Regeneration and game damage in the Krušné hory Mts. assessed on the basis of National Forest Inventory of the Czech Republic

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ABSTRACT: In 2001–2004 National Forest Inventory was realized in the Czech Republic. A great number of variables was measured giving rise to an extensive information database that can be used to assess the state and development of various quantitative and qualitative dendrometric characteristics. This work presents the results of regeneration state and game damage in the Krušné hory Mts. based on the data from both the National Forest Inventory and the second enlarged measurement carried out after five years that was done in a part of the Fláje preserve and enabled basic comparison with the rest of the area. For the calculation of data acquired in the old and recent measurement standard methodology for processing National Forest Inventory was used. Comparison of data showed that the average number of regeneration individuals dropped by more than a third in the interval of 5 years, as well as the number of plots with regeneration; game damage of regeneration also was lower by 4%. The proportion of individuals damaged by peeling did not change during the investigated period. A significant increase in game damage to regeneration was found in the Fláje preserve.

Keywords: National Forest Inventory; game damage; Krušné hory Mts.

A need to monitor the forest state within the complex territory of the countries in Europe arose at the beginning of the 20th century. After World War I, when the role of the State began to change distinctly, there arose a need to have reliable data on the resources and state of national economy and to use them optimally. Information on the forest state as a resource of timber, very important mainly for the Scandinavian countries, was also involved. This was the starting moment for a survey of timber supplies in the whole territory of the country often realized by special methods – National Inventories of Forests (Akça 1997). Norway was one of the first countries realizing inventory: it presented the year 1919 as an official start of its National Forest Inventory (Loetsch et al. 1973). In a short time Finland, Sweden and in 1924 Great Britain followed (e.g. Lindeberg 1924, 1926; Langsaeter 1926, 1932; Östling 1932). The first summarized statistics appeared, summarized forest management plans were introduced in the territory of Germany, Austria-Hungary and in other countries of Central and Eastern Europe, in some other countries information was gathered from forest owners by means of questionnaires. Scandinavian countries were the first to introduce the method of statistical forest inventory (Zöhler 1980). In the course of the 20th century National Forest Inventories were embodied in the legislation of most European countries. The last countries accepting national forest inventory are the Baltic countries, Denmark, Czech Republic and Slovakia.

The National Forest Inventory (NFI) in the Czech Republic, based on measurements of randomly chosen experimental plots, was carried out for the first time in 2001–2004. The Institute of Forestry Ecosystems Research (IFER) in Jílové near Prague prepared and realized the pilot investigation for the whole project, and measurements were done by the

Forest Management Institute (ÚHÚL) in Brandýs nad Labem. The assessment of measured data, followed by still up-to-date discussion, is a subject of interest of both the professional community and the public.

Due to data observed on inventory plots and their great volume the Czech Republic has taken a prominent position among the European countries (Holický 2002).

The system of forest inventory must be effective and statistically justifiable. At the same time the structure of forest inventory must be dynamic with a possibility to do changes. The whole system is built on interconnected measurements in defined time intervals on the same plots. A series of repeated and interconnected investigations is a basis for determination of developmental trends (like an increase or decrease in growing stock, current increment development of tree species composition, etc.) (Šmelko 2000).

The database acquired directly in a forest has a great information potential. Mathematical and statistical methods enable to get series of data and phenomena both by simple assessment of measured variables or by observation of their dependences. A project was realized in the Krušné hory Mts. involving a part aimed at the assessment of game damage from the data of the National Forest Inventory of the Czech Republic and from subsequent measurements on the same plots. The analysis of investigated parameters of forest regeneration and present influence of game on forest ecosystems using data from the National Forest Inventory was carried out for the Natural Forest Area Krušné hory Mts. representing ca 110,230 ha of land determined for forest-producing functions. The territory of the former working-plan area Františkovy Lázně was excluded.

METHODOLOGY

The regulation of the CR government from June 7, 2000, ordered National Forest Inventory in the CR territory in the years 2001 to 2004. The aim of this National Forest Inventory was to collect data on the actual state and development of forests in the Czech Republic. The inventory involved physical investigation of data on plots in areas of basic dimensions 2 × 2 km distributed in a regular network across all forests in the CR territory. Each plot included two separate parts of circular shape with the radius of 12.62 m and their centres 300 m apart from each other.

According to the type of terrain an inventory plot could be divided into partial areas called subplots. Subplots can be differentiated for many reasons (border of the country, forest/non-forest border); for our assessment a distinct boundary of heterogeneous stand parts was important (age, species or altitudinal difference). In the framework of the National Forest Inventory two inventory circles were established: 1. inventory circle with the radius of 2 m used for the investigation of forest regeneration; 2. inventory circle with the radius of 3 m serving for measurements of thin trees with dbh 7–11.9 cm.

The number of individuals according to tree species was investigated in each height regeneration class as well as the number of trees damaged by browsing of terminal shoot, by fraying or by peeling and browsing by ungulate game. Peeling and browsing of trees with dbh 7–11.9 cm were related to the inventory circle with the radius of 3 m, whilst trees with dbh 12 cm and more were investigated all over the inventory plot. The assessment of game damage involved all tree species growing on the inventory plot (ÚHÚL 2003).

The National Forest Inventory uses its own terminology, often different from the terminology commonly used (ÚHÚL 2003). To enable comparison with the other conclusions of National Forest Inventory this terminology is left unchanged in the following cases:

- regeneration – all individuals on an inventory circle (radius 2 m) from height 10 cm up to trees with dbh 6.9 cm overbark (all individuals fulfilling these parameters are counted without regard to the management intention),
- regeneration height class – class I – height 0.1 m to 0.5 m; class II – height 0.5 m to 1.3 m; class III – height 1.3 m to dbh 6.9 cm,
- regeneration under shelterwood – regeneration under the parent stand, regeneration in open space – regeneration outside the parent stand,
- factors negatively influencing regeneration – proportional share is of concern derived from area shares of inventory subplots according to observed signs. For each plot three negative factors could be presented, and therefore the factors are overlapping (sum of percentages is not 100),
- browsing as a negative factor – is derived from area shares of inventory subplots and involves also lateral browsing, unlike the investigation of regeneration individuals where lateral browsing is not assessed,
- factors negatively influencing regeneration – are of biotic or abiotic character. When the actual situation on subplots is assessed, only the three most important factors of all can be chosen and considered,

– group of tree species – tree species are aggregated into 24 groups of tree species according to the following key (see Table 1) (ÚHÚL 2007).

