RESEARCH PAPER

HOLOCENE POPULATION OF AMBROSIA ON SOUTH OF RUSSIAN FAR EAST

Valentina B. Bazarova[1*], Marina S. Lyashchevskaya[1], Ekaterina P. Kudryavtseva[1], Yana V. Piskareva[2], Yelena V. Astashenkova[2]

[1]Pacific Geographical Institute, Far Eastern Branch of the Russian Academy of Sciences, Radio St., 5, 690041, Vladivostok, Russia

[2]Institute of History, Archaeology and Ethnography of the Peoples of the Far East, Far Eastern Branch of the Russian Academy of Sciences, Pushkinskaya St., 89, 690000, Vladivostok, Russia

***Corresponding author:** bazarova@tigdvo.ru

Received: August 15th, 2022 / Accepted: February 15th, 2023 / Published: March 31st, 2023

https://DOI-10.24057/2071-9388-2022-123

ABSTRACT. *Ambrosia artemisiifolia* first appeared on the Eurasian continent in the 18th century. In the south of the Russian Far East *Ambrosia* first appeared in the middle Holocene. The presence of its pollen in the sediments on west of the lacustrine Khanka Plain is correlated with the appearance of early men. The presence of *Ambrosia* pollen in Holocene deposits can be considered as an indicator of ancient agriculture in the south of the Russian Far East. The interval from the 19th century to the 1960s is marked by a complete absence of *Ambrosia* in this region. On boundary of early Holocene and middle Holocene population of ragweed existed on eastern part of Eurasia simultaneously and independently from Northern America population. The modern isolated centre of the *Ambrosia* expansion in the south of the Russian Far East began later than the 1960s – 1970s. The modern secondary settling of this species in the east and west parts of Eurasia formed independently. The ranges of the species in China, Japan, the Korean Peninsula, and the south of the Russian Far East also formed independently.

KEYWORDS: *Ambrosia* pollen, distribution in Holocene deposits, ancient agriculture, Russian Far East

CITATION: Bazarova V. B., Lyashchevskaya M. S., Kudryavtseva E. P., Piskareva Y. V., Astashenkova Y. V. (2023). Holocene Population Of Ambrosia On South Of Russian Far East. Geography, Environment, Sustainability, 1(16), 16-25
https://DOI-10.24057/2071-9388-2022-123

ACKNOWLEDGEMENTS: This work was supported by the Ministry of Education and Science of the Russian Federation (state task # 075-01032-22-02).

Conflict of interests: The authors reported no potential conflict of interest.

INTRODUCTION

Ragweed attributed to the Asteraceae family was first described by Carl Linnaeus in the 18th century. The *Ambrosia* genus is native to the North American continent and includes 40 – 43 species (Basset and Terasmae 1962; Vascular plants … 1992; Flora of China … 2011). Although the native range of *Ambrosia artemisiifolia* is restricted to North America, it has colonized temperate regions of the world, including continental Europe, where it has greatly increased in range and abundance since the mid-20th century. It naturalized and frequently form part of the flora in almost all European countries and some countries in the East Asia. This a noxious invasive species is an important weed in agriculture and a source of highly allergenic pollen. The importance placed on *A. artemisiifolia* is reflected by the number of international projects that have now been launched by the European Commission and the increasing number of publications (Smith et al. 2013). Currently, the *Ambrosia* species is widespread globally. The *A. artemisiifolia* first appeared on the Eurasian continent in the 18th century, which is when this species was first introduced in Europe, and has been continued spreading since (Genton et al. 2005). The earliest French herbarium records of the *A. artemisiifolia* were of specimens found in botanical gardens, revealing its presence during the 18th century in at least three botanical gardens and at least five gardens during the first half of the 19th century (Chauvel et al. 2006). In 1902, ragweed invasion had already occurred in Italy (Mandrioli et al. 1998), and in 1907, it reached the Ponnonian part of Romania (Csontos et al. 2010). In Russia, the ragweed was first recorded in 1918 at the Stavropol experimental station (Mar'yushkina 1986). To date, *Ambrosia artemisiifolia* occurs throughout European Russia, reaching as far north as 60°41′N. The species is widespread in China, Japan, the Korean Peninsula, and in the south of the Russian Far East. In Japan, this plant was introduced at the beginning of the Meiji Era in the 1860s–1870s (Kato and Ohbayashi 2008). In China, *A. artemisiifolia* was first introduced in the 1930s and has since spread from the south to the north (Qin et al. 2014; Zhou et al. 2017). On the Korean Peninsula, *Ambrosia artemisiifolia* and *A. trifida* are thought to have been introduced during the Korean War (1950–1953) when the United Nations forces led by the United States joined South Korea in the conflict (Lee and Oh 1974; Kim and Kil 2016). The first sighting of *Ambrosia* in Primorye, which is south of the Russian Far East, was published in 1966 (Pimenov et al. 1966). In that same year, this species was included in the regional flora (Voroshilov 1966). Its expansion over the Russian Far East region over its first 20 years has been analyzed thoroughly (Nedoluzhko 1984; Aistova et al. 2014; Vinogradova et al. 2020). By the early 21st century, the species was found to have formed two large ranges on the Eurasian continent, western and eastern.

The first information on the presence of *Ambrosia* pollen in buried deposits of the southern Far East was published in the 1990s. Two cultural layers dated to the Holocene were excavated on the Khanka Plain (the first and second halves of the second millennium BC) (Verkhovskaya and Yesipenko 1993). The same species was found in the sediment of the northern coast of Talmi Lake and lagoonal deposits in Boisman Bay, south of Primorye (5.3 – 4.5 ka BP) (Verkhovskaya and Kundyshev 1993, 1995). New data concerning fossil *Ambrosia* pollen were obtained by studying the sedimentary sequences on the western coasts of Khanka Lake (south of the Russian Far East).

In this research, paleogeography- and ecology-based approaches are being used to address the questions of (a) distribution of *Ambrosia* on southern Far East of Russia in Holocene, and (b) how presence of pollen of *Ambrosia* in Holocene records correlates with Neolithic archaeological traditions. As a first step towards answering these questions we studied fossil Ambrosia pollen in Holocene records of southern Far East, and the second step we analyzed the ecological features of *Ambrosia*, and the third step we analyzed spatial and temporal appearance of Neolithic ancient agriculture on this area.

SETTING

There is a high accumulative plain in western Khanka Plain. The beds of the Melgunovka and Komissarovka rivers cut through this plain, and flow into the western part of Khanka Lake.

The climate of the Khanka Plain is under the control of two interacting atmospheric regions as the baric pressure gradient changes its direction twice a year. In the winter, westerlies are dominant, and severe frosts are common. In the summer, air masses move from the ocean to the continent. The most intense cyclonic activity occurs from June to August. The mean annual temperature varies from 3.8 °C in the west to 2.4 °C in the east of the plain, and the annual rainfall is 520 mm in the west of the region and 660 mm in the east. Note that regional winters have moderate snowfall and unstable snow cover.

The vegetation of the Khanka Plain consists of steppified open forests of mongolian oak (*Quercus mongolica Fisch*. ex *Ledeb*.), dahurian birch (*Betula dahurica* Pall.), and thickets of lespedeza and hazel associated with grass and herb steppe meadows. Meadow and mountain steppes occupy more than 30% of the area. These steppes are widespread in the western plain and are less common on the eastern coast of Khanka Lake. Oak forests with pine (*Pinus funebris* Kom.) are found in the low mountains of the northwest, including the steep coasts of Khanka Lake. The ground layer in the forests with steep slopes includes mostly steppe plant communities that are typically dominated by tansy (*Tanacetum boreale* Fisch. ex DC.). There are also communities with feather grass (*Stipa baicalensis* Roshev.) and those consisting of grass, sedges, and herbs. Sagebrush occurs in several plant communities. The southern and eastern coasts of Khanka Lake, as well as river floodplains, host meadows overgrown with small-reed (*Calamagrostis*), sedge- and herb-reed meadows, and grass swamps. The mountain margins of the lake catchment, particularly in the east, are covered with coniferous broadleaf forests of Korean pine (*Pinus koraiensis* Siebold et Zucc.) (Kurentsova 1962; Kolesnikov 1969).

An approximate assessment shows, that currently the *Ambrosia artemisiifolia* occupies more than 300,000 hectares in Primorye, including fields occupied by soybeans (223 thousand hectares), different levels roadsides, vegetable gardens, and settlement wastelands. During the last 12 – 15 years, some arable lands were neglected, and associations with *Artemisia, Sonchus*, and *Cirsium* (Asteraceae family) have occupied these places. *Ambrosia artemisiifolia* absents in these associations. Meanwhile, in freshly ploughed fields, this species primarily dominates in the first two years, whereas in old abandoned arable land, the species disappears in 2–3 years.

