NUMBER OF TOURISTS AS FACTOR INFLUENCING TRAILS´ CONDITION

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Abstract
Tatra National Park with 738 km^2 and 600 km of hiking trails along with 3-4 million visitors, makes it one of the most visited national parks in the Slovakia. This paper examines impacts of trampling on the vegetation and soil along selected trails. The research involves the application of trail condition assessments to 9,6 km of trails with different visitation based on variety of inventory and impact indicators and standards to determine baseline condition of trails. These data can then be used for future comparison and evaluation of development trends. Trail widening and soil loss are the most important types of trail degradation. Correlational analyses of the collected data can also identify the role and influence of various factors (e.g. use level and topography). Insights into the influence of these factors can lead to the selection of appropriate management measures to avoid or minimize negative consequences.

Key words: visitors, impact, trampling, trail, indicator, Tatra National Park & Biosphere Reserve

Introduction
National parks are generally established for conservation purposes, however at same time they belong to most attractive places for recreation in the world. Tatra National Park (TNP) is considered as the most visited protected area in Slovakia (Švajda, 2009). Striking a balance between preservation of natural resources and opportunities for public recreation often forces responsible authorities to make compromises between visitation impacts and protection.
Number of direct and indirect effects (impacts) to resources from visitor use were described in literature – e.g. ground vegetation loss, soil compaction and erosion, shift to trampling resistant species, increased water runoff and soil temperature, reduced soil fauna, disturbance of animal species (Cole, 1989; Marion et al., 2011; Zwijacz-Kozica et al., 2013; Griffin et al. 2007). Degraded resource conditions on trails and number of visitors can have significant impacts also on perceptions of visitors (Leung & Marion, 2000; Manning et al., 2000; Streberová & Jusková, 2015).
This paper presents research and assessment of visitor-related impacts to the natural resources of the park. Research involved application of trail condition assessments (Marion et al., 2011) in two valleys with different level of visitation.
Results can serve as baseline for future update and the inventory of the existing trail system, assessment of the condition of the trail sections, suggestion of periodic trail system maintenance program, application of the visitor experience resource protection and other similar frameworks or establishment of visitor carrying capacities for study areas.
Visitor impacts on the ecological conditions of an area are influenced more by visitor behavior, park infrastructure, and the resilience of soil and vegetation and less related to overall use levels (McCool & Lime, 2001). The research is an example of visitor impact assessment methods and procedures including indicators used for trail monitoring. Relational analyses of the collected data can identify the role and influence of casual factors (e.g. type and amount of use) and non-casual but influential factors (e.g. topography). Insights into the influence of these factors can lead to the selection of more effective actions.

Material and methods
TNP is situated in the highest mountains of Carpathians Mts. along Slovak-Polish border. The major part is located in Slovakia and in 1948 was declared as national park with an area of 738 km^2. In 1993 it was included in a network of biosphere reserves, together with the Polish part. Annually it is visited by about 3 – 4 million visitors (Švajda et al., 2013). The network of hiking trails with a length of 600 km is particularly popular.
The study areas are two valleys – Malá Studená (MSV) accessible by trail from south with higher human impact and visitation (including mountain huts Téryho and Zamkovského chata) and Javorová (JV) accessible from northern part with low number of visitors (see fig. 1). There is marked touristic trail (green colour) starting near Zamkovského chata (elevation 1460 m asl) reaching the highest point

Sedielko (2376 m asl) after 5,9 km in MSV. On the other side there is again green tourist trail starting near Pod Muráňom (elevation 1080 m asl) reaching saddleback Sedielko after 9,2 km in JV. Both areas are situated in national nature reserves with the highest level of protection according Slovak Act on nature and landscape protection.

