# Impact of the European beaver (*Castor fiber* L.) population on the woody vegetation of Wigry National Park

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Research on the impact of the European beaver population on the species composition of forest stands was conducted in Wigry National Park, situated in north-eastern Poland. The study was conducted in forest stands on a dystrophic lake of the 'suchar' type, i.e. a dystrophic lake with high acidity and low species diversity of vegetation on its shores, on the banks of a river and a drainage ditch, and in a field environment. A ThermoPro TP8 thermal imaging camera with an uncooled microbolometer matrix of 384x288 pixels was used to confirm that the designated observation areas were inhabited by beavers. In each research area five transects four metres in width were established, where measurements were taken of five classes of trunk damage and two classes of trunk diameter. We examined the seasonal preferences of beavers in gnawing particular species of woody plants. An analysis was performed for each environment. The results indicate that after an average 15-year presence of beavers in the areas, which they inhabited rotationally, the percentage of healthy woody plants was 73.09%. Of the 17 species of woody plants, the ones most readily cut down by the beavers were grey willow (25.19%) and common hazel (32.36%). The analysis demonstrated that the rodents showed the greatest interest in plants with a trunk diameter of <10 cm (98.28%). The river and drainage ditch were the most exploited environments; here beavers cut down 40.27% and 42.70%, respectively, of the available woody plants.

KEY WORDS: European beaver / woody vegetation / food preferences / gnawing of trees and shrubs

The European beaver population in Wigry National Park (WPN) is one of the oldest in Poland. The first beaver site in the area which is currently within the borders of the park was described in 1944-1949 at the mouth of the river Czarna Hańcza from Wigry Lake. In 1974 Prof. Wirgiliusz Żurowski began implementation of the programme 'Active conservation of the European beaver in Poland'. The programme was implemented with the cooperation of scientists from the Polish Academy of Sciences and hunters from the Polish

Hunting Association [19, 21, 41, 42]. Beavers, including animals from the Wigry area, were caught and reintroduced to other regions of the country. Over decades the beaver population on Wigry Lake grew and the animals occupied all water bodies and watercourses in the park. In the 2014/2015 season 46 beaver colonies inhabited the park (Fig. 1). Due to the many years of beaver activity, particularly in the zone by the water, the woody plant species most attractive to beavers became depleted.

The beaver is a typical herbivore characterized by clear seasonal differences in the type of food it consumes. In spring and summer beavers feed mainly on herbaceous vegetation, but from autumn to spring woody plants constitute a large portion of their diet [4, 10, 13, 15, 23].

In the history of Wigry National Park beavers have occupied all possible watercourses and water bodies, including suboptimal areas such as small flooded depressions in a field and drainage ditches. These areas, due to depletion of the winter feed base (woody plants) are currently inhabited by the animals rotationally.

The aim of the study was to establish beaver preferences in cutting down woody plant species, the diversity and quantity of the food base in the study area, the trunk diameters the beavers most prefer to cut down, and seasonal changes in the tree stand caused by the presence and activity of beavers.

### Material and methods

The study was conducted in Wigry National Park in tree stands on a lake of the *suchar* type (a dystrophic lake with high acidity and low species diversity of vegetation on its shores), on the banks of a river and a drainage ditch, and in a field environment (Fig. 1), during the period from 1 May to 15 October 2015.

The task was carried out under the research project 'The impact of the activity of the European beaver population on the species composition of tree stands in Wigry National Park'. The project was financed from the forest fund by the 'State Forests' National Forest Holding.

Research plots were established in locations with lodges inhabited by beavers. A ThermoPro TP8 thermal imaging camera with an uncooled microbolometer matrix of 384x288 pixels was used to confirm that the beaver sites were inhabited. Tests and measurements using the thermal imaging device were conducted from 1 January to 20 March 2015. Four study areas were established around the following environments: a river—the Maniówka, a drainage ditch—Krzywe, a dystrophic 'suchar' lake—Lake Widne, and a field environment—Leszczewo.

