An attempt to estimate the habitat capacity of reintroduction sites for the forest reindeer in the Nizhny Novgorod region

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Abstract. The article is the first attempt to consider the consumption of food supply by the European subspecies of the reindeer (Rangifer tarandus tarandus) during reintroduction in the central part of the Russian Plain on the territory of the Kerzhensky State Reserve in the Nizhny Novgorod Region. On the territory of the adaptation enclosure (122.44 ha), the vegetation was examined in 2015-16 (before the release of deer) and the changes that have occurred over 2 years of keeping animals (2018-20). The enclosure was used by animals for 5776 deer-days, including 3756 summer days and 2020 winter days. It was found that the area of the adaptation enclosure is fully used by the reindeer. Summer food supply have not changed, but a significant degradation of the lichen layer has been revealed. It was shown that the use of lichens by deer for food during the snowless period is minimal. Lichens of the genus Cladonia are the main food for reindeer after the formation of the snow cover. Winter food supply is the limiting factor that determines the habitat capacity. During the 2020 winter reindeer days, 60.02 tons of lichens were used. The daily consumption of lichens by one deer was 29.71 kg. It is shown that the number of deer kept in the adaptation enclosure exceeds the habitat capacity. The possibilities of keeping different numbers of animals with and without winter feeding have been estimated. The area of winter pastures necessary for a reindeer is calculated: 26.94 hectares of natural reindeer lichen communities, or 14.32 hectares in terms of 100% lichen coverage. These data can be used to calculate the potential capacity of reindeer habitats in forest-swamp complexes of the central part of the Russian Plain

1. Introduction

Until the end of the 19th century, the European subspecies of the reindeer (Rangifer tarandus tarandus) was common in the north of the Nizhny Novgorod region, located in the center of the Russian Plain [1]. In 2020, this subspecies was included in the Red Book of Russia. The nearest remained habitats are located 500–600 km north and north-east of the Nizhny Novgorod region. Currently, the Kerzhensky State Biosphere Reserve is carrying out the program for the reintroduction of forest
reindeer in the Nizhny Novgorod Trans-Volga region. To keep animals on the territory of the Reserve, a total of 3 enclosures were built: for demonstration (1.5 hectares) on the territory of the village of Rustai, for the broodstock (6.42 hectares) near the Chernorechye cordon and for adaptation (122.44 hectares) in the vicinity of the Cherny Khutor natural boundary [2]. Deer are kept on artificial feeding in the breeding and demonstration enclosures. In the adaptation enclosure, they feed mainly on natural food, the living conditions of the animals are close to natural ones.

The first three males were released into the adaptation enclosure in the summer of 2018. At the end of the summer of 2020, 8 deer were kept here. This provides a unique opportunity to study the impact of reindeer on the vegetation cover, to collect material that makes it possible to assess the habitat capacity in the southern zone of the former range of the subspecies. Such data are of great interest for the implementation of plans for the recovery of the subspecies.

The problem of calculating the capacity of reindeer habitats in Russia was developed mainly for the tundra zone and for the tundra reindeer subspecies. The methods for determining the capacity of habitats are based on the distribution of reindeer in the territory, the characteristics of their seasonal feeding and the dates of movements within the range. There are several interesting publications on this problem. Mamaev et al [3] studied the consequences of the reindeer impact on the vegetation and soil cover of the Bering Island using the satellite images analysis. The research of Polezhaev [4] is very useful for us: he studied the growth and distribution of lichens in the north of the Russian Far East under the impact of reindeer grazing. Elsakov [5] patented a technology for resource assessment of reindeer grazing lands based on spectral satellite image data. The greatest part of publications concerns the reindeer nutrition and the role of lichens in their diet both in Russia [6-11] and on the territory of the Scandinavian Peninsula [12-16]. Other important study was carried out by Surov and Pechnikova [2]: they described the “summer” and “winter” diets of reindeer being kept in the Kerzhensky Nature Reserve. Since there was no unified generally accepted technique for calculating the capacity of potential reindeer habitats, Bakka et al. [17] calculated the capacity of suitable habitats for the forest reindeer population reintroducing in the Kerzhensky Reserve on the basis mainly of the area of winter pastures.

