УДК (UDC) 56.591 : 569 (477)
DOI: https://doi.org/10.33782/eminak2023.2(42).640

VERTEBRATES AS BIOINDICATORS OF CLIMATE CHANGE

Yevheniia Yanish
I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine
(Kyiv, Ukraine)
e-mail: tinel@ukr.net
ORCID: https://orcid.org/0000-0001-7446-8392

ABSTRACT

The use of living organisms for stratigraphy or as bioindicators of the state of the environment has been known since the 19th century, but mainly for these studies the remains of invertebrate animals (in particular, molluscs) are used, and from vertebrates – mouse-like rodents. In the course of the work, certain species of vertebrates and invertebrates were selected, based on the presence of which in the material it is possible to reconstruct the climatic conditions in the historical past. Such information is very important for historians and archaeologists, since it allows them to better understand the living conditions of people in the historical past.

The aim of our work is to identify species of vertebrates that are stenotopic in at least one factor and, on the basis of the findings of these species at archaeological sites, to make climatic reconstructions.

Conclusions. To date, work on the identification of other indicator species continues, we have carried out reconstructions of the paleoclimate on the basis of osteological materials found in the excavations, and for a number of monuments we have compared the results with the data of paleobotanists and soil scientists from the same areas. The similarity of the obtained results is significant, which allows us to propose a method of reconstruction of paleoclimatic and paleoecological conditions based on the findings of the indicator species selected by us as effective. The most effective is a comprehensive study of osteological materials, taking into account the presence of the above-mentioned species in the material. In terms of time spent, the identification of zooarchaeological materials is a simpler and faster method than paleobotanical research, and the results are largely comparable. In addition, the same species can be used to model predictions of habitat changes due to climate change in the future.

Keywords: Archeozoology, bones, reconstructions, climate, bioindication

ХРЕБЕТНІ ЯК БІОІНДИКАТОРИ ЗМІНИ КЛІМАТУ

Євгенія Яніш
Інститут зоології імені І.І. Шмальгаузена НАН України (Київ, Україна)
e-mail: tinel@ukr.net
ORCID: https://orcid.org/0000-0001-7446-8392

АНОТАЦІЯ

Використання живих організмів для стратиграфії або як біоіндикаторів стану навколишнього середовища відомо ще з XIX ст., але переважно для цих досліджень використовуються залишки безхребетних тварин (зокрема, молюсків), а з хребетних – мишоподібні гризуни. У ході роботи були виділені окремі види хребетних і безхребетних тварин, за наявністю яких у матеріалі можна реконструювати кліматичні умови в історичному минулому. Така інформація дуже важлива для істориків та археологів, оскільки дозволяє краще зрозуміти умови життя людей в історичному минулому.

Метою нашої роботи є ідентифікація видів хребетних, стенотопних хоча б за одним фактором, і на основі знахідок цих видів на археологічних пам'ятках зробити кліматичні реконструкції.

Висновки. На сьогоднішній день триває робота з ідентифікації інших видів-індикаторів, ми провели реконструкції палеоклімату за знайденими у розкопках остеологічними матеріалами, а для ряду пам'яток порівняли результати з даними палеоботаніків і ґрунтознавців з тих самих областей. Схожість отриманих результатів є значною, що дозволяє запропонувати методику реконструкції палеокліматичних і палеоекологічних умов за знахідками видів-індикаторів, обраних нами як ефективні. Найбільш ефективним є комплексне дослідження остеологічних матеріалів з урахуванням наявності в матеріалі вищевказаних видів. За витратами часу ідентифікація зооархеологічних матеріалів є простішим і швидшим методом, ніж палеоботанічні дослідження, а результати, в значній мірі, тотожні. Крім того, той самий вид можна використовувати для моделювання прогнозів змін середовища існування через зміни клімату в майбутньому.

Ключові слова: археозоологія, кістки, реконструкції, клімат, біоіндикація

INTRODUCTION

The use of animals and their remains as indicators of the state of the environment has been known and studied for a long time. But the vast majority of animals that researchers focus on are, for the most part, invertebrates, fish, and small rodents. Other types of mammals are not often considered as bioindicators, the exception being the mammoth fauna complex. Birds and reptiles, too, usually do not fall into these species. In the past, people were much more dependent on natural conditions than they are now. Accordingly, such information is very important for historians and archaeologists, since it allows them to better understand the living conditions of people in the historical past.

Some species of vertebrates are stenotopic according to certain parameters, which allows us to use them for the reconstruction of paleoclimatic and paleoecological conditions, as well as for predicting changes in the future.

Paleoreconstructions of the climate based on the findings of representatives of various faunal complexes were made, among other things, by the famous

paleontologist Pidoplichko[1]. In the 20th century, the concept of "faunistic complexes" was developed, which was mainly used in paleontology[2], and was also singled out for fish[3]. All this helps to make both paleoclimatic and paleoecological reconstructions.

In the literature there are separate references to the fact that the presence of certain species of animals can determine the natural conditions in which they lived. Thus, well-known zoologist Formozov[4] found that for many animal species, including medium and large vertebrates, the main limiting factor is not cold or the presence of water, but the maximum depth of snow cover in winter.

In the 1990s and in the 2010, climate reconstructions based on finds of animal bones were carried out by E. Antipina[5]. Paleontologist L. Gorobets in his dissertation describes species such as capercaillie and black grouse as bioindicators[6].

Species adapted to live in a wide range of natural conditions are called "eurybionts". Whereas species, the range of which is strictly limited by certain conditions (at least one of the factors), which are limiting for their distribution, are called "stenotopic". There is also such a thing as "ecological criterion of the species" – these are all the environmental conditions that are necessary for a particular species. The environmental factor, which most strongly deviates from the optimum but is necessary for the survival of the species, is called limiting. Using the concepts of stenotopic species, ecological criteria and limiting factors, it becomes possible to reconstruct the climatic and ecological conditions of the past based on finds of animal bones.

Findings of animal bones as indicators for climate reconstruction in the historical past were used in some of his works by the well-known Ukrainian archaeozoologist O. Zhuravlev[7]. However, in most works, mainly individual species were considered and, for example, only mammals or birds.

Today, there is a need to generalize the available data, add new species to the list of bioindicators, and also make tables convenient for archaeologists to use.