MATERIALS AND METHODS

To address the research goals, newly obtained palynological and radiocarbon data from the Holocene floodplains, beach ridge deposits, and deposits of archaeological sites were examined. The new data regarding fossil *Ambrosia* pollen were obtained by studying the sedimentary sequences on the western coasts of Khanka Lake (south of the Russian Far East). Further, the data obtained by previous researchers were also employed (Fig. 1).

Subfossil pollen assemblages were recovered from superficial samples taken from genetically different materials (silt, soil, sand, and moss). Samples 1 – 3, 6 – 7, 10 – 13, and 15 were taken from the eastern part of the Khanka Plain, and samples 4 – 5, 8 – 9, and 14 – from western part (Fig. 2). The samples were collected in June of 2004, which is before the common ragweed flowering. This species begins to bloom in the second half of July, and its seeds mature in mid-September. Deposits on the studied sections were presented with floodplain loams and sands, soils, and lacustrine sands.

Pollen analysis. The sampling technique involved cleaning the wall of the section and collecting samples from the top to the bottom. This approach eliminated samples contaminated with modern pollen as much as possible. The samples for the pollen analyses were taken at intervals of 2 cm from records of Melgunovka River flood plain, and Komissarovka River floodplain deposits, and of 5 cm from records of beach ridge and of the Novoselishche settlement deposits. Pollen was extracted according to a routine procedure as follows: samples are treated using the standard NaOH (10%) method (Sladkov 1967), and pollen grains are concentrated using the heavy liquid flotation method (Pokrovskaya 1966). The saturation of all samples by pollen and spores was sufficient for an adequate statistical calculation of the pollen distribution in the sediments. In the subfossil samples the largest amount of *Ambrosia* pollen found reached 504 grains, and the least was 4 grains. The total amount of collected pollen in the Melgunovka section was 310 – 600 grains, that in the Komissarovka section was 103 – 669 grains, the total in the section of the sandy beach ridge was 167 – 709 grains, and that in the Novoselishche settlement section was 186-249 grains.

The percentage of palynomorphs in the three groups, represented by arboreal pollen (AP), non-arboreal pollen (NAP), and spores, was estimated for each sample, wherein it was assumed that the total amount of the main genera pollen was counted as a percentage within each group, and the total amount in each group was 100%. We used the TILIA program (Grimm 1992) to construct pollen diagrams. The fossil common ragweed pollen was identified by species, wherein it was found that the pollen corresponds to characteristics of *Ambrosia artemisiifolia* (Meier-Melikyan et al. 2004).

Radiocarbon dates. The ages of the studied deposits are based on radiocarbon dating obtained from the V.B. Sobolev's Institute of Geology and Mineralogy, Siberian Branch of RAS (SOAN; Novosibirsk, Russia), and Tomsk Regional Centre, Siberian Branch of RAS (IMKES; Tomsk, Russia). The samples were cleaned with acid/alkali/acid (Arslanov 1987), and the activity was measured via liquid scintillation counting using Quantulus 1220 (PerkinElmer) spectrometry-radiometry. The conventional ages were converted to calibrated ages using the radiocarbon age calibration program CALPAL_A (Weninger et al. 2002) (Table 1).

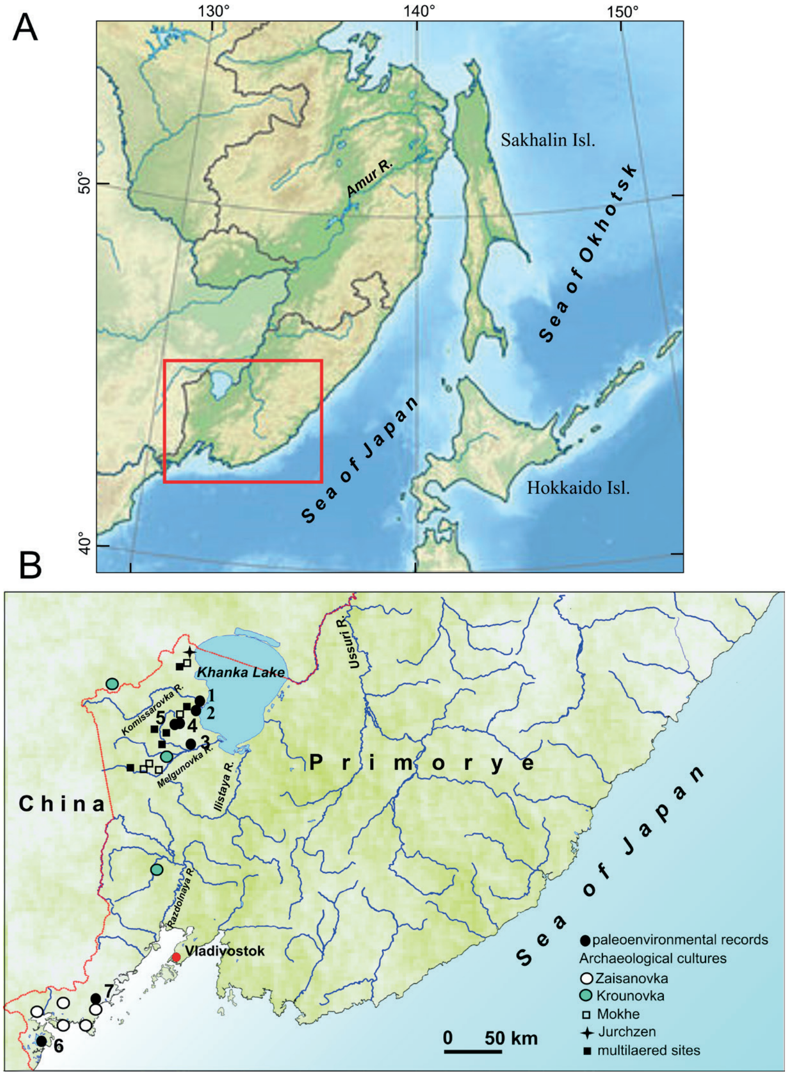

Fig. 1. Map of the studied area (A) and location of the archaeological sites and paleoenvironmental records (B): 1 – Komissarovka River floodplain deposits, 2 - the beach ridge deposits, 3 - Melgunovka River floodplain deposits, 4 - deposits of the Novoselishche settlement; 5 – Novoselishche settlement (Verkhovskaya and Esipenko, 1993), 6 - deposits of Talmi Lake, 7 - lagoonal deposits of Boisman Bay (Verkhovskaya and Kundyshev, 1995)

