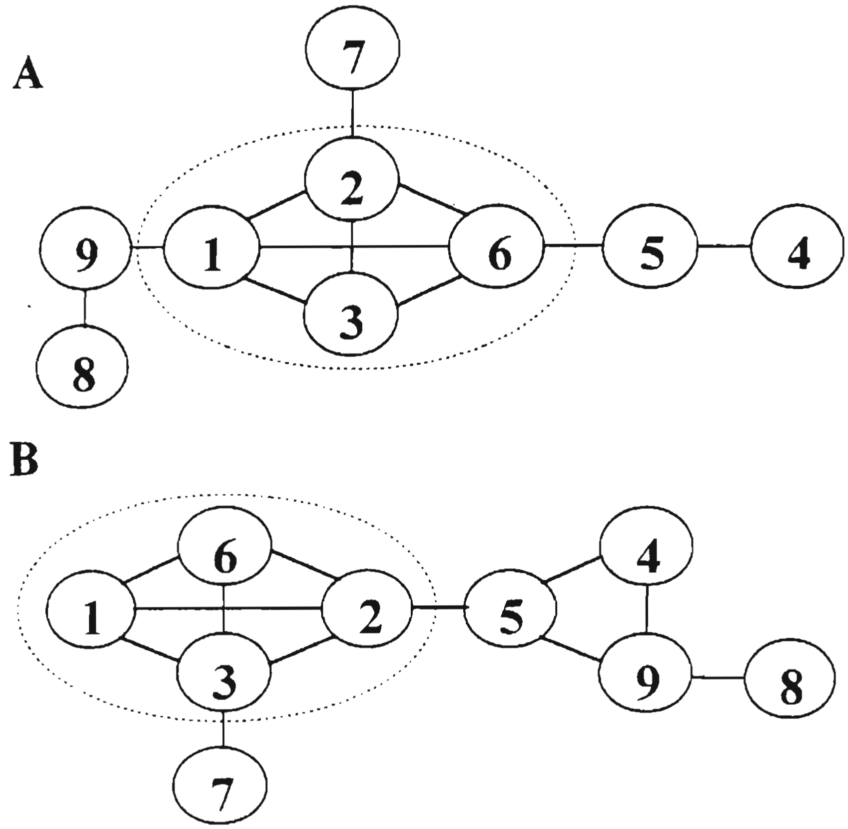

Fig. 1. Similarity graphs between craniological measures based on the correlation matrix: (A) for the sample 1972-73 of males aged 3-6; (B) for the sample 1981-85 of males aged 3-6. Dimensions numbered as in Table 1.

studies (Reyment *et al.* 1984). The multivariate discriminant analysis of chrono-age groups (Fig.2) assigns most taxonomic weight to skull length dimension (1,2), skull width (5), and interorbital width (9). The results are only for chrono-age groups of males aged 3-6, but results of older age groups and females are identical.

On the plane of 2 canonical axes (Fig.2), 4 chrono-groups of moose population are divided into 3 taxa. The 1975-76 and 1978-79 samples can be excluded because they overlapped considerably. Verification of results were obtained using relation theory methods, where each sample element is considered (Yelkin 1990, Yelkin and Istchenko 1979). Three taxa have no common elements, and chrono-samples of 1975-76, 1978-79 overlap by 42%.

Visual changes of cranial morphometry were apparent in the time series. The 1981-85 samples were subdivided into 2 groups using factor analysis. Animals born in the early- to mid-1970's have morphometrics that are closer to the 1975-79 samples. Average cranial morphometry from the other areas of eastern Europe are closely related to chrono-samples of South-Ural moose. The moose living in the Ural mountains most certainly belong to the subspecies *A. a. alces*, L.

When cranial morphometrics of South-Ural moose were compared with larger eastern Siberian moose significant differences were observed. Consequently we hypothesize that in the past, South-Ural

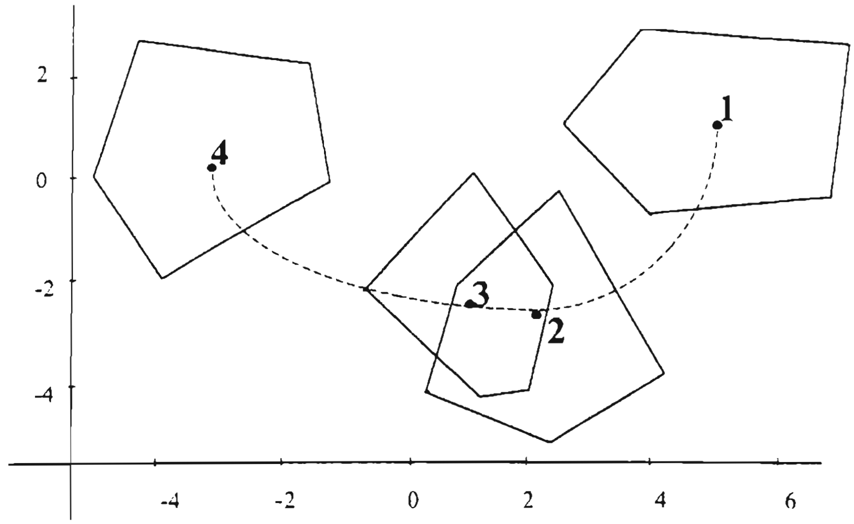

Fig. 2. Chronograph variability of morphological appearance of males from South-Ural population (discriminant analysis). Samples of different years (aged 3-6): (1) 1972-73; (2) 1975-76; (3) 1978-79; and (4) 1981-85.

moose were larger or eastern Siberian moose were smaller. The species *Alces alces* is a dynamic morphophysiological system (Vavilov 1931). South-Ural moose exhibit highly variable cranial morphology which may be expected to vary through time and space.

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