



Monitoring System of tourist traffic (MSTT) for tourists monitoring in mid-mountain national park, SW Poland

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Abstract: National parks are highly valuable natural areas and have the potential to attract a large number of visitors. The number of visitors at national parks is systematically increasing, often exceeding Tourism Carrying Capacity (TCC) of trails. This situation requires adjusting the number of park visitors to adapt to sustainable management systems of visitor flow, thus preventing or counteracting overtourism. The aim of the study is to propose a comprehensive method for tourists monitoring in mid-mountain national park presented on the example of the Stołowe Mountains National Park (SMNP) in Poland, called as Monitoring System of tourist traffic (MSTT). The study describes six stages procedure of tourists Monitoring System creation and application as an optimal measurement technique. The MSTT enabled a multidimensional analysis of tourist traffic in SMNP. With the help of 39 pyroelectric sensors and surveys data spatio-temporal characteristic of visitor flow was obtained. The data generated in MSTT included hourly, daily, weekly, monthly, and annual reports, taking into account the direction of traffic measuring both directions: entries (IN), exits (OUT) and passages (IN+OUT). The results from pyroelectric sensors were supplemented with field surveys, where visitor's motivations, preferences, and behaviours were determined. In 2017 a total of 871,344 visitors were recorded in SMNP what causes one of the most popular national parks in Poland. The SMNP is a suitable destination for short breaks leisure visits in wilderness. In order to sustain MSTT methodology in the long-run the set of guidelines together with the workload estimates were presented. In the future, the

MSTT can be further developed, including monitoring of climbing, cycling, cross-country skiing, car traffic and illegal tourism assessment. The MSTT can be considered as a useful tool for tourism management in mid-mountain national parks throughout the entire calendar year.

Keywords: Tourist traffic; Visitor flow; Pyroelectric sensors; Eco-Counter; Hiking; Stołowe Mts. National Park

Introduction

National parks are highly valuable natural areas and they have the potential to attract a large number of visitors¹. The establishment of a national park is considered to be a major asset to its local area (e.g., Stasiak 2007) and motivates visitors to come. The number of visitors to national parks is systematically increasing in Poland, which is prompted not only by the desire to visit the wilderness and pursue environmental experiences, but also by the need to relax and practice outdoor sports (Kruczek and Przybyło-Kisielewska 2018). The main effect of these activities is an increase in number of visitors, which has exceeded capacity of trails in some national parks at this point. This issue of "overtourism" in national parks is the subject of study in many papers (Menzione 2018). This situation requires such a large number of visitors to adapt to sustainable management

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¹ In this paper the word "visitor" means number of peoples who visited in study area and its behavior describing