The dietary selectivity of beavers varies depending on the season. These animals cut down the most trees and shrubs in the autumn and winter [32]. For this reason, in order to observe seasonal changes associated with gnawing of woody plants, the first measurements were made in the spring, from 1 to 30 May (first stage of the study), at the start of the growing season. The research carried out during this period was aimed at showing the impact of beavers on woody vegetation from the moment they colonized the area until spring. The next inventory of beaver damage was carried out in the autumn, from 1 to



Fig. 1. Distribution of active beaver sites and research areas in Wigry National Park in the 2014/2015 season (data from Wigry National Park)

15 October 2015 (second stage of the study). Stage I involved an inventory of all traces of damage, even the oldest ones, while stage II took into account only new damage. This enabled detection of changes in the species composition of woody plants caused by beaver activity at the height of plant growth. During this period beavers limit their exploitation of woody plants in favour of herbaceous vegetation [16, 26].

Damage to all species of trees and shrubs present on the established transects was described and classified. For each research area five transects were established, each with a constant width of 4 m. Their length depended on the location of the last damage observed on a woody plant (tree or shrub) on the transect.

The classification of damage was as follows: class I - a stump, class II - a stump with a fallen tree or shrub beside it, class III - damage to the wood and phloem of a standing tree or shrub, class IV - removal of some of the bark of a standing tree or shrub, class 0 - no damage.

The inventory of all classes of damage did not include trees and shrubs with a diameter of less than 2 cm. This is because in the case of woody plants with such a small diameter beavers eat or otherwise use the entire plant, and it is difficult to directly establish their felling in the field.

In addition, the trunk diameter of each damaged woody plant was measured at a height of about 15-20 cm above the ground. Depending on the diameter the plants were divided into two classes: diameter >10 cm and <10 cm.

Statistical analysis of the results was performed with the SAS<sup>®</sup> software package (SAS, 2011). Distributions of numbers of woody plants in the habitats described and the classified damage in the two stages of the study were compared by the chi-squared test (proc freq) at  $p \le 0.05$ .

#### **Results and discussion**

During the study 15,110 woody plants (17 species of trees and shrubs) were inventoried. The most abundantly represented species in all research areas were grey willow (61.48%) and common hazel (19.92%), while the least numerous( $\leq 0.20\%$ ) included Norway maple, European bird cherry, pedunculate oak, goat willow, common juniper and European ash (Tab. 1).

Earlier reports indicate that grey willow is one of the woody plant species preferred by beavers [6, 7, 11, 13, 17, 24, 34, 38]. Common hazel is also very popular among beavers [22].

Examination of the gnawing preferences for woody plants revealed (Tab. 1) that the availability of particular tree and shrub species in the research areas does not correspond in most cases to the preferences of beavers in gnawing these species (result of the chi-square test for the 6 most abundant species:  $chi^2=541.95$ , v=5, p<0.0001; for the 11 most abundant species  $chi^2=630.30$ ; v=10; p<0.0001; and for all 17 species  $chi^2=646.86$ , v=16, p<0.0001). In percentage terms, the species most gnawed by beavers was goat willow, which was extremely rare in the areas studied. The most abundantly represented species

in all study areas, grey willow (9,290 trees), was felled at a rate of 25.19% (Tab. 1). The most frequently felled woody plants also included downy birch (37.24%) and common hazel (32.36%). No damage was noted on alder buckthorn, common juniper or European ash; the last two of these species were extremely rare. From the moment the beavers appeared in the study areas to the end of May 2015, beavers cut down or completely removed (damage classes I and II) a combined 26.75% of available trees and shrubs (Tab. 1).

During the study an attempt was made to determine how long-term beaver activity alters the numerical composition of available woody plants. Analysis of numerical and percentage distributions of classes of damage (Tab. 2 and 3) inventoried from the moment beavers appeared in the study areas until the end of May 2015 (stage I) showed that healthy plants undamaged by animals were most abundantly represented in the study areas. Despite the presence of beavers for many years, class 0 damage was as high as 73.09%. This indicates that despite long-term pressure from beavers on woody vegetation, the share of healthy trees and shrubs usually remains the highest [22]. The second largest group was stumps of trees and shrubs that were completely removed from the study areas by beavers (class I damage) – 26.29%. Classes II, III and IV were very rare and not found in all the environments studied: class II – 0.46%, class III – 0.07%, and class IV – 0.09% (Tab. 2).