2. Materials and methods
Detailed studies of flora and vegetation in the territory of the adaptation enclosure in the Kerzhensky Reserve were carried out in August 2015 and in August 2016, that is, before the release of deer began. A total of 46 samplings were made. Based on the sampling results plant associations were identified and the list of vascular plant species, epigeic bryophytes and lichens was compiled. The vegetation map of the territory of the adaptation enclosure was designed. The total coverage was determined for herbs, shrubs and the moss-lichen layer, species composition, and the coverage of each species. For estimating the productivity of herbs, shrubs and moss-lichen layer, the samples of vegetation mass were taken on the plots 1x1 m that set up in each identified association according to the adopted method [18]. Phytomass estimation was carried out on 25 sample plots, 10 of which were characterized by the developed layer of lichens. 30 species of vascular plants, 10 lichen and 6 mosses species were accounted in the collected samples (sphagnum in the samples was identified to genus). Most of these species comprise the important part in the reindeer diet: cladonia, reed grass, purple moor-grass, hairy sedge, marsh cinquefoil, etc.

The study of the use of natural food by forest reindeer and their effect on the vegetation cover were carried out in an adaptation enclosure (122.44 ha) on the territory of the Kerzhensky State Nature Biosphere Reserve in August-December 2020. The total length of pedestrian routes was 68 km, including 48.3 km during the snowless period, 19.7 km in the presence of snow cover. To encompass a number of vegetation types represented in the enclosure 30 transects with a total length of 3492 m and 20 study plots of 400 m² each were set up in August, 24-26, 2020. Three subsequent surveys of the plots and transects were carried out with an interval of about a month. In order to monitor the consumption of lichens (winter food) by deer during the snowless period, repeated surveys of the plots and transects were carried out on September 27-28, 2020 (the first month after the setting) and
November 3, 2020 (the second month after the setting). The state of the lichen cover was re-estimated visually; weighing was not performed in order to avoid high research pressure.

During the snowy period (12/09/2020), the mapping of the main lichen excavations in the territory of the adaptation enclosure was carried out using a GPS navigator. 683 excavations have been identified (most of the existing ones).

Three levels of the lichen coverage were determined: low (less than 30%), medium (31-60%), high (61% and more), as well as three levels of lichen destruction: weak (less than 30% of biomass), moderate (30-50 %), heavily (60% or more). We determined the areas of reindeer moss with different initial coverage of lichens, as well as areas with different levels of lichen layer destruction with use of the GIS-methods. Overlaying the maps of the initial state and the current degree of lichen layer destruction in the adaptation enclosure we determined the areas of sites with different lichen coverage and with a different degree of its lost.

Considering the known dates of release, birth and death of animals the number of reindeer-days of using the enclosure area during summer and winter season was calculated. One reindeer-day was recognized as a day of feeding of an adult female. The coefficient of 1.5 was used for adult males; 0.7 – for young (regardless of gender) from birth to the beginning of the winter period; and 1.0 – for young (regardless of gender) in the first winter of life. Since the beginning of the release of animals, the adaptation enclosure has been used for 5776 deer-days, including 3756 summer days and 2020 winter days (basing on the duration of the winter period of 152 days).

The calculation of the food capacity of habitats has been made, and the forecast of the depletion of lichen layer has been made under different conditions of the reindeer keeping.

3. Results

The presence of reindeer trails and other traces of activity indicate that the area of the adaptation enclosure is fully used by reindeer. We have noted no changes in the volumes of summer supply in general on the territory of the adaptation enclosure. At the same time, even visual observations (without special measurements) revealed a significant degradation of the lichen cover over the entire area of its distribution within the enclosure.

