BEAVER IMPACT ON WATER COVERAGE OF FOREST-STEPPE TERRITORIES (PENZA REGION, EUROPEAN RUSSIA)

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The impact of the European beaver (*Castor fiber*) on the water coverage of natural territories was assessed by analysing public available satellite images. Four model squares with a total area of 900 km^2 were chosen, with coverage of the vicinity of four sectors of the Privolzhskaya Lesostep' State Nature Reserve (Penza region). This study showed that modern public satellite images can clearly distinguish beaver ponds even of small sizes, as well as elements of their activity, namely beaver dams, canals and tracks. We identified 373 water bodies that were made by beavers, with an average area of 1040 ± 4843 m^2, 107 man-made ponds (average area 24 272 ± 65 977 m^2), and 67 lakes and oxbows (average area 8127 ± 17 946 m^2). The proportion of zoogenic ponds was 11% of the total area and 68% of the total number. In certain study sites, these values varied from 7% to 18% (for the area) and from 44% to 84% (for the number). But within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve, where there were no man-made water bodies, the proportion of beaver ponds reached 100% in three sectors. The total water body' area percentage of the studied territories was 0.39%. In different sites, beavers increased the proportion of water bodies by 0.02–0.10%, in total by 0.04%. If we consider only the area of natural water bodies, then beavers increased it in 1.7 times, while within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve this increase was 3.6 times. Since the water coverage of the central regions of European Russia was considerably increased due to the construction of man-made ponds, this could affect the structure of habitats in the floodplains of small rivers, and favour the activity of beavers in the forest-steppe regions. Therefore, there was a slight correlation between the number and area of beaver ponds and the size of downstream man-made water bodies. Our data have shown that the zoogenic contribution to water resources is comparable to the contribution of natural lakes and ponds. In some areas with low anthropogenic impact, water bodies created by beavers are the only lentic habitats in the landscape. However, the obtained results do not completely cover the real beaver impact, since narrow channel-like ponds hidden by the canopy of floodplain trees fall out of analysis. It is impossible to take into account the length of the backwater zone with a cascade of zoogenic water bodies, neither is it possible to remotely assess the contribution of animals to the retention capacity of old man-made ponds, and the role of the ecological engineer in maintaining and increasing the surface area of pre-existing lakes. Therefore, the contribution of beavers to the water coverage of the territory is actually more remarkable.

Key words: *Castor fiber*, lake, man-made pond, Privolzhskaya Lesostep' State Nature Reserve, remote methods, water body area percentage, water resources, zoogenic pond

Introduction

One of the global problems of humankind is the conservation of freshwater ecosystems, which are rapidly degrading and losing their biodiversity (Vaughn, 2010). The combination of climatic and anthropogenic factors considerably affects the water resources. This is clearly seen by the example of the forest-steppe natural zone and black-soil regions that have been substantially cultivated by humans. Along the existing lakes shortage of the territory (Izmailova & Korneenkova, 2020), the annual river runoff decreases by 5–15%, and by 10–20% in the spring (Shiklomanov et al., 2011), due to climate changes. For this reason, the level of spring floods decreased. This leads to a reduction of the length of small watercourses, an increase in the number of dry channels and episodic watercourses (Dmitrieva, 2020). Floodplain lakes are not filled by a river (Buchik & Dmitrieva, 2019) and regression of valley landscapes is observed (Zhigulina & Mikhno, 2019).

Beaver (*Castor fiber* Linnaeus, 1758 and *C. canadensis* Kuhl, 1820) activities could be an important factor that impacts the state and sustainability of freshwater ecosystems. This key species has recovered its area in Europe after centuries of absence (Halley et al., 2021). Damming of water courses by beavers lead to appearances of a high amount of beaver ponds, so-called «zoogenic lakes» (Kitaev, 2007). There are a lot of papers showing the role of this species in increasing the number of water resources (e.g. Hood & Bayley, 2008; Karran et al., 2018). Apart from obvious benefits for lentic components of biota (e.g. Nummi & Holopainen, 2014; Dalbeck et al., 2020), the zoogenic water table could have economic value (Thompson et al., 2020), prevent spreading of forest fires (Zavyalov et al., 2016), and even improve population health (Elpiner et al.,

2007). In arid regions of North America, special projects of water restoration using beaver dams exist (Pollock et al., 2015; Bouwes et al., 2016).

In modern regional reports on water resources, beaver ponds were not taken into account and were not analysed (e.g. Dmitrieva, 2011; Izmailova, 2016), primarily because of their small sizes. However, in recent decades, many studies have been published highlighting the ecosystem significance of small water bodies (Downing, 2010; Céréghino et al., 2013). Quantitative estimates of pond resources are possible mainly at a local level. Larger-scale studies are complicated by the difficulties in recognition of these objects on satellite images. The use of remote sensing methods for beaver studying started a long time ago (Johnston & Naiman, 1990), but such studies are still rare (Syphard & Garcia, 2001; Hood & Bayley, 2008; Martin et al., 2015). In Russia, identification of beaver ponds on satellite images were tested previously (Goryainova et al., 2012, 2018). However, such methods were used for small areas and did not elaborate more.

