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Rodents in Mongolian steppe ecosystem				

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THE EFFECT OF RODENTS ON THE RATE OF MATTER AND ENERGY CYCLING IN ECOSYSTEM OF ARID STEPPE OF CENTRAL EASTERN MONGOLIA*

During two subsequent vegetation seasons investigations were carried out aiming at determination of role of the Brandt vole populations (*Microtus brandti* Radde, 1861) and bobac marmot (*Marmota bobac* Müller, 1776 *Marmota* ssp., *M. sibirica* Radde, 1862) in arid steppes of Central eastern Mongolia.

Depending on numbers, the rodents penetrated 12-40% of the steppe area. They eliminated from 500 kg dry weight x ha^{-1} x year^{-1} to 1000 kg d.wt. x ha^{-1} x year^{-1} of primary production returning at the same time from 57.2 kg d. wt. x ha^{-1} x year^{-1} to 115 kg d. wt. x ha^{-1} x year^{-1} of faeces easily decomposed and rich in mineral substances. Due to increased quantity of nutrients in soil and amelioration of its physical and chemical properties the biomass of plants was increasing as well as the content of nutrients in it.

It seems that the rodents cause restriction of the erosion process leading to desert habitats in arid steppes of this part of Mongolia by stimulation of pri-

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mary production and acceleration of elements cycling and retardation of water evaporation.

1. INTRODUCTION

Broad sense of impact of consumers on ecosystem functioning was dealt with by numerous researches. A basis for such estimates were energy flow assessments by populations or trophic levels (e.g. Grodziński et al. 1970). Most of papers were restricted to such comprehended role of consumers. Recently attempts are initiated to evaluate non-energetic effects of consumers in various ecosystems especially their role in matter cycling (Lee and Inman 1975, Petrusewicz and Grodziński 1975, Wiener 1975, Schwartz 1975, Batzli 1978, Abaturov 1979, Zimina and Zlotin 1980).

The effect of consumers on ecosystem functioning is a complex one and its univocal estimation is very difficult, hardly possible, in fact. By relying on the estimation of consumers' proportion in energy or matter flow many authors suggest that the role of this trophic level in majority of ecosystems is rather small. It is thought in general (Wiener 1975, Golley, Ryszkowski and Sokur 1975) that the consumers' impact can be considerable one only in relatively simple ecosystems which, by the way, are much easier to be studied. That is why the majority of existing quantitative data on the role of consumers originates from relatively simple grassland and agrarian ecosystems (Grodziński et al. 1977, Tertil 1977, Zimina and Zlotin 1980) characterized by a lower number of layers than forest ecosystems.

The estimation of consumers' impact only in trophic categories is relatively easy, providing that such population or species parameters as numbers, food preference, consumption rate and food supply are known. However, even in such beneficial case the determination of relative importance of a given consumers' group renders fundamental difficulties. It is very difficult to estimate quantity of primary production that has been really eliminated by consumers. In spite of accordant opinion of numerous authors that single populations of herbivores take up only insignificant percentage of total primary production (e.g. G o l l e y, R y s z k o w s k i and S o k u r 1975) it is not clear what a part of this production can be considered as food available sensu G r o d z i ń s k i (1968). It is thought that various populations can exploit from several to a score of per cents of available food.

Former investigations do not take into account many non-trophical impacts of regulatory character (stimulating or restricting other ecosystem processes) which cannot be expressed in categories of matter or energy although such endeavours have been recently initiated (D e t l i n g et al. 1980).

The present paper focuses around estimations of importance of two rodent species: Brandt vole (*Microtus brandti* Radde, 1861) and bobac marmot (*Marmota bobac* Müller, 1776), which are prepondering over other species in *Caragana* steppes of Central Mongolia (W e i n e r and G ó r e c k i 1982). An attempt was made not to end with determination of the incidence of these species in energy and chosen nutrients flows through this ecosystem but try to describe also non-trophic impact of these consumers. In spite of the prerogatives limiting the latter estimates to qualitative aspects or verbal expression, our circumstantial evidence suggests that this category of consumers action under conditions of arid steppes is of a prepondering significance.