The analysis of the impact of beaver activity on the species composition of tree stands during stage II of the study was based on the assumption that plants with class III and IV damage, inventoried during stage I (24 in total), were healthy trees and shrubs. The inventory of damage five months after completion of stage I showed that of 10,805 available woody plants, beavers cut down and completely removed the trunks of 263, which was 2.38% of all plants identified in the research areas (Tab. 3). After five months of beaver activity no damage of classes II, III or IV was observed. This means that during the growing season beavers only cut down and removed entire trunks of trees and shrubs. Some of the material obtained was used as building material. The results of the present study confirm observations by other authors [3, 25, 26, 30], who found that beavers use woody vegetation almost exclusively during the autumn and winter.

Because beavers show little interest in woody vegetation during the growing season, the percentage of undamaged plants as compared to stage I increased from 73.09% to 97.62% (chi<sup>2</sup>=2,785.84, v=1, p<0.0001) – Tables 2 and 3. A comparison was also made of the numerical distribution of damage classes of woody plants inventoried on all research areas during stages I and II (chi<sup>2</sup>=2,787.28, v=4, p<0.0001) – Tables 2 and 3.

We also analysed whether there were differences in the numerical and percentage share of classes of damage to woody plants inventoried at each of the research areas duing stages I (Tab. 2; chi<sup>2</sup>=750.58, v=3, p<0.0001) and II (Tab. 3; chi<sup>2</sup>=134.93, v=3, p<0.0001). The trunks of woody plants most frequently cut down were around the drainage ditch (39.40%). Similar values were obtained in the river environment (41.59%) – Table 2. By comparison, beavers removed 21.72% of trees and shrubs in the field environment and 16.96% on the 'suchar' lake. The highest percentage of felled woody plants whose trunks

## Table 1

Distribution of woody plants inventoried in the areas examined and those most often cut down by beavers among all available species

|   | Inventorio<br>areas exa | ed in the<br>amined | Most down b                          | often cut<br>y beavers                   |
|---|-------------------------|---------------------|--------------------------------------|--|
| Species of woody plants                       | total number            | percentage          | number in damage<br>classes I and II | percentage in damage<br>classes I and II |
| 1   | 2                       | 3                   | 4                                    | 5  |
| Grey willow<br>(Salix cinerea)                | 9290                    | 61.48               | 2340                                 | 25.19                                    |
| Common hazel<br>(Corylus avellana)            | 3010                    | 19.92               | 974                                  | 32.36                                    |
| Silver birch<br>(Betula pendula)              | 1188                    | 7.86                | 539                                  | 45.36                                    |
| Norway spruce<br>(Picea abies)                | 500                     | 3.31                | 20                                   | 4.00                                     |
| Alder buckthorn<br>(Frangula alnus)           | 358                     | 2.37                | 0                                    | 0.00                                     |
| Downy birch<br>(Betula pubescens)             | 290                     | 1.92                | 108                                  | 37.24                                    |
| Rowan<br>(Sorbus aucuparia)                   | 107                     | 0.71                | 1                                    | 0.93                                     |
| Scots pine<br>(Pinus sylvestris)              | 101                     | 0.67                | 3                                    | 2.97                                     |
| Black alder<br>(Alnus glutinosa)              | 88                      | 0.58                | 16                                   | 18.18                                    |
| Small-leaved lime<br>( <i>Tilia cordata</i> ) | 50                      | 0.33                | 4                                    | 8.00                                     |
| Aspen<br>(Populus tremula)                    | 46                      | 0.30                | 18                                   | 39.13                                    |
| Norway maple<br>(Acer platanoides)            | 30                      | 0.20                | 9                                    | 30.00                                    |
| European bird cherry ( <i>Padus avium</i> )   | 24                      | 0.16                | 2                                    | 8.33                                     |

| 1                                      | 2      | 3      | 4    | 5     |
|--|--------|--------|------|-------|
| Pedunculate oak<br>(Quercus robur)     | 20     | 0.13   | 3    | 15.00 |
| Goat willow<br>(Salix caprea)          | 6      | 0.04   | 5    | 83.33 |
| Common juniper<br>(Juniperus communis) | 1      | 0.01   | 0    | 0.00  |
| European ash<br>(Fraxinus excelsior)   | 1      | 0.01   | 0    | 0.00  |
| Total                                  | 15 110 | 100.00 | 4042 | 26.75 |