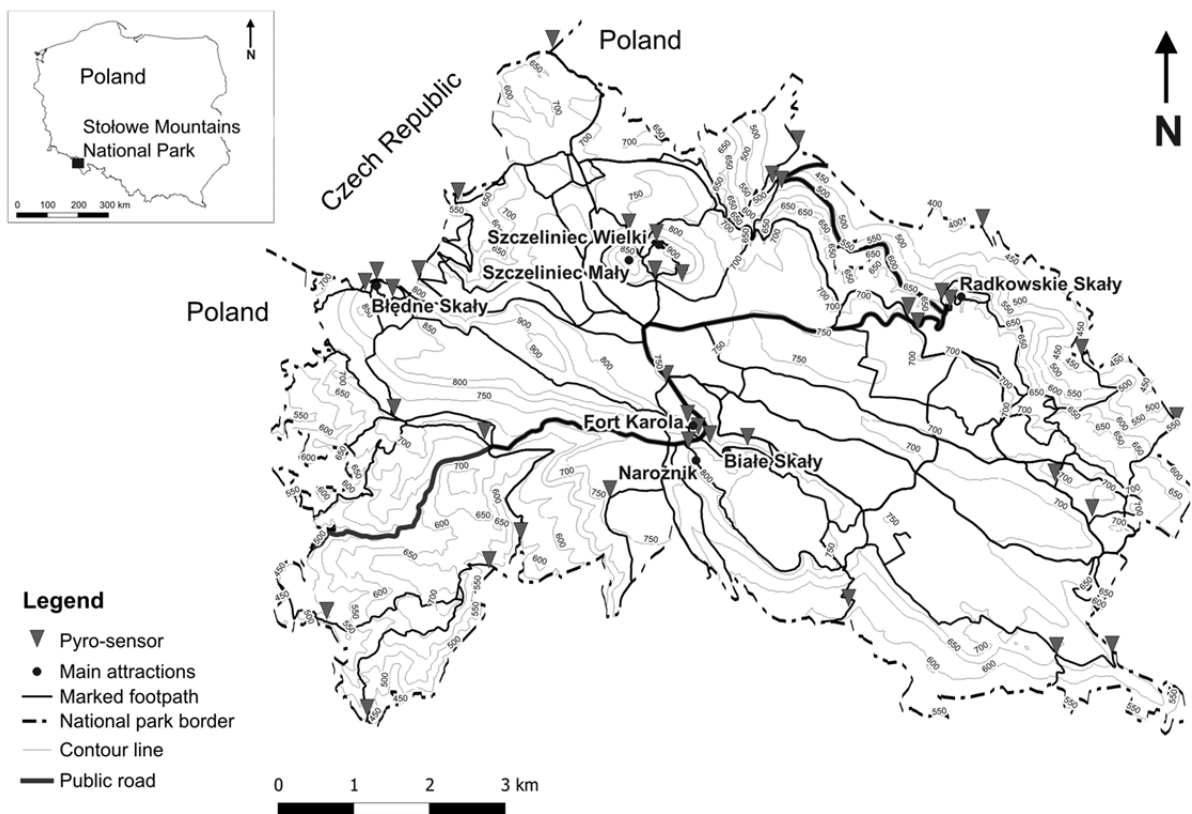


Figure 1 Location of pyroelectric sensors in Stołowe Mts. National Park in the Sudety Mountains in south-western Poland.

systems of visitor flow. To achieve this, it is important to assess the size, variability, and behaviour of visitors using an effective visitor monitoring systems in a national park.

The monitoring of tourist² traffic volume is carried out by examining traffic at attractions, on tourist trails and in specific geographic areas. Area monitoring is the most difficult undertaking in terms of planning, formulation, and implementation of tools and requires a multidimensional approach. Monitoring in national parks is needed to monitor not only the natural environment, but also tourist traffic. Monitoring can help assess the spatial distribution of visitors, routes of their movement, most frequently visited places, time spent in the park, as well as the preferences and geographic origin of tourists. This should serve to highlight the relationship between visitors, their interests and the specific area that meets their expectations to the fullest extent possible (Rogowski 2018a).

This study aims to propose a comprehensive

method for tourists monitoring in mid-mountain national park presented on the example of the Stołowe Mountains National Park (SMNP) in Poland, called as Monitoring System of tourist traffic (MSTT). The main focus is to determine the procedure for tourists monitoring system development, system creation and application as an optimal measurement technique. In addition, the MSTT data allowed for spatio-temporal characteristic of visitor flow in SMNP.

The issue of monitoring of tourist traffic is important in the management of natural protected areas and the planning of sustainable tourism. Initial research in the form of handbooks described the purpose and means of the monitoring of tourist traffic by way of visitor counting, visitor surveys, and reporting and interpretation of results (Kajala et al. 2000; Watson et al. 2000) in order to understand visitor motivations, preferences, and behaviour (Beunen et al. 2008; Konu and Kalaja 2012; Geoffrey et al. 2019). Furthermore there exist other types of visitor groups – especially in mountain areas: conservationist casual, contemplative, and active adventure visitors

² In this paper the word “tourist” means general of tourism phenomenon in study area.

(Farias Torbidoni et al. 2005); nature minded, sports-oriented and general-purpose hikers (Farias Torbidoni 2011). Yet other studies focus on determining the natural landscape preferences of visitors (De Lucio and Mubica 1994) and the experiences of visitors (Chhetri et al. 2004).

An important issue is the monitoring of visitors flow in national parks (Cessford and Muhar 2003) in order to determine priorities in national park tourism (Eagles 2014) in view of the increasing incidence of “overtourism” in national parks (Menzione 2018; Kruczek and Przybyło-Kisielewska 2018).