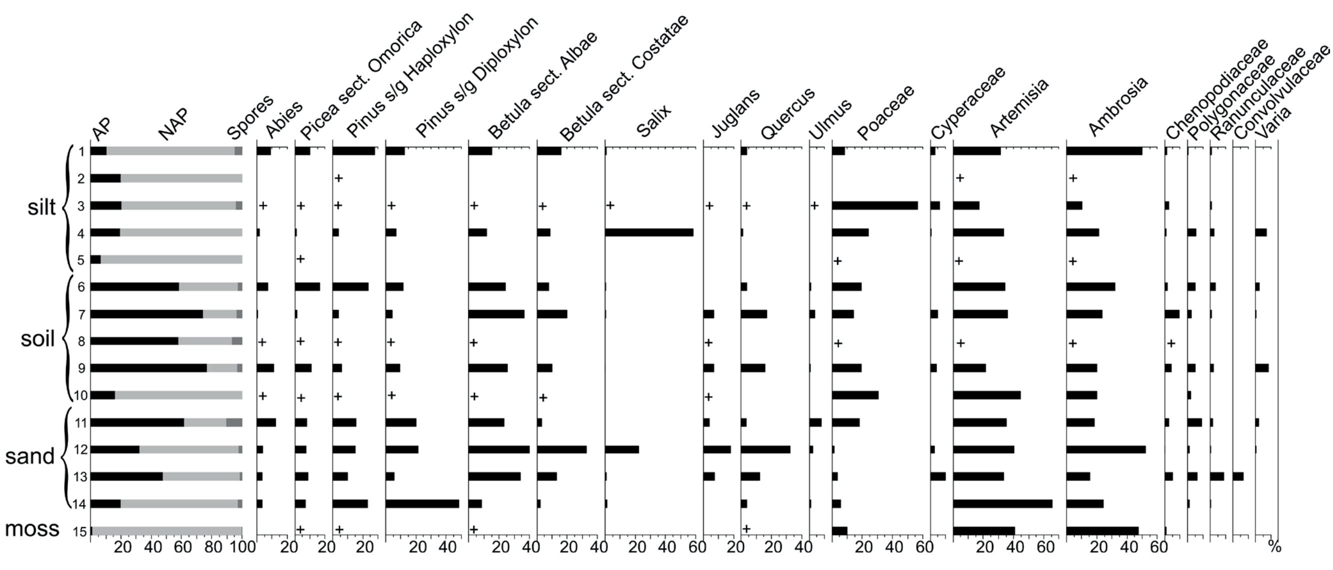

Fig. 2. Pollen diagram of the subfossil deposits on the Khanka Plain

Table 1. Radiocarbon dates

Lab. number	Depth, cm	Material	Date ^{14}C yrs BP	Cal. yrs AD/BC
Section of Melgunovka R. flood plain deposits				
SOAN-9007	10-12	humus loam	370±40	1536±68 AD
SOAN-9008	41-42	humus loam	2190±55	265±79 BC
SOAN-9009	56-58	humus loam	3830±120	2279±170 BC
SOAN-9010	63-65	humus loam	4710±100	3495±111 BC
SOAN-9011	70-72	humus loam	5690±120	4551±130 BC
SOAN-9012	98-100	humus loam	7920±135	6878±177 BC
Section of Komissarovka R. flood plain deposits				
SOAN-9017	10-12	soil	550±50	1367±46 AD
SOAN-9018	40-42	humus loam	1135±45	892±63 AD
Section of the beach ridge at Komissarovka R. mouth				
SOAN-5891	12-17	humus sand	290±50	1577±63 AD
SOAN-5892	27-32	humus sand	545±56	1369±46 AD
Section of the moat from Novoselishche settlement				
IMKES-1575	38-40	charcoal	1535±90	507±85 AD

RESULTS

Subfossil Ambrosia pollen. An analysis of the subfossil pollen spectra revealed that forest landscapes were best presented in the samples of mud left by floods, the forest-steppe environments were best recognizable in the soil samples, and floodplain communities were most easily found in the sandy samples. An abundance (10% – 52%) of *Ambrosia* pollen was found in all the samples (Fig. 2). In particular, the greatest proportion appears in the mud and sand samples in the western part of Khanka Lake, while a somewhat smaller amount was found in the soil samples. The data of other specialists shown, the herbs identified in the subfossil pollen assemblages were mostly Asteraceae throughout the Khanka Plain, wherein the proportion of *Ambrosia* pollen reached, at most, 9% (Petrenko et al. 2009). In the 1970s, subfossil pollen assemblages were studied in sediments of different genesis (fluvial, lacustrine, swamp, and soils) sampled in the eastern, southern, and western parts of the Khanka Plain. None of these samples contained *Ambrosia* pollen (Aleshinskaya and Shumova 1978).

Ambrosia pollen in Melgunovka River floodplain deposits. In the section of deposits studied on the Melgunovka River floodplain (44°34′ N, 132°04′ E, total thickness of 108 cm) there is an alluvial horizon of fine sand at a depth of 28 – 41 cm, in which occasional grains of *Ambrosia* pollen occur in the lower part of the horizon (36 – 38 cm). A calibrated 14C date of 265 ± 79 years BC (4th – 3rd centuries BC) was obtained from the underlying humified loam (depth of 41 – 42 cm) (Table 1). Therefore, the sand with *Ambrosia* pollen cannot be older than the third century BC (Fig. 3). The first minor peak of *Ambrosia* (8.4%) appears at 18 – 20 cm, which is in the lower part of the silty sand horizon dated to the Mediaeval Climatic Optimum. The pollen assemblages at that time were dominated (in the NAP group) by *Artemisia* (up to 45%) with a considerable proportion of the Poaceae (up to 24%), while the participation of the Cyperaceae and hygrophytic plants was lower than that in the underlying Subatlantic deposits. Moving upward, beginning at a depth of 36 – 38 cm, *Ambrosia* pollen is continually present in all the samples. The second peak is documented in the upper part of the humified loam deposited on the floodplain at the time of the Little

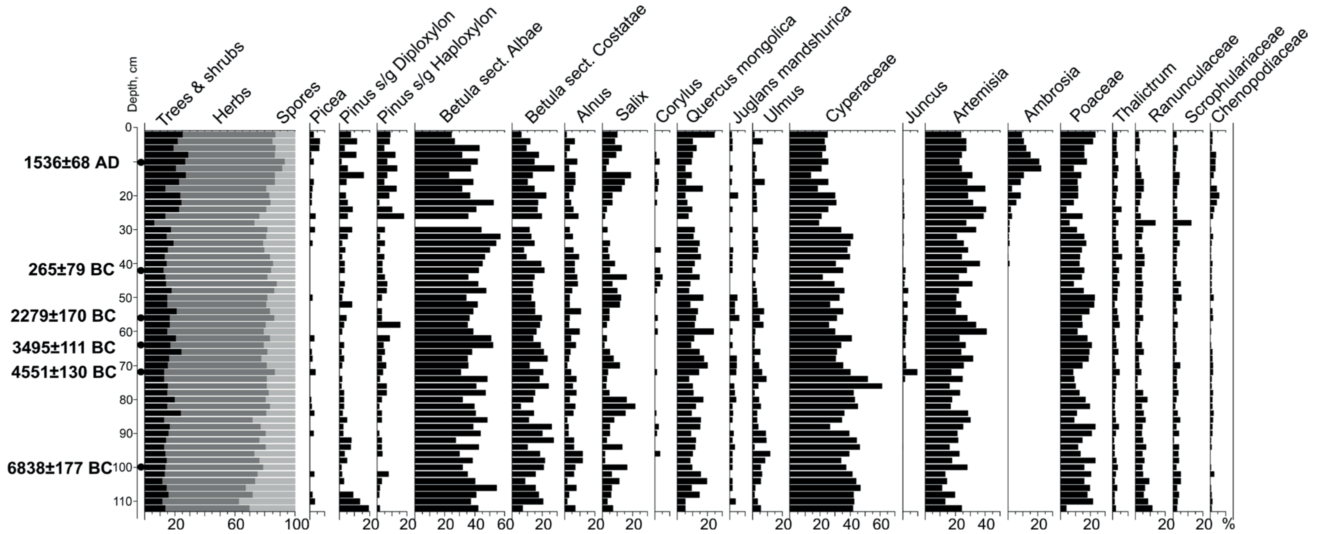

Fig. 3. Pollen diagrams of the Melgunovka River floodplain deposits

Ice Age, which was confirmed by the calibrated ^{14}C date of 1536 ± 68 years AD, which corresponds to the 15th – 16th centuries (Table 1). At this time, the mean annual temperature was approximately 1 °C lower than the current mean annual temperature (Bazarova et al. 2014). This cooling was also accompanied by reduced rainfall. Further, note that the same interval is distinguished by an increased amount of synanthropic plants (*Urtica*).

Ambrosia pollen in Komissarovka River floodplain deposits. Single grains of *Ambrosia* pollen were found in the floodplain deposits of the Komissarovka River (44°50′ N, 132°02′ E) (Bazarova et al. 2018b), which have a total thickness of 60 cm, wherein the *Ambrosia* pollen appears in the 52 – 54 cm interval (Fig. 4). The same horizon revealed the presence of single grains of synanthropic plants (*Urtica* and *Plantago*) in the pollen spectra. The nearest calibrated ^{14}C date of 892 ± 63 years AD (the 9th –10th centuries) was obtained for a sample of the overlying humified loam (40 – 42 cm). Supposedly, *Ambrosia* pollen first appeared in the floodplain deposits of the Komissarovka River in the 5th – 6th centuries. This period was marked by short-term cooling and an insignificant decrease in moisture supply. From the 52 – 54 cm interval and upward, *Ambrosia* pollen presents in every sample. The first peak was recorded in the deposits accumulated on the floodplain at the Medieval Climatic Optimum (the 9th – 10t^{h} centuries). Over the course of the subsequent 3rd or 4th centuries, the warm and relatively humid conditions changed to cooler and drier conditions. The second peak of the species occurred in the soil horizon formed during the Little Ice Age, which occurred during the 14th – 15th centuries (1367 ± 46 years AD) (Table 1). The pollen assemblages at this time are dominated by *Artemisia* (up to 60%), and various forb and herbs were also abundant (up to 59%). The peaks of *Urtica* and *Plantago* are synchronous with the maximum peak of *Ambrosia*.

