PARAMETERS OF ECOSYSTEM AND INTERACTION OF MAN AND NATURE IN SAND DESERTS DURING DIFFERENT PREHISTORICAL PERIODS

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Introduction

The ecology and demography of ancient societies have created much current interest in natural-scientific and historical-archaeological investigations. The problem of palaeoclimatic changes, based on data from soil science (I.V. Ivanov, V.A. Demkin, A.L. Alexandrovsky) and palynology (N.S. Bolikhovskaya, K.K. Kremenetsky, Ye.A. Spiridonova) in the steppe zone during different archaeological periods is still only partially understood.

At the same time, progress achieved in studying modern ecosystems and establishing certain correlations between their components make it possible to reconstruct the basic parameters of the past, namely the phytoproduction of the ground, phytomass used and the number of wild mammals.

Object of the study

In this paper the above is discussed and applied to the pasture ecosystem of Ryn sands located on the lower reaches of the River Volga and the River Ural. The relevant data are described in the publication "Man, nature and soils in the Ryn sands in the territory between the Rivers Volga and Ural during the Holocene" (1995). Investigations were carried out in a model area of 10,000 km^2 where 183 archaeological dwelling sites (settlements) were found belonging to different archaeological periods and cultures.

Methodical aspects and results

Phytoproduction. Phytoproduction required for the existence of mammalian phytophagans during the Holocene has been estimated by an actualistic approach.

Annual phytoproduction above ground level in a modern equilibrium ecosystem of semidesert and pasture is roughly 1200 kg/ha, in desert conditions ≈ 1000 kg/ha, in a dry-steppe area with chestnut soils ≈ 1700 kg/ha, and in steppe conditions with chernozems ≈ 2800 kg/ha (Bazilevich 1993). Parallel to phytoproduction above ground level, the most important parameter for estimating the state of the ecosystem is the value which corresponds to 30% of the mean phytoproduction utilised. It is thought that consuming less than 60–70% of the total production does not trigger phytogetic degradation, and that in this case the grass ecosystem remains in quasi-equilibrium and preserves its ability to self-regulate. If the utilised phytomass is more than 60–70% the pasture ecosystem deteriorates in terms of productivity, species variability and nutritious properties of the vegetation.

The quantity of utilised phytomass in modern Ryn sands (1950–1980 years) has been calculated for registered mammals (herbivores) using osteological data presented by Dmitriyev (1995) and values of annual consumption of plant food by mammals. The value is as high as 840–940 kg/ha, or 80–95% of phytoproduction above ground level, which indicates a critical state.

For past periods of the Holocene the production above ground level has been estimated by correlating periods of the past with modern landscapes. This is based on an analogy found in lithological-geomorphological and climatic conditions, but also on various plants typical of the Ryn sands.

Natural-climatic conditions of the Ryn sands for the different periods of the Holocene have been reconstructed by I. Ivanov with the help of palaeosol investigations. Palaeosols have been studied at different archaeological monuments using palaeogeomorphological and palynological data. They show that the natural-climatic conditions have changed considerably over the last 11.5 millennia, from arid desert to a less arid steppe (chernozemic). The quantity of utilised phytomass of the surface soil has ranged from 30% to 50% or even higher.

Evaluation of numbers of wild and domestic animals. No data exist for estimating directly numbers of animals in the past. Evaluation of numbers of wild and domestic animals during prehistorical periods starts from the assumption that the biomass of the most typical groups of vertebrae was the same in areas with the same natural conditions. According to Abaturov (1984) and calculations made by the authors, the animal biomass production in a modern equilibrium semidesert ecosystem is 5 kg/ha. The production of the most typical groups of wild and domestic mammals has been estimated by palaeozoological studies (Kuzmina 1988; Dmitriyev 1995). The number of animals per ha has been calculated by dividing 5 kg/ha by the mass (kg) of each animal. During the Neolithic, for example, estimated animal figures of 0.04 kulan/ha or 0.14 saiga/ha can be estimated to have formed a population of 40,000 kulans and 140,000 saigas in total in our model area of 1 million ha.

Table 1 shows that the "density" of wild and domestic animals varied depending on the period of the Holocene due to the influence of changing natural-climatic conditions and the state of the ecosystem. As a whole, mammalian species changed and their diversity diminished.

Evaluation of the population density (K). Several papers exist that deal with the evaluation of population density for different archaeological periods (Sorokin 1975; Zhelezchikov 1984 et al). Estimates of population density for the periods in prehistory are based on different approaches, namely on archaeological data from settlements and burial sites (kurgans) and on the ecological capacity of the territory and the type of economy of ancient tribes.

One problem is calculating the number of isochronous settlements on a model site ('E') and evaluating the mean population density in a settlement ('L') (Table 2). 'P' has been estimated to be 1% for aeolian deflated areas in the Ryn sands due to poor preservation of cultural layers in archaeological sites.

Therefore, $K = L_{*}D_{*}T_{2}$ (1).

Numbers of people during the Developed-Late Neolithic have been evaluated on the basis of data from archaeological excavations (Table 2).