Besides regeneration defined for the National Forest Inventory (ÚHÚL 2003), the term "operationally useable regeneration" was introduced, i.e. such regeneration where its further use in forestry is supposed.

Operationally useable regeneration is represented by:

– individuals found during the National Forest Inventory of the height from 0.1 m to 1.3 m (height class from 1.3 m to dbh 6.9 cm is not taken for regeneration phase here but for the phase of arisen thickets),
– individuals of tree species suitable for the site found in the open space and below the stand in those cases when the principal stand is older than 80 years.

Data on some properties of operationally useable regeneration were evaluated separately (green line) for an altitude above 700 m and below this limit and were then compared with each other. The altitude ranges from 352 m to 1,080 m above sea level. There are 41% of the area below the green line and 59% above it.

The database of National Forest Inventory as the primary information base was used both for repeated measurements and for more detailed investigations in the Fláje preserve.

The concerned area of the Krušné hory Mts. comprises in total 577 plots and 729 subplots that are processed in this investigation (Slodičák et al. 2008).

Data collected experimentally are processed by means of a set of mathematical and statistical methods that are described in the work *Inventory of forests in the Czech Republic, Set of mathematical and statistical evaluation methods, Mathematical and statistical processing of sets with measured data* (Zach 2004).

Estimations of parameters of the basic set differ in qualitative and quantitative variables.

For qualitative variables it is valid:

$$p = \frac{n_i}{n} \quad (1)$$

where:

p – probability of phenomenon (mean value of binomial distribution),

n_i – number of positive occurrences of the attribute and n is the total number of measurements.

Variance is defined by

$$S^2 = \frac{p \times (1 - p)}{n} \quad (2)$$

The accuracy of the mean frequency value of the basic set is determined by the interval of reliability of relative frequency p reached with a certain reliability $1 - \alpha$.

Techniques of estimation:

a) For n high enough, i.e. $n > 40$, the estimation formula for the interval of reliability can be used reaching certain probability $1 - \alpha$.

$$P = p \pm z_\alpha \times \sqrt{\frac{p \times (1 - p)}{n}} \quad (3)$$

where:

z_α – quantile of standardized normal distribution for the probability limit α.

The equation

$$z_\alpha = \sqrt{\frac{p \times (1 - p)}{n}} \quad (4)$$

quantifies the estimation error of mean values of the relative frequency of basic set that is expected with required probability $1 - \alpha$.

b) For low n, i.e. $n < 40$, the estimation formula is used for the lower and upper limit of the interval of reliability reached with a certain probability $1 - \alpha$.

Lower limit

$$\frac{n_0}{n_0 + (n - n_1 + 1) \times F_{\frac{\alpha}{2}; \nu_1; \nu_2}} \quad (5)$$

Upper limit

$$\frac{(n_0 + 1) \times F_{1 - \frac{\alpha}{2}; \nu_3; \nu_4}}{n - n_0 + (n_0 + 1) \times F_{1 - \frac{\alpha}{2}; \nu_3; \nu_4}} \quad (6)$$

$$F_{\frac{\alpha}{2}; \nu_1; \nu_2}, \quad F_{1 - \frac{\alpha}{2}; \nu_3; \nu_4}$$

are the quantiles of Fisher-Snedocorov F-distribution, α is probability, $\nu_1 = 2\,(n - n_0 + 1)$, $\nu_2 = 2\,n_0$, $\nu_3 = 2\,(n_0 + 1)$, $\nu_4 = 2\,(n - n_0)$ are the degrees of freedom, n is the total number of values, n_0 is the absolute frequency of phenomenon (Zach 2004).

For qualitative variables it is valid:

point estimation of parameter μ:

$$\bar{x} = \frac{1}{n} \times \sum_{j=1}^{n} x_j \quad (7)$$

point estimation of parameter s^2:

$$S^2 \times \frac{n}{n - 1}, \text{ when } S^2 = \frac{1}{n} \times \sum_{j=1}^{n} (x_j - \bar{x})^2 \quad (8)$$

interval estimation of parameter μ:

Table 1. Group of tree species

Group of tree species	Tree species
Norway spruce	*Picea abies* (L.) Karst.
Silver fir	*Abies alba* Mill.
Pine	*Pinus sylvestris* L., *Pinus nigra* Arnold, *Pinus banksiana* Lamb., *Pinus strobus* L., *Pinus cembra* L., *Pinus contorta* Loudon, other *Pinus* sp.
Larch	*Larix decidua* Mill., other *Larix* sp.
Mountain pine	*Pinus mugo* Turra, *Pinus rotundata* Link.
Douglas fir	*Pseudotsuga menziesii* (Mirbel) Franco
Grand fir	*Abies grandis* (D. Don) Lindl.
Spruce exotics	*Picea pungens* Engelm., *Picea mariana* (Mill.) Britton et al., *Picea glauca* (Moench) Voss., *Picea omorika* (Pančić) Purkyně, *Picea engelmanni* Engelm., others
Other coniferous species	other coniferous species
Oak	*Quercus robur* L., *Quercus robur* L. f. *slavonica* Gayer, *Quercus petraea* Liebl., *Quercus pubescens* Willd., *Quercus palustris* Muenchh., *Quercus cerris* L., others
Red oak	*Quercus rubra* L.
European beech	*Fagus sylvatica* L.
European hornbeam	*Carpinus betulus* L.
Maple	*Acer platanoides* L., *Acer pseudoplatanus* L., *Acer campestre* L., *Acer negundo* L., others
Ash	*Fraxinus excelsior* L., *Fraxinus angustifolia* Vahl., *Fraxinus americana* L.
Elm	*Ulmus minor* Mill., *Ulmus glabra* Hudson, *Ulmus laevis* Pallas
Locust	*Robinia pseudoacacia* L.
Birch	*Betula pendula* Roth, *Betula pubescens* Ehrh.
Alder	*Alnus glutinosa* (L.) Gaertn., *Alnus incana* (L.) Moench, *Alnus viridis* (Chaix) DC
Linden	*Tilia cordata* Mill., *Tilia platyphyllos* Scop., *Tilia tomentosa* Moench.
European aspen	*Populus tremula* L.
Poplar	*Populus alba* L., *Populus nigra* L., others
Willow	*Salix caprea* L., *Salix alba* L., *Salix fragilis* L.
Other broadleaved species	*Sorbus aucuparia* L., *Sorbus torminalis* (L.) Crantz, *Sorbus aria* (L.) Crantz, *Juglans regia* L., *Juglans nigra* L., *Platanus acerifolia* (Aiton) Willd., *Prunus avium* (L.) L., *Prunus padus* L., *Pyrus communis* L. var. *pyraster*, *Malus sylvestris* Mill., *Aesculus hippocastanus* L., *Castanea sativa* Mill., *Alintus altissima* (Miller) Swingle, others