Ambrosia pollen in sandy beach ridge deposits. The pollen was found in a sandy beach ridge section exposed at a depth of 75 cm near the Komissarovka River mouth (44°50′ N, 132°01′ E). The age of the ridge is estimated to be approximately 1 ka years AD (Bazarova et al. 2008). The *Ambrosia* grains were first found near the base of the sequence, dating back to the Mediaeval Climatic Optimum. In addition, the pollen appeared in the deposits attributed to the Little Ice Age (1369 ± 46 years AD, 1577 ± 63 years AD) (Table 1). In the pollen spectra, *Artemisia* was dominant, Poaceae and Asteraceae were present, and the apophyte pollen, *Urtica*, was occasionally found (Fig. 5).

Ambrosia pollen in Novoselishche settlement deposits. The archaeological site of the Novoselishche settlement is located on top of a gentle hill to the west of Khanka Lake. Samples for this section were obtained by cleaning the moat wall surrounding the settlement (44°39′ N, 131° 50′ E). The total thickness of the deposits is 55 cm, and *Ambrosia* pollen appears in the spectra beginning at a depth of 40 cm. In addition, Asteraceae, Ranunculaceae, *Artemisia*, and Poaceae pollen were found. Further, a large amount of *Urtica* pollen and other ruderal plant pollen (*Cannabis sativa* and Cichoriaceae) were presented (Fig. 6). The radiocarbon date was obtained using the charcoal located at a depth of 38 – 40 cm (507 ± 85 years AD) (Table 1). The pollen assemblages studied in each section strongly suggest that the steppe and forest-steppe landscapes on the Khanka Plain formed during the second half of the Holocene.

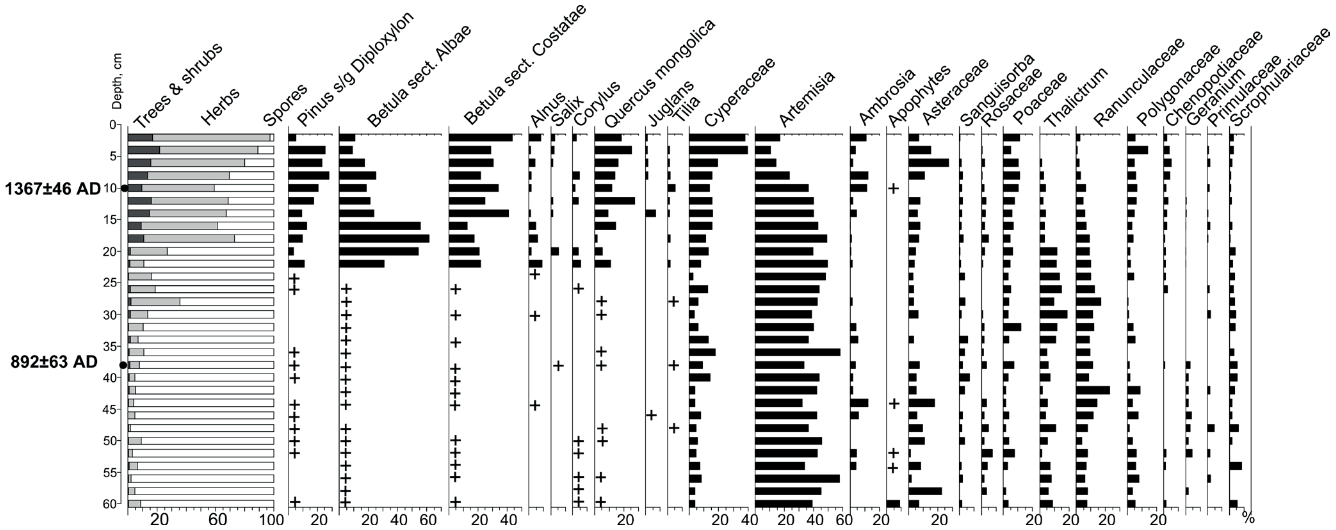

Fig. 4. Pollen diagrams of the Komissarovka River floodplain deposits

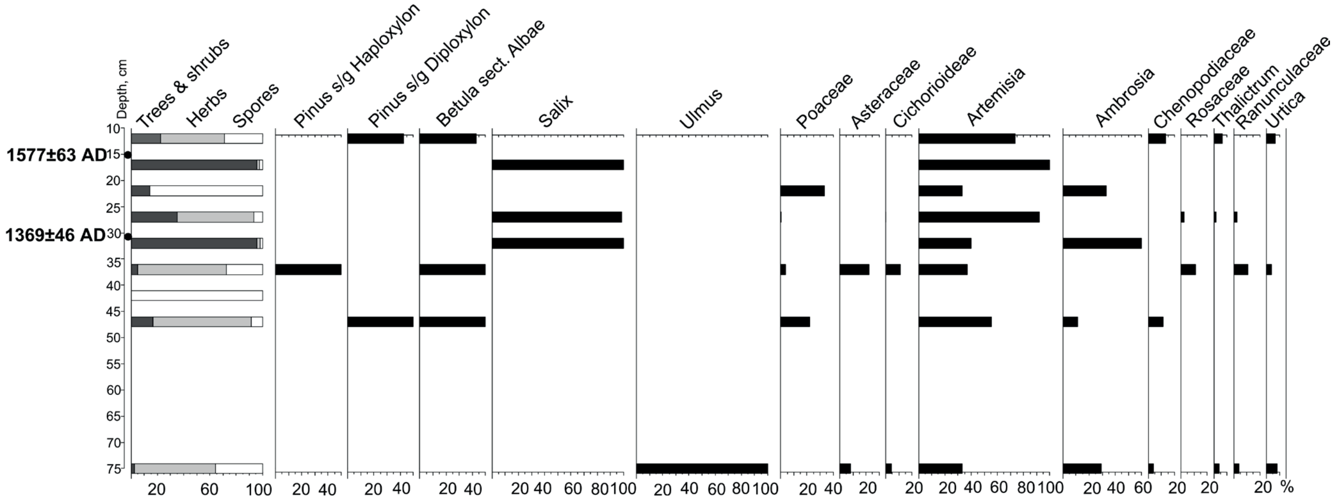

Fig. 5. Pollen diagrams of the beach ridge at the Komissarovka River mouth

DISCUSSION

Ecological features of Ambrosia artemisiifolia. There are two modern distribution ranges of *Ambrosia artemisiifolia* in Russia and adjacent countries (Nadtochii and Budrevskaya 2003). *Ambrosia artemisiifolia* is a heliophyte. Phenological observations show that, at latitudes – 40° – 50° N, common ragweed seed maturation occurs in September when the average temperature remains above 15 °C (Reznik 2009). In Siberia and northern Russia, as the average temperature in September is below 15 °C (8 – 11 °C) (https://ru.climate-data.org/location/459/), the species distribution is primarily limited by climatic conditions. The identification of separate plants or small ragweed parterres is possible in the case of alien seeds (Reznik 2009). *Ambrosia artemisiifolia* colonizes a wide range of habitats, such as cultivated fields, disturbed grasslands, roadsides, and riparian and ruderal habitats, if two conditions are fulfilled: (1) enough availability of seed and (2) soil disturbance (Ziska et al. 2006; Skjøth et al. 2010). Compared to other ruderal species, the ecological characteristics of ragweed have only its inherent differences.

In the Russian Far East, *Ambrosia artemisiifolia* is found in various habitats, both wet and dry, suggesting it can endure temporary excessive moisture even though it does not occur in wetlands. Its seeds require open unsodden places for germination, meaning they usually inhabit arable farmlands, kitchen gardens, fallow lands, roadsides, railroad embankments, and dumping grounds. The species is widely distributed along linear constructions disturbing the natural vegetation, such as wood-transport roads, main highways, and oil and gas pipelines. Note that the plant may occur even at a considerable distance from settlements. As *Ambrosia* seeds are currently abundant, they begin to grow on fallows in the first year, and along pipelines only 1 or 2 years after operation. Further, there is no species penetration in natural undisturbed communities (Kudryavtseva et al. 2018).