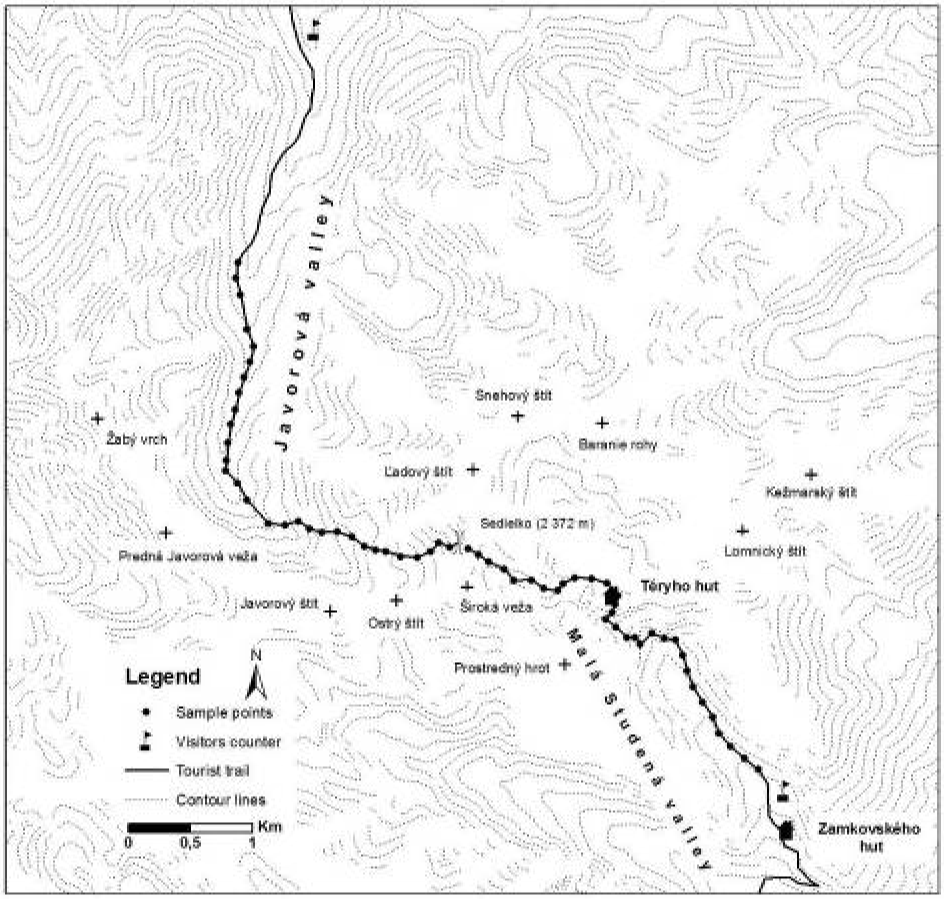

Fig. 1: Location of trails in two study areas – MSV and JV in TNP

In order to quantify exact number of tourists and confirm assumptions about differences in visitation of two study valleys, a direct data collection method was used to monitor visitor numbers in the selected test area (Muhar et al. 2002). We used pyro-electric sensors Linetop with one direction records of passages in hour interval were installed at the entrance points to study areas (fig. 1). Installation, measurement, control calibration and de-installation were realized between 7.7.2014 and 26.9.2014.
During October 2014 we applied impact assessment procedures (Marion et al., 2011) to two study trails. Spatial data were transferred from GPS to EasyGPS. Statistical data were transferred to Microsoft Excel for further analysis.

Results

We assessed 64 sample points along a total length of 9,6 km for two trails within TNP (tab. 1).
Trail grade and trail slope alignment angle were two important inventory indicators assessed in the survey (Dissmeyer & Foster, 1984; Aust et al., 2004;).
Approximately 9% of the trails are located on flat terrain (0-2% grade), 50% of the trail in MSV and 56% in JV has grades exceeding 15% and 22 % resp. 28% of the trails have grades exceeding 30% (see tab. 2). The mean grade of trails in both valleys is 19% and 22%. It should be noted that many of the excessively steep alignments have constructed rock steps or ascend exposed rock faces, which are not susceptible to soil loss.
Regarding trail's slope alignment angle, only 28% of trail in JV and no sample points in MSV valley are aligned within 22° of the landform aspect or fall line (tab. 3), the path naturally taken by water running down a mountain slope. Once a fall-aligned trail becomes incised, water trapped on the tread is exceptionally difficult to direct off and can build in volume, substantially increasing its erosion. The level of erosion also increases exponentially with trail grade, though the natural rockiness of TNP´s trail treads and stonework can limit erosion. In flatter terrain, such trail alignments are susceptible to

muddiness and widening. Fall-aligned trails with higher grades frequently require significant investments in rockwork and ongoing maintenance to keep them sustainable. Water can drain under or over such work, though freezing winter temperatures can increase danger to trail users or harm and loosen the rockwork. Mean elevation of the evaluated points is 1888,60 resp. 1756, 31 m above sea level.