Our results are limited to a chosen trophic chain, consisting of above-ground biomass of grasses and herbs, rodents and the pool soil nutrients. Of plants, *Caragana microphylla* (Pall.) Lam. using the same source of nutrients is excluded as not edible for rodents, although it gives rise to other consumers' chain (invertebrates, birds, etc.).

2. ESTIMATES OF CONSUMPTION

Estimates of consumption rates in two dominant species were carried out basing on field data on numbers of these rodents. In 1977 density of Brandt voles was estimated as 21.8 individuals x x ha^{-1}, and that of bobac marmot - 9.7 individuals x ha^{-1} (W e iner and Górecki 1982). In the following year the number of Brandt voles was about 5 times higher (Zieliński 1982). No changes in numbers of bobac marmots were observed.

The amount of food that was consumed by Brandt voles was estimated from experimental data on consumption and utilization of natural food (Górecki, Weiner and Zemanek 1982), supplemented by energetic data on costs of thermoregulation (Weiner and Górecki 1982), using certain correction terms for reproduction costs (Kaczmarski 1966, Migula 1969). Climatic data were taken from paper by Kovanetz and Olecki (1980). Such estimation of daily consumption based on annual means equaled to 78 g x day^{-1}. Depending on numbers, the whole population of Brandt voles consumes from 62 to 310 kg dry weight of plant food per year (Table 1).

Similar estimates were done for bobac marmots, however, there were no original data from the study area and nolens volens the literature data were used. Thus the metabolic rate and assimilation efficiency were accepted after Grodziński and Wunder (1975). Assumption was made that bobac marmots are active for 120 days per year and during this time they consume about 161 kg d. wt. x ha^{-1}; the hibernation period lasts for the remaining 245 days, the lower consumption in the inactive period was estimated for 16 kg (Kayser 1961). In these calculations appropriate correction terms were taken into account for fat deposits and for reproduction, which corresponds jointly to about 12 kg d. wt. of food per year. Average annual consumption amounted to 53.3 kg d. wt. x ind.$^{-1}$ x 24 hrs^{-1}, and the whole population consumed 189 kg d. wt. x ha^{-1}. These calculations as based on extremely simplified assumptions can be burdened with a considerable error, however, as it seems - these errors should not affect considerably the conclusion on rodent impact on ecosystem at immanent inaccuracy of estimates of rodent numbers.

Total consumption by the two populations of these two species of rodents inhabiting *Caragana* steppe ranged from 239 to 480 kg d. wt. x ha^{-1}. This value can be somewhat underestimated by ignoring other rodent species, which at very low densities also occur in this ecosystem (Weiner and Górecki 1982), this error is being compensated by omittance inconsiderable proportion of animal food in the diet of marmot as well as of Brandt voles.

Table 1

Trophic impact of Brandt voles (*Microtus brandti* Radde, 1861) and marmots (*Marmota bobac* Müller, 1776 ssp. *sibirica* Radde, 1862) upon the arid steppe vegetation

Species	Brandt vole		Marmot
Year	1977	1978	1977
Numbers per ha	21.8	109	9.7
Annual average daily consumption (g dry mass per animal per day)	7.8		53.3
Total consumption of the population ($kg \times ha^{-1} \times year^{-1}$)	62.0	310	189.0
Total impact of the both species ($kg \times ha^{-1} \times year^{-1}$)	502 - 998		
Total consumption of the both species ($kg \times ha^{-1} \times year^{-1}$)	251 - 499		
Total impact ($kg \times ha^{-1} \times year^{-1}$)	124.0	620	378.0