Noteworthy, that many such studies analysed the impact of beavers at a local level, e.g. in Protected Areas or small river valleys (e.g. Dalbeck et al., 2014; Grygoruk & Nowak, 2014; Puttock et al., 2017). While on local areas the consequences of beaver activity are obvious and significant, at a regional level they may be less, due to their impact specifics (Law et al., 2019). A wider level of analysis is still associated with methodological difficulties and need for generalisation. The combination of local data analysis and large-scale assessments may be a promising avenue to a better understanding of the role of key species on contemporary ecosystems. Long-term studies of *Castor fiber* (hereinafter – beaver) in the Privolzhskaya Lesostep' State Nature Reserve (Penza region, European Russia) accumulated a lot of data on the beaver distribution in the forest-steppe, the morphometry of ponds and their features (Bashinskiy & Osipov, 2016, 2018; Osipov & Bashinskiy, 2018; Osipov et al., 2018). This can serve as a basis for a higher level of analysis. Therefore, the aim of this study was to analyse the beaver influence on the water coverage (water body area percentage) of forest-steppe landscapes. To achieve this goal, the following tasks were solved: i) assessment of the suitability of publicly available satellite images for identifying beaver ponds; ii) measurement of the morphometric parameters (areas) of all water body types; iii) calculation of the water table area proportion of all water bodies from the total area of studied territory; iv) searching for patterns between the distribution of various water body types.

Material and Methods

To assess the water resources of the study area, the surroundings of the Privolzhskaya Lesostep' State Nature Reserve (Penza region, European Russia) were considered (Fig. 1). The Protected Area consists of five sectors. Three of them are occupied mainly by steppe and forest-steppe landscapes (Ostrovtsovskaya Lesostep', Poperechenskaya Step' and Kuncherovskaya Lesostep'). The other two (Verkhovya Sury and Borok) are covered by pine (*Pinus sylvestris* L.) forests. In general, each sector reflects the landscape features of the adjacent areas (Dobrolyubov et al., 2013). These territories were taken as a basis, since long-term studies of aquatic ecosystems and annual monitoring of the beaver abundance were carried out here (Osipov & Bashinskiy, 2018).

For the study performing, satellite images available in Google Earth were used. Such images are actively used for the analysis of water resources in the Institute of Limnology of RAS (Izmailova & Korneenkova, 2020). Their processing was carried out using Quantum GIS (QGIS Desktop 3.12.2, the Quick Map Services tool). On the satellite image the model sites were marked by squares with a size of 225 km^2. The study sites were located with sectors of the Privolzhskaya Lesostep' State Nature Reserve in their centre (Fig. 1). Since the sites Borok and Kuncherovskaya Lesostep' are located closer than 15 km to each other, they were considered within the same square. Within these areas, all water bodies were manually digitised, and the water body type (natural, man-made, beaver) was noted separately. The quantitative parameters of the water bodies were measured using QGIS vector layer processing tools. The measurements were carried out in an ellipsoidal co-ordinate system. To digitise the study area, an image scale was used in the range of 1:5000 – 1:10 000, depending on the number and size of objects. Beaver ponds were identified by their characteristic trapezoidal shape. Their boundaries were determined along the dam on one side, and narrowing to the size of the original watercourse, or the dam of the next cascade pond, on the other side. Man-made ponds were identified by their shape, presence of a dam, size, and location near settlements. The remotely located anthropogenic ponds were identified primarily by the presence of a road along a dam or embankment. Small artificial water bodies, additionally maintained by beavers, were classified as man-made.