Such studies are performed for the purpose of visitor volume modelling (Cole and Daniel 2003) as well as the determination of the intensity of park use (Wolf et al. 2012) and the determination of the motivations and preferences of tourists in national parks. Visitor surveys also remain an essential tool in park visitor research (Wolf et al. 2012).

The details of trip itineraries needed to examine variation in tourism intensity at sites, especially if they vary on a fine spatial scale, may likely not be adequately captured. Nevertheless, surveys may provide additional, useful information for explaining travel patterns when they are combined with other monitoring methods (Wolf et al. 2012). Due to the mountainous nature of the study area, the review and discussion herein are limited to the publication of data from other mountain areas of Europe. Numerous monitoring techniques are described in previous research studies and can be grouped after Cessford and Muhar (2003) into four types: i) direct observations - using staff observers or camera recording; ii) on-site counters - devices recording and storing visitor counts; iii) visits registrations – counting permits issued or records in registers; iv) inferred counts - other data used to provide on-site estimates. Based on literature review further methods for visitors monitoring can be distinguished: direct observations by observers (Hartmann 1988; Keul and Kühberger 1997; Murphy 1992; Hibner et al. 2018), self-managed travel diaries (Fennell 1996; Thornton et al. 1997), self-counting techniques such as voluntary visitor registration (Watson et al. 2000), spatial patterns of itinerary mapping (Connell and Page 2008), using of on-site pyroelectric sensor (devices recording and storing on-site visitor count data)

(Hornback and Eagles 1998; Watson et al. 2000) and proxy measures (e.g., camping permits) from which visitor numbers may be estimated (Cessford and Muhar 2003), vehicle counting, automated pyroelectric sensor, and ranger observations (McIntyre 1999), using of statistical measures (regression analysis) (Hlavackova et al. 2018). Nowadays the use of electronic devices has become increasingly popular in visitor monitoring. Specifically in mountain areas, infrared traffic pyroelectric sensors have become prevalent, together with digital imaging and transmission technology (Kammler and Schernewski 2004 Guillen et al. 2008, Svajda 2009; Fairfax et al 2012). Greater use of other methods has also been observed including global positioning systems (GPS) (Shoval and Isaacson 2010, Taczanowska et al. 2014; Bielański et al. 2018, Rota et al. 2019); motion-sensing cameras (henceforth referred to as “camera traps”). The latter are used to gather data on tourists passing a given point along a trail (Campbell 2006; Miller et al. 2017) and on illegal tourism (Sitarz et al. 2018). Other tracking devices such as tourist timing systems (i.e., ankle-mounted transmitters monitored by receivers located in a network) (O’Connor et al. 2005) have also been employed. Arnberger et al. (2005) presented a comparison of visitor-monitoring methods evaluating their costs and data quality in order to recommend the best available methods. For automated methods, counter calibration is an important issue (Ross 2005; Oddgeir et al. 2013; Miller et al. 2017). Additionally, selected authors have presented a verification algorithm for visitor’s data (Farinas and Morera 2018; Hlavackova et al. 2018; Rogowski 2018b).

1 Material and Methods

1.1 Study area

Stołowe Mountains National Park (SMNP) is located in the Sudety Mountains in south-western Poland, along the border with the Czech Republic (Figure 1). The area is situated in the Variscan orogenic belt of Europe. The unique physical appearance of the Stołowe Mts. stands in stark contrast to many other mountains massifs in the Sudety Mts. due to the presence of nearly flat-lying, Cretaceous sandstone beds at relatively high

elevations. Therefore, the overall morphology of the area is of stepped tableland type, climbing from ca. 400 m a.s.l. to 919 m a.s.l. at the highest summit, which gives the mountain range a tiered geomorphological structure. “Normal” mountain relief, with closely spaced deep valleys and narrow watersheds also occurs in the Stołowe Mts. but is not associated with their sandstone bedrock (Migoń 2012).