MATERIAL AND METHODS

The aim of our work is to identify species of vertebrates that are stenotopic in at least one factor and, on the basis of the findings of these species at archaeological

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sites, to make climatic reconstructions. On the graphs, the height of the sinusoids reflects the level of temperature change conditionally: calibration in degrees was not carried out, however, the height of the sinusoid along the Y axis will be greater where cooling or warming was greater compared to other periods. This was done to visualize the results of reconstructions and to facilitate data comparison.

During 2006-2022, we examined zooarchaeological material from more than 85 archaeological sites (more than 184,000 remains of animal origin), from the Neolithic to the late Middle Ages. In terms of the amount of researched material, the most representative are the results of the research of Olbia and the multi-layered site of Ratniv-II.

The remains of mammals and birds were determined by comparing bone fragments with specimens of modern and subfossil species from the collection of the National Natural Science Museum of the National Academy of Sciences of Ukraine. The degree of fragmentation was determined according to the method of E. Antipinova[8], the age of the sawdust – according to G. Klevezal[9]. The fishes were identified by comparing bones and scales with modern specimens from the author's comparative osteological collection. In those cases where it was possible, the exact age of the fish was determined by the scales and vertebrae of the fish. Systematics and types of fish names, given according to Y. Movchan's reference guide[10].

To determine the size of subfossil bones, they were measured with a caliper to the nearest 0.1 mm according to the method of von Drisch[11]. Statistical processing was performed in the PAST program.

In addition, we analyzed the conditions necessary for the life of the most common species of vertebrates, as well as a number of birds, reptiles, mollusks, and even plants. In this paper, the patterns we describe refer to the territory of Europe, including Ukraine. We did not carry out similar studies for other territories. Similar reconstructions, but by different methods, are made by climatologists and paleobotanists (or archaeobotanists).

A prerequisite for correct reconstructions is the origin of the studied animal bones directly from the study area. Because there are situations (for example, archaeologists find a bone carving workshop) in which there are many deer antlers. But they can be brought from other places and are unsuitable for reconstructions of the local paleoclimate. At the end of the reconstruction, we compared our conclusions with the data obtained for these territories by scientists of these specialties.

The method described by us has shown good results, with its help it is possible to trace climate changes – global changes in warm and cold periods, forests by steppes, as well as the species composition of some tree species and grasses. Like any reconstruction, this method does not give a 100% match. The most accurate reconstruction is given by complex analysis based on all available sources of information.

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RESULTS

As a result of the analysis of all the data, we identified a number of species for which it is possible to carry out paleoreconstructions. Thus, the bones of the European roe deer (*Capreolus capreolus*, Linnaeus, 1758) in the materials testify to the presence of woody vegetation of soft species, representatives of such genera as Willow (Salix), Populus (Populus) and Alnus (Alnus) during the studied period. In addition, one of the main limiting factors for the species is the maximum depth of the snow cover in winter (it cannot exceed 25 cm, maximum – up to 30 cm)[12]. The species is found both in the forest-steppe and in the forest zone, but on the edge of the forest. Beaver (*Castor fiber*, Linnaeus, 1758) also indicates the presence of soft rocks in the floodplain, and depending on the hydrological regime, it can either build a hut and a dam, or dig holes in the bank. The species itself can also directly affect the state of the reservoir. Table 1 shows the most relevant species for the territory of Ukraine. Predominantly, wild vertebrate species are the best bioindicators. Although some domestic species are also suitable for this – for example, domestic sheep (*Ovis a*ries, Linnaeus, 1758), which require open spaces and grassy vegetation.

European elk (*Alces alces*, Linnaeus, 1758) in the first line indicates the presence of forests, often broad-leaved, and with interspersed conifers. Either for the presence of young coniferous forests. Also, the species gravitates to wet places, mainly to swampy areas. The maximum depth of the snow cover in winter for this observation should be 80 cm. Wild boar (*Sus scrofa*, Linnaeus, 1758) in the material indicate that the maximum depth of the snow cover was no more than 40 cm – oak, or oak-hornbeam) forest. For the red deer (*Cervus elaphu*s, Linnaeus, 1758), the maximum depth of the winter cover storage is 40 cm[13]. One of the main intermediary factors for the european pound turtle (*Emys orbicularis*, Linnaeus, 1758) is the average winter temperature, which should not be below +2.6°C[14]. The indicator species also include the wood grouse (*Tetrao urogallus*, Linnaeus, 1758) and the hazel grouse (*Tetrastes bonasia*, Linnaeus, 1758), which are typical forest species. The wood grouse primarily prefers coniferous forests, while the latter prefers mixed forests, and does not even approach the edge of the forest closer than 200-300 m. Black grouse (*Lyrurus tetrix*, Linnaeus, 1758) is found in both forest and forest-steppe, as well as in steppe biotopes, but prefers places with a predominance of birch (Betula sp.). One of the limiting factors for the species is the formation of crust in the winter period due to thaws and subsequent frosts. Molluscs – painter's mussel (*Unio pictorum*, Linnaeus, 1758) and thick shelled river mussel (*Unio crassus*, Philipsson, 1788) react to the hydrological regime and water purity; river crayfish (Astqacus sp.) – for water quality; sturgeon (Acipenseridae), pikeperch (*Sander lucioperca*, Linnaeus, 1758) – oxyphilic species, common carp (*Cyprinus carpio*, Linnaeus, 1758), crucian carp (Carassius *sp*.), tench (*Tinca tinca*, Linnaeus, 1758) – are satisfied with a very small

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amount of oxygen in the water[15], common nase (*Chondrostoma nasus*, Linnaeus, 1758), trout (the birthplace of Salmonidae) – loves rapids, clear, cool water with a fast current. The saiga (*Saiga tatarica*, Linnaeus, 1758) and the onager (*Equus hemionus*, Pallas, 1775) mark the steppe areas and indicate the aridization of the climate.

The best results and opportunities for reconstructions are provided by complex studies, which take into account the presence of remains of not only mammals, but also birds, reptiles (european pound turtle), fish and molluscs in the archaeological material, as well as the archaeological context.

In order to reconstruct the paleoclimatic and paleoecological conditions from a specific archaeological site, it is necessary, first, to determine the animal bones to species. Next – to analyze the species composition and ratio of species. For example, let's take the monument of the Scythian time Severinovka[16]. A total of 2196 remains of animal origin have been studied. Of all this number of bones and species, only a few are of the greatest interest for reconstruction: wild boar, beaver, red deer, podust and mollusk. In addition, be sure to pay attention to such domestic species as horses, large and small cattle. Further, we can look at Table 1 and clarify what conditions are necessary for the existence of these species.