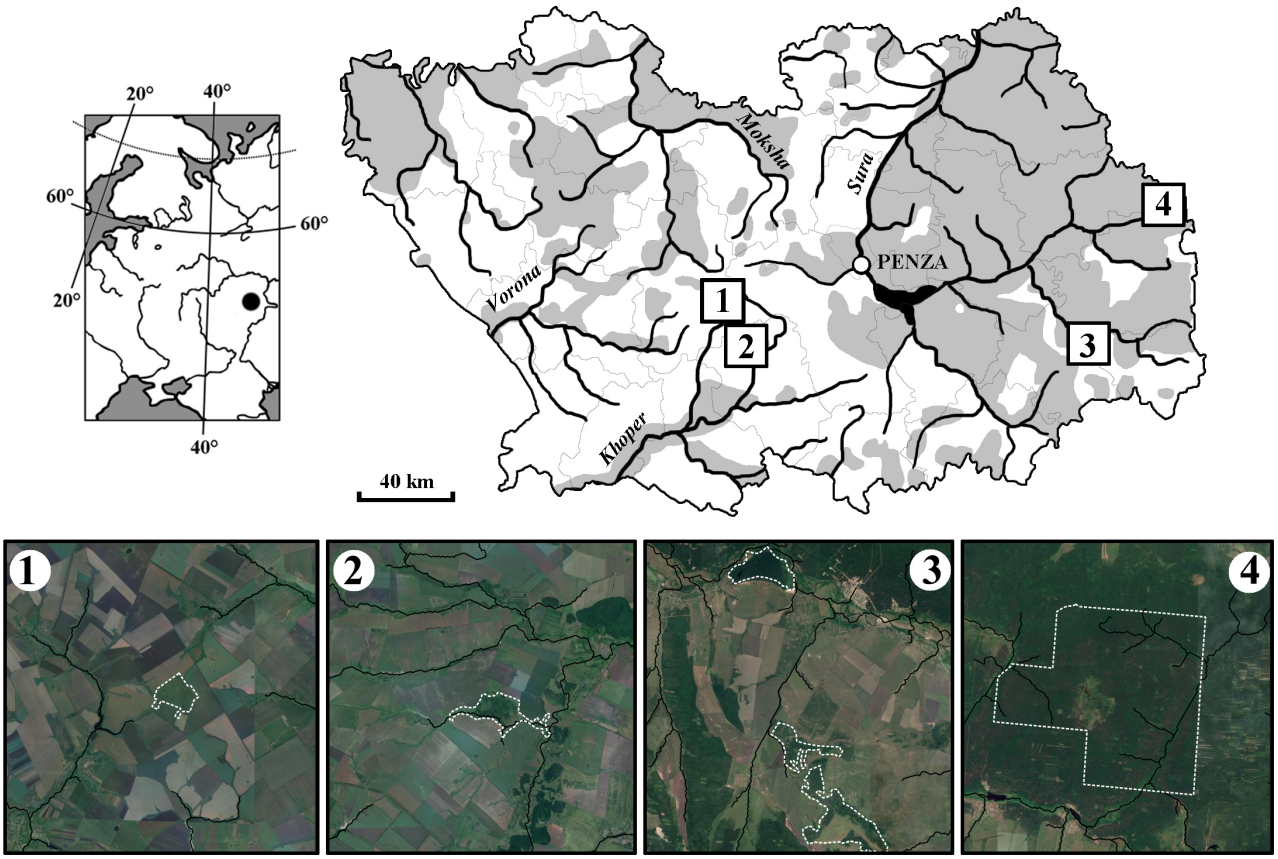

Fig. 1. The map of the study area and model sites indicated by quadrates of 15 km sides. Designations: 1 – Poperechenskaya Step', 2 – Ostrovtsovskaya Lesostep', 3 – Kuncherovskaya Lesostep' and Borok, 4 – Verkhovya Sury. The borders of the Privolzhskaya Lesostep' State Nature Reserve are shown with white dash line.

Based on the results of the morphometric data analysis, the water body area percentage (WBAP) was calculated as the ratio of the total area of water bodies to the total area of the studied territory. At the same time, the total WBAP (all water bodies), pre-existing WBAP (without man-made and zoogenic ponds) and WBAP without zoogenic ponds were calculated. Information on the length of streams was taken from the Catchment Characterization and Modeling database (CCM, 2020).

The Spearman rank coefficient and determination coefficient (R^2) were used to search for correlations between the occurrence of various water body types. Data analysis was carried out using Microsoft Excel software.

Results

We found that beaver ponds, even of small size, are clearly recognisable on modern public satellite images, as well as their zoogenic elements, i.e. dams, canals and tracks (Fig. 2). Moreover, the visibility of beaver ponds was observed not only in open steppe and forest-steppe landscapes, but also in forest areas. However, in a number of cases, beaver ponds were not visible on the images, because of the dense canopy of *Alnus glutinosa* (L.) Gaertn., the thickets of which are widespread along the floodplains of some rivers. For example, it was not possible to recognise four ponds in the Ostrovtsovskaya Lesostep', which were known from field studies. They are characterised by a channel-like form, without flooding the riparian zone and without increase in the area of the water surface. The known approximate boundaries of these ponds made it possible to calculate their proportion of the area, i.e. 3.5%. Thus, this confirms the applicability and accuracy of the method. The remaining 96.5% of the water table area could be identified from the satellite images.