lower limit

$$\bar{x} - t_{\alpha;n-1} \times \frac{S}{\sqrt{n-1}} \quad (9)$$

upper limit

$$\bar{x} + t_{\alpha;n-1} \times \frac{S}{\sqrt{n-1}} \quad (10)$$

where:
$t_{\alpha;n-1}$ – quantile of Student's t-distribution,
α – probability (Zach 2004).

RESULTS AND DISCUSSION

Krušné hory Mts. – regeneration

Fig. 1 illustrates the distribution of regeneration on inventory plots in the territory concerned. Regeneration on only one subplot was sufficient enough for classifying into plots with regeneration. In total, regeneration was indicated on 70.1% of the investigated subplots. The highest share of the plots is represented by regeneration under shelterwood

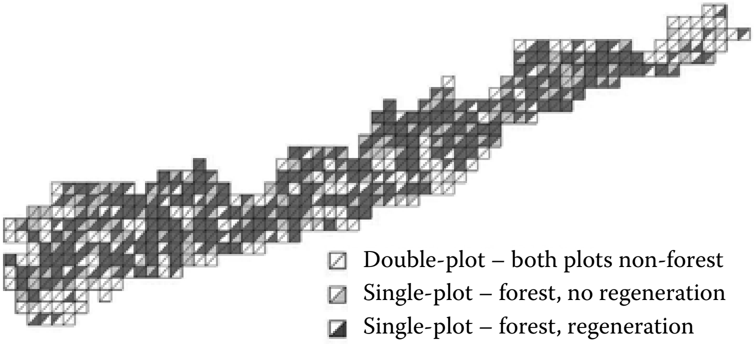

Fig. 1. Distribution of regeneration based on National Forest Inventory data

– nearly 40%, the share of regeneration in the open space is ca 30%, and no regeneration is nearly on 30% of the plots.

Artificial regeneration with a share of natural regeneration up to 20% prevails in the open space, natural regeneration (with a share of artificial regeneration up to 20%) is entirely prevailing below the stand. Natural regeneration with a share of artificial regeneration up to 20% prevails also in the complete evaluation.

The number of individuals is higher in regeneration under shelterwood (over 20,000 pcs/ha), for regeneration in the open space it is "only" 7,900 pcs/ha. The high representation of Norway spruce, dominating in both types of regeneration, is not such a surprise. Spruce is followed by birch and other deciduous tree species (rowan accounts for more than 90% of this group) in the open space, below the stand the other deciduous tree species, maple and beech, are behind the spruce.

Table 2. The occurrence of tree species in regeneration

Tree species	Number of regeneration individuals/ha in investigated territory								
	regeneration in open space			regeneration under shelterwood			totally		
	number	error	(%)	number	error	(%)	number	error	(%)
Picea abies (L.) Karst.	4,168.2	± 1,990.3	52.8	13,929.0	± 4,623.3	69.1	6,418.6	± 1,853.0	65.0
Pinus sp.	80.6	± 74.8	1.0	20.8	–20.8; +30.3	0.1	32.7	± 25.8	0.3
Larix sp.	248.9	± 119.3	3.2	148.5	± 110.6	0.7	132.1	± 55.3	1.3
Pinus mugo	56.1	± 45.3	0.7	0.0	0.0	0.0	17.5	± 14.2	0.2
Picea exots	354.1	± 116.7	4.5	35.6	–25.6; +36.8	0.2	123.4	± 40.2	1.2
Quercus sp.	66.6	± 47.7	0.8	727.5	± 475.4	3.6	288.2	± 176.4	2.9
Quercus rubra (L.)	0.0	± 0.0	0.0	3.0	± 5.8	0.0	1.1	–1.1; +2.1	0.0
Fagus sylvatica L.	581.9	± 423.6	7.4	1,306.5	± 567.4	6.5	661.5	± 248.9	6.7
Carpinus betulus L.	21.0	–21; +41.4	0.3	145.5	–145.5; 186.0	0.7	60.0	–60; +69.5	0.6
Acer sp.	238.4	± 180.0	3.0	1,333.2	± 559.8	6.6	564.4	± 216.8	5.7
Fraxinus sp.	3.5	–3.5; +6.9	0.0	522.6	± 486.8	2.6	193.2	± 179.2	2.0
Ulmus sp.	0.0	0.0	0.0	3.0	–3.0; +5.8	0.0	1.1	–1.1; +2.1	0.0
Betula sp.	1,093.8	± 373.7	13.8	421.6	± 264.1	0.0	495.6	± 154.2	5.0
Alnus sp.	42.1	± 36.2	0.5	103.9	–103.9; 139.2	2.1	51.3	–51.2; 52.3	0.5
Populus tremula L.	52.6	–52.6;+67.1	0.7	11.9	–11.9; 16.5	0.5	20.7	–20.7; 21.7	0.2
Salix sp.	63.1	± 53.0	0.8	0.0	± 0.0	0.1	19.6	± 16.5	0.2
Other deciduous tree species	827.3	± 353.9	10.5	1,455.0	± 401.1	7.2	792.5	± 188.4	8.0
Totally	7,898.2		100.0	20,167.5		100.0	9,873.5		100.0

