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INDICATORS OF CHANGES IN POPULATION GROUPS OF MAMMALS IN THE INFLUENCE AREA OF THE ZEYA RESERVOIR UNDER THE IMPACT OF NATURAL AND ANTHROPOGENIC FACTORS

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Using the long-term data of the Zeya Nature Reserve, we accessed the natural and anthropogenic factors and their significance for the dynamics of the number of population groups of mammals in the influence area of the Zeya reservoir. Siberian musk deer (*Moschus moschiferus*), elk (*Cervus canadensis*), Siberian roe deer (*Capreolus pygargus*) and sable (*Martes zibellina*) were selected as model species. The anthropogenic part of population dynamics is defined on the basis of a comparative analysis of the long-term “test” (shore of the Zeya reservoir within the reserve territory), “control” (reserve territory outside the shores) and “background” (Amur Region) observations. We offer a step-by-step algorithm for studying mammals in the influence area of any large hydraulic structures. *The first step* is to restore the chronology of changes in the population density of the model species, then to determine the time needed for each species to partially adapt to the reservoir, which is as follows: musk deer – 30 years, elk – 25 years, roe deer – 28 years, sable – 20 years. *The second step* is to determine the leading natural factors of population dynamics. For musk deer, elk and roe deer the defining factor is precipitation in the early growing season of May and June, which determines the amount of winter food supply and the survival rate of young animals. For sable the factor is the dynamics of the total number of mouse-like rodents, which has a significant negative correlation with the cycles of solar activity and long-term trends of spring-summer precipitation. *The third step* is to determine the main factors of the influence that the reservoir causes on the population dynamics of the model species. For musk deer this is deteriorating conditions of protection, increasing mortality along the shoreline of an artificial reservoir due to various injuries, predators and epizootics. For elks this is the poaching activities and wolves that hunt them on the surface of the frozen reservoir. For roe deer this is the disrupted routes of seasonal migration, poaching and increasing hunting pressure from the predators. For sable it is the microclimatic influence of the reservoir that causes an increase in morbidity and depletion of the food supply due to decreasing numbers of mouse-like rodents. *The fourth step* is to identify common signs of the hydro construction impact on any mammals. Each model species found in the influence area of the Zeya reservoir experiences prolonged population depressions, low level of correlation between population dynamics and changes in the main limiting natural factors, reduced population density, and increased amplitude of population fluctuations. *The fifth step* is to quantify the impact the reservoir has on the model species. We used such index as the difference between the average (over the adaptation period) population density on the “control” plots and on the reservoir coast, in % of the “control” level. The average annual losses were 51.8% for Siberian musk deer, 51.2% for elk, 78.1% for Siberian roe deer, and 35.4% for sable. While being under protection, each of these model species was able to partially adapt to the

Zeya reservoir over 20-30 years; their population dynamics generally recovered, but the density and migration activity remained significantly lower than it was before the construction of the reservoir.
Keywords: hydro construction, impact assessment, model species, Siberian musk deer, elk, Siberian roe deer, sable, mouse-like rodents, population dynamics, solar activity, precipitation.
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In the influence areas of large water reservoirs the indicators of abundance, the nature of population dynamics, and the spatial distribution of most animal species change. However, while under the impact of hydraulic construction activities, the natural population fluctuations continue to occur due to natural phenomena and processes. To justify compensatory measures accompanying the constructions and an to give an objective assessment to the environmental damage, it is necessary not only to state that hydro construction have an impact on terrestrial animals around, but also to highlight the natural and anthropogenic components of the dynamics of their populations in the affected areas. The solution of this problem is both of practical and scientific interest, making it possible to determine various responses of various species to anthropogenic impact and the relative stability of their population groups.

Usually, the impact of hydro construction on wild animals is determined by the comparison of the population state before/after the creation of a water reservoir (Avakyan, Podolsky, 2002). This approach is without doubt rational, but it should be noted that the natural fluctuations of population may be left out in the absence of any additional data. In this work we determine the anthropogenic component of population dynamic based on a comparative analysis of long-term series of “test”, “control” and “background” observations: test is on the shore of the Zeya reservoir, control is slightly remote from it, and background is throughout the entire Amur Region.

The informational basis of this work is built on the data obtained in the Zeya Nature Reserve during winter censuses of mammals. We selected 4 model species for our analysis: Siberian musk deer (*Moschus moschiferus*), elk (*Cervus canadensis*), Siberian roe deer (*Capreolus pygargus*), and sable (*Martes zibellina*). They are common or abundant in the region and in the Zeya Reserve in particular, of great economic importance, and can be reliably counted using the standard methods in the influence area of the Zeya reservoir and throughout the Amur Region in general. We also included data on the total number of mouse-like rodents, the main component of sables’ diet.

Materials and Methods

The Zeya reservoir is located in the north of the Amur Region, inside the Upper Zeya Lowland and the Zeya Gorge. Our studies took place mainly in the territory of the Zeya Reserve which is located in the eastern part of the Tukuringra Range and on the western shore of the gorge. We used the results of zoological observations carried out in the reserve in 1964-2018, including the data of regular standardized studies that took place in 1982-2018 and covered the influence area of the mountainous part of the water reservoir. Such continuous observations (> 35 years) have never been carried out for any other reservoirs of Siberia and the Far East.

The population idices of model species were determined using the winter route censuses (Kuzyakin et al., 1990) and multi-day census based on calculating the difference in the number of entry and exit tracks of the studied animals within the key site and on its borders (Rusanov, 1986). When calculating population density during winter, the conversion factor to the formula of A.N. Formozov was based on the occurrence of animals’ tracks within the sites of a multi-day census (Podolsky, 1993). The total length of winter routes performed from 1986 to 2018 is about 9500 km. The multi-day census took place at 8 sites, with their total area of about 5000 ha. Every year 3-5 sites were studied; their total area was at least 2.5 thousand ha. In addition, we used data for 1986-2010 from official censuses of game species in the Amur Region. The mouse-like rodents were counted according to the standard method along the routes lined with the spring-loaded bar traps “Hero” (Karaseva, Telitsyna, 1996). We also analyzed the census data for small mammals obtained from 33 permanent trap routes. The total amount of captures for 1982-2018 is about 44600 traps-days. Besides, we used the spring-summer precipitation data from the “Zeya” Hydrometeorological Observatory (May-June) for 1981-2017, and solar activity indicators for the same period (Sunspot Index …, 2019).