In the study area, 107 man-made water bodies (small ponds, with single quarries and borrow pits) were identified, with their total area of 2.6 km^2. The average size of such water bodies was 24 272 ± 65 977 m^2, with the maximum area of 485 203 m^2 and the minimum area of 124 m^2. The number of natural ponds was lower (67). They were presented mainly by floodplain lakes and oxbows. They occupied a total area of 0.5 km^2, with an average area of 8127 ± 17 946 m^2, the maximum area of 108 305 m^2, and the minimum area of 50 m^2. The most abundant water bodies were beaver ponds – 373 water bodies, with a total area of 0.4 km^2. The maximum zoogenic pond size was 85 021 m^2, and minimum 12 m^2. The average area of zoogenic water bodies was 1040 ± 4843 m^2.

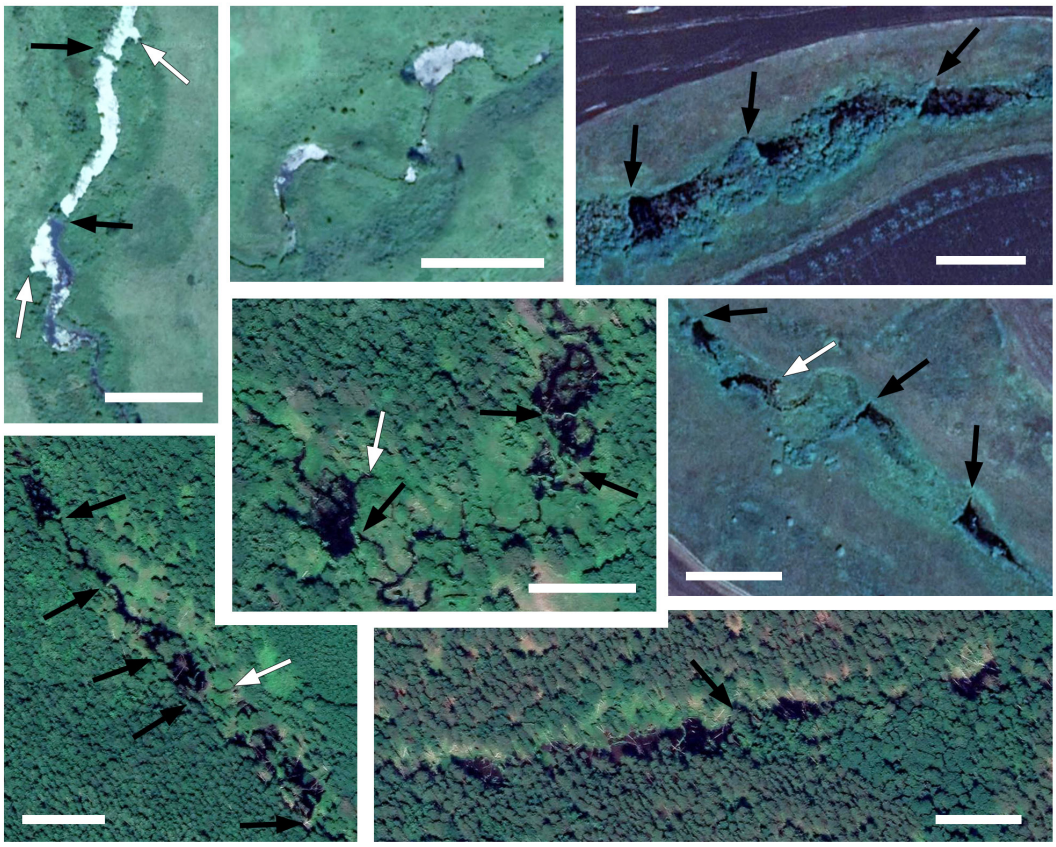

Fig. 2. Examples of satellite images with beaver ponds from various sites. Black arrows show beaver dams, white arrows indicate burrows and tracks. Scale bar: 50 m.

The ratio of various water body types varied among four model sites (Fig. 3). The proportion of beaver ponds varied from 7% to 18% by area, and from 44% to 84% by number. The smallest proportion of zoogenic ponds was observed in two sites, namely in the vicinities of Ostrovtsovskaya Lesostep' and Kuncherovskaya Lesostep', where the rivers (River Khoper and River Kadada, respectively) with a large number of oxbow lakes flow. At the same time, within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve, where man-made water bodies were not presented, the proportion of beaver ponds reached 100% on three sites (Ostrovtsovskaya Lesostep', Poperechenskaya Step' and Kuncherovskaya Lesostep') and 56% on the site Verkhovya Sury. The rest one was represented by Lake Svetloye. There were no beaver ponds within the boundaries of the site Borok.