Visually we recorded no changes in the moss-lichen cover appeared on the study plots and transects in the period from late August to late September 2020. During the second month after the plots and transects setting (late September – early November) we noted some changes in the moss-lichen cover: a degree of its destruction had increased on 3% of the area. In addition, outside the study plots and transects a noticeable increase in the size of some excavations in the ground was also noted, as well as new damage to pine undergrowth.

Of the 683 excavations registered on 12/09/2020, in 92% of cases, deer dug out from under the snow and ate lichens of the genus Cladonia. Along with lichens we noted deer eating common heather, lingonberry, bearberry and mosses (Dicranum polysetum, Pleurozium schreberi and Polytrichum commune). In addition, an excavation of mineral soil with incomprehensible purposes was recorded. Once the deer dug up an anthill.

The total area of lichens on the territory of the adaptation enclosure is 49.3 hectares. Areas with different initial coverage of lichens (before the release of deer) and the ratio of such areas are presented in table 1. Areas with medium coverage of lichens (58.9%) predominate on the territory of the adaptation enclosure. Areas with high coverage comprise almost a third of the total area of lichens. The smallest area is with small coverage of lichens. The area covered by lichens, in terms of 100% of coverage, was 26.2 hectares.

For each area of the lichen cover, the degree of destruction was determined as of September – October 2020. There are few areas of winter pastures with heavily destructed lichen layer in the adaptation enclosure (less than 5% of the lichen cover area). Weakly and moderately destructed sites occupy almost half of the area of winter pastures (table 2).
Table 1. Areas of lichen communities with different initial coverage of lichens.

| Coverage of lichens, % | Area of sites, ha | Share of the total area of lichen communities, % |
|-----------------------|-------------------|-----------------------------------------------|
| Small (less than 30)  | 4.67              | 9.5                                           |
| Medium (31–60)        | 29.06             | 58.9                                          |
| High (61 and higher)  | 15.57             | 31.6                                          |
| Total                 | 49.3              | 100.0                                         |

Table 2. Areas of lichen communities with different degree of lichen layer destruction.

| Degree of lichen layer destruction, % | Area of sites, ha | Share of the total area of lichen communities, % |
|--------------------------------------|-------------------|-----------------------------------------------|
| Weak (less than 30)                  | 23.83             | 48.4                                          |
| Moderate (30–50)                     | 22.92             | 46.7                                          |
| Heavy (60 and higher)                | 2.55              | 4.9                                           |
| Total                                | 49.3              | 100.0                                         |

Areas with a small coverage of lichens are virtually not used by deer. The proportion of heavy destructed sites with medium coverage of lichen is insignificant. The shares of weak and moderate destructed sites with medium coverage of lichens are close to each other; however the share of weak destructed sites is slightly higher. Considering the sites with initially high coverage of lichens we revealed the share of moderate destructed sites prevailing. The heavy destructed fragments seem to predominate, while the share of weak destructed fragments is significantly less than among the areas with the medium coverage of lichens (table 3).

Table 3. Destruction of lichen layer on sites with initially different coverage of lichens.

| Destruction of sites with initially different coverage of lichens | Area of sites, ha | Share of the total area covered by lichens, % |
|------------------------------------------------------------------|-------------------|-----------------------------------------------|
| Small coverage, weak destructed                                  | 4.67              | 9.5                                           |
| Medium coverage, weak destructed                                 | 15.5              | 31.4                                          |
| Medium coverage, moderate destructed                             | 12.91             | 26.2                                          |
| Medium coverage, heavily destructed                              | 0.65              | 1.3                                           |
| High coverage, weak destructed                                   | 3.73              | 7.6                                           |
| High coverage, moderate destructed                               | 10.01             | 20.3                                          |
| High coverage, heavily destructed                                | 1.83              | 3.7                                           |
| Total                                                            | 49.3              | 100.0                                         |