The materials were processed by comparing the population dynamic of the model species in 1982-2018 at the test sites of the slopes and ridges peaks adjacent to the reservoir, at the control sites separated from it by coastal ridges, and throughout the Amur Region, i.e. the background. The starting point was the data obtained in 1963-1974, before the reservoir was filled and the existing zoological observations were not yet standardized. Nevertheless, they provide a general retrospective idea of the state of population groups of the studied model species, such as abundance indicators, their spatial and biotopic distribution, and intensity of their seasonal migrations.

Results and Discussion

Specific Reaction of Model Species to the Creation of the Zeya Reservoir

Siberian musk deer (*Moschus moschiferus*) is a typical inhabitant of the dark coniferous mountain taiga. In the Zeya Nature Reserve musk deer can be found in most forest biotopes, including larch, larch-birch and oak-black birch forests. According to the surveys of the old locals, it was often encountered in the valleys of the Zeya and Gilyuy Rivers in the 1950s (Schetinin, 1973), where its population density could reach 2.5-3.0 individuals per 1000 ha. From the second half of the 1960s to the early 1980s its population experienced a severe depression throughout the region. Along with natural causes, the construction of the Zeya hydroelectric power station could have played a significant role as well. For example, a sharp increase in poaching and habitat destruction (flooding, fires) recently caused a rapid decrease in the number of musk deer in around the Bureya hydroelectric complex, where in some areas it dropped by 30-40% over every year (Podolsky et al., 2009). Therefore, it is possible that a similar situation occurred in the late 1960s and 1970s around the construction area of the Zeya hydroelectric complex. In addition, it was aggravated by the fact that the Zeya reservoir flooded large areas of spruce forests in the valley and rocky sediments on the shore, the main habitats and protective hubs of Siberian musk deer. In the early 1980s there were only 1.2-2.5 deer per 1000 ha of their usual habitats (Bromley et al., 1984).

Starting from the second half of the 1980s the number of musk deer in the Zeya Reserve and around the shores of the reservoir began to increase rapidly (Fig. 1). Its decline on the shore started in 1996-1997, but in the winter of 1999-2000 a sharp drop was registered throughout the entire reserve and the adjacent territories. In 1999-2001 several dead deer were found in the reserve without any signs of damage. In 2000-2002 its population density has decreased to its minimum of 0.3-1.0 ind./1000 ha. In this case the mass death and decrease could be results of an epizootic, although usually epizootics affect only those populations the state of which is dangerously critical.

Both in the Reserve and the Amur Region the population density peaks took place in 1997-1998, while depression were registered in 2000-2002. However, in the region its density was decreasing at a much slower pace, without reaching its minimum indicators and without influence of any epizootics. We can assume that the causes of the decline in the late 90s – early 2000s were due to the similar natural factors. However, under the influence of the Zeya reservoir, the depression turned into a catastrophe.

Usually, the main natural cause of change in the number of wild ungulates is the mortality or survival rate of younglings (Filonov, 1977), which severely depends on the amount and availability of food available during winter. In the Far East and Siberia the main food for musk deer is epiphytic lichens from the Usneacceae family that form more than 80% of their winter ration. The growth of the integral part of the lichen, a specific alga, depends on the air humidity and the amount of precipitation, because a moist substrate makes it possible for the lichens to spread successfully. Therefore, a rainy spring is the suitable condition that ensures the optimal ratio of these indicators. After several wet springs following each other (i.e. the second half of the 1950s, the second half of the 1980s, the middle of the 2000s) the population of Siberian musk deer grows, while several dry springs (early 1970s, second half of the 1990s) are followed by its decrease. Spring is considered dry, if the sum of May and June precipitation is ≤ 120 mm.