Tab. 1: Inventory and impact indicators summarized by trails

Trail	Length	Sample count	Inventory Indicators							Impact Indicators		
			Elevation (m asl)	Trail grade (%)	Landform grade (%)	Slope Alignment Angle (°)	Use Levels (visitors/day)	Slope Ratio (%)	Rugosity (cm)	Trail Width (cm)	CSA (cm^2)	Maximum Incision (cm)
	m	N	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
MSV	4800	32	1888,59	19,47	35,47	59,38	626	0,57	2,30	111,50	389,38	6,92
JV	4800	32	1756,31	21,78	27,06	38,13	46	0,79	2,13	80,66	276,09	6,20

Tab. 2: Trail Grade – MSV / JV (Mean = 19,47 / 21,78%; Median = 15,50 / 16,50%; Range = 0-100%)

Grade	Number of sample points MSV	Totals	Number of sample points JV	Totals
0-2%	3	9	3	9
2-6%	7	22	4	12
6-10%	3	9	1	3
10-15%	3	9	6	19
15-20%	6	19	5	16
20-30%	3	9	4	12
30-100%	7	22	9	28
Totals	32	~100%	32	~100%

Tab. 3: Trail Slope Alignment – MSV / JV (Mean = 59,38° / 38,13°; Median = 60° / 40°; Range = 0-90°)

Slope Alignment	Number of sample points MSV	Totals	Number of sample points JV	Totals
0-22°	0	0	9	28
22-45°	7	22	13	41
45-68°	14	44	8	25
68-90°	11	34	2	6
Totals	32	100%	32	100%

Tab. 4: Elevation – MSV / JV (Mean = 1888,60 / 1756,31 m asl; Median = 1899,13 / 1674,25 m asl; Range = 1419-2326 m asl)

Elevation	Number of sample points MSV	Totals	Number of sample points JV	Totals
-1440 m asl (forest zone)	0	0	3	9
1440-1800 m asl (subalpine zone)	13	41	17	53
1800- m asl (alpine zone)	19	59	12	38
Totals	32	100%	32	100%

Tab. 5: Number and percent of sample points by impact indicator category

Indicator	Sample points MSV / JV	Percentage MSV / JV
Trail Width (cm)		
0-60	1 / 8	3% / 25%
60-90	5 / 12	16% / 38%
90-120	19 / 11	59% / 34%
120-150	4 / 1	13% / 3%
150+	3 / 0	9% / 0%
Mean = 111,50 / 80,66; Median = 110 / 80; Range = 39-168;		
Maximum Incision (cm)		
0-2,5	3 / 1	9% / 3%
2,5-7,5	16 / 23	50% / 72%
7,5-12,5	12 / 6	38% / 19%
12,5+	1 / 2	3% / 6%
Mean = 6,92 / 6,20; Median = 5,75 / 5,50; Range = 1,5-17;		
CSA Soil Loss (cm^2)		
0-250	13 / 18	41% / 56%
250-500	12 / 10	37% / 31%
500+	7 / 4	22% / 13 %
Mean = 389,30 / 276,09; Median = 322,50 / 235,00; Range = 35-1230;		
Mean Trail Depth (cm)		
0-2,5	18 / 15	56% / 47%
2,5-7,5	13 / 17	41% / 53%
7,5-12,5	1 / 0	3% / 0%
12,5+	0 / 0	0% / 0%
Mean = 3,1 / 2,8; Median = 2,4 / 2,6; Range = 0,6-8,2;		

Trail width ranged from 39 to 168 cm with a mean of 111 cm in MSV and 80 cm in JV. Less than 10% of the trails (and only in MSV) exceed 150 cm in width. According historical norm used in Tatras (1,3 ± 0,2 m), trails are generally wide as it is intended by park management. From these numbers also the total area of intensive trampling disturbance for the trail system can be calculated (based on extrapolating mean trail width to the total length of TNP trail system).

Maximum incision ranged from 1,5 to 17 cm with a mean of 6,92 resp. 6,20 cm. Cross-sectional area soil loss measurements (CSA) ranged from 35 to 1230 cm^2, with a mean of 389 resp. 276 cm^2. Extrapolating this measure by the trail system length can yield an estimated aggregate soil loss totally in m^3 or on a per-km basis in m^3/km.

A more representative measure of trail incision is provided by calculating mean trail depth from the vertical measures recorded to compute CSA. This measure ranged from 0,6 to 8,2 cm with a mean of 3,1 resp. 2,8 cm.