The total area of SMNP is 6340 ha with ca. 100 km of hiking trails, 70 km of bike trails and 20 km of cross-country skiing trails and a few climbing routes. The SMNP was selected as the study area because of three following reasons:

1. Until recently, there was a lack of an accurate visitor’s data in the SMNP. Even though, the park is claimed as one of the most popular national park in Poland. The official statistics on the number of visitors were 286 thousand in 2016 (Environment, 2017), were highly inaccurate, and were assessed based only on the entrance fees counts. Entrance fees in SMNP are issued only in two the most popular attractions – Szczeliniec Wielki and Błędne Skały. As shown by the MSTT – see Results section – entrance fees counts represent approximately 60% of total number of visitors;

2. Park managers reported an increasing problem with the mass tourism. Park managers need an accurate visitor’s data in order to efficiently manage the tourist traffic in the park and to update the strategic documents;

3. The relatively small area of the park together with high-developed trail network and easily accessible trailheads make this park suitable for a comprehensive visitors monitoring and testing pyroelectric sensors.

1.2 Monitoring System of tourist traffic (MSTT)

The Monitoring System of tourist traffic (MSTT) in SMNP was established in 2016. The aim of the MSTT was to accurately quantify tourist traffic. Moreover the project aimed to evaluate the usefulness of the automated measuring system of visitor flow in a mountain area. The MSTT had the following measurement techniques:

- pyroelectric sensors mounted on each trailhead,
- questionnaire-type surveys to assess park visitors’ motivations, preferences and behaviour.

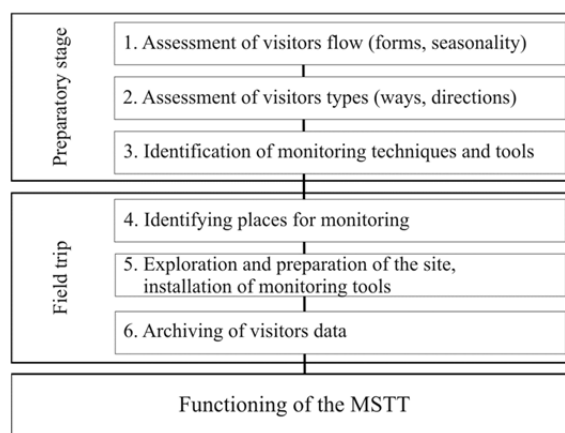


Figure 2 Scheme of the Monitoring System of tourist traffic (MSTT) in Stołowe Mountains National Park.

The creation of the system was preceded by a number of fieldwork tasks (Figure 2).

The preparatory stage included three tasks: assessment of visitor flow, visitor type and determination of monitoring method.

1.2.1 Assessment of visitor flow (forms, seasonality)

The first stage of research involved an assessment of forms of visitor flow in accordance with existing legislation in Poland. Then, the share of each type of flow in the overall tourist traffic structure was assessed based on available data. This step helped to assess the main forms of visitor flow to be covered by monitoring along with seasonality effects. In the study area, visitor flow takes the form of hiking, cycling, cross country skiing, climbing and driving. Hiking prevails within the studied national park and it is allowed throughout the year, with the exception of tourist trails in the area of Błędne Skały and Szczeliniec Wielki, which are closed in the winter. The car traffic is allowed all the time, but there is also a public road running through the park which serves the transportation needs of the local community. Cycling, cross country skiing and climbing are of secondary importance and are highly seasonal. In view of the above, it was decided to hiking monitor throughout the year. Other forms of tourism will be subject to monitoring in subsequent years.

1.2.2 Recognition of visitor flow types (ways, directions)

In the second stage of the MSTT the analysis included the assessment of a network of hiking trails and educational trails, and verification of

rules for tourist traffic in the park. In accordance with these, tourist traffic is only allowed on marked hiking, cycling, cross country skiing trails, educational trails and public roads. In the park there are: 11 hiking trails, 5 educational trails, 5 cycling trails, 3 cross-country ski trails, 5 public roads and 6 climbing areas. There are short sections where specific types of tourist trails come together, as a result of which the given trail is used by different types of tourists, e.g. hiking and cyclists. Moreover, certain sections of trails are marked one-way, and there is one section of road with one-way and alternating-direction car traffic.