The total impact of rodents on primary production in the ecosystem involves also some amount of biomass which has been destroyed but not eaten. Quantitative calculation of this part is very difficult. Hitherto published data pertain mostly to agrocoenoses (Babińska-Werka 1975, Tertil 1977, Grodziński et al. 1977) and to grassland ecosystems (Abaturov and Zubkova 1969, Abaturov, Rakova and Sredneva 1975, Zimina and Zlotin 1980). According to these reports at extremal situations consumption can form only 10% of destroyed biomass which is immediately transferred to the reducers' chain. It seems, however, that in the steppe in question not very high numbers of rodents and sparse vegetation bring about the proportion of destroyed biomass to be not so high. If one accepts that the two analysed populations destroy the same amount of primary production as they consume, the effect on primary production will be doubled. In total 500 to 1000 kg of dry weight $\times ha^{-1}$ would be eliminated yearly, which in relation to the overall biomass production by the steppe (Weiner et al. 1982) would form from 17 to 34%, however, when excluding *Caragana microphylla* unedible by rodents

(G ó r e c k i, W e i n e r and Z e m a n e k 1982) the elimination of available biomass would range from 39 to 77%. In the two years of studies, no complete devastation of vegetation due to grazing of rodents was observed, except for the centers of inhabited colonies of rodents, in spite of five-fold changes in numbers of Brandt voles.

3. ROLE OF RODENTS IN NUTRIENT CYCLING

The role of rodents in the matter cycling and especially in nutrient cycling (N, P, K) in the ecosystem results from diverse types of their action on ecosystem. These are: manuring the steppe with faeces, bringing up the deep layers of soil rich in nutrients to the surface, alteration of vegetation by affecting the physical and chemical properties of soil. Augmented plant production and accelerated geochemical cycles are the effects of these actions.

These actions as based on a simplified scheme of matter cycling in the ecosystem are presented in Figure 1.

Basing on the data collected one can try to produce quantitative estimation of the intensity of some of these actions.

3.1. Manuring

Inferring from the estimated total consumption, coefficients of digestibility and chemical composition of faeces (G ó r e c k i, W e i n e r and Z e m a n e k 1982) the amount of excreta can be estimated for about 57.2 kg d. wt. x ha^{-1} x $year^{-1}$ in the year of smaller population numbers, or 115 kg d. wt. x ha^{-1} x $year^{-1}$ during the year of higher numbers of Brandt voles. These amounts include correspondingly 2.5 and 5.0 kg of nitrogen, 0.3 and 0.6 kg of phosphorus and 0.7 to 1.4 kg of potassium. That these figures are not overestimated can be guessed from the fact that K u č e r u k (1963) estimated the amounts of excreta produced by dormouses (*Citellus* sp.) in a steppe for 250 kg x ha^{-1} x $year^{-1}$.

