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STABLE-ISOTOPE ANALYSIS AS A METHOD OF TAXONOMICAL IDENTIFICATION OF ARCHAEOZOOLOGICAL MATERIAL*

The paper discusses the possibility of using carbon isotope composition (ratio of $^{13}C/^{12}C$) and nitrogen isotope composition (ratio of $^{15}N/^{14}N$) for taxonomic diagnostics of animal bone remains from archaeological sites and other ancient deposits. The world literature pertaining to the use of stable-isotope analysis (SIA) in animal trophic ecology and methodological difficulties of work with subfossil material are reviewed. Several particular cases show a successful application of SIA for taxonomic identification of the archaeozoological remains, especially bones of brown and polar bears, large sea mammals and a few species of Anseriformes.

Keywords: *Stable isotopes, animal bones, taxonomical identification, archaeozoology, Ursus, Hydrodamalis gigas.*

Introduction

Archaeozoological material is represented by subfossil remains of animals living in the last millennia (Reitz, 2008). Usually, these remains are composed of the elements of internal or external skeletons of invertebrate and vertebrate fauna. They are preserved as part of natural deposits (in rocky niches, coastal deposits, permafrost, asphalt lakes, mammal burrows, etc.), but the most massive and numerous burials of the ancient fauna remains are found in the cultural layers at the archaeological sites (Dinesman, 1979; Antipina, 2003; Reitz, Wing, 2008).

Scientific research on archaeofauna bone remains is important in a number of ways. The archaeozoological analysis is used for ecosystem reconstruction. The analysis determines the composition, abundance, spatial distribution, age, and sex structure of particular species that lived in the past, as well as the dynamics of these parameters over time. It is also used to reconstruct a history of human societies. The study

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of animal remains helps to reveal many economic features, trade relations, basic strategies of the minimum subsistence level, type of exploitation of animal populations, and its forms, purpose, seasonal factors, etc. Additionally, the most important task, which combines both of these appproaches, is to determine the degree of mutual influence on animal populations, humans, and environment.

The taxonomic diagnostic of the archaeozoological material is required to achieve the above-mentioned objectives. Identification of the animal remains is usually carried out on the basis of comparing reference-collections of modern animal skeletons with the unambiguous species identity, known sex, age, place of collecting, etc. In addition, references and identification manuals (Gromova, 1950; 1960; Gilbert, Martin, Savage, 1985; Hillson, 1986; Gilbert, 1993; etc.) as well as electronic resources with the three-dimensional images of skeletal elements (for example, http://bones.iri.isu.edu) are used. However, it is often impossible to identify the remains using external morphological indicators. In these cases, the researchers are forced to limit the information to the family/order/class level or to use genetic analysis of fossil material.

This paper discusses the use of stable-isotope analysis to identify species that are similar in terms of a skeleton structure, but vary greatly in feeding ecology.

Stable-isotope analysis: general concepts

Many biogenic elements are represented by several stable isotopes, *i.e.*, by those that are not subject to radioactive decay (^{1}H and ^{2}H, ^{12}C and ^{13}C, ^{14}N and ^{15}N, etc.). The differences in the ratio of a heavier to a lighter isotope in various environments, between the species, or in various tissues are formed as a result of a number of physical and chemical processes (the so called fractionation). It is primarily associated with the molecules that have different weights (for example, $^{13}CO_2$ and $^{12}CO_2$) have different activities and strengths of their internal bonds. Therefore they are involved in chemical reactions and phase transitions with different probabilities (Koch, 2007; Sulzman, 2007). The isotope composition of an element is expressed in relative units called "delta" (δ), which represent the deviation of the isotope composition of the element from the international standard. Because the changes in isotope composition are not very great, the δ value is usually multiplied by 1000 and expressed as per mille (‰).

During the environmental studies, the isotope composition of nitrogen (ratio of $^{15}N/^{14}N$) and carbon (ratio of $^{13}C/^{12}C$) are most commonly used. Stable-isotope analysis is widely used in environmental science, but in this work, we will only discuss its use for studying the animals' feeding ecology and identifying their food chains. In general, the isotope-composition of the consumer tissues corresponds to the isotope-composition of the consumers' food (DeNiro, Epstein, 1978; 1981). However, during the transition from one trophic level to another a little change in the isotope-composition takes place. The amount of change ($\Delta^{13}C$ or $\Delta^{15}N$) is defined as the difference between the isotope-composition of animal tissues and the isotope-composition of the animal's food ($\delta_{consumer} - \delta_{diet}$). It is called a trophic fractionation or an isotope-discrimination factor (Martínez del Rio et al., 2009; Bond, Hobson, 2012). Thus, the isotope-composition of nitrogen and carbon in animal-tissues depends on the position of their species in the food chain, and on the isotope-composition of primary producers forming the base for the food web in the given ecosystem.

The differences between the $\delta^{13}C$ and $\delta^{15}N$ values of primary producers determine corresponding differences between all of the subsequent consumers in different food chains. The variability of the isotope-composition of producers is associated with biochemical peculiarities during the autotrophic fixation of biogenic elements, physical and climatic environmental conditions, and regional isotope variability of biogenic resources (Heaton, 1999; Marshall, Brooks, Lajtha, 2007). Therefore, in addition to trophic position, the isotope composition of animal tissues contains information about the characteristics of the animal's feeding habitat.

Carbon. The significant differences among the $\delta^{13}C$ values of animal tissues (from –28 ‰ to –6 ‰) are mostly associated with the strong variability of $\delta^{13}C$ in primary producers forming the base of the food chain (Kelly, 2000; Koch, 2007). The variability is defined by the nature of CO_2 fixation by different plant types in different environments.

During photosynthesis, all plants discriminate ^{13}C in favor of ^{12}C. They are "depleted" in ^{13}C compared to carbon in the atmospheric CO_2. The extent of discrimination varies among plants using different photosynthesis paths (Park, Epstein, 1960; O'Leary, 1988).

The most distinctive discrimination of ^{13}C is demonstrated in plants that carry out the Calvin cycle (C3-plants—the major part of terrestrial and aquatic producers), and the weakest discrimination is demonstrated in plants that carry out the Hatch–Slack cycle (C4-plants—some grasses, sedges, and other groups of angiosperms in southern, arid habitats). In addition to fractionation at the stage of enzymatic carboxylation, the carbon isotopes are selected during the stomatal breathing process (Heaton, 1999; Marshall, Brooks, Lajtha, 2007).

The isotopic composition of C3 plants substantially differs from that of C4 plants. The average $\delta^{13}C$ values for C3 plants are –27 ‰ (from –35 to –21 ‰), and those for C4 plants are –13 ‰ (from –14 to –10 ‰) (Craig, 1953; Ehleringer, Rundel, 1989; Kelly, 2000; Marshall, Brooks, Lajtha, 2007).