Thus, the wild boar primarily indicates the presence of a forest-steppe, with broad-leaved species, such as oak and hornbeam, and the maximum depth of snow cover in winter is not more than 40 cm. Red deer and beaver – for the presence of broad-leaved forests, possibly floodplain, with such species as willow, aspen, alder. For deer, the maximum depth of snow cover is also 40 cm. It should be remembered that in the past the climate has changed several times, and if now in this area the maximum depth does not exceed 13 cm on average, then in the past the situation could be completely different. The *Discus rotundatus* is a species that lives in dead wood or in old living trees, in broad-leaved forests (oak, hornbeam), sometimes in alder trees in beams among broad-leaved forests (but it is unlikely to be in floodplain forests). The common nase (*Chondrostoma nasus*) species prefers deep rivers with fast currents and rapids. In addition, in the course of the research, teeth of a domestic horse and a domestic cow with hypoplasia were found. This pathology of tooth enamel develops in animals (and humans) in case of lack of nutrition at an early age. Thus, after analyzing the data, we can say that the settlement was located in the forest-steppe zone, but next to it there was a large oak-hornbeam forest, with inclusions of willow, aspen and alder in the river and stream valleys. Open spaces are needed for livestock grazing. Perhaps, in this case, grazing took place in the floodplain of the river. And for large species, nutrition was insufficient (hypoplasia indicates this). Thus, after analyzing the data, we can say that the settlement was located in the forest-steppe zone, but next to it there was a large oak-hornbeam forest, with inclusions of willow, aspen and alder in the river and stream valleys. Open spaces are needed for livestock grazing. Perhaps, in this case, grazing took place in the floodplain

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of the river. And for large species, nutrition was insufficient (hypoplasia indicates this). The climate was quite warm, the snow cover in winter did not exceed 40 cm. The river had a fast current and rifts. Accordingly, the beaver could not build its dwelling and dam on the channel and could either dig holes in the steep banks of the river, or make a dam not on the main channel, but on the stream that flows into the river.

Based exclusively on animal remains, we reconstructed the paleoecological and paleoclimatic conditions for the early Neolithic sites of Starobilske-I (modern Luhansk region). Thanks to the developed method, exclusively due to the findings of bioindicator species it was possible to accurately determine the periods of warming and cooling in the studied periods at the archaeological sites and paleoecological conditions.

Starobilsk – Early Neolithic site (5900-5800 BC), located on the territory of Luhansk region, excavation materials of O.G. Shaposhnikov and Yu. Hurin for 1979-1980. Five species of mammals have been identified: tour, elk, wild boar, roe deer and beaver. In addition, the remains of a representative of the equine family (Equidae) were found, probably a onager. The bird bones cannot be determined to species, all the reptile bones belong to the terrapin species, and the mollusk shell fragment belongs to the Unio genus.

Based on the species composition and the presence of 5 model species (some of them were selected during the work of previous years), we can reconstruct the paleoecological conditions around the ancient site. Thus, the presence of roe deer and beaver indicates the presence of broad-leaved (including floodplain) forests, elk – coniferous forests (probably pine), roe deer and tur to a greater extent forest-steppe species that prefer meadows and edges, the presence of horse bones (kulana?) indicates significant open spaces. The depth of the maximum snow cover in winter is important in the life of animals and is often the main limiting factor in the dispersal of species. So, roe deer is not found where the depth in winter is more than 30 cm, for wild boar the critical depth is 40 cm.

Thus, in the early Neolithic around the Starobilsk-I site there was a forest-steppe with significant areas of the steppe, with a predominance of broad-leaved species (probably with interspersed oaks and pines) and a snow cover depth of 30 to 40 cm in winter. These paleoreconstructions are fully confirmed by the studies of soil experts and paleobotanists who worked at the same site[17].

In addition, the method made it possible to reconstruct for the Northern Black Sea region not only the end of the Roman climatic optimum 200 years later than previously thought, but also the beginning – in the 5th century BC, 200 years earlier than the generally accepted dating (fig. 1). At the same time, most of the finds of lions (*Panthera leo*, Linnaeus, 1758) from this territory date back to the 5th – 2nd centuries BC. Since the beginning of the 20th century, enough data has already accumulated to confirm that lions (not only cavemen) were in the fauna of Ukraine. And just the transition of the climate from a colder one, with woody vegetation, through the forest-steppe stage to the steppes, is most suitable for the distribution of this species in the Black Sea region. This is in good agreement with our dating data.

[17] *Герасименко Н.П.* Природная среда обитания человека на юго-востоке Украины в позднеледниковые и голоцене (по материалам палеогеографического изучения археологических памятников). *Археологический альманах*. 1997. № 6. С. 3-64.

Among others, the unique site of Ratniv-II (Volyn region) was investigated. Zooarchaeological materials from 18 objects of different times have been identified, due to which two historical periods, which are almost continuous in terms of the availability of materials, have been identified (from 5400 BC to 1100 BC and the 8th – 12th centuries AD). Paleoclimatic conditions on the site of modern Ratnov were reconstructed and a comparison was made with own reconstructions in the Poltava region (fig. 2).

1. Object 17, Linear Pottery culture (LBK). According to the results of the analysis of the osteological collection, it can be assumed that the settlement was located in a forest-steppe landscape, most likely with mixed forests (the main species are oak, linden, elm, pine). During the studied period, the climate was warm, the average winter temperature did not fall below +2.3°C, which corresponds to the Holocene climatic optimum (early Atlantic period AT1).

2. Tshinetsko-Komariv culture. The settlement was located in a forest-steppe landscape, most likely with mixed forests (the main species are oak, linden, elm, pine). In the studied period, the climate was warmer than today, but colder and drier than the previous Atlantic period.

3. Mezhanovitska culture/Stzhizhov culture and the Middle Ages (8th – 9th century AD and the beginning of the 11th century AD). Thanks to the presence of indicator species in the material, paleoclimatic and paleoecological conditions for the studied objects were reconstructed. Thus, the period of existence of objects 21 and 36 fell on the subboreal – at the end of cooling and the beginning of warming. Settlements were located in the forest-steppe, but with a predominance of coniferous forests and heather plants in the undergrowth. But the average winter temperature did not fall below +2.3°C.

The period of existence of object 24 refers to the sub-Atlantic period, in particular to the end of the climatic pessimism of the early Middle Ages. The settlement was located in the forest-steppe zone, the forests were mainly mixed: represented by broad-leaved (oak–hornbeam) and coniferous (pine and spruce) species. The maximum depth of the snow cover in winter ranged from 30 to 40 cm.