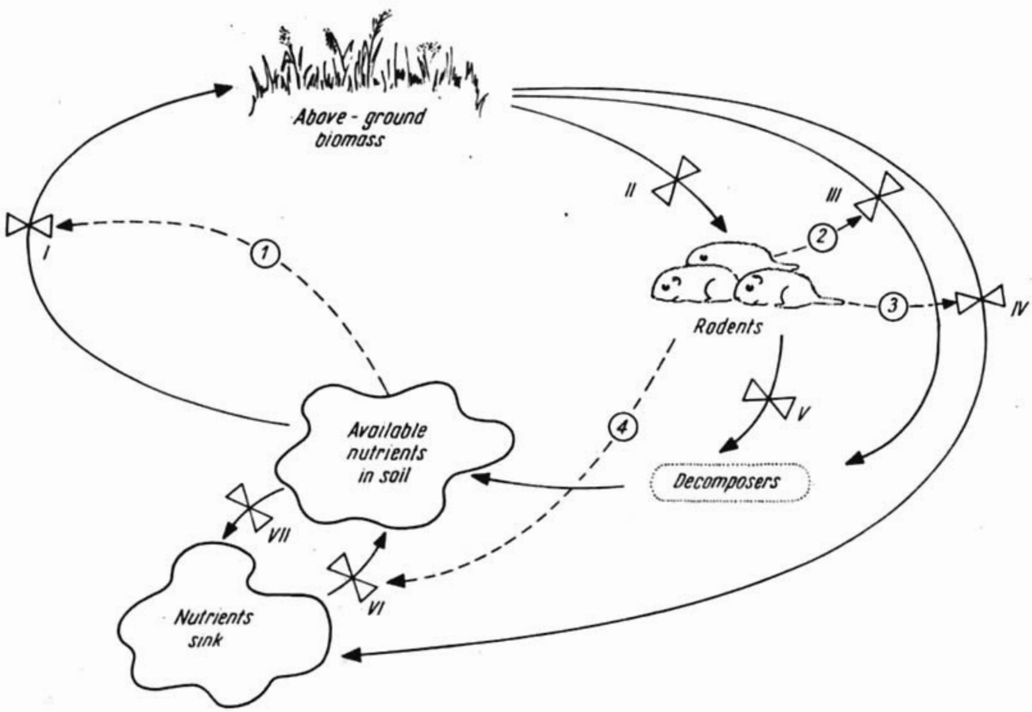

Fig. 1. Scheme of impact of rodent population on element cycling in steppe ecosystem. Chosen cycle pertains only to above-ground parts of grasses and herbs, rodents, pool of elements available in soil for plant vegetation, pool of elements inaccessible (together with export)

Solid arrows and Roman numerical represent flows, dashed arrows and Arabic numericals - controls, valves flow rates. Flows: I - accumulation of nutrients in primary production, II - rodents' consumption, III - fall of dead plant biomass used by destruents, IV - fall of dead biomass transported eolitically outside of ecosystem, V - faeces and urine, VI - transport of nutrients to the surface from deep layer of soil, VII - export of nutrients outside of ecosystem. Controls: 1 - amount of available nutrients in soil affects the rate of primary production and its chemical composition, 2 and 3 - destruction of plant vegetation by voles accelerates the fall, 4 - digging burrows brings about transport of nutrients from deep to surface soil layers

The major part of this manure is left in burrows not deep under the surface and is mechanically mixed with soil which prevents its rapid drying occurring on the soil surface under Mongolian conditions. Deposit of faeces in burrows prevents thus its blowing off by wind to the terrain crevices, where usually brackish or dead salt water bodies are temporarily formed. On the other hand, the faeces produced by domestic animals and deposited on the soil surface dry up almost immediately and its incidence in elements' cycling is therefore very limited, even if one neglects the fact that animal manure is intensely exploited as fuel by native inhabitants.

The supply of manure by rodents is important because decomposition of dry plant matter on the surface of steppe soil is very slow on account of unfavourable conditions of humidity. Besides temperature, the humidity is a main factor that determines the rate of organic matter decomposition (W a k s m a n and G e r r e t s e n 1931, W i t k a m p and F r a n k 1970). Faster rotation of nutrients from manure results from two reasons: firstly from better hydrothermic conditions found in the spots of defecation (burrows), secondly, from better chemical composition of this manure for decomposing processes. It holds a large proportion of nitrogen, which is mainly responsible for liability to decomposition (S m i t h and D o u g l a s 1971, P a r n a s 1975, P a r k 1976).

3.2. Changes in soil properties

Changes in soil due to digging activity of rodents are rather well investigated. Z i m i n a and Z l o t i n (1980) reported on changes in water regime, humus increase, changes in soil profiles and their effect of plant succession. C e l i š č e v a and D a i n e k o (1967) described changes in soil salinization in dry steppe, depending on increased amounts of carbohydrates and chlorides, even in colonies abandoned by the rodents about 200 years ago.

In the study area, B o r z y ṡ z k o w s k i (1978) carried out detailed studies on the effect of Brandt voles on the steppe soil properties. This author has found clear changes in physical and chemical properties of soil in old and abandoned colonies.

Soil in active colonies - outside of burrows - does not show any changes.

In old colonies B o r z y s z k o w s k i (1978) has distinguished at a depth higher than 10-15 cm a new sublevel of humus accumulation, so-called chestnut soil layer with zoogeic alteration. This level is characterized by vanishing the crumb structure of soil due to digging activity of rodents, the soil is more loose with large hollows in which organic substance transferred from outside has been deposited and decomposed to a greater degree. Physical-chemical character of this soil in old colonies is totally different. The volume weight of altered soil is 1.20 g x x cm^{-3}, and that of outside the colonies - 1.47 g x cm^{-3}. Capilary capacity of old colony soil amounts to 42.1%, outside colonies - 37.6%. General porosity of soil in colonies reaches 53.4% as compared with 43.1% outside colonies.