The initial average biomass of epigeic lichens in the air-dry condition (in terms of 100% coverage) was calculated for cenoses of the adaptation enclosure before the release of deer. It was $630.0 + 510.5 \text{ g/m}^2 (n = 10)$ with a confidence interval from $364.4 \text{ g/m}^2$ to $895.5 \text{ g/m}^2$ and ranging from $107.2 \text{ g/m}^2$ to $2044.8 \text{ g/m}^2$. In 2020, the control measuring of lichen biomass on a plot with well-developed lichen layer (coverage was 100%) outside the adaptation enclosure showed a biomass of $1024 \text{ g/m}^2$, which is included into the range of measurements made earlier: slightly higher than the average value, but within the range. The current average biomass of lichens in the adaptation enclosure in August 2020 (air-dry weight in terms of 100% coverage) was calculated, which was $401.2 \pm 214.9 \text{ g/m}^2 (n=20)$ with a confidence interval of $322.2 \text{ g/m}^2$ to $480.2 \text{ g/m}^2$ and the range from $48 \text{ g/m}^2$ to $948 \text{ g/m}^2$. The area covered by lichens, in terms of 100% coverage, was $26.2335 \text{ ha}$.

Basing on the calculated values of lichen biomass before and after the reindeer release, as well as the area covered by lichens in the adaptation enclosure we calculated the initial, consumed by the reindeer and the remaining volumes of winter food supply (Table 4). This calculation has shown deer
using about 60 tons of lichens during the periods up to the autumn of 2020. According our estimates the remained available food supply of lichens in the adaptation enclosure ranges from 63 to 84 tons that exceeds the already consumed one by 5–40%.

Table 4. Calculation of the initial volumes of winter supply used by the reindeer and remained in the adaptation enclosure.

| Criteria                                                | Lichen biomass, t |
|---------------------------------------------------------|-------------------|
| Average biomass of lichens before deer release          | 165.27            |
| Average biomass of lichens in autumn 2020              | 105.25            |
| Food supply consumed by reindeer (average value)        | 60.02             |
| Remained food supply (average value)                    | 105.25            |
| Food supply unavailable for deer:                       |                   |
| min (20% of available food supply)                      | 21.05             |
| max (40% of available food supply)                      | 42.10             |
| Food supply available for deer:                         |                   |
| min                                                     | 63.15             |
| max                                                     | 84.20             |

4. Discussion
The general factor limiting the capacity of the reindeer habitat seems to be the winter food supply, mainly lichens of the genus Cladonia. Therefore, during the study, the main attention was paid to the estimation of lichen layer on the territory of the adaptation enclosure. The survey has shown that the consumption of lichens by deer, leading to the degradation and destruction of the lichen layer, is minimal during the snowless period. We have noted no visible changes in the lichen layer for two autumn months in 2020. Epigeic lichens become the main food for reindeer after the formation of snow cover. The density of excavations and accordingly the lichen consumption depends on the density of tree canopy. The most part excavation sites were located on open spaces. In pine forests, even with a high coverage of lichens, deer consumption of winter food supply is minimal.

We used the number of winter reindeer-days to calculate the habitat capacity. During the 2020 winter reindeer-days 60.02 tons of lichens were consumed. The daily consumption of lichens by one deer was estimated as 29.71 kg. This figure includes both eating and trampling. And it significantly exceeds the level of the daily eating (2.6 kg dry weight lichens) in a captive content in Finland [14].

The remaining available food supply of lichen in the adaptation enclosure will be used: minimum (63.15 tons) – during 2125 reindeer-days, maximum (84.20 tons) – during 2834 reindeer-days. The number of deer (from 1 to 10 individuals) that can be kept in the adaptation enclosure without additional feed and the periods of their keeping are presented in the table 5.

When 8 reindeer were kept in the adaptation enclosure, the habitat capacity had been exceeded, which led to the degradation of the lichen layer and a significant reduction (approximately by half) of the winter food supply available for the reindeer. As a result, the current capacity of habitats in the adaptation enclosure, even taking into account the self-recovery process of lichens, does not exceed two individuals. For 5 years, 3-5 deer can be kept in the enclosure without additional feeding in winter. If these reindeer are provided with 15–20 tones of lichens during the winter, the degradation of the lichen layer can probably be avoided. If 8–10 deer are kept in the adaptation enclosure, the available winter food supply will be fully consumed by the animals during two years.