The functioning of object 32 also belongs to the sub-Atlantic period, in particular to the Middle Ages climatic optimum, which is indicated by the presence of roe deer bones in the material. The settlement was located in the forest-steppe zone, but the area of forests increased, broad-leaved forests with species with soft wood (aspen, alder, willow, poplar) prevailed, especially in river floodplains. The maximum depth of the snow cover in winter did not exceed 25.0 cm. The average monthly temperature was ≥+10°C for 150-160 days a year, and the annual amount of precipitation was 450-650 mm.

The results were compared with the data of paleobotanists and climatologists from the territories of these monuments in the studied period. To a large extent, the reconstructions coincided, which gives us the opportunity to recommend the above-mentioned species as indicators of paleoclimatic and paleoecological changes.

CONCLUSIONS

To date, work on the identification of other indicator species continues, we have carried out reconstructions of the paleoclimate on the basis of osteological materials found in the excavations, and for a number of monuments we have compared the

results with the data of paleobotanists and soil scientists from the same areas. The similarity of the obtained results is significant, which allows us to propose a method of reconstruction of paleoclimatic and paleoecological conditions based on the findings of the indicator species selected by us as effective. The most effective is a comprehensive study of osteological materials, taking into account the presence of the above-mentioned species in the material. In terms of time spent, the identification of zooarchaeological materials is a simpler and faster method than paleobotanical research, and the results are largely comparable. In addition, the same species can be used to model predictions of habitat changes due to climate change in the future.

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Надійшла до редакції / Received: 02.01.2023 *Схвалено до друку / Accepted: 27.06.2023*

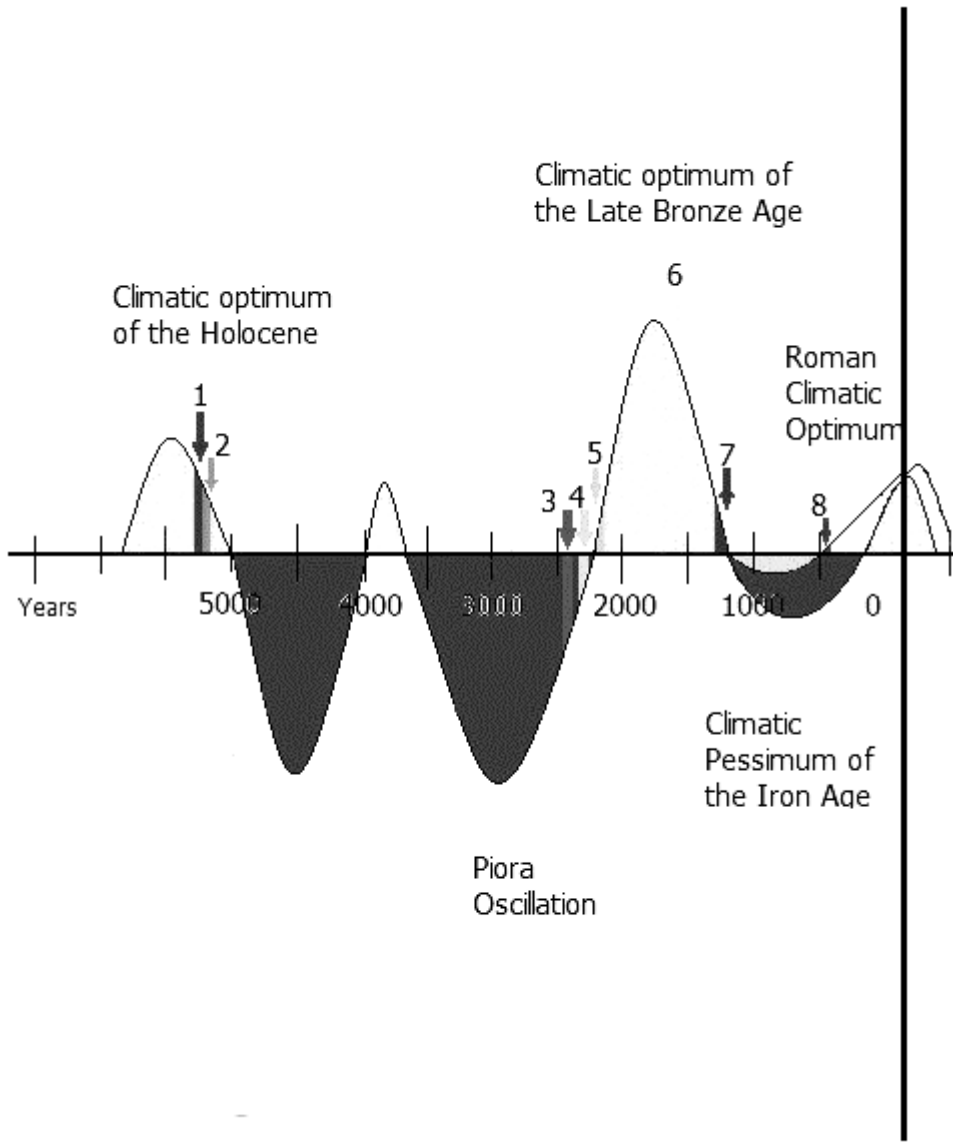

Fig. 1. Dating of the studied materials and their relationship with climatic optimums and pessimums (BC). 1-2, 4-7 – archaeological sites on the territory of of Ratniv-II; 3 – archaeological sites of Kolyadka island, 8 – archaeological sites of Olbia, R-25.