The total density of the found beaver ponds was 1.7 ponds/km^2 of the area. The same value was observed for watercourses, i.e. 1.7 ponds/km^2 of a stream. The highest density was found for completely different sites (Poperechenskaya Step' and Verkhovya Sury): 0.5 ponds/km^2 of an area (3.3 ponds/km of a stream) and 0.8 ponds/km^2 of an area (2.5 ponds/km of a stream), respectively. The lowest density was found on the adjacent sites Kuncherovskaya Lesostep' and Borok: 0.1 pond/km^2 of an area (0.4 ponds/km of a stream), and in the vicinity of the Ostrovtsovskaya Lesostep': 0.3 pond/km^2 of an area (1.2 ponds/km of a stream). If we consider the data within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve only, then in the Verkhovya Sury the pond density was 1.5 ponds/km^2 of an area (2.4 ponds/km of a stream), 4.6 ponds/km^2 of an area (2.2 ponds/km of a stream) in the Ostrovtsovskaya Lesostep'. These values are considerably less than the data on the dam density obtained previously during field studies on these sites, i.e. 9.7 dams/km and 7.7 dams/km, respectively (Osipov & Bashinskiy, 2018). This could be explained by underestimation of a number of small dams (1–2 m width), which can be observed only during field studies.

The total WBAP of the studied area was 0.39% (Table). The beaver contribution to the increase of the water coverage was relatively low. On different sites, the beaver activity increased the proportion of water bodies by 0.02–0.10%, with a total value of 0.04%. However, if we consider only the area of natural lentic water bodies, then beavers increased it by 1.7 times. This is especially evident within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve, where a very low number of water resources and no man-made ponds are present. The beaver activity increased the to-

tal area of water bodies by 3.6 times. The WBAP of the Ostrovtsovskaya Lesostep' exceeded the regional one for Penza region by 7 times, due to the appearance of several large zoogenic ponds.

This study did not reveal a statistically significant correlation between the number and area of beaver ponds and the number of man-made water bodies or the density of the river network (Spearman correlation, $p > 0.05$). Nevertheless, in the model site Poperechenskaya Step', characterised by the lowest river network density (0.2 km/km^2) and the lowest pre-existing WBAP, we observed some confinement of zoogenic water bodies to the upper reaches of a large artificial pond on the River Archada (Fig. 4a). In the zone of its backwater, 46 beaver ponds were identified, which accounted for 43% of the total number and 22% of the total area of beaver ponds.

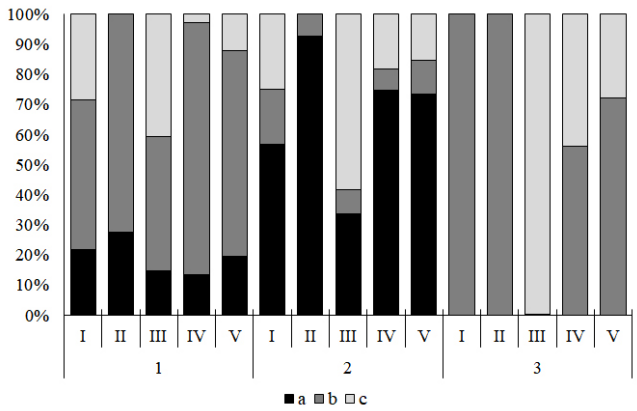

Fig. 3. The proportion of various water body sites on model sites (1 – by total number; 2 – by total area; 3 – by total area within the Privolzhskaya Lesostep' State Nature Reserve). Water bodies: a – man-made, b – beaver ponds, c – pre-existing natural water bodies. Model sites: I – Poperechenskaya Step', II – Ostrovtsovskaya Lesostep', III – Kuncherovskaya Lesostep' and Borok, IV – Verkhovya Sury, V – total number of sites.