Ambrosia artemisiifolia pollen is easily recognizable as it is different not only from the pollen of other composite tribes but also from close species of the Ambrosieae tribe. N. Verkhovskaya and L. Yesipenko (1993) compared the *Ambrosia* pollen from the buried sediments with reference specimens of the present-day *Ambrosia trifida* L., *A. artemisiifolia* L., *A. dumosa* (A. Gray) Payne, and *A. ilicifolia* L., and established that the fossil pollen is morphologically similar to that of *A. artemisiifolia*

We have received picture of the pollen grain (Fig. 7) from records of the Khanka Plain using microscope Axio Imager A2 Zeizz (x400), and have determined its morphological characteristics. The pollen grain has spherical shape, its diameter is 21.5-22 µm, polar axis (P) is 23.0 µm, equatorial diameter (E) is 24.0 µm, and P/E=0.96. The contour of grains is finely toothed. Grain surface is covered by thorns, its height is about 1.7 µm. They closely adjoin to each other, almost touching the bases. The distance between the thorn peaks is about 3 µm. Comparison of the measured parameters with the morphological data from atlas (Meier-Melikyan et al. 2004) allow assume that fossil *Ambrosia* pollen from records of the Khanka Plain correspond to the characteristics of *Ambrosia artemisiifolia*.

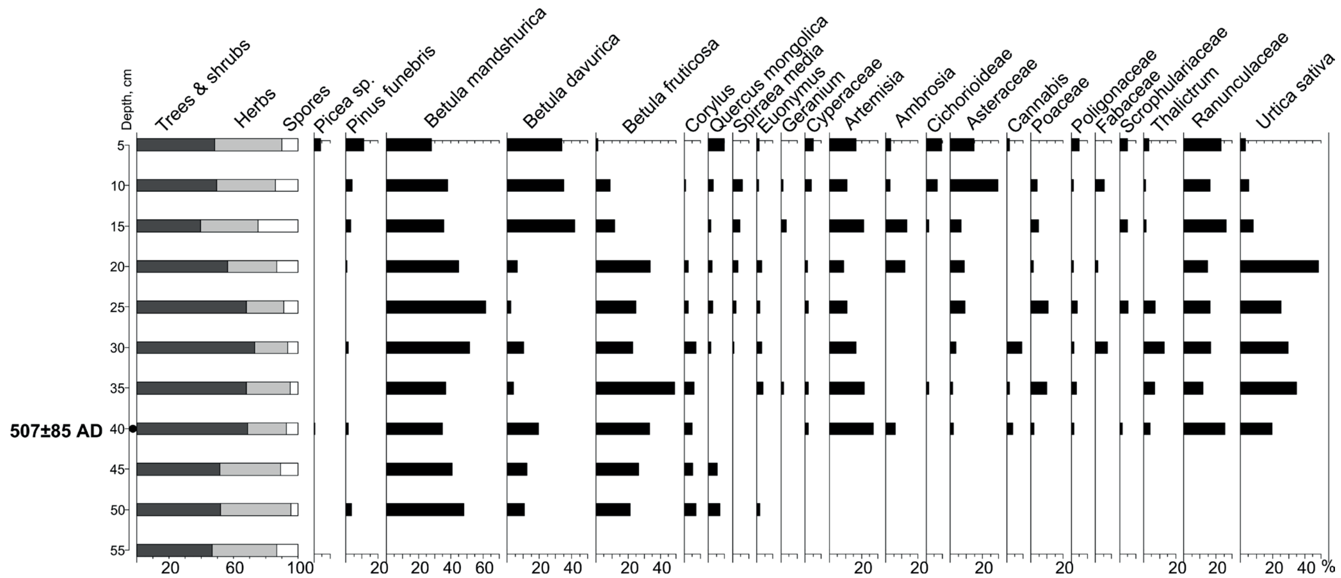

Fig. 6. Pollen diagrams of the moat deposits on archaeological site of the Novoselishche settlement

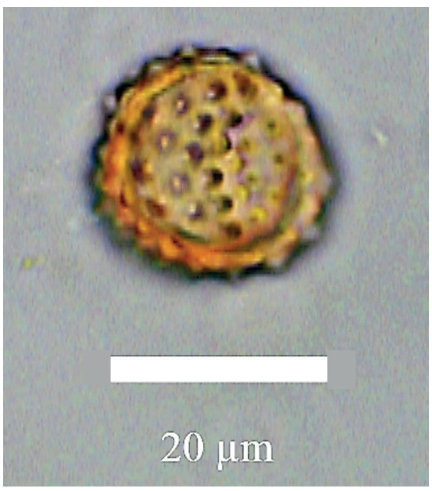

Fig. 7. Pollen grain of the *Ambrosia* artemisiifolia

Spatial and temporal correlations fossil Ambrosia pollen and Neolithic archaeological cultures. A records of pollen assemblages are one of the most common proxies employed to detect the impact of human activities on the environment. In particular, the presence of *Urtica, Plantago, Ambrosia*, Cichoriaceae, Caryophillaceae, Ranunculaceae, and *Polygonium* pollen in the sediments is evidence of human habitation in this area. These species, which are related to synanthropic (apophytes) plants, grow in the vicinity of dwellings, roadsides, and disturbed lands, and thus, indicators of human habitation (Li et al. 2008; Behre 1981).

The first information on the presence of *Ambrosia* pollen in buried deposits of the southern Russian Far East was published in the 1990s (Verkhovskaya and Yesipenko 1993; Verkhovskaya and Kundyshev 1993, 1995). Two cultural layers dated to the Holocene were excavated on the Khanka Plain in the vicinity of the Novoselishche village. The lower layer was attributed to the Final Neolithic (the first half of the 2nd millennium BC), and the upper layer was attributed to the early Bronze Age (the second half of the 2nd millennium BC). In the lower cultural layer, *Ambrosia* dominated the pollen assemblages in the NAP group (47.1% – 55.5%) (Verkhovskaya and Yesipenko 1993). Single grains of *Ambrosia* were found in the sand and gravel deposits of an old beach ridge on the northern coast of Talmi Lake and lagoonal deposits in Boisman Bay (south of Primorye). These deposits were formed at the end of the Holocene optimum (5.3 – 4.5 ka years BP). The climate changes at this time resulted in a reduction of forested areas and an expansion of forest-steppe communities in the south of Primorye (Verkhovskaya and Kundyshev 1993, 1995).

During 5.5-3.5 ka years BP the Zaisanovka cultural tradition became widespread in Primorye (Lyashchevskaya et al. 2022). A new population arrived with a new economic system – agriculture in the middle Holocene (Vostretsov 2005; Sergusheva 2013, and references therein). The earliest of them settled in the southern and western Primorye (Moreva et al. 2002). Apparently, they are associated with the first migration wave, which came from Manchuria through the Razdolnaya River valley. The middle stage (4.2-4.0 ka years BP) of this culture development is represented by the sites located on the coast of Peter the Great Gulf, which were likely a result of the next migration wave along the valley of the Tumannaya River (Krutykh 2012). The final stage of this culture (4.0-3.3 ka years BP) is represented by the group of sites located near Lake Khanka (Klyuev et al. 2002). One of the causes of the rapid expansion of *Ambrosia* could be the population growth in the south of the Russian Far East during the late Holocene. The ecological properties of common ragweed and a comparison of the obtained data with archaeological materials indicated that the presence of *Ambrosia* pollen in the Holocene deposits can use as an indicator of ancient agriculture in the south of the Russian Far East. The fossil pollen from our records is morphologically similar to *Ambrosia artemisiifolia*.

On western part of the Khanka Plain the first men appeared in paleometal epoch. The *Ambrosia* pollen appeared in deposits west of the Khanka Plain can be correlated with regional colonization by early men of this territory. For example, in the Melgunovka River floodplain, *Ambrosia* pollen was found in deposits accumulated in the 3rd century BC. Between the 4th – 3rd centuries BC and the 2nd–3rd century AD the continental part of Primorye was settled by people of the Krounovka Culture. The archaeological sites confined to the regions west of the Khanka Plain belong to the Khanka group of the Krounovka Culture. The archaeological materials of this time suggest they were advanced agricultural communities (Krounovka I … 2004; Sergusheva 2007; Vostretsov 2013).

In the floodplain sequence at the Komissarovka River mouth, *Ambrosia* pollen was identified in sediments dating back to the 5th – 6th centuries AD. This period was marked by cooling and reduced humidity, which contributed to an increase in the steppe area of the Khanka Plain (Bazarova et al. 2018a). The archaeological sites at this time are mostly related to the Mokhe culture (Tungusic and Manchur people), which was first mentioned in literature dating back to the 5th – 7th centuries AD. At this time, the Mokhe culture first appeared in the Manchuria, Primorye, and the Amur River basin. There are several territorial-chronological groups, including the Khanka group. Settlements near Khanka Lake were positioned in small valleys or on mountain slopes. The population was engaged in agriculture, hunting, and livestock farming (Klyuev et al. 2002; Piskareva 2013; Sergusheva 2018; Piskareva et al. 2019).