We did not take into account the possibility of self-recovery of the lichen layer. The recovery rate of lichens averages only 5% per year [19; 20], thus it takes about 20 years for the lost lichen layer complete recovering. At the same time, the rate of recovery of lichens varies significantly depending on the degree of degradation [4]. The study of the lichen restoration under conditions of the Kerzhensky Reserve requires a special long-term research.

Considering the area and biomass of epigeic lichens on the territory of the adaptation enclosure, we have calculated the area of winter pastures necessary for a reindeer. It comprises 26.94 hectares of
natural lichen communities, or 14.32 hectares in terms of 100% lichen coverage. These figures can be used to calculate the potential capacity of reindeer habitats in the forest-bog complexes of the central part of the Russian Plain.

Table 5. Periods of possible keeping of different numbers of deer without additional food supply.

| Deer number | Number of winter deer-days per year | Period of possible deer keeping without additional food supply (years) |
|-------------|-------------------------------------|---------------------------------------------------------------------|
|             |                                     | min | max      |
| 1           | 152                                 | 14  | 19       |
| 2           | 304                                 | 7   | 9        |
| 3           | 456                                 | 5   | 6        |
| 4           | 608                                 | 3   | 5        |
| 5           | 760                                 | 3   | 4        |
| 6           | 912                                 | 2   | 3        |
| 7           | 1064                                | 2   | 3        |
| 8           | 1216                                | 2   | 2        |
| 9           | 1368                                | 2   |          |
| 10          | 1520                                | 1   | 2        |

To calculate these parameters for a particular territory, it is also necessary to identify, map and determine the area of lichen layer with coverage of more than 30%. Unfortunately, the forest inventory data do not allow to reliably determine this area. In metrics of forest inventory areas with lichen coverage of 40-50% can be identified as pine forests of different types (Vaccinieta, Calluneta, etc.). The same types of pine forests include fragments with lichen layer coverage of less than 20%, which should be excluded from the calculations.

5. Conclusion
The area of the adaptation enclosure (122.44 ha) is fully used by the reindeer. There are no visible changes in summer food supply. A significant degradation of the lichen layer was revealed over the entire area of its distribution within the territory of the enclosure. A total of 60.02 tons of lichens were consumed during the 2020 winter reindeer-days. The daily consumption of lichens by one deer was 29.71 kg. Biomass of epigeic lichens (mainly Cladonia), which comprises the winter food supply, limits virtually the capacity of reindeer habitats.

When 8 reindeer were kept in the adaptation enclosure, the habitat capacity had been exceeded, which led to the degradation of the lichen layer and a significant reduction (approximately by half) of the winter food supply available for the reindeer. As a result, the current capacity of habitats in the adaptation enclosure, even taking into account the self-recovery process of lichens, does not exceed two individuals. For 5 years, 3-5 deer can be kept in the enclosure without additional feeding in winter. If these reindeer are provided with 15–20 tones of lichens during the winter, the degradation of the lichen layer can probably be avoided. If 8–10 deer are kept in the adaptation enclosure, the available winter food supply will be fully consumed by the animals during two years.

The area of winter pastures necessary for a reindeer is 26.94 hectares of natural lichen communities, or 14.32 hectares in terms of 100% lichen coverage. These figures can be used to calculate the potential capacity of reindeer habitats in the forest-bog complexes of the central part of the Russian Plain.

We recommend monitoring the state of the vegetation every year for any use of the adaptation enclosure: for any number of deer, with and without additional feeding.