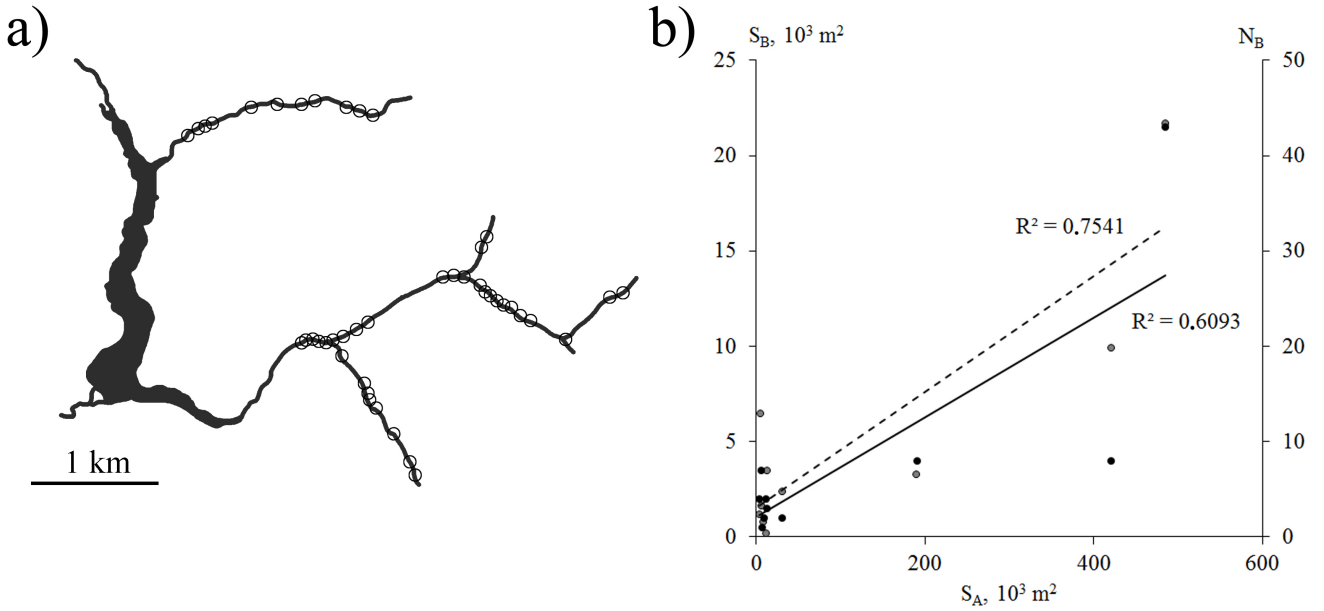

Fig. 4. Man-made pond on the River Archada and beaver ponds (indicated by circles) in backwater zone (a), and correlations between number (N_A, black dots and solid line) and area (S_B, grey dots and dash line) of beaver ponds and area (S_A) of downstream man-made ponds (b).

Table. Water body area percentage (WBAP) of the model sites in the Privolzhskaya Lesostep' State Nature Reserve

Parameters	Model sites				
	OL	PS	K and B	VS	Total
Total WBAP	0.52	0.62	0.08	0.34	0.39
Pre-existing WBAP	0.14	0	0.05	0.06	0.06
WBAP without zoogenic ponds	0.44	0.57	0.07	0.31	0.35

Model sites within the boundaries of the Privolzhskaya Lesostep' State Nature Reserve						
Parameters	OL	PS	K	B	VS	Total
Total WBAP	2.42	0.18	0.001	0.68	0.11	0.002
Pre-existing WBAP	0	0	0	0.007	0.0005	0.0006
WBAP without zoogenic ponds	0	0	0	0.68	0.05	0.0006

Note: OL – Ostrovtsovskaya Lesostep', PS – Poperechenskaya Step', K – Kuncherovskaya Lesostep', B – Borok, VS – Verkhovya Sury.

In total, on the site Poperechenskaya Step', 82 zoogenic ponds (76%) were located in the upper reaches of artificial ponds. At the same time, only 10 (41%) man-made ponds had beaver settlements in the backwater zone. But their area was 92% of the total water surface of artificial water bodies. This is associated with the large pond located on the River Archada. Therefore, there was a slight correlation between the number and area of beaver ponds and the size of man-made water bodies downstream (Fig. 4b).

If we consider all steppe sites together (with the exception of Kuncherovskaya Lesostep'), then 60% of the beaver ponds were located in the upper reaches of man-made water bodies. In the surroundings of Kuncherovskaya Lesostep' and Borok, anthropogenic ponds were rare, and were not associated with beavers.

Discussion

This study has shown that the majority of beaver ponds are well identified using modern publicly available satellite images. Although the data obtained from such analyses do not allow us to assess the state of populations and the impact on specific ecosystems, they can be used to supplement our knowledge about the state of water resources and understanding the zoogenic contribution to the increase in water coverage area. In the study area (900 km^2), beaver ponds occupied 0.4 km^2, which was 11% of the total area of water bodies, and 0.04% of the entire area. These values seem low compared to some similar studies. For example, in Minnesota, USA, landscapes created by beavers (*Castor canadenis*) occupied from 1% to 13% of the territory in various years, while the open water area was 4% (Johnston & Naiman, 1990). In Virginia, USA, the proportion of beaver ponds was 0.75% of the total studied area (Syphard & Garcia, 2001). In some locations of Europe, the percentage of the area occupied by zoogenic water bodies is also higher, namely 0.14% in Poland (Grygoruk & Nowak, 2014), 0.07% in Germany (Dalbeck et al., 2014). Results comparable to those from our study were obtained in the Canadian Rocky Mountains (0.04%: Morrison et al., 2015), and in Michigan, USA (0.03%: Martin et al., 2015).