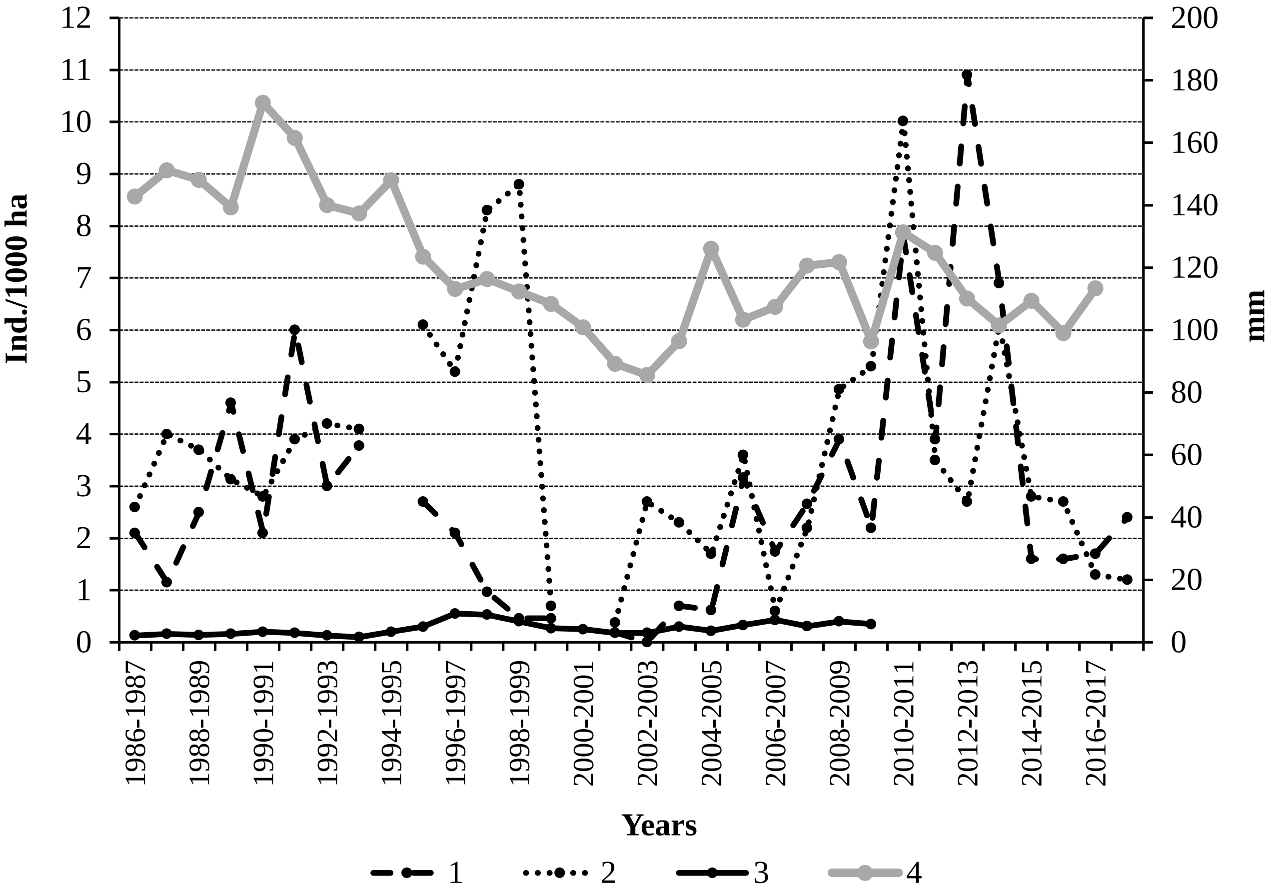

Fig. 1. Dynamic of Siberian musk deer population density in the Zeya Nature Reserve and the Amur Region. *Legend:* 1 – shores of the water reservoir (test sites), 2 – outside the shores of large water bodies and streams (control sites), 3 – forests of Amur Region (background), 4 – sum of May and June precipitation according to the Zeya hydrometeorological station, smoothed by the moving average for 5 years.

The population density of musk deer outside the reservoir shores and throughout the entire reserve territory correlates well with the dynamics trend of the total May and June precipitation over the previous 4-6 years ($R = 0.45$, $p = 0.05$) that was obtained by smoothing the moving average method for 5 years (Fig. 1). The registered delay in the population dynamics could be associated with the slow growth of the mentioned lichens. Thus, the main natural factor for the Siberian musk deer population is the precipitation of the previous 4-6 springs, determining the successful spread of epiphytic lichens.

The shores of a large water reservoir can be a nidus of instability for the musk deer population, since the frequency of deer death is increased there due to predators and injuries, mass poaching, and the spread of dangerous infections (Podolsky et al., 2009). The influence of a large artificial reservoir severely disturbs the natural course of the population dynamics. The population group of musk deer along the shores of the Zeya Reservoir is known for its increased amplitude of their population density fluctuations at the stage of growth of the population, as well as for the prolonged depressions (Fig. 1). The difference between the maximum and minimum numbers of deer is 53.7 times (0.19 to 10.2 ind./1000 ha) at the test sites on the shores, and up to 22.0 times (0.4 to 8.8 ind./1000 ha) at the control sites of low mountains remote from the shore. Therefore, the maximum long-term amplitude of fluctuations in the influence area of the reservoir (test territory) is *2.4 times* higher than the one in the control territory. Additionally, in the influence area (test sites) depressions usually begin 1-3 years earlier and end 1-2 years later than they do at the test sites (Fig. 1).

From 2003-2004 the population dynamics of Siberian musk deer at the test sites (shores) have mostly synchronized with the control ones (Zeya Nature Reserve outside the shores), as well as with the Amur Region (background; Fig. 1). This may be a sign of partial adaptation of the deer population to the construction of a large artificial water reservoir. If the beginning of its filling in 1974 is considered a starting point, then the *time required for adaptation* of the population to the creation of the Zeya reservoir is *about 30 years*.

Elk (*Cervus canadensis*) is one of the most representative ungulates of the Zeya Nature Reserve. It inhabits all forest biotopes and can be found everywhere except for the subalpine Ezo spruce forests, where its encounters are extremely rare. Like the Siberian musk deer, the main factor of its population dynamics is mortality or survival rate of its younglings, determined by the amount and availability of food during winter. In its turn, the amount of food depends on the weather conditions at the beginning of the growing season (May-June), when the growth of willow shoots and other trees and shrubs is at its peak, providing the future fodder for elks.

The curve of dynamic of the elk population density in the reserve is slightly similar with the graph of the long-term changes in the amount of spring-summer precipitation (Fig. 2). However, there are also significant differences, which are most noticeable at the reservoir shores. Before it was constructed in the late 1960s – early 1970s, the average population density of elk there was about 1.3 ind./1000 ha. After its filling, these numbers dropped drastically, and in 1979-1980 the density was about 0.6-0.7 ind./1000 ha. This decrease can be explained by the deterioration of food and protective conditions along the shores of the reservoir, and especially by the increased hunting pressure from the wolves, which tend to chase their prey out onto the smooth ice of the reservoir. The pressure is also confirmed by the long-term data on the cases of elks' deaths, since the proportion killed by wolves specifically on ice after the reservoir was created increased from 25% to 36% (Podolsky, 2013).

In the middle and late 1980s, the population of elk reached the same level it was at in the late 1960s, and even slightly exceeded it. Several years after the reservoir was filled to a normal retaining level, the dynamics was generally close to natural. With the increased atmospheric humidity in 1984-1989, there were a consistently high population (more than 100 ind.) and population density (1.1-1.7 ind./1000 ha) in the reserve. In 1989-1994, the numbers decreased significantly (more than two times) to about 30-40 individuals; the especially sharp drop was noticed at the shore, where the density quickly changed from 2.5-1.2 to 0.3-0.2 ind./1000 ha. This drop seemingly contradicted the natural processes, because it took place during a well-known period of increased atmospheric humidity (1988-1994). In fact, the reasons for the drop were anthropogenic, a result of intensive poaching along the shores, since with the reservoir construction made it easier to use high-speed vehicles when hunting elks. Besides, the social crisis and deterioration of the protective activities in the nature reserve in 1989-1999 also contributed to an abrupt intensification of poaching. However, later protection measures improved. From 2000-2002 the population dynamics of elk at the test sites (shores) have mostly synchronized with the control ones (outside the shores of large water bodies), as well as with the Amur Region (background; Fig. 2). If the beginning of its filling in 1974 is considered a starting point, then the *time required for adaptation* of the elks' population to the creation of the Zeya reservoir is *about 25 years*.