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References

[1] Kharitoncychev AT 1978 *The nature of the Nizhny Novgorod Volga region: history, use, protection* (Gorky: Volgo-Vyatka book publishing house) 368

[2] Surov SG and Pechnikova ND 2018 Progress in the implementation of the program to restore the forest reindeer population in the Kerzhensky Reserve in 2014-2018. *Proceedings of the All-Russian (with international participation) the conference "Contribution of protected areas in the environmental sustainability of the regions: Current State and Prospects" Kologriv* 194-198

[3] Mamaev E G, Rybakov I A and Shienok A N 2016 Impact of reindeer *Rangifer tarandus* on the soil and plant cover on Bering Island (Commander Islands) *Proceedings of the XVII international scientific conference, dedicated to the 25th anniversary of Kamchatka Research Institute of Ecology and Management FEB RAS "Conservation of biodiversity of Kamchatka and coastal waters" Petropavlovsk-Kamchatsky 294-298

[4] Polezhaev A N 2005 Growth and distribution of fruticose lichens in the north of the russian far east. *Bulletin of the North-East Scientific Center, Russia Academy of Sciences Far East Branch* 2 56-63

[5] Elsakov V V 2014 A technology of on-line resource estimation of reindeer pastures from optical remote sensing data, *Current problems in remote sensing of the Earth from space* 11(1) 245

[6] Aleksandrova VD, Andreev VN, Vakhitina TV, Dydina RA, Karev GI, Petrovsky VV and Shamurin VF 1964. *Forage characteristics of plants in the Far North* (Leningrad: St. Petersburg publishing bookseller "Science") 480

[7] Borozdin E, Zabrodin VA, Vostryakov PN, Dyachenko NO, Kryuchkov VV and Andreev VN 1979. *Reindeer husbandry* (Moscow: Kolos Publishing House) 286

[8] Syroechkovsky E E 1986 *Reindeer* (Moscow: Agropromizdat) 255

[9] Sablina T B 1989 Feeding of the reindeer on the Karelian coast of the White Sea. *Proceedings of the I Soviet-Finnish Symposium "Forest reindeer of Fennoscandia" Petrozavodsk 26-29

[10] Danilkin AA 1999 Deer (Mammals of Russia and neighboring regions). (Moscow: GEOS) 552

[11] Mamontov VN and Efimov VA 2011 Ecological and ethological features of isolated groups of forest reindeer in the Arkhangelsk region. *Hunting Bulletin, 8 (2)* 139-147

[12] Sulkava S, Erkinaro E, Heikura K, Lindgren E and Pulliainen E 1983 Food of the wild forest reindeer, rangifer tarandus fennicus, in finland in winter and summer 1981 (lake lentua, finland). *Acta Zoologica Fennica* 175 17-19

[13] Lindgren E, Pulliainen E, Sulkava S, Erkinaro E and Heikura K. 1983 Lichen resources and their use in winter by wild forest reindeer in the area of lake lentua. *Acta Zoologica Fennica, 175* 21-23

[14] Kumpula J 2001 Winter grazing of reindeer in woodland lichen pasture: Effect of lichen availability on the condition of reindeer. *Small Ruminant Research* 39(2) 121-130

[15] Kumpula J, Lefrere S C and Nieminen M 2004 The use of woodland lichen pasture by reindeer in winter with easy snow conditions. *Arctic* 57(3) 273-278

[16] Kivinen S, Berg A, Moen J, Östlund L and Olofsson J 2012 Forest fragmentation and landscape transformation in a reindeer husbandry area in sweden. *Environmental Management* 49(2) 295-304

[17] Bakka S V, Kiseleva N Yu and Vedyashkina E P 2016 Possibility and prospects for re-acclimatization of forest reindeer (Rangifer tarandus fennicus Lonn.) In the Kerzhensky nature reserve. *Proceedings of the State Natural Biosphere Reserve "Kerzhensky"* 8 25-38

[18] Dylis NV (Ed.) 1974 *Program and methodology of biogeocenological research* (Moscow: Nauka) 404

[19] Andreev VN 1954 Growth of forage lichens and methods of its regulation. *Proceedings of Bot. Institute of the USSR Academy of Sciences* 3(9) 11–74

[20] Fadeeva M.A. (2006). Lichens. *Nature and historical and cultural heritage of Kozhozerie* (Arkhangelsk: Ural Branch of the Russian Academy of Sciences) 75-102