Parameter 'T_2' has been determined by calculating flesh mass per 3 years from the minimum number of animals determined osteologically. The foundations of Neolithic dwellings were also used to demonstrate that ancient people had lived there for more than 1 year.

For the other archaeological periods we have no reliable data for determining 'M', 'N' and 'T_2'. We have therefore used the constant 'X' obtained by dividing 'K' by

Table 1. Parameters of ecosystems and interaction of man and nature in Ryn-sands during different archaeological epochs (notes in text).

Periods, cultures, peoples	Time	Soil-vegetation sub-zones	Coefficient of phyto-production relative to modern semidesert zone (SD)	Phytomass eaten, % of overground phyto-production	Wild mammals, thousand/million ha					Domestic mammals, thou/m ha				No. of population		
					Auroch	Kulan	Pleisto-cene horse	Saiga	Camel	Sheep	Horse	Camel	Cattle	D (see in text)	Thousand person/ million ha	Person/ km²
Mesolithic	11000–8000 BP	SD, Chn	1.2	35	< 5	48	20*	170	< 12	–	–	–	–	0.7	0.1–0.2	0.01–0.02
Early Neolithic	8000–7500 BP	SD	1.2–1.4	35										0.4	0.2	0.02
Developed-Late Neolithic	7500–6000 BP	SD	1.2–1.4	35	< 5	40	17*	140	< 10	–	–	–	–	1.3	0.6	0.06
Eneolithic	6000–5000 BP	Chn	1.7	35	< 8.5	68	29*	240	< 17	+	+	+	+	3.0	1–1.5	0.1
Yamnaya	5000–4000 BP	D	0.8	30	–	+	14*	110	–	80**	13	+?	–	0.4	0.2	0.02
Poltavkin-skaya	4000–3600 BP	Chr	2.3	50	–	+	40*	320	–	230	18		+?	8.8	4–11	0.4–1
Srubnaya	1500–1300. BC	D	0.8	30	–	+	14*	110	–	100**	17	+?		1.0	–.5	0.05
Late Bronze	1200–700 BC	SD, Chn	1.2	35	–	+	20	170	–	120**	20		+?	3.2	1.6	0.16
Savromats	600–500 BC	SD, Chn	1.2	50	–	+	20	170	–	120**	20		+?	0	0	0
Sarmats	400 BC–500 AD	SD	1.2	35	–	+		170	–	120**	20		+?	0	0	0
Khazars, oguzes	600–1000 AD															
Late nomads	1100–1200 AD															
Gold Orda, Astrakhan kingdom	1300–1600 AD	SD	1.1	50	–	+	18	150	–	50	10	+	5	5.0	4	0.4
Nogaizes	1600 AD	D	1.1	50	–	+	18	150	–	40	10	+?	+	–	2	0.2
Kalmyks	1700 AD	SD	1.0	35	–	–	17	140	–	60	9	+?	+?	–	3–10	0.3–1.0
Kazakhs of	1801–1803 AD	SD	1.2–1.3***	50	–	–	–	70	–	420	70	17	44	–	10–11	1
Bukeyev-skaya Orda	1840 AD	SD	< 0.9***	70**	–	–	–	< 70	–	190	57	16	50	–	20–25	2–2.5
	1897 AD	SD	< 1.0***	80–90**	–	–	–	< 10	–	140	27	13	42	–	40–45	4–4.5
Modern	1960–1980 AD	SD	0.7	70–95**	–	–	–	30	–	500	6	6	50	–	25	2.5

D – desert, SD – semidesert, desert-steppe, Chn – dry steppe with chestnut soils, Chr – chernozem steppe
\+ Small numbers of mammals of certain species.
+? A few mammals of certain species assumed.
– No mammals.
No data available.
* – Potential natural possibility for cattle breeding of domestic animals was not realised due to social and historical circumstances.
** – Ecosystems degraded due to overgrazing and development of aeolian processes.
*** – Coefficient of phytoproduction estimated from atmospheric humidification (according to Dinesman 1960)

Table 2. Calculation of the population for a model area during the Developed-Late Neolithic *(Permanent dwelling sites in the model area is the primary condition for calculation).*

Parameter	Designation	Value
Duration of archaeological epoch	T_1	1500
Lifetime of settlement	T_2	3
Potential number of settlements left by a group of people living compactly	$A = T_1/T_2$	500
Number of found settlements dating from T_1	B	20
Density of found settlements per 100 years	$D = (B/T_1)*100$	4/3
Probability of finding archaeological monuments, %	P	1
Total number of archaeological settlements for time T_1	$C = (B/P)*100$	2000
Number of isochronous settlements	$E = C/A = (D*T_2)/P$	4
Number of persons in a dwelling ("house")	M	10–15
Number of dwellings in an archaeological settlement	N	5–10
Population density in a settlement	$L = M*N$	50–150
Isochronous number of population on a model site	$K = (L*D*T_2)/P$	200–600
Neolithic standard	$X = K/D = L*T_2$	150–450

'D': X = K/D (2), meaning the number of persons at D = 1 settlement/100 years. Connecting formulae (1) and (2) gives $X = L*T_2$ (3).