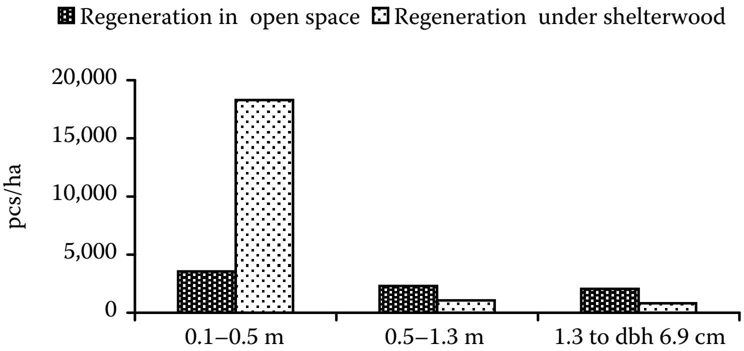

Fig. 2. Number of individuals/ha in regeneration height classes – pieces/ha

Total regeneration of coniferous tree species is represented by 68% and of deciduous tree species by 32%. Regeneration of coniferous tree species in the open space is 62.2% and of deciduous tree species 37.8%. And there are 70.1% of coniferous trees species and 29.9% deciduous tree species represented in regeneration under shelterwood. Table 2 shows the distribution of tree species in regeneration.

While the number of individuals regenerating in the open space is relatively balanced in height classes, a reduction in the number of individuals with increasing height is evident for regeneration under shelterwood (where natural regeneration prevails and reduction of individuals is a natural phenomenon) (see Fig. 2).

Game browsing is the most important factor negatively influencing regeneration. The lack of light cannot be generally taken for a negative factor, especially in such localities where natural regeneration is not intended (young stands, unsuitable species composition). Further negative factors prevailing in the open space (climate, weeds and waterlogging) show that regeneration under shelterwood should be preferred.

Protective measures in regeneration are realized in the open space, by coating or by spraying against browsing in 12.5% and by fencing in 3.8%, sporadically they are used under shelterwood.

Operationally useable regeneration is more limited than that defined by methodology for the National Forest Inventory. Of the plots realizing regeneration according to National Forest Inventory only 38.2% comply with the definition of operationally useable regeneration; totally 26.8% of all forest plots are comprised.

When operationally useable regeneration is realized, then there is no principal difference between localities at altitudes above or below 700 m a.s.l., which concerns approximately 42 to 44% of all subplots. It is interesting that the base for operationally useable regeneration for plots above 700 m a.s.l. is in the open space and, on the contrary, for plots lying below 700 m a.s.l. it is under shelterwood (see Table 3) (the plot proportion is an average of relative frequency according to Formula 1, errors for defining the interval estimation are in brackets, calculated according to Formulas 9 and 10).

When the species composition of individuals in operationally useable regeneration is compared (see Table 4) with total regeneration (Table 2), two differences are the most evident: higher spruce representation in operationally useable regeneration and relatively identical representation of beech.

Game damage is defined as the browsing of terminal shoot, repeated and single, peeling, fraying,

Table 3. Survey of operationally useable regeneration in total

Conditions	% of plots – totally	% of plots above 700 m a.s.l.	% of plots below 700 m a.s.l.
No regeneration	41.3 (–3.8; 3.9)	44.0 (–4.1; 5.1)	37.4 (–5.8; 6.1)
Regeneration in open space	21.6 (–2.9; 3.1)	27.4 (–4.3; 4.5)	13.3 (–3.4; 4.0)
Regeneration under stand	37.3 (–3.8; 3.9)	28.6 (–4.6; 4.9)	49.3 (–6.3; 6.4)
– of that in stands over 80 years of age	20.9 (–2.8; 3.1)	16.8 (–3.3; 3.8)	28.6 (–5.0; 5.5)
Totally useable regeneration (open space + regeneration in stands over 80 years of age)	42.5	44.2	41.9

Operationally useable regeneration includes only individuals from 0.1 m to 1.3 m

Table 4. The occurrence of tree species in operationally useable regeneration (average number of individuals/ha of plot with useable regeneration)

Species	Open space	Under stand over 80 years of age	Average (according to share of plot) open space + under stand over 80 years of age	(%)
	(pcs/ha)			
Picea abies (L.) Karst.	4,976.0 (± 2,682.4)	21,743.4 (± 8,114.61)	12,526.9 (± 4,027.0)	74.0
Pinus sp.	119.9 (± 97.4)	35.1 (–35.1; 58.9)	81.7	0.5
Larix sp.	86.3 (± 68.5)	93.6 (–93.6; 101.3)	89.6 (± 58.8)	0.5
Picea exotics	182.2 (± 88.7)	none	101.1 (± 49.6)	0.6
Quercus sp.	86.3 (± 61.6)	1,100.0 (± 924.5)	542.8 (± 418.7)	3.2
Fagus sylvatica L.	685.5 (± 557.5)	1,626.7 (± 976.5)	1,109.3 (± 535.3)	6.5
Carpinus betulus L.	28.8 (–28.8; 56.8)	187.2 (–187.2; 297.1)	100.1	0.6
Acer sp.	297.2 (± 229.6)	1,193.7 (± 840.1)	700.9 (± 399.4)	4.1
Fraxinus sp.	4.8 (–4.8; 9.5)	380.3 (–380.3; 496.9)	173.9 (–173.9; 223.3)	1.0
Betula sp.	776.6 (± 409.2)	204.8 (± 148.7)	519.1 (± 235.8)	3.1
Alnus sp.	19.2 (–19.2; 23.1)	–	10.54 (–10.5; 12.7)	0.1
Populus tremula (L.)	62.3 (–62.3; 88.0)	–	34.3 (–34.3; 48.3)	0.2
Salix sp.	67.1 (± 63.6)	–	36.9 (± 35.0)	0.2
Sorbus aucuparia L.[1]	599.2 (± 241.8)	1,293.1 (± 501.4)	911.7 (± 263.3)	5.4
Totally	7,991.3 (± 2,760.6)	27,858.0 (± 8,037.21)	16,937.9 (± 4,056.58)	100.0

[1]Rowan (*Sorbus aucuparia* L.) is classified into the group of other deciduous tree species according to the methodology of forest inventory

etc., and their combination, which means that the category of game damage is the sum of damage types investigated during National Forests Inventory according to its methodology.