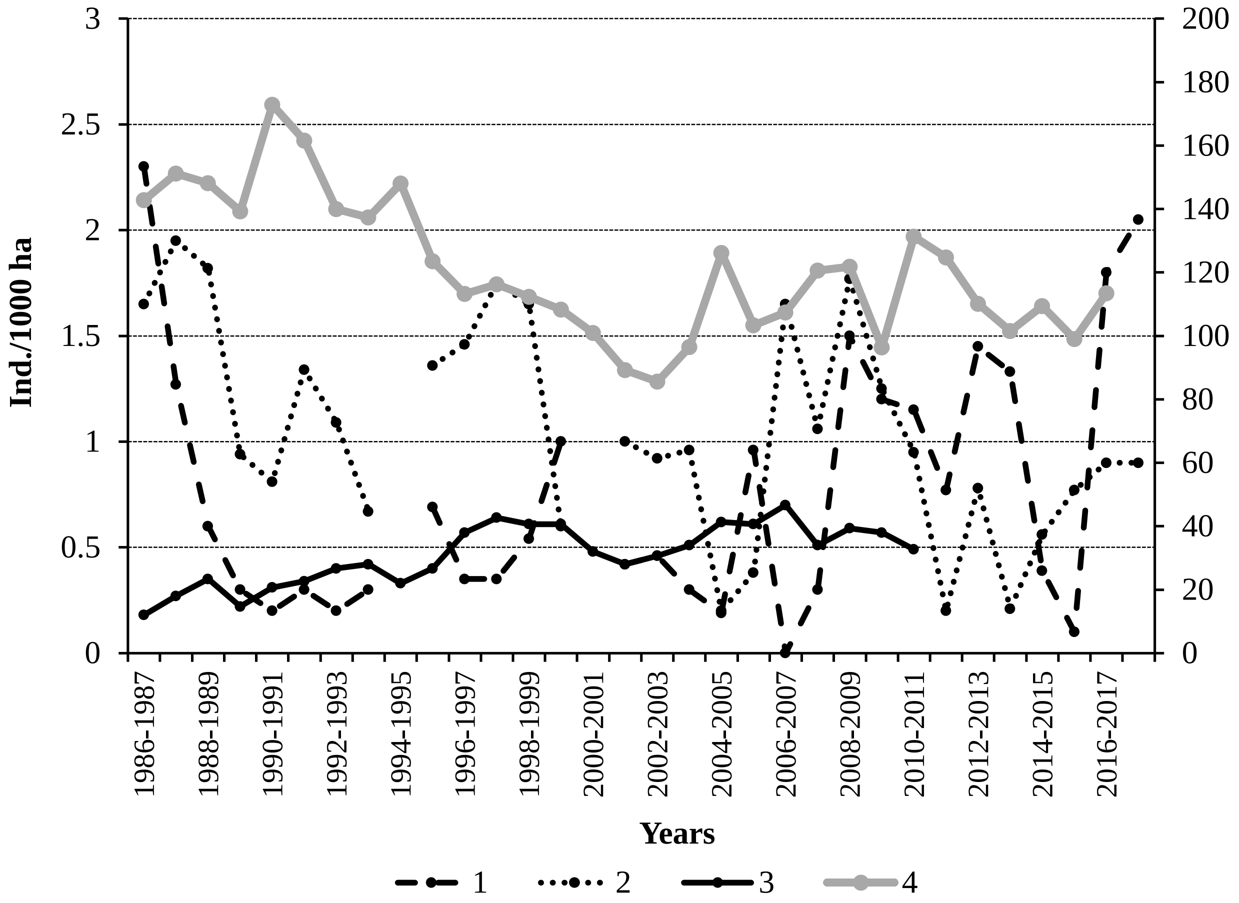

Fig. 2. Dynamic of elk population density in the Zeya Nature Reserve and the Amur Region. *Legend:* 1 – shores of the water reservoir ("test" plots), 2 – low mountains outside the shores of large water bodies and streams ("control" plots), 3 – forests of Amur Region ("background"), 4 – sum of May and June precipitation according to the Zeya hydrometeorological station, smoothed by the moving average for 5 years.

In the Amur Region (background) the maximum population density (0.64 ind./1000 ha in 1997-1998) was 3.2 times higher than the minimum density (0.2 ind./1000 ha in 1985-1986). This value was 11.5 (0.2 to 2.3 ind./1000 ha) at the test sites of the reservoir shores, and 5.1 (0.38 to 1.95 ind./1000 ha) at the control sites of the low mountains remote from the shore. Therefore, the maximum long-term amplitude of elks' population fluctuations in the influence area of the reservoir (test territory) is *2.3 times* higher than the one in the control territory, and *3.6 times* higher than in the background territory.

Siberian roe deer (*Capreolus pygargus*) was one of the most significant species of the southern macroslope of the Tukuringra Ridge before the creation of the Zeya reservoir. Here was its main route of seasonal migrations of its northernmost population of the Amur Region, passing through the Zeya Gorge and the mouth of the Gilyui River (Shchetinin, 1973). For wintering the main population would migrate south of the Soktakhan and Tukuringra Ridges; in the spring it would return to the summer pastures of the Upper Zeya Lowland to calve.

The main natural factors that determine the number of roe deer in this area are the spring-summer precipitation, depth of snow cover and intensity of seasonal migrations. The amount of precipitation determines the amount of food, and the snow volume determines the intensity of migrations and deer' spatial distribution during winter. Roe deer are much smaller than elks and, unlike Siberian musk deer, lacks specific physiological adaptations to the conditions of deep snow. Therefore, migration and concentration of roe deer increases in the areas with less snow during the years of high (more than 30-40 cm) snow cover.