We believe that the constant "Neolithic standard" reflects an essential parameter in the life of ancient peoples (population density and staying in the same place). It is well known (Kradin 1992) that the economy of nomadic tribes has been very conservative and is manifested by similarities in socio-economic conditions in different periods and even areas. It is therefore justified to suppose that 'X' did not change within the Holocene.

Thus we have used the Neolithic standard 'X' to calculate the population density in other archaeological periods according to the formula $K_i = X*D_i$ (4), where 'X' is 150–450 persons/settlement/100 years, and 'K_i' and 'D_i' are the parameters for the particular period (Table 1).

The number of dwelling sites per century found so far (parameter 'D') is of great interest, as some conclusions can be drawn from it about the character of temporal settlements of ancient peoples. If 'D' is less than 0.3–1, the population density of the territory observed for this period should be considered sporadic with the area having remained uninhabited for years or decades. A value of 'D' above 0.3–1 indicates continuous inhabitation. (Calculations were made with 'T_2' = 3–1 years and 'P' = 1%).

Conclusions

The parameters of the ecosystem and population density estimated for different archaeological periods in the Ryn sands were correlated with natural-climatic conditions.

During the climatic changes from Pleistocene to Periglacial (11.5–8.0 thousand years BP) the Ryn sands were sparsely populated. A small population (0.01–0.03 persons/km^2) was engaged in hunting (density of aurochs < 0.5; kulans 5, Pleistocene horses 2, saigas 2 and camels 1 head/km^2) and gathering. The economy was of the appropriating type and no domestic animals existed.

Arid desert conditions prevailed during the periods 8–7.5 (Early Neolithic, AT[1]), 5–4 (Yamnaya period, SB[1]), 3.6–3.3 (Srubnaya period, SB[2]), and 1.5–0.7 (Late nomads, SA[2]) thousand years BP. The territory was sporadically populated (mean densi-

ty 0.05 person/km^2) and people were engaged in mobile cattle breeding. Tribes often had to leave the Ryn sands due to aeolian processes. The number of wild hoofed animals was relatively high (tarpans 1.4 and saigas 11 head/km^2 in the Yamnaya and Srubnaya periods, sheep 0.4–0.5 head/km^2 in the 16th–17th centuries AD).

Semi-desert conditions were typical of the Neolithic, AT^2 (7.5–6) and the period between 2.4–0.2 thousand years BP. The population density reached 0.06 persons/km^2 in the Neolithic and 0.4 during the Golden Orda. Tarpans numbered roughly 1.4–1.8 head/km^2, saigas 14–15 and sheep 12. Kulans were hunted most, some 10% of the herd being killed. More intensive hunting of wild animals and increased numbers of domestic animals during the Neolithic period led to displacement of kulans from the Ryn sands by the end of the Eneolithic period.

The semi-arid conditions of the steppe prevailed in the Ryn sands during the periods 6–5 (Neolithic period, AT^3) and 4–3.5 (Poltavka period, SB^2) thousand years BP. The population density increased up to 0.4–1 persons/km^2 and high numbers of wild hoofed and domesticated animals were typical of the period. Hence during the Poltavka period the density of horses was 4 head/km^2, saigas 30 and sheep 20, which caused an increased load on pastures (utilised phytomass as high as 50%).

During the last 200 years the state of the ecosystem has not been so much dependent on climatic fluctuation as on human activity which has led to ecological crises of overgrazing and deflation. The population density has changed from 1 to 4.5 persons/km^2 (2.5 at present). Tarpans disappeared in the 18th century, the number of saigas ranged from 3 to 7 and the number of sheep from 14 to 50 head/km^2 (50 at present). Thus during the Holocene the development of nature and society in the Ryn sands was mainly of a discrete-deflated character.

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References

Abaturov, B.D. 1984. Mammals as an ecosystem component. Moscow: Nauka. 285 p. (in Russian)

Bazilevich, N.I. 1993. Biological production of ecosystems in North Eurasia. Moscow: Nauka. P. 293. (in Russian)

Cradin, N.N. 1992. Nomadic societies (problems of formation). Vladivostok: Dalnauka. 240 p. (In Russian)

Dinesman, L.G. 1960. Change of nature in North-West area of Precaspian lowland. Moscow: Acad. of Sciences of the USSR. 160 p. (In Russian)

Dmitriyev, A.I. 1995. Formation of rodent fauna in North Precaspian land during the Late Quaternary Age. Man, nature and soils in Ryn sands on the area between Volga and Ural rivers. Moscow: Intellect (eds. Ivanov I.V., Vasilyev I.B.). Appendix. P. 217–234. (In Russian)

Kuzmina, I.Ye. 1988. Mammals of North Precaspiy in Holocene. Archaeological cultures of North Precaspiy. Kuibishev. P. 173–188. (In Russian)

Sorokin, S.S. 1975. About chronological formulas and the meaning of term "burial ground". Progress in Middle Asian archaeology. Vol. 3. P. 20. (In Russian)

Zhelezchikov, B.F. 1984. Probable number of savromats-sarmats in South PreUral and Zavolzhye in the VIth century BC following demographic and archaeological data. Antiquities of Eurasia in Scyphian-sarmatian times. Moscow. (In Russian)