In the investigated territory regeneration damaged by game browsing was found out on 32% of individuals in regeneration (type of damage, tree species, type of regeneration and regeneration height classes were not regarded). Of total regeneration found, 34% of individuals were damaged in the open space and 32% of individuals under shelterwood (see Table 5). The intensity of damage varied territorially (see Fig. 3).

Damage was evaluated for the particular tree species or groups of tree species (according to their representation in regeneration) occurring in this area more frequently and can be compared with the CR results (see Table 6). The tree species are grouped in agreement with Table 1.

Spruce, the most frequently represented tree species in regeneration, shows damage of 32% of individuals in the investigated area (open space 34% of damaged individuals, below the stand 32% of damaged individuals) whilst average damage in the CR is 21% of damaged individuals.

Table 5. Total damage to individuals in regeneration by game

Species	Totally		Open space		Under stand	
	number of individuals/ha		number of individuals/ha		number of individuals/ha	
	average	(%)	average	(%)	average	(%)
Total regeneration	9,873.50	100.00	7,898.15	100.00	20,167.54	100.00
Game damage	3,190.74	32.32	2,688.81	34.04	6,401.83	31.74

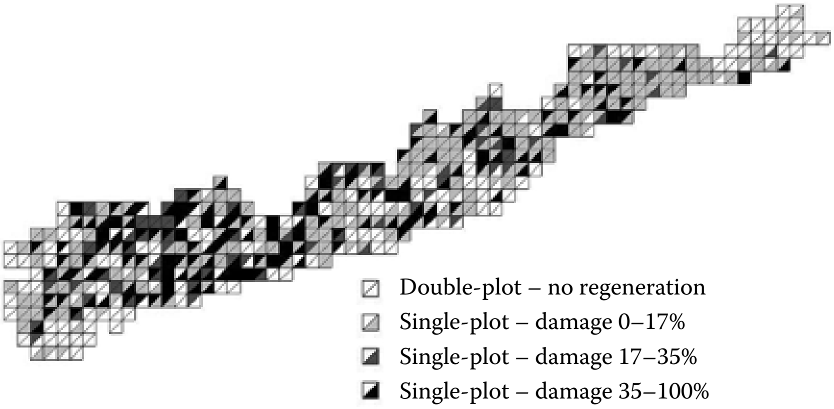

Fig. 3. Damage to regeneration – all tree species

Table 6. Damage to tree species (comparison with results of National Forest Inventory in the CR)

	1st measurement in investigated area			2nd measurement in investigated area			In CR from Forests Inventory		
Tree species	number	error		number	error		number	error	
Picea abies (L.) Karst.	31.9	–1.2	1.2	16.9	–1.9	2.0	21.0	–0.3	0.3
Abies alba Mill.	–	–	–	0.0	–	97.5	34.4	–2.2	2.2
Pinus sp.	16.7	–11.0	18.1	0.0	–	26.5	18.8	–1.1	1.1
Larix sp.	45.9	–9.1	9.3	32.8	–11.5	13.2	29.3	–2.4	2.5
Pinus mugo Turra	12.5	–10.9	25.8	11.1	–10.8	37.1	23.3	–13.4	19.0
Pseudotsuga menziesii (Mirbel) Franco	–	–	–	–	–	–	30.0	–9.2	10.6
*Abies grandis (*D. Don) Lindl.	–	–	–	–	–	–	13.2	–8.7	14.9
Picea exotics	18.3	–6.6	8.3	11.3	–6.3	9.7	13.9	–3.4	4.0
Other coniferous species	–	–	–	–	–	–	11.1	–8.8	18.0
Quercus sp.	12.4	–3.6	4.4	12.1	–5.9	8.5	26.3	–0.5	0.5
Quercus rubra L.	0.0	–	97.5	50.0	–48.7	48.7	22.6	–1.6	1.7
Fagus sylvatica L.	26.8	–3.4	3.6	25.7	–4.1	4.4	21.2	–0.5	0.5
Carpinus betulus L.	11.1	–6.2	9.6	30.4	–12.7	15.3	49.3	–0.8	0.8
Acer sp.	19.7	–3.2	3.5	41.8	–6.4	6.6	36.5	–0.5	0.5
Fraxinus sp.	54.7	–8.1	7.9	67.4	–8.4	7.7	40.2	–0.7	0.7
Ulmus sp.	100.0	–97.5	–	–	–	–	54.3	–3.5	3.5
Robinia pseudoacacia L.	–	–	–	–	–	–	22.3	–5.0	5.7
Betula sp.	8.8	–2.4	3.0	2.7	–1.5	2.6	18.3	–0.8	0.8
Alnus sp.	36.2	–13.5	15.3	20.0	–17.5	35.6	26.8	–2.8	2.9
Tilia sp.	–	–	–	66.7	–57.2	32.5	30.4	–1.8	1.8
Populus tremula L.	5.9	–5.7	22.8	0.0	–	97.5	40.3	–1.8	1.9
Populus sp.	–	–	–	–	–	–	22.0	–10.5	14.0
Salix sp.	5.6	–5.4	21.7	25.0	–24.4	55.6	37.0	–3.8	3.9
Other deciduous	65.8	–3.5	3.4	42.0	–5.1	5.2	55.3	–0.7	0.7
Coniferous trees	31.8	–1.1	1.2	17.1	–1.8	1.9	21.3	–0.3	0.3
Deciduous trees	31.9	–1.7	1.7	30.7	–2.2	2.3	34.4	–0.2	0.2
Total	31.9	–0.9	1.0	24.0	–1.5	1.5	29.8	–0.2	0.2

Table 7. Damage to the particular height classes of total regeneration

Height class	Open space	Under stand	Totally
	% of damaged individuals		
From 0.1–0.5 m	32.77	30.73	31.02
0.5–1.3 m	43.58	49.30	45.60
1.3 m up to dbh 6.9 cm	25.60	31.62	27.51

Damage of **beech** amounts to 27% of individuals in the investigated area, average for the CR is 20% of damaged individuals. This tree species shows a marked difference in damage between the open space and under shelterwood (damage of 67% individuals in the open space, under shelterwood 13% of individuals). This was confirmed also by the investigation in the Fláje preserve; game were much more interested in beech individuals in the open space and from planting than those regenerated naturally below the stand.