## Table 2

Distribution of damage classes of woody plants inventoried in different environments during the first stage of the study

|                |       |       | Environment                 |                | _      |       |
|----------------|-------|-------|-----------------------------|----------------|--------|-------|
| Damage classes | field | river | dystrophic<br>lake "suchar" | drainage ditch | Tota   | al    |
|                | %     | %     | %                           | 0⁄0            | number | %     |
| 0              | 77.97 | 58.27 | 82.96                       | 57.30          | 11044  | 73.09 |
| Ι              | 21.72 | 39.41 | 16.96                       | 41.58          | 3973   | 26.29 |
| II             | 0.31  | 0.86  | 0                           | 1.12           | 69     | 0.46  |
| III            | 0     | 0.66  | 0                           | 0              | 10     | 0.07  |
| IV             | 0     | 0.80  | 0.08                        | 0              | 14     | 0.09  |

were not removed (class II) was registered by the drainage ditches (1.12%). The remaining damage classes in the other environments did not exceed 0.90%. After five months it was determined that during the growing season (stage II) the beavers preferred to completely remove the woody plants on the river bank (6.01%) – Table 3. A similar value was noted by the drainage ditch (4.59%), which again indicates that the vegetation at watercourses was most used by beavers. This suggests that the species diversity of plants growing by watercourses leads to a concentration of these animals. Moreover the hydrological arrangement of the environments allows beavers to seasonally, maximally exploit individual stretches of the watercourses, followed by relocation of the entire colony to new areas with

#### Table 3

|                |       |       | Environment                 |                |        |       |
|----------------|-------|-------|-----------------------------|----------------|--------|-------|
| Damage classes | field | river | dystrophic<br>lake "suchar" | drainage ditch | Tot    | al    |
|                | %     | %     | %                           | %              | number | %     |
| 0              | 98.92 | 93.99 | 96.96                       | 95.41          | 10 805 | 97.62 |
| Ι              | 1.08  | 6.01  | 3.04                        | 4.59           | 263    | 2.38  |
| II             | 0     | 0     | 0                           | 0              | 0      | 0     |
| III            | 0     | 0     | 0                           | 0              | 0      | 0     |
| IV             | 0     | 0     | 0                           | 0              | 0      | 0     |

Distribution of damage classes of woody plants inventoried in different environments during the second stage of the study

abundant winter food. Their greater interest in the woody material on watercourses may also be due to the fact that the animals used woody material to build dams on the drainage ditches and rivers.

The most woody plants were noted in the field environment (54.12%), followed by the drainage ditch (18.37%) and the 'suchar' lake (17.56%), and the fewest on the river bank (9.96%). Changes were evaluated in the percentage of damage classes identified in each environment with respect to all woody plants inventoried in the research areas. During stage I (Fig. 2) the highest percentage of plants wholly exploited by beavers, in comparison with the other research areas, was noted in the field environment (11.75%) and the lowest on the 'suchar' lake (2.98%). During the growing season the most exploited were the trees and shrubs growing by the drainage ditch (0.66%), while the least exploited were those on the river (0.49%) – Fig. 2. Overall, however, during the five-month period the beavers' interest in woody vegetation was similar in all research areas.