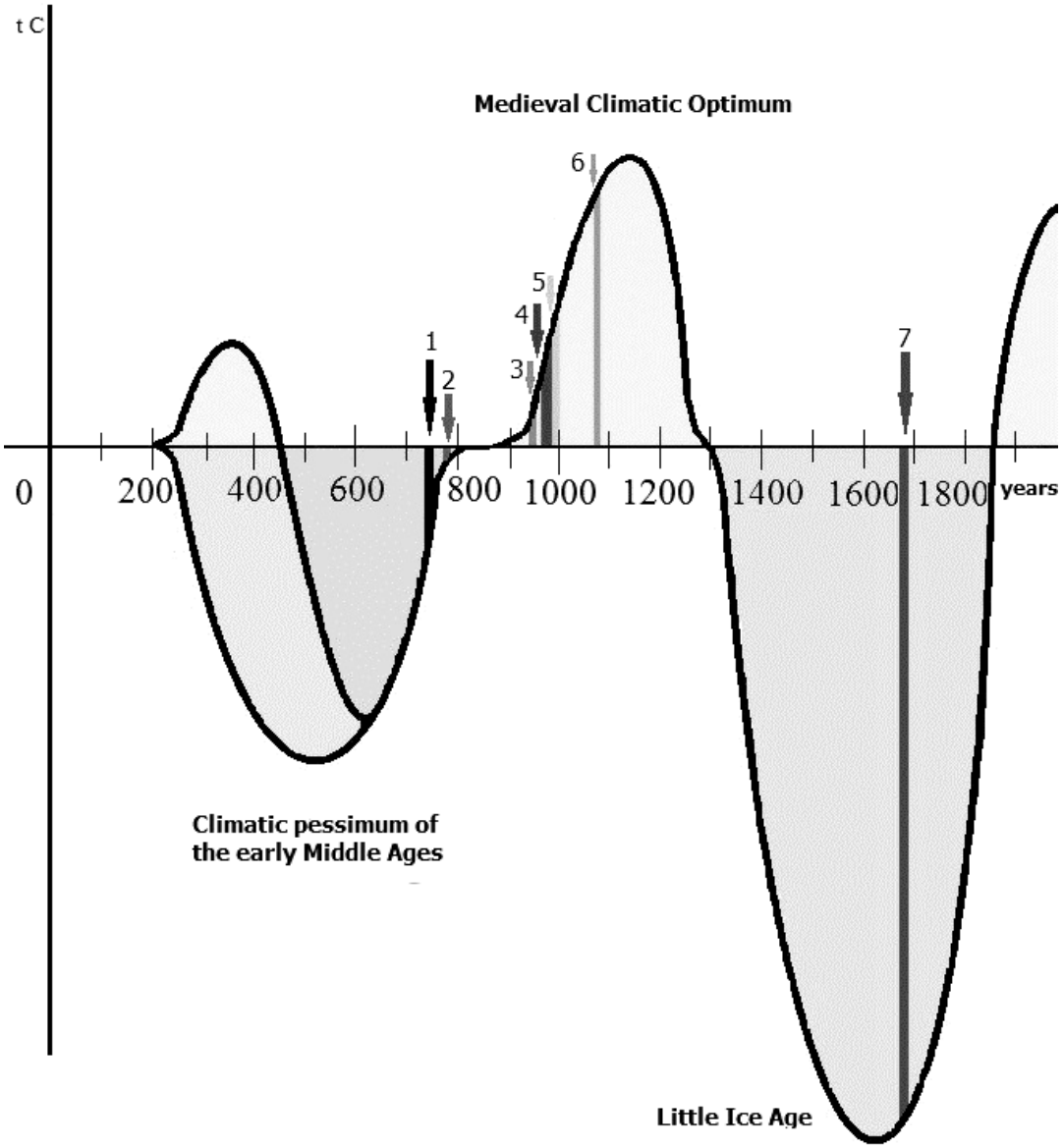

Fig. 2. Dating of the studied materials and their relationship with climatic optimums and pessimums (AD). 1, 4, 7 – archaeological sites on the territory of Poltava; 2, 3, 5, 6 – archaeological sites on the territory of Ratniv-II

Table 1.
Optimal and limiting environmental factors for a number of animal and plant species.

Species	1[1]	2	3	4	5
Mammals					
Roe deer	Forest-steppe	Broad-leaved and mixed forests, sometimes floodplain forests. Optimal: +10°C at least 150-160 days a year. The total annual precipitation is no more than 450-650 mm.	25-30 cm	1. Maximum depth of snow cover 2. Vegetation and nature of the area 3. Rivalry with deer, elk and hares	Alder, aspen, poplar, willow, hornbeam, birch, ash, maple, linden, rowan, also eat acorns, chestnuts and beech nuts.
Beaver	Forest	Broad-leaved, mixed or floodplain forests. If the river is fast and it is not possible to build a house and a dam, dig burrows in the riversides		1. Hydrological regime. 2. Press of predators 3. Feed availability	Alder, aspen, poplar, willow
Wild boar	Forest-steppe	Broad-leaved, mixed forests or reed thickets.	30-40 cm	1. Maximum depth of snow cover	Oak-hornbeam, beech and mixed forests
Elk	Forest	Broad-leaved and mixed forests (birch, pine, aspen and willow), there may be floodplain forests and areas of swamps.	90-100 cm	1. Drying up of swamps 2. Maximum snow depth	Elk eats leaves of such species (preferring soft breeds): mountain ash, ash, maple, buckthorn, aspen, bird cherry, willow. They love marsh, aquatic and near-water plants, a three-leafed watch Moose reluctantly eat spruce. From herbaceous: dandelion, fireweed, forest angelica, blueberries, lingonberries, speedwells, wild raspberries, lilies of the valley, sorrel, hellebore, nettle, meadowsweet. They eat mushrooms, including fly agarics, moss and lichens. In winter, they eat needles, willow branches, gnaw the bark. In the deep snow period of the year, moose always adhere to those types of land where per unit area there are maximum reserves of branch food under good protective conditions (pine undergrowth, willow, aspen, birch forests, fieldfare growing in burnt areas, clearings or in river valleys). At frosts down to -20°C and especially below with the wind, elks go deep into continuous forests, mainly spruce and spruce-fir. In severe frosts, the percentage of food consisting of fir increases, and sharply decreases from deciduous trees and shrubs.