1.2.3 Identification of monitoring techniques and tools

In the third stage, the final selection of monitoring techniques and tools was carried out. Identification of monitoring techniques and tools included both natural and infrastructural conditions of the national park: uniqueness of landscape features, network of tourist trails, location of the national park boundary, data precision, data processing capacity and tools maintenance. Previous visitors monitoring techniques (based on entrance fees counts) were not accurate. Therefore two monitoring techniques were chosen: i) infrared pyroelectric sensor (Eco-Counter sensors that allowed the measurements of visitors flow in both directions were utilized); ii) Pen-and-Paper Personal Interview (PAPI) surveys conducted in order to find out the visitor's motivations, preferences and behaviour. The selection of these monitoring techniques was based on pilot studies conducted. One pyroelectric sensor has been tested for two years preceding the MSTT and provided first quantitative assessment of visitors flow. As well PAPI surveys were performed in 2015. According to park managers the results of both pilot studies were satisfactory.

1.2.4 Identifying places for monitoring

In order to obtain valuable results corresponding to reality, it was crucial to analyse the studied network of hiking trails along with the location of the national park boundary to identify places to install counting devices. It was decided to install infrared traffic pyroelectric sensor on every hiking trailhead at the national park boundary and on parking areas located by the public road

running through the national park.

A total of 38 sites for the installation of pyroelectric sensors were identified: 22 at the national park boundary, 11 close to parking spots by the public road. An additional 5 locations for pyroelectric sensors were identified inside the park at sites with the most intense tourist traffic: 3 near Szczeliniec Wielki and 2 near Błędne Skały. All the devices were installed in 2016. One pyroelectric sensor had already been installed earlier on a trail inside the rocky-labyrinth of Błędne Skały. The scope of the data generated included hourly, daily, weekly, monthly, and annual reports, taking into account the direction of traffic measuring both directions: entries (IN), exits (OUT) and passages (IN+OUT).

As a result, data were collected using 39 pyroelectric sensors (Figure 1). There were five types of pyroelectric sensor locations:

1. on the national park border (22 pyroelectric sensor); counting visitor entrances (IN) and exits (OUT) into/from the national park ;
2. on tourist trails marked on public roads (11 pyroelectric sensor), counting visitor entrances (IN) and exits (OUT) from tourist trails from public roads inside the national park;
3. located at the most popular attractions (i.e., Szczeliniec Wielki, Błędne Skały) (6 pyroelectric sensor), counting visitors on one-way trails.

Approximately 936 hourly automated measurements were recorded every day in the course of the study. Data was downloaded from counting devices via Bluetooth technology through an application on a mobile device. Due to weak cell-phone reception in the study area the remote data download was not available. The data were analysed using a statistics spreadsheet.

The PAPI surveys were made in the area of the most popular attractions, i.e., Szczeliniec Wielki and Błędne Skały. These are the most attractive places in the park which would allow to assess the opinion of a large group of respondents. Tourist traffic in these areas includes both visitors who are inexperienced and experienced in nature conservation issues and those who do not know the specificities of the area as well as those who are experienced and informed about the park. The surveys were performed in 16 randomly chosen days, i.e. 8 weekdays and 8 weekends during each tourist season (i.e. in mid-spring, mid-summer,

mid-autumn and mid-winter). In each survey day, four interviewers were performed survey questionnaires from 9 a.m. to 5 p.m. In total there were c.a. 2500 survey questionnaires performed in period from 2016 to 2019. For the purpose of this paper 468 questionnaires from 2017 have been summarized.

The survey questionnaire consisted of questions designed to determine visitor socio-demographic structure as well as visitors' motivations, preferences and behaviour. Survey questions concerned issues such as ways of reaching the national park and its attractions, purpose of tourist visits and their duration, frequency of visits, names of the visited places, types and locations of tourist accommodation and catering facilities, and requested an assessment of the tourist offering in the region (Rogowski and Małek 2016).

1.2.5 Exploration and preparation of the site, installation of monitoring tools

As part of fieldwork, it was necessary to visit pre-selected sites in order to approve them and prepare each site for the installation of pyroelectric sensors. The installation of pyroelectric sensors involved their placement inside wooden poles or somewhere in natural field conditions (e.g., in rock cracks or tree trunks). Each sensor was mounted at 0.7 m height off the ground. Measurement points were selected taking into consideration the width of the trail and the maximum pyroelectric sensor detection range, which is up to 2 meters. The pyroelectric sensors were installed in places hidden from tourists' sight, which allowed the devices to count visitor passes in both directions. Right after installation, each device was checked for its ability to accurately transfer data.