In addition, a significant relationship was observed between the trunk diameter of woody plants and their exploitation by beavers ( $chi^2=1,258.49$ , v=3, p<0.001). Measurements were taken of plants in all damage classes in the first stage of the study (Tab. 4). Woody vegetation with trunks <10 cm in diameter were found to be most often (98.28%) gnawed by beavers. This was due to the effort the animals had to put into cutting down and transporting the material [39, 40] and to the very large numbers of available plants belonging to species with a small diameter (grey willow, common hazel), whose availability in the research areas was as high as 81.40% (Tab. 1). These species were also the most preferred woody plants, in terms of numbers, that were completely cut down (in total 3,314, 57.55%) – Table 1. Damage classes III and IV were associated with trunk diameter. In these classes trees with diameter >10 cm



Fig. 2. Percentage distribution of damage classes in each environment for all tree species inventoried in the areas examined during both stages of the research

were gnawed. Damage to black alder, Norway maple, silver birch, pedunculate oak, small-leaved lime, and even Scots pine and Norway spruce was characterized as class III and IV. These species attain a considerable trunk diameter, which was why it was possible to register damage classes III and IV among plants with a diameter >10 cm. During the growing season (stage II), beavers' interest in vegetation with the thinnest trunks did not change. During the five-month period the animals reached exclusively for vegetation with a diameter <10 cm (263 instances of class I damage to woody plants). Exploitation of plants with the thinnest stems is thus typical behaviour for the animals [2, 3, 17, 31].

## Table 4

Share of damaged woody plants by diameter during the first stage of the study

|                                |       |      | Damage | e classes |        |       |
|--------------------------------|-------|------|--------|-----------|--------|-------|
| Diameter class of woody plants | Ι     | II   | III    | IV        | tot    | al    |
|                                | %     | %    | %      | %         | number | %     |
| >10 cm                         | 0.91  | 0.27 | 0.20   | 0.34      | 70     | 1.72  |
| <10 cm                         | 96.80 | 1.43 | 0.05   | 0.00      | 3996   | 98.28 |
| Total                          | 97.71 | 1.7  | 0.25   | 0.34      | 4066   | 100   |

In numerical terms, beavers were most interested in cutting down grey willow and common hazel (Tab. 1). Grey willow, considered one of the species most preferred by beavers [14, 37], grew most abundantly on the banks of the drainage ditch and the body of accumulated water in the field. Its percentage among all the plants growing by the drainage ditch was as high as 55.57%. Due to the long-term presence of beavers it was cut down at a rate of 47.99%, but its percentage of all felled woody plants by the drainage ditch was 62.45%. In the field environment the species most often gnawed was grey willow (94.75%). During their many years of activity beavers removed 20.65% of the willow. This species accounted for 88.84% of all species cut down in this environment (Tab. 5 and 6).

Common hazel, which is a boreal species, was highly abundant on the river (70.56%) and the 'suchar' lake (74.82%). On the river bank 50.56% of this species was cut down, and on the lake 21.81%. In comparison with other woody plants cut down in these environments, the percentage of felled hazel trees was 88.61% on the river bank and 96.22% on the 'suchar' lake. Therefore common hazel was the most attractive woody plant species for beavers (Tab. 6 and 8).

Aspen, considered the species most preferred by beavers [9, 20, 28, 29, 35, 36, 38], grew in small numbers near the drainage ditch (1.33%; Tab. 5) and river (0.53%; Tab. 6). Beavers felled 35.14% of aspens in the environment of the drainage ditch (Tab. 5) and 62.50% on the river (Tab. 6), which is the highest value among all woody plant species registered in the research areas. While it is true that goat willow, with an availability of 6 (0.40%), was cut down at a rate of 83.33% (5 trees; Tab. 6), these very low numbers cannot reflect the actual species preferences of beavers.

Silver birch, with a relatively high percentage in the drainage ditch environment (29.08%), was felled at a rate of 45.23% (Tab. 5). Its percentage in the field environment was much lower (4.26%), but here too it was exploited by beavers (47.99%; Tab. 7). The situation was similar in the environment of the river, where the availability was 1.73% and 26.92% of the trees were removed by beavers (Tab. 6).

Downy birch, with a relatively low percentage in the environments investigated, i.e. 4.90% in the drainage ditch, 0.99% in the field environment, and 2.75% on the 'suchar' lake, was cut down at a rate of 46.32%, 41.98% and 15.07%, respectively (Tab. 5 and 7).