The main anthropogenic factor affecting roe deer is the disruption of migration routes due to the creation of the Zeya water reservoir. According to surveys, during the period of its filling that took place at the time of roe deer seasonal migrations, there was a high death rate of deer that tried to pass the forming bays. Similar cases have been reported for the territory of the Bureya reservoir (Ignatenko et al., 2007). Additionally, a large part of the reservoir flooded a significant area of summer pastures on the Upper Zeya Plain. Another important anthropogenic factor is the increased poaching along the shores of the reservoir.

In the 1960s the population density of roe deer on the southern macroslope of the Tukuringra Ridge was very high (15-17 ind./1000 ha); during the snowy years the density could be twice as high. The beginning of the reservoir filling and disruption of migration routes were followed by a long and severe population depression in 1975-1987 with an almost full stop of well-pronounced seasonal migrations within the Zeya Gorge. The total number of the Upper Zeya population decreased significantly, from 5 thousand to 500-1000 ind. (Darman, Kolobaev, 1993).

In 1988-1996 due to the period of increased precipitation in 1984-1995, the number of roe deer in the reserve slightly increased, seasonal migrations resumed. Since 2002-2003, the Zeya Gorge has once again become a place for the winter concentration of Siberian roe deer (Fig. 3). Partial restoration of seasonal migrations and spatial distribution can be considered a sign of population's partial adaptation to the water reservoir.

If the beginning of its filling in 1974 is considered a starting point, then the *time required for adaptation* of the roe deer population to the creation of the Zeya reservoir is *28 years*. However, their migratory activity is still much lower than it used to be. Additionally, the migratory population group has managed to restore only 30% of its former range within the Upper Zeya Plain.

Sable (*Martes zibellina*) used to be the original inhabitant of the mountain taiga of the Amur Region. However, the overhunting of the XIX and early XX centuries destroyed its population, and in the 1920s sable remained only in some areas, in particular, on the northwestern tip of the Tukuringra Ridge. In 1934-1939 hunting for sable was completely prohibited. In the late 1940s the sable inhabited the eastern part of the Tukuringra Ridge once again. Its numbers continued to grow even during the first years of the filling of the Zeya reservoir. In the winter of 1980-1981 its average population density in the nature reserve was at the maximum of 13.7 ind./1000 ha (Bromley et al., 1984). In 1987-1999 the number of sables decreased in most of the Amur Region, but the sharpest and deepest drop took place at the coast of the reservoir itself, and this depression continued until 2005-2006. Over these years, the average population density decreased in the region by about two times, by 2.4 times at the test sites outside the shore, and by about 12 times at the experimental sites on the shores of the reservoir.

Starting from the winter of 2005-2006, the population dynamics of sable at the test sites (shores) have mostly synchronized with the control ones (Zeya Nature Reserve outside the shores), as well as with the Amur Region (background; Fig. 4). This may be a sign of partial adaptation of the sables' population to the construction of a large artificial water reservoir. If the completion of its filling up to a normal retaining level in 1985 is considered a starting point, when a decrease at the shores began to clearly manifest itself, then the *time required for adaptation* of the population to the creation of the Zeya reservoir is *about 20 years*.

The abundance of sable at the shore (test), in the eastern part of the ridge (control), and in the entire region (background) was changing almost simultaneously (Fig. 4). This suggests that the natural long-term trends in its population dynamics are dependent on the leading natural factors that affect the entire region. One of such factors is the total abundance of mouse-like rodents, which are the basis of the sables' diet, as well as solar activity and the amount of spring-summer precipitation. An indicator of solar activity is the average annual sum of sunspots, also known as the Wolf number (Sunspot Index …, 2019).