The pollen diagram of the Komissarovka River floodplain displays a peak of this species in the layers corresponding to the Mediaeval Climatic Optimum (Fig. 4). The grains of *Ambrosia* pollen were found in the deposits of a beach ridge not far from the Komissarovka River mouth, in sands datable to that event (Fig. 5). At this time (the 8th – 10th centuries AD), the Bohai State existed in the Manchuria territory and the northern Korean Peninsula. The Bohai settlements were mostly confined to fertile lands in the valleys of the Razdolnaya, Ilistaya, and other rivers, primarily in their middle and lower reaches. *Ambrosia* pollen was found in the pollen spectra from the cultural layer of the Starorechenskoe settlement (7th – 10th centuries AD) in the valley of the Razdolnaya River (Razzhigaeva et al. 2020). The majority of the Bohai settlements were concentrated in places favourable for agriculture (State of Bokhai …, 1994). The climate characteristics during the Mediaeval Climatic Optimum were higher than those currently, and therefore were beneficial not only for agriculture but also cattle breeding.

The pollen diagrams of the floodplain sequences of the Melgunovka and Komissarovka rivers show two peaks of *Ambrosia* pollen and a distinct gap between them, wherein the latter peak belongs to deposits dated from the 13th to the late 14th century. However, deposits of the same age in the beach ridge near the Komissarovka River mouth were devoid of *Ambrosia* pollen. According to archaeological materials, the Bohai State collapsed in the 10th century, and shortly after, the Jurchzhen Golden Empire (1115 – 1234) ceased to exist. The absence of any states and settlements from the 14th century suggests a desolation of the territory (State of the Bokhai … 1994).

Fossil Ambrosia pollen in Holocene deposits of adjacent and other territories. The pollen diagram of the deposits studied in the Yangtze River delta shows the presence of occasional *Ambrosia* grains in layers dated to 8320 ± 170 years BP, and approximately 4 ka years BP (Liu and Qiu 1994). By 8.5 ka years BP ago, more prehistoric societies with rice remains occurred in the middle and lower Yangzi Basin (Lu 2006; Jiang and Li L. 2006; Long et al. 2021; and references therein). Recent systematic archaeobotanical research conducted in the Lower Yangtze region revealed rice domestication is a very long process, which probably started 10–8 ka years BP (Fuller et al. 2009). In the south of the Korean Peninsula (the Paju-Unjeong area) oldest *Ambrosia* pollen was found in deposits dated 8425 – 7520 cal. years BP. Then it was found in deposits dated to the end of the middle and beginning of the late Holocene

(4700 – 2170 cal. years BP) (Yi 2011). Comparable data were obtained by other authors, revealing that single grains of *Ambrosia* were recovered from deposits dated to 8 – 4.5 ka years BP on the Korean Peninsula (Evstigneeva and Naryshkina 2013). Humans have been influencing Chinese landscape for thousands of years (Zhao and Piperno 2000; Cohen 2011; Betts et al. 2014). Thus, the appearance of the ragweed on south of the Russian Far East was most likely related to the first contacts, general widening, and the gradual migration of humans from China and Korea.

In North America (New England) ragweed pollen was found in found in sediments dated 10-8 ka years BP (Faison et al., 2006; Oswald et al., 2018, 2020).

Before present the palaeobotanical data for eastern Asia were insufficient to draw a conclusion regarding the absence of certain historic plants. In general, the floras of eastern Eurasia and North America are very similar in their evolution, and a species comparison provided proof of their resemblance. Considering this connection, it is conceivable to suggest existing of second centre (Asian) of the *Ambrosia* in China during the past millennia. Obtained new data allow us suppose that in eastern part of Eurasia ragweed population existed simultaneously and independently from Northern America population on boundary of early Holocene and middle Holocene.

Probably, a further increase of the average annual temperature in the south of Russian Far East will lead to shift of the *Ambrosia* population boundary to the north along the Middle and Lower Amur basin, on the territory of the Amur Region and the Khabarovsk Territory. In China, projections of potential distribution under future climate change scenarios suggest further expansion of the *Ambrosia artemisiifolia* and *A. trifida* to ecologically friendly the southeastern coastal regions, to northern Taiwan and to the Beijing-Tianjin-Tangshan region of northern China (Qin et al. 2014).

Atmospheric conditions affect the release of anemophilic pollen, and the timing and extent are depended by climate change. Simulations using pollen emission model and future climate data show that higher temperatures at the end of the century shift the start of spring emissions 10–40 days earlier, and summer/autumn weeds and grasses 5–15 days later and lengthen the duration of the pollen season. Observational data suggest that many taxa are projected to have higher pollen production at higher temperatures (e.g., late-flowering *Ulmus*, Cupressaceae, *Ambrosia,* Poaceae). Phenological shifts depend on the temperature response of individual taxa, with convergence in some regions and divergence in others. Temperature and precipitation alter daily pollen emission maxima by −35 to 40% and increase the annual total pollen emission by 16–40% due to changes in phenology and temperature-driven pollen production. Increasing atmospheric CO_2 may increase pollen production, and doubling production in conjunction with climate increases end-of-century emissions up to 200% (Zhang and Steiner 2022).

Currently, the *Ambrosia* species is widespread globally. It naturalized and frequently form part of the flora in almost all European countries and some countries in the East Asia. Steps are being taken to reduce further geographical expansion and limit increases in population densities of the plant in order to protect agriculture and the allergic population. This is particularly important when one considers possible range shifts, changes in flowering phenology and increases in the amount of pollen that could be brought about by changes in climate.

CONCLUSIONS

An analysis of the obtained data allowed to take answers on the questions of this research.

In the south of the Russian Far East, *Ambrosia* appeared in the middle Holocene (Verkhovskaya and Yesipenko 1993; Verkhovskaya and Kundyshev 1993, 1995). The new data presented in this study confirm that it did not occur earlier than the second half of the middle Holocene in the south of the Russian Far East.

The presence of *Ambrosia* pollen in the middle and late Holocene sediment suggests that this species is an extinct archeophytes. Further, our data suggest that an origin centre of the common ragweed distribution existed in the east of Eurasia long before of 18th century. In eastern Asia the oldest deposits with *Ambrosia* pollen dated to 8320 ± 170 years BP were found in the Yangtze River delta (Liu and Qiu 1994). In central China (Ren, 2000) and the Korean Peninsula (Yi 2011; Evstigneeva and Naryshkina 2013) *Ambrosia* pollen was found in deposits of the middle Holocene. An analysis of the pollen assemblages recorded the presence of *Ambrosia* in layers formed over an extended period.

Comparison of the obtained pollen records with archaeological materials indicated that the presence of *Ambrosia* pollen in the Holocene deposits has good spatial and temporal correlation with Neolithic agriculture in the south of the Russian Far East.

From the 19th century to the 1960s, *Ambrosia* was practically absent in the south of the Russian Far East. The reasons for this absence remain unknown. The absence of *Ambrosia* pollen in the subfossil pollen spectra of the Khanka Plain (Aleshinskaya and Shumova 1978) supports the conclusion that the modern isolated population of the *Ambrosia* expansion in the south of the Russian Far East occurred later than the 1960s – 1970s. On adjacent areas modern populations of this plant appeared before. In Japan it was introduced in the 1860s – 1870s (Kato and Ohbayashi 2008). In Chine, *Ambrosia artemisiifolia* was first introduced in the 1930s (Qin et al. 2014; Zhou et al. 2017), and finally, in the Korean portion, *Ambrosia artemisiifolia* and *A. trifida* were introduced at the beginning of the 1950s (Lee and Oh 1974; Kim and Kil 2016). We did not find data regarding the distribution of this plant in the Chinese and Korean territories from the 19th century to the 1930s. We believe that the modern secondary settling of this species in the east and west of Eurasia formed independently. The ranges in China, Japan, the Korean Peninsula, and the south of the Russian Far East also formed independently.

Currently *Ambrosia artemisiifolia* become naturalized and frequently forms part of the flora. Simulation forecast show that higher temperatures at the end of the century can lead to phenological shifts and pollen emission. Increasing atmospheric CO_2 also may increase pollen production.

REFERENCES

Aistova E.V., Bezborodov V.G., Gus'kova E.V. and Rogatnykh D.Yu. (2014). Formation of trophic relations of native leaf-beetle species (Coleoptera, Chrysomelidae) with Ambrosia artemisiifolia (Asteraceae) in Primorskii krai of Russia. Zoologicheskii Zhurnal. 93, 960-966 (in Russian).