1.2.6 Archiving of visitors data

The visitors data reading and transfer process required at each site an activation of the counting device and data transfer via Bluetooth to an application downloaded onto a mobile device. As data are registered in the pyroelectric sensor memory, it is possible to prepare a visitor flow report at various resolutions (i.e., hourly, daily, weekly and monthly) and distinguish between IN and OUT tourist passages. Data readings from each pyroelectric sensor were performed on a bi-monthly basis. In this paper only the sample data

from year 2017 are presented. This was done in order to highlight the utility of the MSTT and not to discuss the results of visitors monitoring itself. Details description of results was presented in previous works (Rogowski 2017a, b; Rogowski 2018a).

1.2.7 Functioning of the MSTT

Visitors data were summarized and presented in tabular form, whereas selected results were illustrated on a map. The frequency of entries was determined based on the location of pyroelectric sensor for different seasons and regions in order to determine fluctuations and the intensity of visitors flow in the park. For attractions near which no pyroelectric sensors were located, an algorithm was developed to calculate visitor traffic volume. In order to estimate the total number of visitors in SMNP the number of entries (IN) from 33 pyroelectric sensors located at the trailheads were summarized. Whereas, in order to estimate the total number of visitors in two the most popular tourist attractions - Szczeliniec Wielki and Błędne Skały – the number of entries (IN) from each pyroelectric sensor mounted at these attractions were considered.

Pyroelectric sensors data were subjected to on-site calibration. The on-site calibrations were performed during three daily campaigns executed in high, mid- and low season, i.e., mid-August, mid-October and mid-January respectively. This procedure consisted of manual counting of each visitor passing by two selected pyroelectric sensors. The measurements were performed from 8:00 AM to 6:00 PM on one heavily loaded (Szczeliniec Wielki) and one less loaded trail. In total, in three days there were 449 counts of visitor passes recorded on two measuring points. The results with errors range from the entire studied year were analysed in a report submitted to the national park's management and were also made publicly available.

2 Results

The data obtained from the MSTT allowed to produce a detailed description of tourist traffic in the studied national park as a whole (Table 1). The data collected by the MSTT enabled multidimensional analysis of visitors.

The first completed data of visitors flow were acquired for entire 2017 and 2018 year, and were previously presented in separate study (Rogowski 2017a,b; Rogowski 2018a). The results presented in this section aim to highlight the potential of the MSTT and not to characterize the visitor flow in the SMNP *per se*.

The visitors flow is distinguished by its strong spatial and seasonal concentration. In 2017 a total of 871,344 visitors were recorded to have visited the park. The SMNP is the second most popular tourist destination in the Sudety Mountains. It is one of the most popular national parks in Poland, as evidenced by the MSTT data. Almost 2/3 of the total visitors (511,303) were recorded in summer (i.e. from June 1 to August 31). July and August (380,350) generated 44% of the total annual number of visitors. The number of visitors recorded in spring, i.e. from March 1 to May 31

(211,077) was little more than the number of visitors recorded in July (190,517). Considering spring season, the highest number of visitors was recorded in May (162,840). This was due to high frequency of school groups visits. From May 1 to August 31 there were 674,143 visitors recorded, which encompassed 77% of the total annual number of visitors in the SMNP. This period constitutes the high tourist season. In autumn (i.e. from September 1 to November 30) and in winter (i.e. from December 1, 2017 to February 28, 2018) there were 111,828 (13 %) and 26,348 (3%) visitors noted in the SMNP respectively. The months of September, October and April generated mean monthly number of visitors from 35,000 to 60,000. These months represent the mid-season. The low season was represented by the period from November 1, 2017 till February 28, 2018 (Figure 3). Visitors flow seasonality obtain from pyroelectric

Table 1 Typology of visitors data collected by the Monitoring System of tourist traffic (MSTT) in Stołowe Mountains National Park

The data via pyroelectric sensors	The data via survey questionnaires
Number of visitor entries (IN) and exits (OUT) on tourist trails aggregated into annual, monthly, weekly, daily and hourly reports for the studied national park and for selected attractions	Socio-demographics of tourists (sex, age, origin)
Level of tourist attraction popularity aggregated for annual, monthly, weekly, daily and hourly periods	Motivation for tourist activity
Estimated time periods and sites with the largest and smallest numbers of visitors	Characteristics of tourist stay (ways of reaching the national park, purpose of visit, visit duration, frequency of visits, visited attractions, use of lodging and catering facilities and their location)
Tourist trail volumes	Evaluation of the local tourist offering
	Assessment of strengths and weaknesses of tourism in region