A substantial change is that of nutrients content. Outside colonies the soil contains 0.13% of nitrogen whereas in older colonies surface layer holds 0.19%, and the altered layer as much as 0.21% of nitrogen. Similar was found for carbon content, which amounts to 1.18, 1.69 and 2.21%, respectively. Hence the C:N ratio characterizing the degree of mineralization points to inconsiderable lower mineralization in altered layer (C:N = 10.4) as compared with intact soil (C:N = 9.1). C:N values close to 9 have been reported by K o w a l k o w s k i (1980) for the area near Gurwan Turuu. These values are somewhat higher that those given for other arid steppes of Mongolia, where they range from 6 to 8 (S k i b a 1980).

The Brandt vole colonies not only make the soil less compact and more porous, but also remove surface, unpermeable soil layer. This layer brings about that under the climatic conditions of Mongolia water originating from short showers evaporates very rapidly, or by surface runout reaches periodical salinated water bodies, washing out also accumulated nutrients before they reach deeper layer where they could have been accessible for root systems of plants.

Marmots, which oposite to Brandt voles, dig deep burrow systems can also play an important role in excavating to the surface deep soil layer, not deprived of nutrients by both erosion and vegetation. Huge root system of steppe plants spreads out mainly in shallow soil layers (M a t u s z k i e w i c z, R o o-Z i e l i ń s k a and S o l o n 1979).

The morphological structure altered by the rodents (hollows of collapsed burrows, marmot burrow embankments) favours augmented accumulation of organic matter brought by wind to the terrain inhabited by these rodents.

3.3. Stimulation of growth and decomposition of plant biomass

As a result of all above described processes the increase in primary production was observed followed by accelerated rate of decomposition of dead organic matter. The effect of higher humidity and accessibility of minerals, especially of nitrogen and phosphorus on the rate of primary production is obvious. This effect is clearly perceivable. Augmented contents of N, P, K in soil bring about not only faster growth of plants but the increased contents of these elements in their tissues (Z i e l i ń s k i 1982, W e i n e r et al. 1982). This depends both on changes in species composition of plants and on increased contents of nutrients in these species which grow within the colony area. Such enrichment of chemical composition of plant biomass must accelerate its decomposition after they die out. Hence although a considerable part of vegetation consists of species unedible to mammals (e.g. *Artemisia* sp., Z i e l i ń s k i 1982), the augmented contents of nutrients enhances acceleration of elements cycling affecting by this on total primary production rate.

4. OVERALL ESTIMATION OF RODENT IMPACT ON STEPPE ECOSYSTEM

The scope of investigations carried out by the authors in Mongolia was too limitted to allow quantitative estimation of changes in element cycling due to activity of rodents. However, data on composition and quantity of dry matter and nutrients in steppe vegetation seem to corroborate the rightness of postulated ecological processes.

Maximum level of dry biomass of vegetation (herbs and grasses only) outside colonies, as approximating primary production, was higher by 17% in the year of low vole numbers (1299 kg x ha^{-1}, W e i n e r et al. 1982) than in the following year (850 kg x x ha^{-1}, Z i e l i ń s k i 1982). Taking into account the incidence of vole colonies in the steppe area one can calculate average state of biomass and nutrients in the whole steppe. In the year of lower vole numbers (1977), the colonies occupied 12% of steppe area (W e i n e r and G ó r e c k i 1982), in the following year - 40% (Z i e l i ń s k i 1982). In the two years the effect of Brandt voles inconsiderably increased total plant biomass (in 1977 by 0.9% and in 1978 by 3.9%). The difference in the biomass storage between the two years can result from various reasons, one of which stems from grazing and destroying plants by rodents. This difference is of the same order that in the estimated amount of eaten and destroyed plant biomass. In the two years the difference in the dry matter storage was about 423 kg, and the difference in consumed and destroyed biomass (the total impact) was 496 kg dry weight x ha^{-1} (Table 1). The total storage of nutrients in plants was inconsiderably higher in the year of low number of rodents and amounted to 19.12 kg x ha^{-1} of nitrogen for the whole steppe with colonies, 1.95 kg x ha^{-1} of phosphorus and 12.9 kg x ha^{-1} of potassium (W e i n e r et al. 1982) whereas in the following year the contents of these nutrients were 17.56, 1.93 and 11.1 kg x ha^{-1}, respectively (Z i e l i ń s k i 1982). In the two years, the taking into account the activity of rodents means significant increase in contents of nutrients in plants of the steppe area outside colonies; in 1977, the rodents caused an increase in N, P, K storage by 7.8, 4.8 and 1.1% respectively, whereas in the year of five-fold higher vole numbers this increase amounted to 25.2, 8.4 and 11.4% respectively.