The greatest damage by browsing occurs in the other deciduous tree species, represented by more than 95% of **rowan** in the investigated area. Damage was found out on 65% of individuals whilst the CR average is 41%.

Of other important tree species represented in regeneration 19% of individuals of blue spruce are damaged, especially their annual shoots are browsed in the initial growth period. Due to the good regeneration ability of this species this damage is removed quickly, and the individuals keep their upright growth. **Birch** regeneration was damaged in 9% of individuals within the investigated area.

Distribution of damage is remarkable when regeneration height classes are considered.

The survey (Table 7) shows that individuals from 0.5 m to 1.3 m (44 to 49%) are damaged to the greatest extent and individuals over 1.3 m to a lesser extent. No marked difference occurs in damage of the particular height classes between the open space and under shelterwood.

The repeated investigation in the Krušné hory Mts. revealed a very serious failure of regeneration both under shelterwood and in the open space. Out of the average 9,787 individuals/ha only 2,996 individuals persisted in regeneration during the repeated investigation (see Fig. 4).

Combining meteorological data and forest experiences it is obvious that the extremely high regeneration values in 2001 and 2002 were caused by the coincidence of seed year and suitable climatic conditions (see Table 8).

Krušné hory Mts. – peeling

Peeling and browsing are defined as the overall damage to the bark and phloem of growing trees caused by red deer feeding; peeling, i.e. the ripping of phloem and bark strips lengthwise, can be done only during the mobilization phase of tree species growth in early spring and during the vegetation period. Browsing appears mostly in winter; there are seen teeth on the attacked plant part. Peeling and browsing are classified into one category. During fraying trees are damaged by antlers of ungulate game.

The assessment of peeling and browsing intensity was carried out in two categories including individuals with dbh from 7 cm to 11.9 cm and individuals with dbh from 12 cm to 20 cm. Individuals with dbh

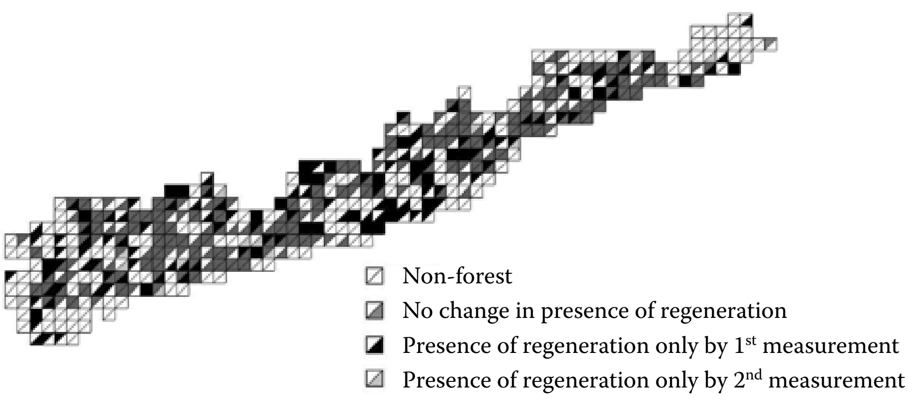

Fig. 4. Reduction of regeneration during repeated measurement

Table 8. Development of regeneration

Conditions	Repeated investigation			National Forest Inventory		
	p (%)	error		*p* (%)	error	
No regeneration	50.0	–4.2	4.2	29.9	–3.4	3.6
Regeneration in open space	23.1	–3.3	3.5	30.6	–3.4	3.6
Regeneration under shelterwood	26.9	–3.7	3.9	39.5	–3.9	4.0
Totally	100.0			100.0		

over 20 cm were not evaluated because they do not reflect the present state of damage by browsing and peeling. Results are presented in Table 9.

Fraying was assessed for the category of regeneration individuals in the height class from 1.3 m to dbh 6.9 cm. The total proportion of individuals damaged by fraying (in this category) approaches 10% (8.2% of damaged individuals). Of that the proportional share of the other deciduous tree species (33.1% of individuals) and larch (19.7% of individuals) is the highest whilst fraying of the basic tree species spruce is around 1% of individuals.

During the repeated investigation peeling remained nearly unchanged.

The maps were processed aimed at summarizing the damage (browsing, peeling) and at expressing both types of damage together. As average values from the preceding maps of browsing and peeling were used as a basis, damage is not expressed in degrees but only territories with lower, mean and higher degree of damage are connected informatively (Fig. 5).

Fláje preserve

Game damage in the Fláje preserve was measured in the framework of the project *Game Impact on Forest Ecosystems in the Krušné hory Mts*. The primary aim was to investigate a variety of impacts on the ecosystem inside the preserve designated for game in the whole territory of the Krušné hory Mts. In the framework of this project the existing network of forest inventory in the CR was deepened and the results became more provable. A more detailed investigation of game damage was carried out in the Fláje preserve during the second measurement in order to compare damage in this territory (higher load and game presence) with the rest of the territory.

The determined original 9 points of inventory in forests comprised 12 subplots while 6 of them were with regeneration (during the first measurement – 5 subplots). The calculation for the needed number of plots was based on the first measurement, i.e. on the measurement of forest inventory. The aim was to reduce the interval estimation so that the relative error did not approach 100%, as it was in the majority of measured variables of regeneration. Due to tens of trees measured in the given territory results for peeling were more qualified.

To improve the results additionally 56 plots with regeneration (in total 64 plots, or 79 subplots, of which 46 with regeneration) and 18 plots with regard to peeling (totally 26 plots) were measured. Another outside investigation was realized in 2007 (2 weeks).