Species such as grey willow, common hazel, aspen, silver birch, and downy birch ensure animals attractive winter food which allows them to survive outside the growing season [30, 38].

An interesting situation was observed in the case of Norway spruce and Scots pine, which are considered to be the least preferred species [8, 18, 27]. Spruce, with a moderate share in the river environment (10.50%), was felled at a rate of 12.66% (Tab. 6), while 4.92% of the 61 Scots pines on the 'suchar' lake were cut down (Tab. 8). In all cases these were plants with a trunk diameter <10 cm. Beavers showed a similar level of interest in coniferous trees in Drava National Park [9]. On the river banks the

| tent in both stages of research                           |  |
|---|--|
| ses I and II in the drainage ditch environ                |  |
| ss in all damage classes and in damage clas               |  |
| Table 5           Share of individual woody plant species |  |

| Ι               |   | Stage  |   |  |   | Stag   | eII   |  |
|-----------------|---|--|---|--|---|--|---|--|
| Species         | number of<br>plants in<br>all damage<br>classes | percentage of<br>species in all<br>classes of all<br>species | percentage<br>of class<br>I and II<br>within<br>species | percentage<br>of species in<br>class I and II<br>among all<br>species of<br>class I and II | number of<br>plants in<br>all damage<br>classes | percentage of<br>species in all<br>classes of all<br>species | percentage<br>of class<br>I and II<br>within<br>species | percentage<br>of species in<br>class I and II<br>among all<br>species of<br>class I and II |
| Grey willow     | 1542  | 55.57  | 47.99   | 62.45  | 802   | 50.44  | 8.23  | 90.41  |
| Common hazel    | 17  | 0.61   | 23.53   | 0.34   | 13  | 0.82   | 0   | 0  |
| Silver birch    | 807   | 29.08  | 45.23   | 30.8   | 442   | 27.8   | 0.68  | 4.11   |
| Alder buckthorn | 236   | 8.5  | 0   | 0  | 236   | 14.84  | 0   | 0  |
| Downy birch     | 136   | 4.9  | 46.32   | 5.32   | 73  | 4.59   | 2.74  | 2.74   |
| Aspen           | 37  | 1.33   | 35.14   | 1.1  | 24  | 1.51   | 8.33  | 2.74   |
| Total           | 2775  | 100  |   | 100  | 1590  | 100  |   | 100  |
|                 |   |  |   |  |   |  |   |  |

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| Table 6         Share of individual wood | y plant species                                    | in all damage cla  | isses and in dar  | nage classes I and II  | in the river env                                | vironment in both  | stages of rese  | urch   |
|--|--|--|---|--|---|--|---|--|
|  |  | Stage  | eI  |  |   | Stag   | ge II   |  |
| Species                                  | number<br>of plants<br>in all<br>damage<br>classes | percentage of<br>species in all<br>classes of<br>all species | percentage<br>of class<br>I and II<br>within<br>species | percentage<br>of species<br>in class I and II<br>among all<br>species of<br>class I and II | number of<br>plants in<br>all damage<br>classes | percentage of<br>species in all<br>classes of all<br>species | percentage<br>of class<br>I and II<br>within<br>species | percentage<br>of species<br>in class I and II<br>among all<br>species of<br>class I and II |
|  | 2  | 3  | 4   | s  | 9   | 7  | 8   | 6  |
| Common hazel                             | 1062   | 70.56  | 50.56   | 88.61  | 471   | 52.39  | 10.4  | 90.74  |
| Silver birch                             | 26   | 1.73   | 26.92   | 1.16   | 19  | 2.11   | 5.26  | 1.85   |
| Norway spruce                            | 158  | 10.5   | 12.66   | 3.3  | 138   | 15.35  | 0   | 0  |
| Alder buckthorn                          | 0  | 0  | 0   | 0  | 54  | 6.01   | 0   | 0  |
| Rowan                                    | 28   | 1.86   | 0   | 0  | 28  | 3.11   | 3.57  | 1.85   |
| Scots pine                               | 40   | 2.66   | 0   | 0  | 40  | 4.45   | 0   | 0  |
| Black alder                              | 88   | 5.85   | 18.18   | 2.64   | 72  | 8.01   | 0   | 0  |
| Small-leaved lime                        | 28   | 1.86   | 14.29   | 0.66   | 24  | 2.67   | 0   | 0  |