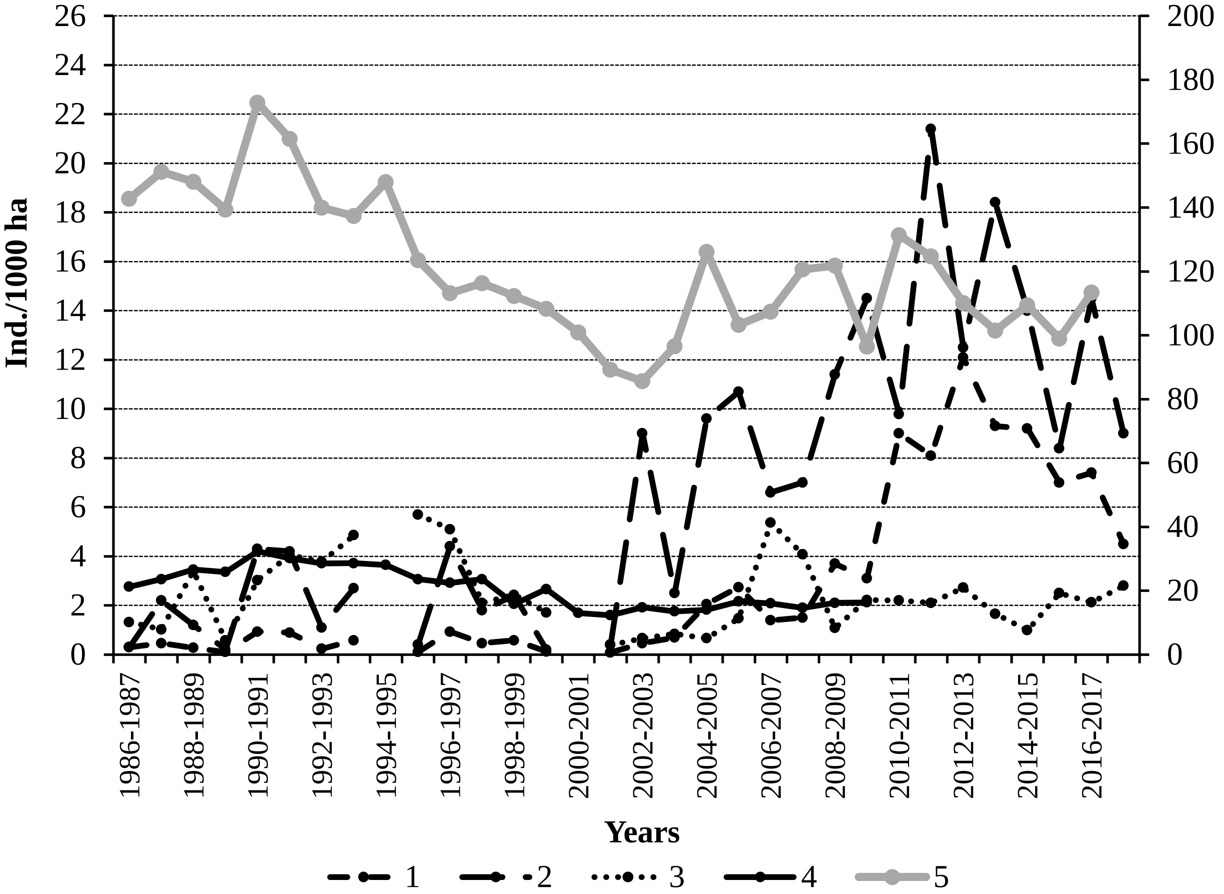

Fig. 3. Dynamic of Siberian roe deer population density in the Zeya Nature Reserve and the Amur Region. *Legend:* 1 – shores of the water reservoir ("test" plots), 2 – Zeya gorge (southern part of the "test" plots), 3 – low mountains of the southern macroslope of the Tukuringra Ridge outside the shores of large water bodies and streams ("control" plots), 4 – Amur Region ("background"), 5 – sum of May and June precipitation according to the Zeya hydrometeorological station, smoothed by the moving average for 5 years.

Along with the short cycles of 3-6 years in the Zeya Reserve, a long, approximately 30-year-long cycle of population dynamics of mouse-like rodents was registered. Additionally, the long periods of increased sum of rodents are associated with the periods of minimal peaks of 10-year-long cycles of solar activity. And, on the contrary, prolonged depressions of rodents' populations are associated with the periods of maximal Wolf numbers (Fig. 5).

We found a significant negative correlation between the abundance of mouse-like rodents, the long-term trends of solar activity changes (r = -0.5, p = 0.01) and the amount of spring-summer precipitation (r = -0.36, p = 0.05) that was smoothed using a moving average for 11 years (Table 1). It is a common case for the Amur Region to have a direct dependence between long-term humidity cycles and the dynamics of solar activity (Parilov et al., 2006). Intense precipitation in May and June usually disturbs the breeding of rodents, which, in its turn, affects the dynamic trends of the sables' population.

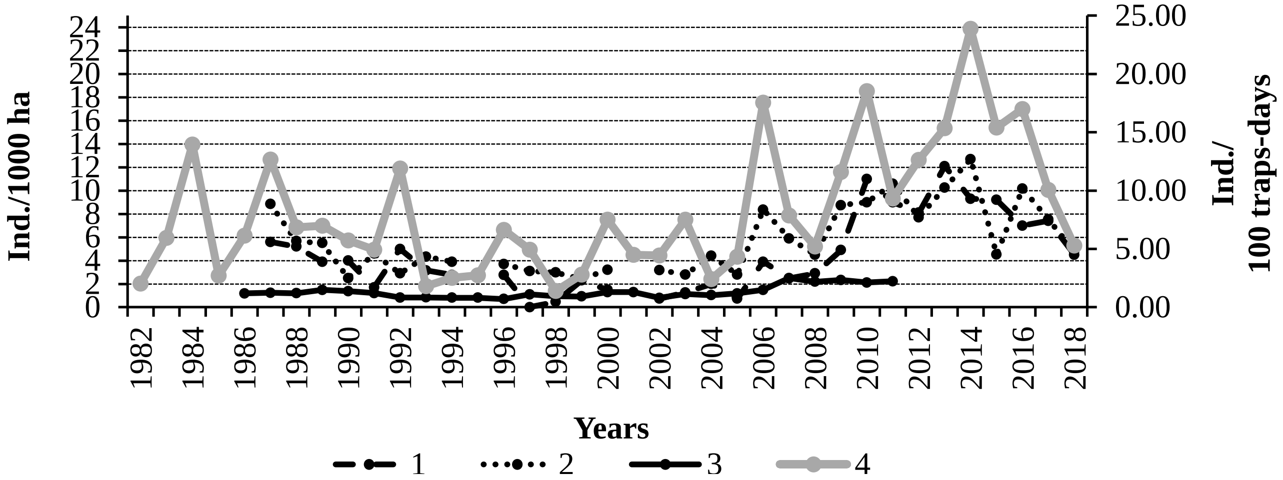

Fig. 4. Dynamic of sable population density in the Zeya Nature Reserve and the Amur Region. *Legend:* 1 – shores of the water reservoir ("test" plots), 2 – outside the shores of large water bodies and streams ("control"), 3 – Amur Region ("background"), 4 – sum of the mouse-like rodents caught with the spring-loaded bar traps "Hero" according to the autumn results, average for the entire Zeya Reserve.