[1] 1 – Natural zone; 2 – Vegetation, optimal conditions; 3 – Maximum depth of snow cover; 4 – Limiting factors (natural); 5 - Fodder objects

European pond turtle (Emys orbicularis)	Forest, steppe, forest-steppe	Water objects, swampy area, fresh water bodies.		1. The average winter temperature is not lower than +2.3C 2. Availability of silt for wintering. 3. appears after wintering in April-May, at air temperature from +6 to +14°C and water from +5 to +10°C. 4. Hibernates at the end of October-beginning of November	
European pine marten	Forest	Mixed and broad-leaved forests: spruce, oak, linden, fir and tall forests with dense thickets of deadwood and large, hollow trees.		1. The presence of a forest. 2. Avoids young and small-leaved forests.	Voles, squirrels, as well as birds and their eggs. In addition, reptiles, frogs, snails, insects and carrion. In autumn, fruits, berries and nuts can be part of their food.
Stone Marten	Forest-steppe, rocky landscape	Rock crevices, piles of stones serve as natural shelters for them. Near settlements, attics or stables are often used.		1. Suitable shelters. 2. Feed base	Small mammals (rodents or rabbits), birds and their eggs, frogs, insects. In summer - berries and fruits. Sometimes they penetrate chicken coops or pigeon houses.
Brown bear	Forest	Continuous forests with windbreak and burnt areas with dense growth of deciduous species, shrubs and grasses, interspersed with swamps, glades, reservoirs		1. The presence of large forests 2. Drainage of raised bogs 3. Worry factor	Omnivorous: berries, acorns, nuts, roots, tubers and stem parts of plants, they eat spruce and pine needles, blueberry shoots and its roots, aspen buds, linden, mountain ash, maple, willow, and sometimes chaga; insects - ants, butterflies; worms, lizards, frogs, rodents (mice, marmots, ground squirrels, chipmunks) and fish (salmon). Ungulates are hunted: roe deer, fallow deer, elk, deer. Brown bear loves honey, eats carrion
Red deer	Forest	Mixed forests. Prefers broad-leaved, subtropical and taiga forests, river banks	40 cm	1. Depth of snow cover 2. Predators - wolf, lynx, bear 3. A competitor with a roe deer	The main food is herbaceous vegetation (cereals, legumes). In winter, it takes advantage of the opportunity to extract leaves from trees that have fallen in autumn, various stems and bark of shrubs. They also use pine and spruce needles, acorns, chestnuts, nuts, seeds of many plant species, mushrooms, lichens, fruits and berries. They lick salt, use mineral springs.
Saiga	Steppe	Open territories		1. Snow depth, 2. Availability of watering holes. 3. Critical drought, especially during the calving period and until October 4. Frosts	Welsh fescue ('tipchaky'), wormwood, couch grass, chasteberry, saltwort, ephedra, kermek, liquorice, beetroot, irises, tulips
Onager (*Equus hemionus*)	Steppe	Open territories		1. Snow depth, 2. Availability of watering holes.	Herbaceous vegetation: fresh grass, cereals (bluegrass, bonfire), saltwort, saxaul, camel thorn, kandym, etc.

European polecat	Forest, forest edge, forest-steppe	Often seen in the floodplains of small rivers, as well as near other bodies of water		1. Habitat change. 2. Avoids continuous taiga massifs	The basis of nutrition for the black ferret is voles and mice, in summer it often catches frogs, toads, as well as snakes, wild birds, large insects (locusts, etc.), penetrates hare holes and strangles young hares.
White hare	Tundra, forest, partially forest-steppe	Prefers forests sparse with meadows, river valleys, as well as with areas of old, overgrown burnt areas and felling areas		1. High snow cover or ice crust, preventing food from being obtained from under the snow. 2. Epizootics.	In spring and summer, it feeds on the green parts of plants: clover, dandelion, mouse pea, yarrow, goldenrod, bedstraw, sedge, cereals, oats and clover in the fields. It eats shoots and fruits of blueberries, horsetails and mushrooms. In winter, it feeds on the shoots and bark of various trees and shrubs. Almost everywhere, its diet includes various willows and aspens. Birches and larches overeat not so willingly. In the south, it often feeds on shoots of broad-leaved species - oak, maple, hazel. In some places, the role of mountain ash, bird cherry, alder, juniper, rose hips is great in nutrition. If possible, even in winter it digs up and eats herbaceous plants and berries; feeds on hay in stacks. Willingly visits salt licks, gnaws the bones of fallen animals and antlers shed by elks and deer.
European hare	Forest-steppe, steppe	An inhabitant of open spaces (edges, extensive clearings, felling areas, burnt areas), forest-steppe, steppe, desert-steppe landscapes. It is rare in the depths of coniferous massifs, more common in deciduous forests, although here it prefers light forests. In the forest-steppe and steppe zones, it occurs along the gullies, floodplains, along fallows and crops of grain crops. gravitates towards water bodies		1. High snow cover, ice crust, which interfere with getting food from under the snow. 2. Epizootics.	The composition of the summer diet is very diverse - various wild (dandelion, chicory, tansy, mountaineer, colza, clover, alfalfa) and cultivated (sunflower, buckwheat, cereals) plants. Willingly eats vegetables and gourds. In winter, it continues to feed on seeds and grass rags, winter crops, the remains of garden crops, digging them out from under the snow. With deep snow cover, it switches to feeding on tree and shrub vegetation (shoots, bark). It most readily eats maple, oak, hazel, broom, as well as apple and pear trees. aspen and willow consumes less frequently.
Squirrel	Forest, forest-steppe	Mixed coniferous-deciduous forests. He also likes mature dark coniferous plantations - cedar forests, spruce forests, fir forests; they are followed by larch forests, thickets of elfin cedar and mixed pine forests		1. Natural enemies (owls, goshawk, pine marten, foxes and cats) 2. Lack of food 3. Epizootics.	In areas where oak forests grow with hazel undergrowth, it feeds on acorns and hazelnuts. In addition, the squirrel consumes mushrooms, buds and shoots of trees, berries, tubers and rhizomes, lichens, herbaceous plants, seeds of coniferous trees - spruce, pine, fir, larch. In starvation, it intensively eats flower buds of spruce. During the breeding season - animal feed: insects and their larvae, eggs, chicks, small vertebrates. Gnawing on the bones of dead animals, visiting salt licks