On the other hand, all above mentioned studies were carried out in forested and humid landscapes. Thus it can be assumed that the natural water coverage of these areas is remarkably higher than in the forest-steppe zone. According to data for the Penza region (Izmailova, 2016), the natural lake area in the Penza region is 0.06%, which exactly corresponds to the data obtained on the model sites (Table). Thus, the total coverage of zoogenic water bodies (0.4 km^2) is relatively close to the total water coverage of natural lakes (0.5 km^2). Taking into account the underestimation of the number of beaver ponds (see below), and the gradual degradation of floodplain water bodies due to a decrease in river runoff (Buchik & Dmitrieva, 2019; Bashinskiy et al., 2019), the zoogenic contribution to water resources may be of key importance for both lentic and lotic ecosystems in the forest-steppe natural zone.

At the same time, the total water coverage in the centre of European Russia considerably increased (by 1–2 times), due to the construction of artificial ponds (Izmailova & Korneenkova, 2020). In the forest-steppe zone, it took place through several stages (Prytkova, 1982); all of them occurred during the absence of beavers in the ecosystems. Human activities have considerably changed the ratio of water resources not only through the creation of new reservoirs, but also due to the disappearance of natural lakes, due to the alteration of drainage during hydraulic construction (Izmailova, 2018). Our study suggests that the creation of systems of man-made water bodies could have facilitated the beaver introduction into some steppe watercourses. It is known that the zones of influence of artificial water bodies can be rather extended. It is especially pronounced in places of bays, and they affect the ground and soil water levels and ravine erosion (Dyakonov & Anoshko, 1995), which leads to landscape changes of river floodplains (Dobrov, 2000). Thus, the habitat structure and food supply of beavers could improve, which led to an increase in their number and in the intensity of building activities in the forest-steppe regions.

It is important to mention the meaning of these results in context of global climate changes. Beavers have re-colonised these areas just in recent decades (Osipov & Bashinskiy, 2018). In the past, their settlements were usual on large and middle rivers, where dam building was impossible. Small watercourses were avoided because they were easily reached by humans, who actively hunted beavers as the most valuable game animals (Kirikov, 1966). Therefore it could be assumed that beaver ponds were rarer than nowadays. At the same time, in the study area the tendency to the decreasing in river discharge, length of small streams, level of spring floods and water table area of floodplain

water bodies are observed during the last century (Frolova et al., 2015; Chernova et al., 2020; Dmitrieva, 2020). Actually, beaver activity leads to opposite processes and could lighten the impact of climate changes. In addition, beaver-made ponds can influence storage and fluxes of greenhouse gas (Lazar et al., 2015; Gatti et al., 2018). Therefore, an increase in the proportion of zoogenic water bodies along decrease in coverage of pre-existing natural waters is of great importance.

Definitely, it should be noted, that our results do not give a complete picture of the real situation of the area and prevalence of beaver ponds. It is obvious that the contribution of beavers to the total water coverage of the territory may actually be more significant. This is due to a number of objective reasons. First of all, not all ponds are visible on the satellite images, as it was demonstrated on the sites where field research was carried out. Google's publicly available satellite imagery reflects a summertime situation where water may be not visible through canopy cover. This was found on channel-like ponds, and in valleys with a wide distribution of *Alnus glutinosa*, which grows on a flooded surface. Secondly, even if we can clear outline the pond, its borders may not reflect the flooding zone. A large number of cascade ponds on small rivers leads to the situation when the entire river turns into a slow-flowing water body. In addition, during the analysis it is difficult to take into account the beaver role in maintaining of man-made ponds and reservoirs. In the study area, there were some old unexploited man-made ponds, where zoogenic activities were repeatedly observed during field studies. Artificial dams were actively maintained by beavers. They plugged pipes with branches, and created additional dams on the flowing watercourse. Another important unaccounted aspect of beaver impact is their activity in floodplain lakes and oxbows. Existing studies show that the construction of canals and dams on channels can considerably increase the water surface area (Hood & Bayley, 2008) and prevent the drying of water bodies (Pankova & Pankov, 2010).

On the other hand, satellite images of various years may not reflect the current situation, because beaver ponds are a dynamic environment, and their state depends on the activity of animals, available food resources and the level of floods. The area of water bodies can remarkably decrease in a short time. For example, a decrease of the beaver population from five to three families on the River Kshemianka (Poland) led to a 7.6-fold decrease in the water surface area (Grygoruk & Nowak, 2014). However, our data from the site Ostrovtsovskaya Lesostep' showed that since 2013 the water level of most beaver ponds stays stable, even if animals leave the habitat. Therefore the zoogenic water bodies could be hardly considered as temporal objects.

When assessing the impact of beaver activity on water coverage, two difficulties in interpretation of the results could be faced. On the one hand, by studying the impact of the key species at the local level, it is possible to overestimate the consequences of its activity, which can be very considerable on small areas. For example, a study of beavers on a small river in the United Kingdom showed an increase in water area from 93 m^2 to 1832 m^2 (Puttock et al., 2017). Extrapolation of such data to the landscape and regional levels can give the impression of a considerable beaver contribution to water resources. On the other hand, during assessments at regional and wider level, beavers are often ignored and not included in the analysis (Izmailova, 2016). Our data showed that the zoogenic contribution to water resources, although being not significant, is comparable to the coverage of natural lakes. In some areas with low anthropogenic impact, beaver-made water bodies are the only lentic habitats in the landscape.