These data seem to point to the fact that effect of grazing and destroying plants and the process of growth stimulation compensate each other. It seems, however, that in the region of studies the years with high rodent numbers are less frequent than those with low rodent numbers (personal communication from native inhabitants and own observations in 1979), thus in a long period the processes of biomass growth stimulation and nutrient increase overwhelm the grazing effect. The acceleration of element cycling occurs irrespective to the numbers of rodents in a given year.

Thus it seems that in spite of fragmentary character of studies the results permit to put forward a working hypothesis that the rodents hinder the erosion process of deserting the arid steppes of Central Mongolia by stimulation of primary production, acceleration of elements cycling, withdrawal of water and these elements which are important for the live part of the ecosystems, preventing from their escape to outletless periodical lakes and delaying evaporation. This effect dominates over biomass consumption. The problem of competition between rodents and cattle, often rised in literature (M u r z a j e v 1952) seems to be not so sharp, especially that the accelerated nutrient cycling makes the plant biomass more digestible and increases the total primary production.

There are no doubts that the above postulated hypothesis claims for verification in more intensive studies than these carried out within two consecutive vegetation seasons. Hitherto data on the role of rodents in steppe ecosystems of this part of Asia are lacking. The results gathered during the two years, so much different in numbers of rodents seem tc suggest the occurrence of phenomena tc which little attention was paid in estimation of their impact on ecosystem of the Mongolia steppe.

5. STRESZCZENIE

Wpływ gryzoni na tempo obiegu materii i energii w ekosystemie suchego stepu środkowo-wschodniej Mongolii

Na podstawie badań przeprowadzonych w ciągu dwu sezonów wegetacyjnych w suchym stepie środkowej Mongolii oceniono troficzne i pozatrcficzne efekty działalności populacji nornika Brandta (Microtus brandti Radde, 1861) oraz Caragana (Marmota bobac Müller, 1776 Marmota ssp., M. sibirica Radde, 1862) - gatunków zdecydowanie dominujących w tym ekosystemie. Liczebność norników Brandta oszacowano na średnio 21,8 os. x ha^{-1} w roku 1977 i 109 os. x ha^{-1} w rcku 1978, natomiast liczebność tarbaganów na 9,7 os. x ha^{-1} w obu latach badań. Oceniono, iż populacje te zjadają w ciągu roku od 251 kg suchej masy x ha^{-1} do 499 kg suchej masy x ha^{-1}, natomiast niszcząc roślinność w trakcie żerowania eliminują dodatkowo łącznie od 500 kg s. m. x ha^{-1} x rok^{-1} do 1000 kg s. m. x ha^{-1} x

x rok^{-1} roślin. Stanowi to od 17 do 34% produkcji pierwotnej, zaś po odliczeniu niejadalnej dla gryzoni Caragana microphylla (Pall.) Lam. - od 39 do 77% (tab. 1).