The horse is domestic	Forest-steppe, steppe	Open areas, possible grazing in river floodplains.	Up to 50 cm tebenevka (winter grazing) is possible	1. Lack of places for grazing and harvesting hay	Herbaceous vegetation
Cattle	Forest-steppe, steppe	Open areas, possible grazing in river floodplains.	Up to 10 cm tebenevka is possible	1. Lack of places for grazing and harvesting hay	Herbaceous vegetation
Sheep	Forest-steppe, steppe	Open, well-lit areas.	Up to 25 cm tebenevka is possible	1. Lack of places for grazing	Herbaceous vegetation
Lynx	The forest, taiga, sometimes enters the forest-steppe	Prefers deaf, inaccessible areas of the forest with dense undergrowth, blockages and windbreak. Most often, animals keep in ripe mixed coniferous-deciduous and pine forests. interspersed with old, overgrown felling areas. She avoids small-leaved forests, light forests or pure pine forests.	Loose snow with a height of more than 50 cm makes it difficult to move	1. Number of main food objects. 2. Destruction and destruction of breeding sites 3. Forest fragmentation.	White hare, red hare, roe deer, young wild boars, grouse, chipmunk, fox, beaver, squirrel
Eurasian otter	Forest reservoirs, in the open area – reservoirs with reeds	It prefers places with washed-out waters and littered with windbreak shores, where there are many reliable shelters and places for burrowing. Otters live permanently in rivers, and in reservoirs with stagnant water - only during the ice-free period, since during freezing the otter has no access to water		1. The purity of the water in the reservoir 2. Deforestation and shrubs along the river banks, 3. Grazing in the floodplain, 4. Decline in fish stocks	It feeds mainly on fish (carp, pike, trout, roach, gobies, etc.), willingly eats river mollusks and caddisfly larvae. In summer it also catches water voles and other rodents, frogs and lizards; in some places systematically hunts waders and ducks. In places where beavers and otters coexist, the latter may eat beaver cubs.
Steppe polecat	Steppe, forest-steppe			1. Habitat change – overgrowing or plowing of steppes	Hunts for ground squirrels, hamsters, pikas, mouse-like rodents, less often for birds, snakes and frogs, in summer for invertebrates

European bison (*Bison bonasus*)	Forest, forest-steppe	Broad-leaved and mixed forests		1. Reduction of suitable territories 2. Anthropogenic factor	Leaves and green parts of plants, succulent grass. In winter, they eat shoots of shrubs, bark of oak and alder, ash and aspen, willow, maple, pine and spruce, rowan and raspberry branches. A total of 350 species of various herbaceous plants, shrubs and trees, including thorny comfrey, hellebore and cow parsnip
Greater blind mole-rat (*Spalax microphthalmus*)	Steppe, forest-steppe	It is distributed in areas occupied by grassy vegetation, does not go far into forests, although it is found on the edges, in forest belts, in glades and along forest roads. In plowed areas, the population decreases, individuals concentrate on hay and pasture lands, near beams, on the boundaries between fields		1. Natural enemies (steppe polecat, fox and large birds of prey). 2. Disappearance of suitable territories	The basis of nutrition is rhizomes, bulbs and tubers of plants. In spring and early summer, aerial parts of plants (stems and leaves) are also actively used for food. The range of fodder plants is several dozen species, among which *Compositae*, *Umbelliferae* and legumes predominate.
Pygmy field mouse (*Apodemus uralensis*)	Forest	Broad-leaved and mixed forests, but prefer open forest areas. Less common in steppe biotopes		1. Natural enemies (steppe polecat, fox and large birds of prey). 2. Epizootics	
Birds					
Western capercaillie	Forest	Coniferous mature forests, in a state of climax. in continuous high-stemmed conifers, as well as in mixed forests, rarely in deciduous ones. He likes mossy swamps in the forest, rich in berrie		1. Availability of forests 2. A sufficient amount of snow in winter to spend the night in (at least 40 cm for females, 50 cm for males). Either the temperature is not lower than -10C, then they do not spend the night in the snow. 3. long cooling periods during the reproduction period and warm winters with frequent changes of heat and cold, during which an ice crust forms. 4. Natural enemies (foxes, martens, wild boars and goshawks). 5. Drainage and improvement of heath wastelands, afforestation, use of fertilizers in agriculture and cattle grazing	Food in spring and summer consists of shoots, flowers, tree buds, leaves, grass, wild berries (blueberries, blueberries), seeds and insects. In autumn, birds feed on larch and aspen needles, in winter - pine and spruce needles, buds. Chicks eat insects and spiders.

Black grouse (*Lyrurus tetrix*)	Forest, forest-steppe	Birch forests, the beginning of succession. It occurs on forest edges, in the valleys of large rivers. It avoids continuous dark forest, however, it is found on extensive felling areas or burnt areas.		1. A sufficient amount of snow in winter to spend the night in (at least 30 cm for females, 40 cm for males). Either the temperature is not lower than –10C, then they do not spend the night in the snow. 2. Ice crust on the snow. 3. Natural enemies (foxes, martens, wild boars and goshawks). 4. Drainage and improvement of heath wastelands, afforestation, use of fertilizers in agriculture and cattle grazing	In spring, inflorescences of cotton grass (*Eriophorum*), birch, larch, and alder buds are harvested; various parts of heather shrubs and herbs, such as *Caltha palust*ris or buttercups. In summer and autumn, it eats berries (blueberries, lingonberries, blueberries), various parts of herbaceous plants (clover leaves, aspen, cuffs, blueberries, Hieracium; bird cherry fruits, etc.). In winter, birch shoots, buds and catkins form the basis of nutrition, and where there is little of it, then parts of other woody plants - depending on the region, these can be spruce needles, juniper needles and berries, larch shoots, young pine cones, willow and alder buds and etc.
Hazel grouse (*Tetrastes bonasia*)	Forest, taiga	Boreal forests. Avoids approaching the edge of the forest closer than 200-300 m. Plots of forest with an abundance of deadwood, dense dense spruce forest and interspersed with birch and aspen in the interfluves and slightly swampy, low-lying places. Birds avoid clean birch and alder plantations, but prefer to stay where there are spruce forests. The hazel grouse does not live in a pure pine forest, except when there are abundant thickets of ferns in which the bird finds refuge. The hazel grouse avoids clearings with tall and dense grass. He willingly stays along forest roads, overgrown with edible plants along the roadside, with the constant presence of water in the ruts and placers of pebbles.		1. Ice crust on the snow 2. Little snowy winter, snow up to 15 cm deep. At temperatures higher than 0 – do not bury in snow 3. Natural enemies (fox, lynx, animals from the weasel family (marten, ermine, sable, etc.), various owls, hawks 4. Boar destroys masonry 5. Fires	Young birds feed mainly on animal food - mainly insects, as well as ant pupae ("eggs"), but very soon they begin to eat more and more plant food - greenery of herbaceous plants and berries (cranberries, strawberries, blueberries, lingonberries). Summer-autumn - mountain ash. On Sometimes, instead of gastroliths, he uses bird cherry seeds, rosehip seeds. Autumn and winter food for hazel grouse is mainly catkins and buds of deciduous trees (birch and hazelnut). Eats seeds dropped from spruce cones