Results show a distinct reduction in relative errors of measured variables, for example for the occur-

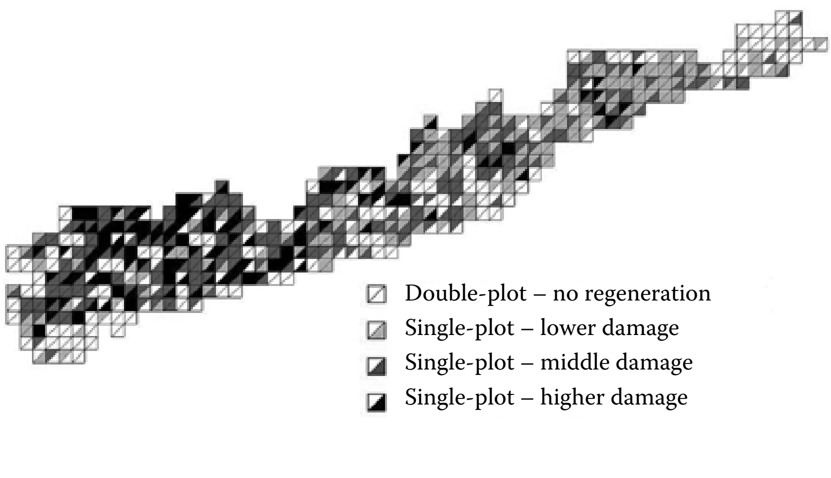

Fig. 5. Damage by game – combination of browsing and peeling – all tree species

Table 9. Damage caused by fraying, peeling and browsing of ungulate game

	Type and volume of damage	From dbh 7.0–11.9 cm			From dbh 12–20 cm		
		damage	error		damage	error	
All tree species	stem without damage	69.5	–3.8	3.6	66.7	–1.3	1.3
	damage up to 1/8 of stem girth	3.7	–1.3	1.8	6.1	–0.6	0.7
	damage over 1/8 of stem girth	26.8	–3.4	3.7	27.3	–1.2	1.2
	totally	100.0			100.0		
Conifers	stem without damage	56.3	–5.6	5.5	52.6	–1.7	1.7
	damage up to 1/8 of stem girth	5.7	–2.3	3.1	8.2	–0.9	1.0
	damage over 1/8 of stem girth	38.1	–5.4	5.6	39.1	–1.6	1.6
	totally	100.0			100.0		
Broadleaves	stem without damage	83.1	–4.7	4.0	93.2	–1.3	1.1
	damage up to 1/8 of stem girth	1.6	–1.1	2.1	1.8	–0.6	0.7
	damage over 1/8 of stem girth	15.3	–3.8	4.5	5.0	–1.0	1.1
	totally	100.0			100.0		
Picea abies (L.) Karst.	stem without damage	33.9	–6.7	7.2	36.4	–1.9	1.9
	damage up to 1/8 of stem girth	7.9	–3.4	4.8	11.0	–1.2	1.3
	damage over 1/8 of stem girth	58.2	–7.4	7.1	52.6	–2.0	2.0
	totally	100.0			100.0		
Larix sp.	stem without damage	75.6	–15.1	11.6	97.1	–1.8	1.3
	damage up to 1/8 of stem girth	4.4	–3.9	10.7	0.8	–0.6	1.2
	damage over 1/8 of stem girth	20	–10.4	14.6	2.1	–1.0	1.6
	totally	100.0			100.0		
Picea exotics	stem without damage	98.5	–6.7	1.5	97.9	–2.7	1.4
	damage up to 1/8 of stem girth	1.5	–1.5	6.7	0.8	–0.7	2.1
	damage over 1/8 of stem girth	0			1.2	–1.0	2.3
	totally	100.0			100.0		
Fagus sylvatica L.	stem without damage	100.0	–13.7	0.0	0.0		
	damage up to 1/8 of stem girth	0.0			0.0		
	damage over 1/8 of stem girth	0.0			0.0		
	totally	100.0			100.0		
Betula sp.	stem without damage	100.0	–2.0	0.0	99.9	–0.4	0.1
	damage up to 1/8 of stem girth	0.0			0.1	–0.1	0.4
	damage over 1/8 of stem girth	0.0			0.0		
	totally	100.0			100.0		
Other deciduous tree species	stem without damage	25.4	–9.8	12.1	50.8	–6.5	6.4
	damage up to 1/8 of stem girth	4.5	–3.5	8.1	12.7	–3.9	4.8
	damage over 1/8 of stem girth	70.1	–12.4	10.6	36.5	–6.0	6.4
	totally	100.0			100.0		

Table 10. Regeneration on subplots

Conditions	Fláje preserve			Krušné hory Mts.		
	average	negative error	positive error	average	negative error	positive error
No regeneration	40.7	–11.3	12.0	50.0	–4.2	4.2
Regeneration in open space	46.3	–11.6	11.8	23.1	–3.3	3.5
Regeneration under shelterwood	13.1	–7.1	10.6	26.9	–3.7	3.9
Totally	100.0			100.0		

Totally is the sum of rounded values

Table 11. Total damage to regeneration by game

Type	Fláje preserve		Krušné hory Mts.	
	average (pcs/ha)	(%)	average (pcs/ha)	(%)
Total regeneration	2,236	100	2,996	100
Game damage	1,148	51	834	28

rence of regeneration on the plot from min. 70% to min. 26%. Regeneration in the open space in Fláje preserve is high – 46.3% in contradiction with 23.1% in the whole territory of the Krušné hory Mts. Regeneration under shelterwood is 13.1% and 40.3% of plots are without regeneration (see Table 10).

Artificial regeneration in the preserve (41.9%) fully prevails over natural regeneration (15.7%). However, the whole territory of the Krušné hory Mts. shows the opposite trend (artificial – 16.3%, natural – 30.9%).

Except for the lower species richness there is a high representation of spruce exotics (18.0%).

The high proportion of beech in the preserve must be taken cautiously; beech occurs only on a small amount of plots along a stream but in abundance which causes a high relative error.

A high proportion of protective measures was found out in the preserve – 17.2% compared to the whole territory 6.5%.

The regeneration damaged by browsing is proportionally higher in the preserve than in the whole territory of the Krušné hory Mts. (see Table 11).

If the original nine points of forest inventory are taken for a basis and if the first and second measurements are compared, it is interesting that very high damage to regeneration is observed ranging from original 19% (in 2002) to 58% (in 2006). When the number of measurements is higher, then the final result is lower, although similar – 51%.

In total more trees damaged by peeling are in the preserve – by more than 10% – than in the whole territory of the Krušné hory Mts.

The Institute of Forest Ecosystem Research (IFER) has conducted a survey of game damage at the national level in the five-year cycle since 1995. Random sample of the sample plots is designed especially for the whole area of the Czech Republic (three-stage sampling). The results for the smaller area are not possible (Černý et al. 2002).