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| 1                    | 2    | 3    | 4     | 2    | 6   | 7    | 8     | 9    |
|----------------------|------|------|-------|------|-----|------|-------|------|
| Aspen                | ×    | 0.53 | 62.5  | 0.83 | 6   | 0.33 | 33.33 | 1.85 |
| Norway maple         | 28   | 1.86 | 32.14 | 1.49 | 19  | 2.11 | 10.53 | 3.7  |
| European bird cherry | 24   | 1.59 | 8.33  | 0.33 | 22  | 2.45 | 0     | 0    |
| Pedunculate oak      | ×    | 0.53 | 12.5  | 0.17 | L   | 0.78 | 0     | 0    |
| Goat willow          | 9    | 0.4  | 83.33 | 0.83 | 1   | 0.11 | 0     | 0    |
| Common juniper       | 1    | 0.07 | 0     | 0    | 1   | 0.11 | 0     | 0    |
| Total                | 1505 | 100  |       | 100  | 899 | 100  |       | 100  |

beavers were also interested in black alder, which among broadleaved species is considered to be one of the least preferred by beavers [10]. The animals felled 18.18% of the 88 trees (5.85%) available in this environment (Tab. 6). In contrast with Norway spruce, trees with a trunk diameter >10 cm were cut down.

A relatively high proportion of felled trees was recorded on the river in the case of Norway maple, small-leaved lime and pedunculate oak. Norway maple, with a 1.86% share, was felled at a rate of 32.14% (Tab. 6). The percentages of lime and oak were 1.86% and 0.53%, and they were cut down at a rate of 14.29% and 12.50%. A similar situation was observed for pedunculate oak on the 'suchar' lake, which had a share of 0.45% and was felled by beavers at a rate of 16.67% (Tab. 5, 6, 7 and 8).

The percentage of the remaining species cut down in various environments was small, or in some cases they had not been felled by beavers at all (Tab. 4 and 5).

The observations conducted at the end of the 2015 growing season (stage II) confirmed that grey willow and common hazel were still the species of most interest to beavers in the environments of the drainage ditch and the field (Tab. 6 and 7). Grey willow by the drainage ditch was 8.23% exploited by beavers, and common hazel by the river at a rate of 10.40%. This indicates that these species are multi-seasonal food which is also used by beavers in the summer, when food is abundant (herbaceous vegetation). Beavers continued to show an interest in silver birch at the 'suchar' lake (14.29%; Tab. 8) and the river (5.26%; Tab. 6) and aspen by the drainage ditch (8.33%; Tab. 5) and river (33.33%; Tab. 6), although they cut down these trees in small numbers. The low interest in the remaining species demonstrates that the growing season is not a time when beavers are interested in woody vegetation.

During the study it was noted that the range of penetration of the land by beavers is linked to the availability of food in the area they inhabit. In the case of the Leszczewo and Krzywe research areas, the range of penetration by beavers was 100 m and 80 m, respectively. In the phytologically richest habitat, the Maniówka River, damage was noted up to 50 m from the bank, while in the case of Lake Widne the last signs of damage were observed as far as 160 m from the shore. This is because on the 'suchar' lake, a phytosociologically poor environment, the animals had to migrate long distances in search of food. The considerable availability of food by the river did not require the animals to roam such distances. Similar behaviour in beavers has been observed on the Pasłęka River [33] and in Knyszyń Forest [5].

Like most herbivores, the European beaver exhibits clear food preferences. The study confirmed that the beaver, unlike other herbivores, is able to cut down not only young trees but also mature ones. Other authors also state that beavers have a key role in shaping the structure and dynamics of tree stands near water [1, 12].

The results of the study show that in stabilized populations long-term pressure by beavers on woody vegetation depletes the food base. The animals are then forced to feed on less attractive species such as Scots pine and spruce.