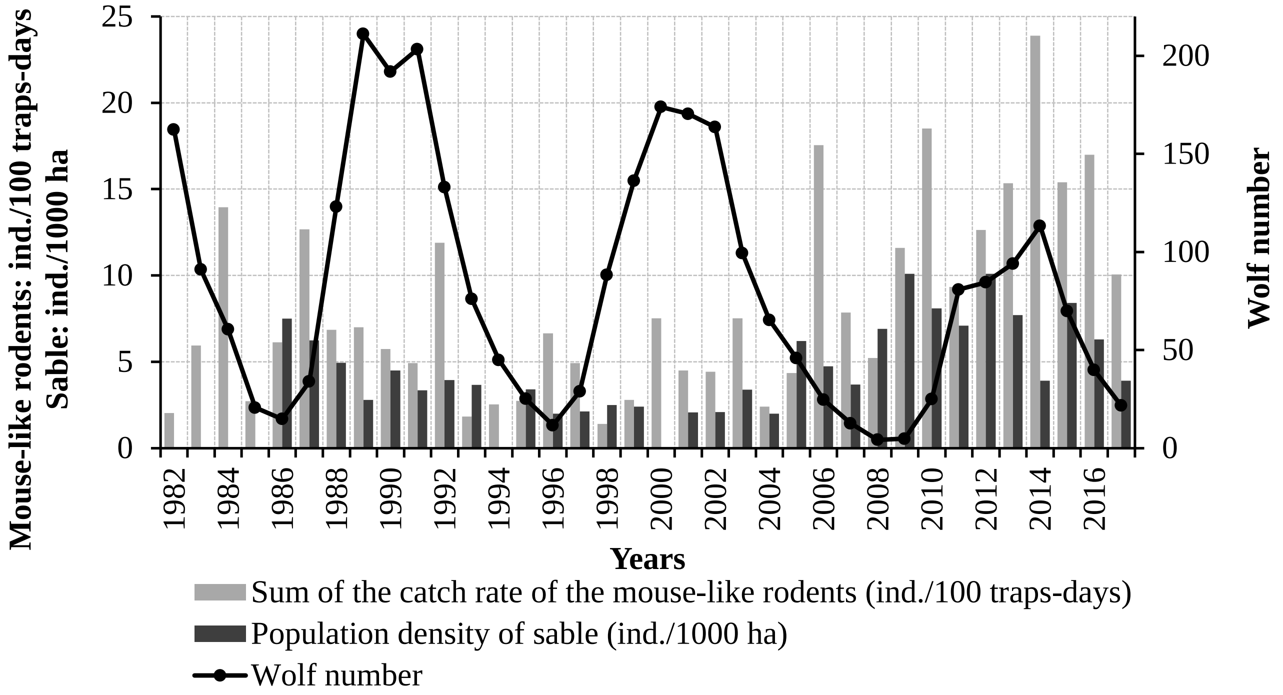

Fig. 5. Dynamic of sable population density in the Zeya Nature Reserve, solar activity and the sum of the mouse-like rodents caught with the spring-loaded bar traps "Hero".

Table 1. Main indices of the Zeya Reservoir impact on the population groups of the mode; species.

Indices	Model species							
	Siberian musk deer		**Elk**		**Siberian roe deer**		**Sable**	
	Test	**Control**	**Test**	**Control**	**Test**	**Control**	**Test**	**Control**
Period of maximal impact	1974-2005	–	1974-1999	–	1974-2002	–	1984-2005	–
Approximate time needed for adaptation	30 years	–	25 years	–	28 years	–	20 years	–
Duration of depressions	8 years (1997-2005)	6 years (2000-2005)	7 years (1988-1994)	4 years (1990-1994)	8 years (1996-2004)	6 years (1998-2004)	9 years (1993-2002)	5 years (1994-1999)
Correlation between population dynamic and natural limiting factors	r = 0.03; p > 0.1 (with May and June precipitation of the previous 5 years)	r = 0.45; p = 0.05 (with May and June precipitation of the previous 5 years)	r = 0.06; p > 0.1 (with May and June precipitation)	r = 0.36; p = 0.1 (with May and June precipitation)	r = 0.27; p > 0.1 (with May and June precipitation)	r = 0.39; p = 0.05 (with May and June precipitation)	r = 0.47; p = 0.01 (with the summed population of mouse-like rodents)	r = 0.51; p = 0.001 (with the summed population of mouse-like rodents)
Correlation with the population dynamic in Amur Region	r = -0.03; p > 0.1	r = 0.49; p = 0.05	r = -0.12; p > 0.1	r = 0.22; p > 0.1	r = 0.39; p = 0.1	r = 0.64; p = 0.001	r = 0.42; p = 0.05	r = 0.6; p = 0.001
Fluctuations range of the population density (ind./1000 ha)	0.19 – 10.2	0.4 – 8.8	0.2 – 2.3	0.38 – 1.95	0.1 – 12.1	0.99 – 5.37	0.46 – 15.27	2.42 – 10.57
Times of the max density exceeding the min density	53.7	22.0	11.5	5.1	121.0	5.4	33.2	4.4
Average annual population density (ind./1000 ha)	1.97 (1987-2005)	3.8 (1987-2005)	0.63 (1987-2001)	1.29 (1987-2001)	0.43 (1974-2002)	1.96 (1974-2002)	2.54 (1987-2005)	3.93 (1987-2005)
Average annual losses (ind./1000 ha)	1.83	–	0.66	–	1.53	–	1.39	–
Average annual losses (%)	51.8	–	51.2	–	78.1	–	35.4	–

The depression was the deepest and longest at the shores of the Zeya Reservoir (Fig. 4). The reason for this could be the microclimatic influence of the reservoir that breaks free from ice too late and warms up too slowly, causing s significant cooling effect on the adjacent territories in spring and early summer (Dyakonov, 1992). An increase in air humidity, a decrease in average monthly temperatures in the spring-summer, and a shift in phenophases worsened the conditions for the rodents' reproduction, caused a long-term decrease in their abundance, and depleted sables' food supply on the slopes of the reservoir shores (Podolsky et al., 2009). Additionally, it was established that the same factors, such as increasing air humidity and decreasing average monthly spring temperatures, led to increased mortality rate in one-year-old animals (Astafiev, 1988). With increasing summer humidity, the cases of dermatitis in sables increase as well (Lobanov, 1977). Gradually, the population groups of mouse-like rodents and sable have been able to partially adapt to the influence of the water reservoir, and the "predator – prey" system on the shore has finally stabilized.

Conclusions

An essential step for an objective characterization of anthropogenic impact of the reservoir on terrestrial vertebrates is a long-term zoological monitoring, which includes observations in the test and control plots, background data on the dynamics of the number of the studied species for the chosen region. Using the example of the Zeya reservoir, we developed a 5-step algorithm to determine the impact that hydro constructions have on model mammal species.

The first step is to restore the chronology of changes in the population density of the model species in the chosen territory and the region in general for the longest period possible. Apart from the data obtained during regular censuses, the literary, fund and survey data is also used. We worked with the sources dating back to 1950 for Siberian musk deer, the 1960s for elk and Siberian roe deer, and the 1920s for sable. Comparison of "test", "control" and "background" data makes it possible to roughly determine the period of "maximal reservoir influence" on each species and the time they needed to partially adapt, which was 30 years for musk deer, 25 years for elk, 28 years for roe deer, and 20 years for sable (Table 1). The reasons for identifying the period of "maximum reservoir influence" were the asynchronization/synchronization of population dynamics, and the abrupt growth/decline of the differences between the population density in the "test" and "control" plots.