Conclusions

This study has shown that modern public satellite images are suitable for large-scale assessments of beaver impact on water coverage. Beaver ponds and their zoogenic elements (i.e. dams, canals and tracks) are clearly recognisable in open landscapes as well as in forested areas. Though the results underestimate the real water area of zoogenic ponds, they show the beaver importance for water resources in forest-steppe regions. Previous studies showed much more pronounced zoogenic effect on water coverage, but the majority of such publications concerned forested and humid regions. Forest-steppe areas have a low amount of natural water bodies. Most of them are on the risk of degradation due to climate changes. A lot of man-made ponds were made in these areas during the absence of beavers in the landscape, while these animals altered the regime of water courses. Thereafter this could promote beaver inhabitations into some steppe regions. Nowadays in the Penza region, the proportion of beaver ponds is comparable with area of pre-existing lakes. Therefore, the increasing of the beaver population in the last decades could lighten effect of human-impacted environmental changes on water resources in the forest-steppe zone.

The results of this study emphasised the special beaver importance for the conservation of small water body ecosystems within Protected Areas. In case of the Privolzhskaya Lesostep' State Nature Reserve, where are no man-made ponds, beaver activity increased the total area of water bodies by 3.6 times, and in some sectors zoogenic ponds were the only lentic habitats. Thus, beaver activity contributes greatly to conservation of freshwater habitats and biodiversity.

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ВЛИЯНИЕ БОБРОВ НА ОБВОДНЕННОСТЬ ЛЕСОСТЕПНЫХ ТЕРРИТОРИЙ (ПЕНЗЕНСКАЯ ОБЛАСТЬ, ЕВРОПЕЙСКАЯ РОССИЯ)

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Проведена оценка влияния бобров (*Castor fiber*) на обводненность территории путем анализа общедоступных спутниковых снимков. Были заложены четыре модельных квадрата суммарной площадью 900 км^2, охвативших окрестности четырех участков заповедника «Приволжская лесостепь» (Пензенская область, Европейская Россия). Данное исследование показало, что на современных общедоступных космических снимках хорошо различимы бобровые пруды даже небольших размеров, а также следы их деятельности (бобровые плотины, каналы и вылазы). Было идентифицировано 373 водоема бобрового происхождения, средней площадью 1040 ± 4843 м^2, 107 водоемов антропогенного происхождения средней площадью 24 272 ± 65 977 м^2 и 67 озер и стариц, средней площадью 8127 ± 17 946 м^2. Доля зоогенных водоемов составила 11% по площади и 68% по количеству. На отдельных модельных участках эти показатели варьировали от 7% до 18% (по площади) и от 44% до 84% (по количеству). При этом в границах заповедника «Приволжская лесостепь», где не было представлено антропогенных водоемов, доля бобровых прудов достигала 100% на трех участках. Общая обводненность исследованной территории составила 0.39%. На разных участках бобры увеличили долю водоемов на 0.02–0.10%, суммарно на 0.04%. Если рассматривать только естественные водоемы, то бобры увеличили их долю в 1.7 раз, а в границах заповедника «Приволжская лесостепь» – в 3.6 раз. Так как общая обводненность территории регионов центра Европейской России была существенно увеличена за счет строительства искусственных прудов, это могло повлиять на структуру местообитаний в поймах малых рек, и благоприятствовать деятельности бобров в лесостепных регионах. Поэтому наблюдалась небольшая корреляция числа и площади бобровых прудов с размерами антропогенных водоемов ниже по течению. Наши данные показывают, что зоогенный вклад в увеличение водных ресурсов сопоставим с площадью естественных озер. На некоторых участках с низким антропогенным воздействием созданные бобрами водоемы являются единственными лентическими местообитаниями в ландшафте. Однако полученные результаты не в полной мере отражают экологическое значение бобровых прудов, так как из анализа выпадают узкие пруды руслового типа, скрытые кронами пойменных деревьев. Нельзя учесть протяженность зоны подпора при каскадном расположении зоогенных водоемов. Невозможно дистанционно оценить вклад животных в удерживающую способность старых искусственных прудов, а также роль средопреобразователя в сохранении и увеличении площади поверхности уже существующих озер. Поэтому реальный вклад бобров в увеличение обводненности населяемых ими территорий более значим.

Ключевые слова: *Castor fiber*, водные ресурсы, дистанционные методы, заповедник «Приволжская лесостепь», зоогенный пруд, искусственный пруд, коэффициент озерности, озеро