 Table 7

 Share of individual woody plant species in all damage classes and in damage classes I and II in the field environment in both stages of research

|              |  | Stag  | e I   |  |   | Stage  | П   |   |
|--------------|--|---|---|--|---|--|---|---|
| Species      | number of<br>plants<br>in all<br>damage<br>classes | percentage<br>of species<br>n all classes<br>of all species | percentage<br>of class<br>I and II<br>within<br>species | percentage<br>of species in<br>class I and II<br>among all<br>species of<br>class I and II | number of<br>plants in all<br>damage<br>classes | percentage of<br>species in all<br>classes of all<br>species | percentage<br>of class<br>I and II<br>within<br>species | percentage of<br>species in class<br>I and II among<br>all species of<br>class I and II |
| Grey willow  | 7748   | 94.75   | 20.65   | 88.84  | 6148  | 96.42  | 1.01  | 89.86   |
| Silver birch | 348  | 4.26  | 47.99   | 9.27   | 181   | 2.84   | 1.66  | 4.35  |
| Downy birch  | 81   | 0.99  | 41.98   | 1.89   | 47  | 0.74   | 8.51  | 5.8   |
| Total        | 8177   | 100   |   | 100  | 6376  | 100  |   | 100   |

Impact of the European beaver (Castor fiber L.) population on the woody ...

| Table 8Share of individual wof research | /oody plant spe                                 | ecies in all dama  | ge classes and in t                                  | damage classes I ano   | I II in the environ                             | ment of the dystr  | ophic 'suchar' l                                     | ake in both stages  |
|---|---|--|--|--|---|--|--|---|
|   |   |  | Stage I  |  |   | Stag   | ge II  |   |
| Species                                 | number of<br>plants in<br>all damage<br>classes | percentage<br>of species<br>in all classes<br>of all species | percentage of<br>class I and II<br>within<br>species | percentage of<br>species in<br>class I and II<br>among all<br>species of<br>class I and II | number of<br>plants in<br>all damage<br>classes | percentage of<br>species in all<br>classes of all<br>species | percentage<br>of class I and<br>II within<br>species | percentage of<br>species in class I<br>and II among all<br>species of class I<br>and II |
| 1                                       | 2   | 3  | 4  | 5  | 9   | 7  | 8  | 6   |
| Common hazel                            | 1985  | 74.82  | 21.81  | 96.22  | 1552  | 70.45  | 4.12   | 95.52   |
| Silver birch                            | 7   | 0.26   | 0  | 0  | 7   | 0.32   | 14.29  | 1.49  |
| Norway spruce                           | 342   | 12.89  | 0  | 0  | 342   | 15.52  | 0  | 0   |
| Alder buckthorn                         | 68  | 2.56   | 0  | 0  | 68  | 3.09   | 0  | 0   |
| Downy birch                             | 73  | 2.75   | 15.07  | 2.44   | 62  | 2.81   | 0  | 0   |
| Rowan                                   | 79  | 2.98   | 1.27   | 0.22   | 78  | 3.54   | 2.56   | 2.99  |
| Scots pine                              | 61  | 2.3  | 4.92   | 0.67   | 58  | 2.63   | 0  | 0   |
| Small-leaved lime                       | 22  | 0.83   | 0  | 0  | 22  | 1  | 0  | 0   |

| 1               | 2    | 3    | 4     | 5    | 6    | 7    | 8 | 9   |
|-----------------|------|------|-------|------|------|------|---|-----|
| Aspen           | 1    | 0.04 | 0     | 0    | 1    | 0.05 | 0 | 0   |
| Norway maple    | 2    | 0.08 | 0     | 0    | 2    | 0.09 | 0 | 0   |
| Pedunculate oak | 12   | 0.45 | 16.67 | 0.44 | 10   | 0.45 | 0 | 0   |
| European ash    | 1    | 0.04 | 0     | 0    | 1    | 0.05 | 0 | 0   |
| Total           | 2653 | 100  |       | 100  | 2203 | 100  |   | 100 |

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