Jednocześnie obie populacje zwracały do ekosystemu od 57,2 kg s. m. x ha^{-1} x rok^{-1} do 115 kg s. m. x ha^{-1} x rok^{-1} odchodów bogatych w substancje mineralne, przyczyniając się w dużym stopniu do jego nawożenia. Pozostawianie odchodów oraz działalność ryjąca powodowały istotne zmiany we właściwościach fizykochemicznych gleby. Gleba na starych koloniach posiadała mniejszy ciężar objętościowy, większą kapilarną pojemność wodną, większą porowatość ogólną oraz większą ilość przyswajalnych substancji mineralnych w porównaniu z glebą, na której nie obserwowano badanych gatunków zwierząt. Zwiększona zawartość N, P, K w glebie powoduje przyspieszony wzrost roślin oraz zwiększenie zawartości tych pierwiastków w ich tkankach. Polega to zarówno na zmianach składu gatunkowego roślinności, jak i na zwiększeniu zawartości biogenów u tych gatunków roślin, które rosną na obszarze kolonii (fig. 1). Wzbogacanie składu chemicznego roślin wpływa też na przyspieszenie ich rozkładu po obumarciu. Tym samym zostaje przyspieszone tempo obiegu badanych pierwiastków w ekosystemie sprzyjając intensyfikacji produkcji pierwotnej (fig. 1).

Działalność gryzoni powodowała zwiększenie produkcji pierwotnej stepu o 0,9% w 1977 i 3,9% w roku 1978 w porównaniu do hipotetycznego stepu pozbawionego kolonii. Wydaje się więc, iż efekt wyjadania i niszczenia roślinności stepu przez gryzonie jest kompensowany z nadwyżką procesami prowadzącymi do powstrzymania procesu erozyjnego pustynnienia stepów środkowej Mongolii poprzez stymulowanie produkcji pierwotnej i przyspieszenie obiegu pierwiastków oraz opóźnienie ewaporacji wody opadowej.

6. РЕЗЮМЕ

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Влияние грызунов на темп круговорота веществ и энергии с участием экосистемы сухой степи центрально-восточной Монголии

На основании исследований, проведенных в сухой степи центральной Монголии, авторы оценили трофические и нетрофические эффе-

кты деятельности популяции Microtus brandti Radde, 1861, а также Marmota bobac Müller, 1776 - видов, доминирующих в данной экосистеме. Подсчитали, что количество M. brandti в среднем, равняется 2I,8 особям на га (I977 г.) и I09 особям на га (I978 г.) количество M. bobac равняется 9,7 особям на га (I977 и I978 г.). Оценили, что исследуемые популяции поедают в течении года от 25I кг. сухой массы на га до 499 кг. сухой массы на га. Уничтожая растительность в процессе питания - элиминируют дополнительно, в сумме, от 500 до I000 кг. сухой массы на га на год растений. Это составляет от I7 до 34% всей первичной продукции после отсчёта насъедобной для грызунов Caragana microphylla (Pall.) Lam. - от 39 до 77% (Табл. I).

Одновременно с этим, отходы обеих популяций грызунов обогащают экосистему минеральными соединениями, они равняются от 57,2 до II5 кг. сухой массы на га на год способствуя, таким образом, удобрению экосистемы. Отходы животных и их роющая деятельность являются причиной существенных изменений физикохимических свойств почвы. Почва старых колоний отличалась меньшим объёмным весом, более значительным капилярным водным объёмом, более значительной общей пористостью, а также более значительным количеством ассимилируемых минеральных веществ, по сравнении с почвой, на которой отсутствуют исследуемые виды животных. Увеличенное количество N, P, K в почве ускоряет рост растений и увеличивает количество элементов в их тканях. Это отражается как в изменениях видового состава растительности так и в увеличении количества биогенов у видов, растущих на территории колонии (Фиг. I). Обогащение химчского состава биомассы растений влияет также на ускорение процесса разложения отмирающих растений. Таким образом происходит ускорение темпа обмена исследуемых элементов в экосистеме и вместе с ним интенсификация первичной продукции.

Деятельность грызунов увеличивает первичную продукцию степи на 0,9% в I977 и 3,9% в I978 г. по сравнении с гипотетической степью, лишённой колоний. Таким образом, можно предполагать, что эффект поедания и уничтожения грызунами степной растительности, компенсируется с избытком, благодаря процессам, вызывающим торможение эрозионного процесса и процесса образования пустыни на территории степи центральной Монголии, путём стимулирования первичной продукции и ускорения циркуляции химических элементов, а также замедление испарения осадочных вод.

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