The last measurement was done in 2005. Sample localities are 1.41 × 2.82 km. There are 6 localities of this type in the survey area of the Krušné hory Mts. Total damage to regeneration is 34.43%, which is not far from the result obtained from NFI measurements, i.e. 32.32%. The methods are different mainly in the forms of sampling individuals of regeneration, when the targeted sampling by major tree species (spruce, pine, beech, oak) was used (Černý et al. 2007).

Another method of monitoring the activity of game is the method of control fences (Decree No. 101/1996 of the Ministry of Agriculture), which was modified by IFER in 1998. The development of vegetation cover inside and outside the fence was evaluated. A similar method is used in Saxony (Germany), where this method encounters practical difficulties in the interpretation. This method is significantly different by its nature from the investigation of National Forest Inventory.

In Saxony, the other method has successfully been applied. It is presented in the regulations concerning the assessment of the forest vegetation status, damage caused by grazing and peeling and restoration of forest (VERWALTUNGSVORSCHRIFT 2000). It is the methodics with targeted sampling again,

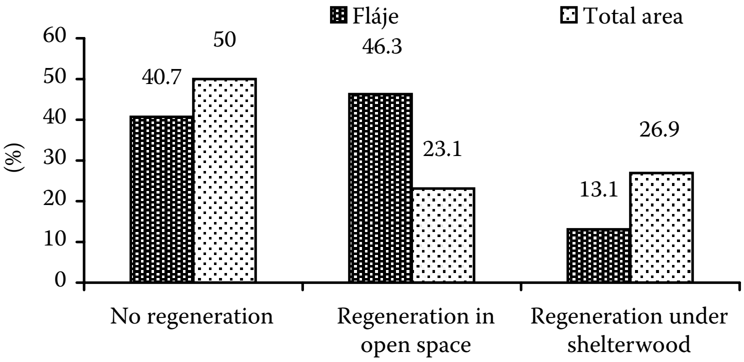

Fig. 6. Comparison of regeneration in the Krušné hory Mts. and Fláje preserve

where is selected one stand for the measuring of the regeneration and one stand for peeling on 100 ha. 7–10 temporary sample plots are located in sample stands (VERWALTUNGSVORSCHRIFT 2000). The result is then taken into account by approving the plan of hunting.

The methodology for *Inventory of Game Damage in the Smaller Territorial Units* was designed by IFER. The measuring was realized in two different regions – Bruntál and Vlašim. The method is different in the selection of sample plots. The intensity of selection is greater by IFER and the results have a smaller standard deviation (Beranová et al. 2005).

Still, I tried to compare concrete results. I took the results only from Vlašim. There are 900 sample plots with 10,649 individuals from measuring by IFER and 71 inventory sample plots (94 subplots, i.e. 70 subplots with regeneration, i.e. 2,036 individuals) from National Forest Inventory. Damage to the terminal shoot for all species: IFER 19%, NFI 25%. But the damage is 19.5% when only the individuals of regeneration in the open space are taken from the database. The regeneration in the open space corresponds better with the regeneration defined in this project. When I take only the regeneration in the open space, then I also get a similar result for spruce, i.e. 18%. For beech, there is a larger difference: IFER 24%, NFI 11%.

The methods are not equivalent. It can be simply said that where the possibilities of National Forest Inventory for the evaluation end, there comes the *Inventory of Game Damage in the Smaller Territorial Units.*

CONCLUSION

Results from National Forests Inventory can be used for the evaluation of game damage in a small territory like the Krušné hory Mts. Their interpretation can bring a lot of interesting knowledge. Needed information can be acquired even for smaller areas by suitable completion of measurements.

The original database was assessed and the following results were obtained:

– Regeneration was found out on 70.1% of plots. Norway spruce with its 52.8% has the highest representation, followed by birch 13.8%, the other tree species (mainly rowan) 13.8% and beech 7.4%.
– Operationally useable regeneration occurred only on 26.8% of plots and its volume did not principally differ from localities below 700 m a.s.l. and above 700 m a.s.l. The distribution of operationally useable regeneration is different, on plots below 700 m a.s.l. operationally useable regeneration prevails under the stand and on plots above 700 m a.s.l. in the open space.
– Total damage to regeneration in the Krušné hory Mts. was 32.3% (there was no principal difference in damage between plots under shelterwood and in the open space). When compared with data for the whole CR, regeneration damage in the Krušné hory Mts. is higher. The most damaged was rowan.
– The repeated investigation showed a marked reduction in individuals in regeneration, total regeneration damage by game decreased to 28%.
– Damage by peeling and fraying was observed in the category from height 1.3 m to dbh 6.9 cm – 13.4%, in the category from dbh 7–11.9 cm – 30.5% and in the category from dbh 12–20 cm – 33.3%. No important change was found out during the repeated investigation.
– A higher number of regeneration individuals was found in the Fláje preserve during repeated investigation in comparison with the rest of the investigated territory. In the course of five years, in relation to the original points and on the basis of a new investigation, an increase in game damage was observed.

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Received for publication September 26, 2008
Accepted after corrections November 24, 2008

Obnova a škody zvěří v Krušných horách z měření Národní inventarizace lesů České republiky

ABSTRAKT: V letech 2001–2004 proběhla v České republice Národní inventarizace lesů. Měřením celé řady veličin vznikla rozsáhlá informační databáze využitelná pro hodnocení stavu a vývoje různých kvantitativních a kvalitativních dendrometrických veličin. V práci jsou prezentovány výsledky zjištění stavu obnovy a škod zvěří v Krušných horách na podkladě údajů Národní inventarizace lesů a druhého měření provedeného po pěti letech, které bylo v části obory Fláje rozšířeno pro základní srovnání se zbytkem území. Ve výpočtech z dat starého i nového měření bylo použito standardní metodiky použité při zpracování dat Národní inventarizace lesů. Srovnáním se zjistilo, že průměrný počet jedinců obnovy v intervalu pěti let klesl více než o třetinu, klesl počet ploch s obnovou a kleslo i poškození obnovy zvěří o 4 %. Podíl jedinců poškozených loupáním se za sledované období nezměnil. V oboře Fláje byl zjištěn výrazný nárůst škod zvěří na obnově.

Klíčová slova: Národní inventarizace lesů; škody zvěří; Krušné hory

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