Finally, assessments of the tread substrate as a proportion of transect width are used to characterize the typical trail system substrates described in fig. 2. The predominant tread substrate on both trails is rock, followed by gravel and soil

Discussion

Results suggest that trail width is predominantly a function of use level. Some authors (Wimpey and Marion, 2010) investigated also relation of trail width with trail and landform grade and trail slope alignment which may help to restrict lateral dispersion of hikers (e.g. with increasing trail grade). Important factors are also behavior of tourists and absence of trail borders. Tread rugosity can widen trails when hikers often looking for easier passage along trail sides. To address these problems managers can manipulate with level of trail use, create trail boarders or educate visitors how to decrease their impact on trails.

Soil loss was assessed for trails using three measures: mean trail depth, maximum incision and cross-sectional area. Some studies revealed influence of level of trail use, trail grade and trail slope alignment angle to soil loss (e.g. Wimpey & Marion, 2010). Managers may have little control over level of use but could consider relocations of trail segments that are excessively steep or that are aligned closely to the fall line (landform aspect) of mountain slopes. Other option is regular maintenance and higher attention towards these sections of trails (Birchard & Proudman, 2000). Some authors commonly recommend to prevent soil loss keep grades of less than 10-12% (Hooper, 1988; Hesselbarth et al., 2007), trail slope alignment higher than 22° (Olive & Marion, 2006) and trail slope ratio less than 0,5 (IMBA, 2004). Soil erosion would be much higher than assessed were it not for the substantial amount of granitic rock in the soils and the extensive use of rock steps.

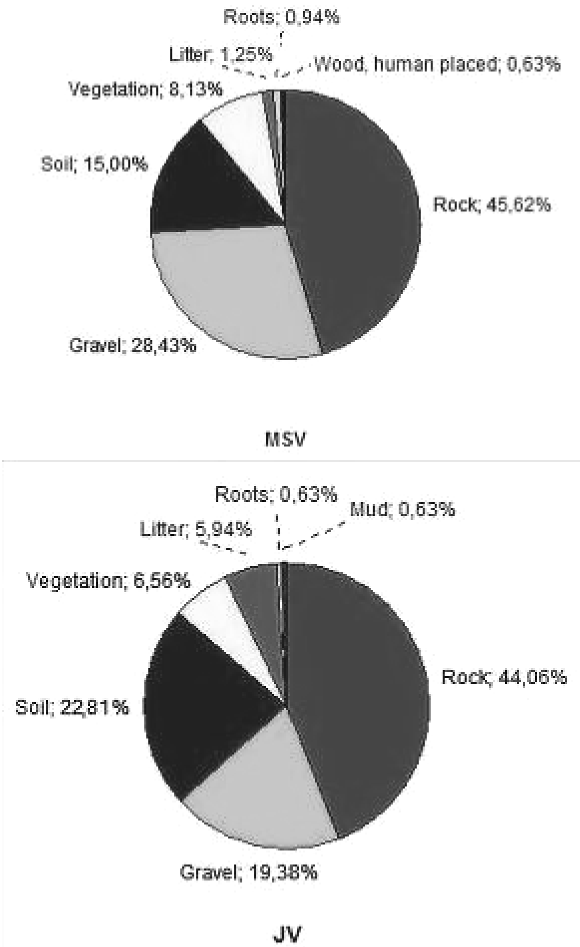

Fig. 2: Mean trail substrate cover as a proportion of transect (tread) width

Conclusion

National parks should provide appropriate opportunities for recreation, protection and preservation of park resources and natural processes. This research provides information and basis for management of visitors and recreational impacts on resources. Variety of inventory and impact indicators and standards have been documented as baseline data about the current condition of trails, but this can also be used for future comparison and evaluation of trends. Trail widening and soil loss are the most important types of trail degradation.

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Souhrn
Tatranský národní park se 738 km^2 a 600 km turistických stezek, spolu s 3 až 4 miliony návštěvníků, z něj činí jeden z nejnavštěvovanějších národních parků na Slovensku. Tato práce se zabývá dopady pošlapávání na vegetaci a půdu po vybraných trasách. Výzkum zahrnuje aplikaci posuzování stavu 9,6 km stezek s různou návštěvností na základě různých ukazatelů. Tyto údaje pak mohou být použity pro budoucí porovnání a vyhodnocení vývojových trendů. Rozšíření stezek a ztráty půdy jsou nejdůležitějšími typy degradace. Pomocí korelační analýzy získaných dat lze také identifikovat úlohu a vliv různých faktorů (např. úroveň využití a topografie). Pohled do vlivu těchto faktorů může vést k výběru vhodných opatření pro minimalizaci negativních důsledků.

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