Aleshinskaya Z.V. and Shumova G.M. (1978). Subfossil pollen spectra of the Khanka Plain. In: Grichuk, M.P., Korotkii, A.M. (Eds.), Pollen studies on Far East. DVNTs Press, Vladivostok, 60-66 (in Russian).

Arslanov Kh.A. (1987). Radiocarbon: Geochemistry and Geochronology. Leningrad state university, Leningrad (in Russian).

Basset I.J. and Terasmae J. (1962). Ragweeds, Ambrosia species in Canada and their history in postglacial time. Canadian Journal of Botany. 40, 141-150, DOI: 10.1139/b62-015.

Bazarova V.B., Mokhova L.M., Orlova L.A. and Belyanin P.S. (2008). Variation of the Lake Khanka Level in the Late Holocene, Primorye. Russian Journal of Pacific Geology. 2, 82-86 (in Russian).

Bazarova V.B., Grebennikova T.A. and Orlova L.A. (2014). Natural-Environment Dynamics Within the Amur Basin During the Neoglacial. Geography and Natural Resources. 35(3), 275-283.

Bazarova V.B., Lyashchevskaya M.S., Makarova, T.R. Makarevich, R.A. and Orlova, L.A. (2018a). Holocene overbank deposition in the drainage basin of Lake Khanka. Russian Geology and Geophysics, 59, 410-1418, DOI: 10.15372/GiG20181102.

Bazarova V.B., Lyashchevskaya M.S., Makarova T.R. and Orlova L.A. (2018b). Environments of the middle-late Holocene sedimentation in river floodplains of the Prikhanka Plain (southern Far East). Russian Journal of Pacific Geology, 37, 94-105, DOI: 10.1134/S1819714018060106.

Behre K-E. (1981). The interpretation of anthropogenic indicators in pollen diagram. In: Pollen et Spores, 23, 225-245.

Betts A., Jia P. and Dodson J. (2014). The origins of wheat in China and potential pathways for its introduction: A review. Quaternary International. 348, 158-168, DOI: 10.1016/j.quaint.2013.07.044.

Chauvel B., Dtssant F., Cardinal-Legrand C. and Bretagnolle F. (2006). The historical spread of Ambrosia artemisiifolia L. in France from herbarium records. Journal of Biogeography. 6, 665-673, DOI: 10.1111/j.1365-2699.2005.01401.x.

Cohen D.J. (2011). The Beginnings of Agriculture in China. A Multiregional View. Current Anthropology, 52, 273-293, DOI: 10.1086/659965

Csontos P., Vitalos, S.M., Barina, Z. and Kiss I. (2010). Early distribution and spread of Ambrosia artemisiifolia in Central and Eastern Europe. Botanica Hevletica. 120, 75-78, DOI: 10.1007/s00035-010-0072-2.

Evstigneeva T.A. and Naryshkina N.N. (2013). Mid-Holocene Vegetation and Environments on the Northeast coast of Korean Peninsula. Botanica Pacifica. A Journal of plant science and conservation. 2, 27-34.

Faison E.K., Foster D.R. Oswald W.W., Hansen B.C.S. and Doughty E. (2006). Early Holocene openlands in southern New England. Ecology, 87(10), 2537-2547.

Flora of China (Asteraceae). (2011). Science Press (Beijing) and Missouri Botanical Garden Press (St. Louis).

Fuller D., Qin L., Zheng Y., Zhao Z., Chen X., Hosoya L.A. and Sun G.P. (2009). The Domestication Process and Domestication Rate in Rice: Spikelet Bases from the Lower Yangtze. Science, 323(5921) 1607-1610, DOI: 10.1126/science.1166605.

Genton B., Shykoff A. and Giraud T. (2005). High genetic diversity in French invasive populations of common ragweed, Ambrosia artemisiifolia, as a result of multiple sources of introduction. Molecular Ecology (Chichester). 14, 4275-4285.

Grimm E.S. (1992). TILIA and TILIA GRAPH: pollen spreadsheed and graphic program, in: 8th International Palynjlogical Congress. Program and Abstracts. Aixen-Provence, France, 56.

Kato A. and Ohbayashi N. (2008). Insect Communities Associated with an Invasive Plant the Common Ragweed, Ambrosia artemisiifolia L. in Western Japan. Japanese Journal of Environmental Entomology and Zoology. 19, 125 -132.

Kim Ch-G. and Kil J. (2016). Allien flora of Korean Peninsula. Biological Invasions. 18, 1843-1852, DOI: 10.1007/s10530-016-1124-3.

Klyuev N.A., Sergusheva Ye.A. and Verkhovskaya N.B. (2002). Agriculture on final Neolithic (by data of the Novoselishche-4 site). In: Bolotin D.P., Zabiyako A.P. (Eds.), Traditional culture in Eastern Asia. Amurskii State University, Blagoveshchensk, 102-126 (in Russian).

Kolesnikov B.P. (1969). Vegetation. In: Gerasimov I.P. (Ed.), Southern part of the Far East. Nauka, Moscow, 206-250 (in Russian).

Krounovka 1 site in Primorye, Russia. Report of excavation in 2002 and 2003. 2004. In: Komoto M. and Kumamoto O.H. (Eds.), Study of Environmental Change of Early Holocene and the Prehistoric Subsistence System in Far East Asia, Shimoda Print Co. Ltd.

Krutykh Ye.B. (2012). Zaisanovskaya archaeological culture: the problem of interpretation. Russia and the Pacific. 1, 139-154 (in Russian).

Kudryavtseva E.P., Bazarova V.B., Lyashchevskaya M.S. and Mokhova L.M. (2018). Common ragweed (Ambrosia artemisiifolia): the present-day distribution and the presence in the Holocene deposits of Primorskii Krai (south of the Russian Far East). Komarov readings, LXVI, 125-146 (in Russian).

Kurentsova G.A. (1962). Vegetation of the Khanka Plain and surround areas. AN SSSR Press, Moscow-Leningrad (in Russian).

Lee Y.N. and Oh Y.C. (1974). Korean of naturalized plants (1). Korean Journal of Life Sciences. 12, 25-31.

Jiang L. and Li L. (2006). New evidence for the origins of sedentism and rice domestication in the Lower Yangzi River, China. Antiquity 80(308), 355-361.

Li Y-Y., Zhow L-P. and Cui H-T. (2008). Pollen indicators as human activity. Chinese Science Bulletin. 53, 1281-1293.

Liu K-B. and Qiu H-L. (1994). Late Holocene pollen records of vegetation changes in China: climate or human disturbance? Terrestrial, Atmospheric and Oceanic Sciences. 5, 393-410.

Long T., Chen H., Leipe C., Wagner M. and Tarasov P. (2022). Modelling the chronology and dynamics of the spread of Asian rice from ca. 8000 BCE to 1000 CE. Quaternary International. 623, 101-109, DOI: 10.1016/j.quaint.2021.11.016.

Lu T.L-D. (2006). The Occurrence of Cereal Cultivation in China. Asian Perspectives. 45(2), 130-158.

Lyashchevskaya M.S., Bazarova V.B., Dorofeeva N.A. and Leipe C. (2022). Late Pleistocene–Holocene environmental and cultural changes in Primorye, southern Russian Far East: A review. Quaternary International, 623, 68-82, DOI: 10.1016/j.quaint.2022.02.010.

Mandrioli P., Di Cecco M. and Andina G. (1998). Ragweed pollen: the air allergen is spreading in Italy. Aerobiologia. 14, 13-20.

Mar'yushkina V.Ya. (1986). Ambrosia artemisiifolia and basis of biological control. Naukova dumka, Kiev (in Russian).

Meier-Melikyan N.R., Bovina I.Yu., Kosenko Ya.V., Poleva S.V., Severova E.E., Tekleva M.V. and Tokarev P.I. (2004). Atlas of aster pollen grains (Asteraceae). Pollen morphology and development of Asteraceae family species sporoderma. Comradeship of scientific publications KMK, Moscow (in Russian).

Moreva O.L., Popov A.N. and Fukuda M. (2002). Ceramics with rope ornament in the Neolithic of Primorye. Vladivostok. In: Kradin N.N. (Ed.), Archaeology and cultural anthropology of the Far East and Central Asia, 57-67 (in Russian).

Nadtochii I.N. and Budrevskaya I.F. (2003). Agroecological maps of the Russia and adjacent countries. Ambrosia artemisiifolia L. http://www.agroatlas.ru/ru/content/weeds/Ambrosia_artemisiifolia/map/index.html (accessed 23 October 2003).