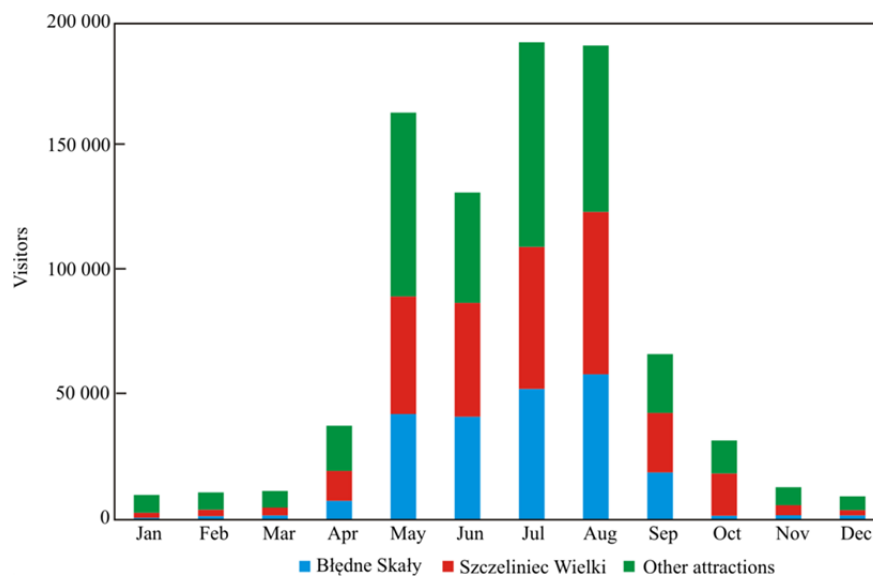


Figure 3 Total monthly distributions of visitors counts (entries only) in the Stołowe Mountains National Park in 2017. Visitor counts at two of the most popular attractions included Błędne Skały (black bars) and Szczeliniec Wielki (dark grey bars). Light grey bars represent all other monitored spots.

sensors was confirmed by the PAPI surveys, where 60% of the respondents decelerated (in multiple choice questions) summer visits, 33% spring visits, 28% autumn visits and 17% winter visits.

Holiday periods generated from 19% to 64% of the monthly number of visitors. These periods were associated with Christmas, New Year's, Easter, as well as holiday weekends in May (Labour Day), June (Corpus Christi), August (Assumption of the Virgin Mary) and November (Impendence Day). During these holiday periods, daily visitor counts were always the highest. In addition, the high season of school group visits was shown to be from the 16th to the 25th of May 2017 with almost 65,600 visitors, which accounted for nearly half of the monthly number of visitors (Rogowski 2018a).

The daily number of visitors in the SMNP in 2017 varied substantially. On average, there were 2,300 visitors per day. Maximum daily visitors exceeded 10,000 and were recorded during the following holiday periods (Table 2).

Daily visitor counts confirmed the division into a low, mid and high season. Medians for high seasons daily were from 4,000 to 6,000 visitors. The highest medians were noted for July and August. Maximum daily visitors in the high season were associated with holiday periods (Figure 4). Minimum visitors were higher than the maximum daily visitors recorded in the low season. Visitor counts for September and October were represented by a broader distribution and higher maximum values, however, with lower medians. The daily visitor count distribution in April was the broadest, which indicates the onset of the high tourist season, as shown by some of the highest daily maximum numbers of visitors recorded on April 30th. Medians for daily visitors in April were low. In three months, assigned mid-season, an increased number of visitors was noted specifically

Table 2 Days of 2017 with largest number of visitors in in Stołowe Mountains National Park

Date	July 18 th	May 1 st	May 2 nd	August 14 th	August 13 th	August 15 th	April 30 th
Visitors	1,822	13,359	13,169	12,323	11,318	10,557	10,211