The second step is to determine the leading natural factors of population dynamic of the model species. For musk deer, elk and roe deer the main defining factor is precipitation in the beginning of the growing season of May and June that determines the amount of winter food supply and the survival rate of young animals. Due to the slow growth of epiphytic lichens, the main food source for musk deer during winter, the population dynamics of this species is 4-6 years behind the course of spring-summer precipitation. For sable the leading factor is the dynamics of the total number of mouse-like rodents that has a significant negative correlation with the cycles of solar activity and long-term trends of spring-summer precipitation (Fig. 5, Table 1).

The third step is to determine the main factors of the influence that the reservoir causes on the population dynamics of the model species. For musk deer this is the deteriorating conditions of protection, increasing mortality along the shoreline of an artificial reservoir due to various injuries, predators and epizootics. For elks it is the poaching activities and wolves that hunt them on the surface of the frozen reservoir. For roe deer it is the disrupted routes of their seasonal migration, the poaching and increasing hunting pressure from the predators. For sable it is the microclimatic influence that causes a depletion of food supply (decreasing numbers of mouse-like rodents) and leads to growing rates of dermatitis cases.

The fourth step is to identify the common signs of the hydro construction impact on mammals. Each model species found in the influence area of the Zeya reservoir is experiencing prolonged population depressions, low level of correlation between population dynamics and changes in the main limiting factors, reduced population density, and increased amplitude of population fluctuations. This can be illustrated by objective measurable indicators of the hydro construction impact on the populations of mammals (Table 1).

The fifth step is to quantify the losses in the population groups of the model species under the impact of the reservoir. We decided that the most objective index is the difference between the average population density in the "test" and "control" plots, in % of the "control" level. The average annual population indices were calculated for the period of "maximal reservoir influence", which matches the time required for partial adaptation of the species, i.e. 20-30 years (Table 1). Every year during that period the population groups of the model species along the mountainous shores of the Zeya reservoir kept losing lots of animals: musk deer – 51.8%, elk – 51.2%, roe deer – 78.1%, sable – 35.4%.

In the end we can confirm that over 20-30 years each of these model species, while being under protection, was able to partially adapt to the construction of Zeya reservoir. Their population dynamics generally recovered on the slopes of its shores, the numbers recovered as well, however, only partially, and the seasonal migrations renewed. But the population density of most of the species and migration activity of roe deer remained significantly lower than it was before the construction.

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ПОКАЗАТЕЛИ ИЗМЕНЕНИЙ ПОПУЛЯЦИОННЫХ ГРУППИРОВОК МЛЕКОПИТАЮЩИХ ЗОНЫ ВЛИЯНИЯ ЗЕЙСКОГО ВОДОХРАНИЛИЩА ПОД ВОЗДЕЙСТВИЕМ ПРИРОДНЫХ И АНТРОПОГЕННЫХ ФАКТОРОВ

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На основе многолетних данных Зейского заповедника оценивается значение природных и антропогенных факторов в динамике численности популяционных группировок млекопитающих зоны влияния Зейского водохранилища. В качестве модельных видов выбраны кабарга (*Moschus moschiferus*), изюбрь (*Cervus canadensis*), сибирская косуля (*Capreolus pygargus*) и соболь (*Martes zibellina*). Выделение антропогенной составляющей популяционной динамики проводится на основе сравнительного анализа многолетних рядов «опытных» наблюдений (побережье Зейского водохранилища в пределах заповедника), «контрольных» (заповедник вне побережий) и «фоновых» (Амурская область). Предложен пошаговый алгоритм изучения млекопитающих в зоне влияния крупного гидросооружения. *Первый шаг* – восстановление хронологии изменений плотности населения модельного вида и определение длительности его частичной адаптации к водохранилищу: кабарга – 30 лет, изюбрь – 25 лет, косуля – 28 лет, соболь – 20 лет. *Второй шаг* – определение ведущих природных факторов динамики численности. Для кабарги, изюбря и косули это – осадки начала вегетационного периода (май, июнь), определяющие запас зимних кормов и выживание молодняка; для соболя – динамика суммарной численности мышевидных грызунов, демонстрирующая значимую отрицательную корреляцию с циклами солнечной активности и многолетними тенденциями хода весенне-летних осадков. *Третий шаг* – установление основных факторов влияния водохранилища на динамику численности модельных видов. Для кабарги это – ухудшение защитных условий, рост смертности на побережье искусственного водоема от травм, хищников и эпизоотий; для изюбря – браконьерство и гибель от волков на льду водохранилища; для косули – нарушение путей сезонных миграций, браконьерство и рост пресса охоты хищников; для соболя – микроклиматическое влияние водохранилища, ведущее к росту заболеваемости и обеднению кормовой базы за счет снижения численности мышевидных грызунов. *Четвертый шаг* – выделение общих признаков влияния гидростроительства на млекопитающих. Для всех модельных видов в зоне влияния Зейского водохранилища отмечены повышенная длительность популяционных депрессий; пониженный уровень корреляции динамики численности с изменениями основных лимитирующих природных факторов; пониженная плотность населения; повышенная амплитуда колебаний численности. *Пятый шаг* – количественная оценка влияния водохранилища на модельные виды. В качестве показателя взята разность между средней (за период адаптации) плотностью населения на «контрольных» участках и на побережье искусственного водоема, выраженная в % от «контрольного» уровня. Средние ежегодные потери составили для кабарги – 51.8%, для изюбря – 51.2%, для косули – 78.1%, для соболя – 35.4%. При условии охраны все модельные виды за 20-30 лет смогли частично адаптироваться к появлению Зейского

водохранилища: популяционная динамика в целом восстановилась, но плотность населения и миграционная активность остались существенно ниже исходных.
Ключевые слова: гидростроительство, оценка влияния, модельные виды, кабарга, изюбрь, косуля, соболь, мышевидные грызуны, динамика численности, солнечная активность, осадки.
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