Nedoluzhko V.A. (1984). The distribution of Ambrosia artemisiifolia (Asteraceae) in the Prymorskii region. Botanicheskii zhurnal. 69, 527-529 (in Russian).

Oswald W.W., Foster D.R., Shuman B.N., Doughty E.D., Faison E.K., Hall B.R., Hansen B.C. S., Lindbladh M., Marroquin A. and Truebe, S.A. (2018). Subregional variability in the response of New England vegetation to postglacial climate change. Journal of Biogeography. 45, 2375-2388, DOI: 10.1111/jbi.13407.

Oswald W. W., Foster D.R., Shuman B.N., Chilton E.S., Doucette D.L. and Duranleau D. L. (2020). Conservation implications of limited Native American impacts in pre-contact New England. Nature Sustainability. 3, 241-246, DOI: 10.1038/s41893-019-0466-0.

Petrenko T.I., Mikishin Yu.A. and Belyanina N.I. (2009). Subfossil pollen complex of the Khanka Plain, Primorye. Natural and technical sciences, 4, 162-171(in Russian).

Pokrovskaya I.M. (1966). Methods of paleopollen studies. In: Pokrovskaya I.M. (Ed.), Paleopalynology. Nedra, Leningrad, 29-60 (in Russian).

Pimenov M.G., Khokhryakov A.P. and Pimenova R.Ye. (1966). Floristic records from Southern Primorye. Bulletin of Main Botanical Garden. 63, 78-79 (in Russian).

Piskareva Ya.V. (2013). New investigation results of the Mokhe culture in Primorye. Bulletin of Tomskii State University. History. 2, 80-85 (in Russian).

Piskareva Ya.V., Sergusheva Ye.A., Dorofeeva N.A., Lyashchevskaya M.S. and Sharyi-ool M.O. (2019). Economy of early-middle centuries people in Primorye (on data of Mokhe archaeological culture). Bulletin of archaeology anthropology and ethnography. 1, 25-36 (in Russian).

Qin Z., Ditommaso A., Wu R.S. and Huang H.Y, (2014). Potential distribution of two Ambrosia species in China under projected climate change. Weed Research. 54, 520-53, DOI: 10.1111/wre.12100.

Razzhigaeva N.G., Ganzei L.A., Grebennikova T.A., Kornyushenko T.V., Ganzey K.S., Kudryavtseva E.P., Gridasova I.V., Klyuev N.A. and Prokopets, S.D. (2020). The ratio of natural and anthropogenic factors in the development of the landscapes of the Razdolnaya River, Primorye. Izvestiya RAS. Seriya Geographical. 84, 246-258, DOI: 10.31857/S2587556620020119.

Ren G. (2000). Decline of the mid- to late Holocene forests in China: climatic change or human impact? Journal of Quaternary Science. 15, 273-281. https://doi.org/10,1002 / (SICI) 1099-1417 (200003) 15: 33.3.CO; 2-U.

Reznik S.Ya. (2009). Factors determining geographic ranges and population densite of common ragweed Ambrosia artemisiifolia L. (Asteraceae) and ragweed leaf beetle Zygogramma suturalis F. (Coleoptera, Chrysomelidae). Bulletin zaschity rastenii. 2, 20-28 (in Russian).

Sergusheva Ye.A. (2007). Early agriculture in the Primorye on data of the Krounovka 1 settlement. Bulletin of Novosibirsk State University. History, Philology. 6, 94-103 (in Russian).

Sergusheva Ye.A. (2013). Dynamics of agriculture in late neolithic of Primorye on archaeobotanical data. Vestnik arheologii, antropologii i etnografii. 1(4), 25-36 (in Russian).

Sergusheva Ye.A. (2018). Agriculture on south of the Far East in the early Middle Ages: archaeobotanical studies on Sinelnikovo-1 settlement. Bulletin of ancient technology laboratories. 14, 83-97 (in Russian).

Skjǿth A.S., Smith M., Šikoparija B., Stach A., Myszkowska D., Kasprzyk I., Radisic P., Stjepanovic B., Hrga I., Apatini D., Maguyar D., Páldy A. and Ianovici N. (2010). A method for producing airborne pollen source inventories: an example of Ambrosia (ragweed) on the Pannonian Plain. Argic for Meteorology. 150, 1203-1210.

Sladkov A.M. (1967). Introduction on pollen analysis. Nauka, Moscow (in Russian).

Smith M., Cecchi L., Skjøth C.A., Karrer G. and Šikoparija B. (2013). Common ragweed: A threat to environmental health in Europe. Environment International. 61, 115-126, DOI: 10.1016/j.envint.2013.08.005

State of the Bokhai (698-926 years) and tribes of the Russian Far East, 1994. Nauka, Moscow (in Russian).

Vascular plants of the Soviet Far East. Asteraceae V. 6. 1992. Nauka, St.-Petersburg (in Russian).

Verkhovskaya N.B. and Kundyshev A.S. (1993). Environment of southern Primorye during Neolithic and early Iron century. Bulletin of FEB RAS. 1, 18-26 (in Russian).

Verkhovskaya N.B. and Kundyshev A.S. (1995). Vegetation of Peter the Great Bay coast in the optimum of the Holocene. In: Kuzmin Ya.V. (Ed.), Complex studies of Holocene deposit sections on Peter the Great Bay coast (Sea of Japan). Bagira-Press, Moscow, 8-17 (in Russian).

Verkhovskaya N.B. and Yesipenko L.P. (1993). The time of the Ambrosia artemisiifolia (Asteraceae) appearance in the south of the Russian Far East. Botanicheskii zhurnal. 78, 94-101 (in Russian).

Vinogradova Yu.K., Aistova E.V., Antonova L.A., Chernyagina O.A., Chubar E.A., Darman G.F., Devyatova E.A., Khoreva M.G., Kotenko O.V., Marchuk, E.A., Nikolin E.G., Prokopenko S.V., Kudryavtseva E.P. and Krestov P.V. (2020). Invasive plants and flora of the Russian Far East: the checklist and comments. Botanica Pacifica. A Journal of plant science and conservation. 9, 103-129, DOI: 10.17581/ bp.2020.09107.

Voroshilov V.N. (1966). Flora of the Soviet Far East. Nauka, Moscow (in Russian).

Vostretsov Yu.Ye. (2005). The Interaction of Marine and Agricultural Adaptations in the Basin of the Sea of Japan. Dalnauka, Vladivostok. In: Andreeva Zh.V. (Ed.), The Russian Far East in Prehistory and the Middle Ages: discoveries, problems, hypotheses, 159-186 (in Russian).

Vostretsov Yu.Ye. (2013). Ecological factors of cultural dynamics formation on coastal zone of Eastern Asia in the paleometal epoch. Bulletin of FEB RAS. 1, 109-116 (in Russian).

Weninger B., Jöris O. and Danzeglocke U. (2002). Cologne radiocarbon calibration and paleoclimate research package. CALPAL_A (Advanced) in the Ghost of Edinburgh Edition, Universal zu Kuln, Institut fur Ur-und Fruhgeschichte, Radiocarbon Laboratory. Weyertal 125, D-50923. Kuln, 2005. http://www/calpal-online.de/cgi-bin/quickcal.pl

Yi S. (2011). Holocene vegetation responses to East Asian monsoonal changes in South Korea. In: Blanco J., Kheradmand H. (Eds.), Climate change – Geophysical Foundation and ecological effects. Publisher inTech, Rijeka, 157-178.

Zhang Y., Steiner A.L. (2022). Projected climate-driven changes in pollen emission season length and magnitude over the continental United States. Nat. Commun. 13, 1234, DOI: 10.1038/s41467-022-28764-0.

Zhao Z. and Piperno D. (2000). Late Pleistocene/Holocene environments in the middle Yangtze River valley, China, and rice (Oryza sativa l.) domestication: the phytolith evidence. Geoarchaeology: An International Journal. 15(2), 203-225.

Zhou Z. Wan F. and Guo J. (2017). Common ragweed Ambrosia artemisiifolia L. In: Wan F, Jian M, Zhan A (Eds.), Biological invasions and its management in China, V. 2. Springer Science+Business Media B.V., Dordrecht, 99-109.

Ziska L.H., George K. and Frenz D.A. (2006). Establishment and persistence of common ragweed (Ambrosia artemisiifolia L.) in disturbed soil as a function of an urban–rural macro-environment. Global Change Biology, 12, 1-9, DOI: 10.1111/j.1365-2486.2006.01264.x.