Bustard	Steppe, forest-steppe	Prefers flat and slightly hilly areas of steppes and meadows with fairly high, but not very dense vegetation, avoiding ravines, gullies, high elevations and rocky terrain. wormwood and cereal (mainly feather grass) steppes, dried-up peat bogs, meadow lake basins and river floodplains. annual rainfall does not exceed 600 mm		1. The number of individuals decreases with an increase in temperature and moisture. 2. The thickness of the snow cover, as a result of which the birds lose the ability to get their own food 3. Foresting or plowing of steppes 4. Natural enemies: eagles (golden eagle, steppe eagle, imperial eagle) and white-tailed eagle, fox, corsac, wolf, badger, stray dogs and cats and steppe polecat, corvids (rook, gray and black crows, magpie), harrier, buzzard	Adult birds willingly feed on shoots, leaves, seeds and inflorescences of wild and cultivated plants from the Asteraceae families (dandelion, goat-beard, kulbaba, garden thistle, common tansy, skerda, arnozeris), Legumes (creeping clover, meadow clover, sowing pea, vikolist sainfoin, sowing alfalfa), Cabbage (field radish, sowing radish, turnip, rapeseed, black mustard, garden cabbage), Plantain, Bluegrass (fescue, etc.). With a lack of the above feed for a short period of time, it can feed on shoots with a tougher, fibrous structure - for example, beets. Sometimes it eats the rhizomes of herbs - creeping wheatgrass, umbellifera, onion. The basis of animal feed is insects and their larvae (locusts, crickets, grasshoppers) and beetles (ground beetles, dead beetles, lamellar, weevils and leaf beetles). The latter include the Colorado potato beetle. Bed bugs and butterfly caterpillars are less commonly caught. The chicks are fed by Formica ants and their pupae. On occasion, birds eat earthworms, snails, isopods, earwigs, frogs, lizards, nestlings of ground-nesting birds (such as skylark). During the years of mass reproduction, small rodents are hunted. Bustards also need drinking water. In summer, flocks of birds periodically fly to the watering place, in winter they use snow
Quail	Meadows, steppes, fields			1. The amount decreases with increasing temperature and humidity	
Molluscs					
Painter's mussel (*Unio pictorum*)	Fresh water reservoirs	Inhabits lakes and slow-flowing rivers, on sandy, silty ground.		1. Clean water. 2. Hydrological regime	
Thick shelled river mussel (Unio crassus)	Fresh water reservoirs	It lives in rivers with clear water and a fast current.		1. Clean water. 2. Habitat change 3. Hydrological regime	
Discus rotundus	Terrestrial mollusc	Broad-leaved, oak-hornbeam forests. It is found in the depths of the forest. These gastropods live in forests and damp shady places, in dead logs, under stones, on humus and in soil litter, sometimes in colonies. The species can tolerate non-calcareous substrate.		1. Habitat changes	

Planorbidae	Fresh water reservoirs	They can be found in slowly flowing or stagnant shallow water bodies, as well as overgrown backwaters, in places where there is no fast current. Such reservoirs are distinguished by an abundance of rotting vegetation, which serves for coils not only as a refuge, but also as food.		1. Medium-pure water 2. Hydrological regime	
Grape snail	Terrestrial mollusc	Prefers grape leaves. It lives in thickets of bushes, on light forest edges, in gardens, parks. The colour of the shell in some individuals is darker, in others it is lighter. The color saturation depends on the habitat and is related to the intensity of illumination and the background of the environment. Accordingly, by the colour of the shell, it can be determined whether its habitat was well lit or more overgrown. Winters in the soil. That is, they were mined in the warm season.		1. Warm humid climate 2. Natural enemies: hedgehogs, shrews, lizards, moles and other animals, including some beetles and predatory snails	Uses leaves of grapes and wild strawberries, cabbage, nettle, burdock, lungwort, dandelion, plantain, radish, horseradish. An animal needs calcium salts to grow its shell.
European oyster	Seawater	There is an edible oyster in the intertidal zone. They live on hard soils - stones, rocks or on mixed sandy-stony soils at depths from 1 to 50-70 m. The optimum water temperature for the growth and development of oysters is 18-22°C, salinity is 17-25‰ the minimum salinity at which they can exist is 12‰.		1. Water temperature and salinity	

Crustaceans					
European crayfish (*Astacus astacus*)	Fresh water reservoirs	Fresh clean water: rivers, lakes, ponds, fast or flowing streams (3-5 m deep and with depressions up to 7-45 m). In summer, the water should warm up to 16-22°C.		1. Water purity 2. Hydrological regime	Vegetable (up to 90%) and meat food (mollusks, worms, insects and their larvae, tadpoles, carrion). In summer, crayfish feeds on algae and fresh aquatic plants (weed, elodea, water lily,), in summer it lives in shallow water, in winter it moves to a depth where the soil is strong, clay or sandy.
Danube crayfish (*Astacus leptodactylus*)	Fresh water reservoirs	Prefers warm, warmed up in summer, nutrient-rich low-lying reservoirs or slowly flowing rivers. It also lives in polluted water bodies. In suitable coastal slopes, he digs residential holes. more resistant to pollution than European crayfish		1. Hydrological regime	It feeds on algae (especially calcium-rich chara algae) and fresh aquatic plants - this is a pondweed, elodea
Plants					
Elm	Forest, forest-steppe	In the form of impurities, they are distributed mainly in the subzone of deciduous forests; they are also found in the southern and middle parts of the subzone of spruce forests. Pure stands are rare. Successfully grow on fertile soils, especially on alluvial. Some species tolerate saline soils and relatively dry habitats. All species are quite shade-tolerant, especially when young; in full light form a powerful crown.		1. Warm climate	

Pine	Forest	On typical forest sites, birch, white alder, and some willows are occasionally mixed with pine; in lower places, with moister soil, there is a more significant admixture of various hardwoods, with even greater soil moisture, spruce is often mixed in very significant quantities, and in northern forests, other conifers.		1. Light-loving. 2. Sandy and sandy soil	
Grape		Wild species of grapes grow in humid places along river valleys, in gorges, deciduous forests and on the mountain slopes of the temperate and subtropical zones of the northern hemisphere.		1. Warm climate	
Ivy	Forest	Ivy loves shady places		1. Warm climate	
Water caltrop (*Trapa natans*)	Fresh water reservoirs	Grows in lakes, backwaters and oxbow lakes of slow-flowing rivers, in shallow waters Prefers silty soils of slowly flowing or stagnant reservoirs. Often forms continuous thickets. It is sensitive to the composition of water, illumination and temperature, the water temperature is about 25–30°C.		1. Hydrological regime	