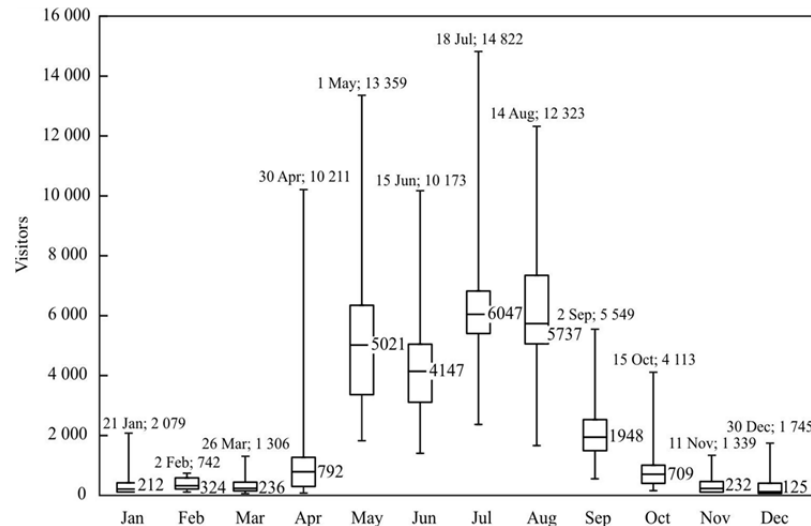


Figure 4 Daily visitors in the SMNP recorded of the Monitoring System of tourist traffic (MSTT) in 2017. The number and dates above each box plot indicate the maximum number of daily visitors in each month. Additionally, the median number of daily visitors in month is shown.

during weekends. Low medians and a narrow distribution of daily visitor counts indicated a low tourist season in January, February, March, November, and December (Figure 4).

Szczeliniec Wielki was a most popular attraction (Figure 5). In 2017 were recorded a total of 283,214 visitors. In Błędne Skały were recorded in while 231,209 visitors. This is confirmed by the statements of PAPI survey respondents who state that they visit these two tourist attractions most frequently: Szczeliniec Wielki (73% of respondents) and Błędne Skały (57%). More than half visitors were recorded in summer in Szczeliniec Wielki (168,656) and in Błędne Skały (152,830). August was the month when both attractions were visited most frequently: 65,464 visitors in Szczeliniec Wielki and 58,617 in Błędne Skały. Other attractions were less often visited, i.e. Skalne Grzyby (31,719 visitors), Narożnik (20,080), Radkowskie Skały (16,755) and Karol's Fort (8,602). These attractions were also mentioned in the PAPI surveys, i.e. Skalne Grzyby (7%), Narożnik (6%), Radkowskie Skały (3%), Karol's Fort (2%).

The results of the PAPI surveys have shown that 66% of respondents have visited the SMNP for

leisure-related purposes, 20% to nature-based tourism and 10% to pursue active tourism. The differences in responses depending on the season of the year were found to be minor. The greatest difference was reported for active tourism. Due to the low popularity of winter activities (in this case, cross-country skiing), this purpose of tourism was the least often reported by tourists in the park (1%). During other seasons of the year, 8% to 13% of survey respondents reported pursuing active tourism. Tourists' motivations for visiting have an important impact on the choice of destination. Tourists visiting SMNP usually arrive there by car (81%), which is facilitated by convenient and successively improved road infrastructure. A car is particularly popular among those travelling with their families (91%), while other tourists travel by public transport: by train or bus (about 10%). In comparison with a previous study, the number of visitors in the park increases every year; the latest data indicate that visitors flow in 2018 increased about 20%. These are mostly young people (up to 26 years old - 12%). For moving around the park area, the car remains the most frequently used means of transport given the under-development of public transport in the region. In 2017 the car was selected by 45% of survey respondents, but its share in subsequent years decreased in favour of increasingly common pedestrian access to main attractions; walking was the main mode of transport of 50% of survey respondents.

Initial research results revealed relationships between motivation, duration of visits and their place of residence. Leisure tourism was the primary motivation to visit the park for all the survey respondents. Tourists arrived to the SMNP from distant regions and stayed an average of 4 to 7 days. A secondary motivation to visit the SMNP was to nature-based tourism and active tourism. Tourists visited the SMNP most frequently in summer (68%) and spring (37%). This result was confirmed via qualitative monitoring by means of pyroelectric-

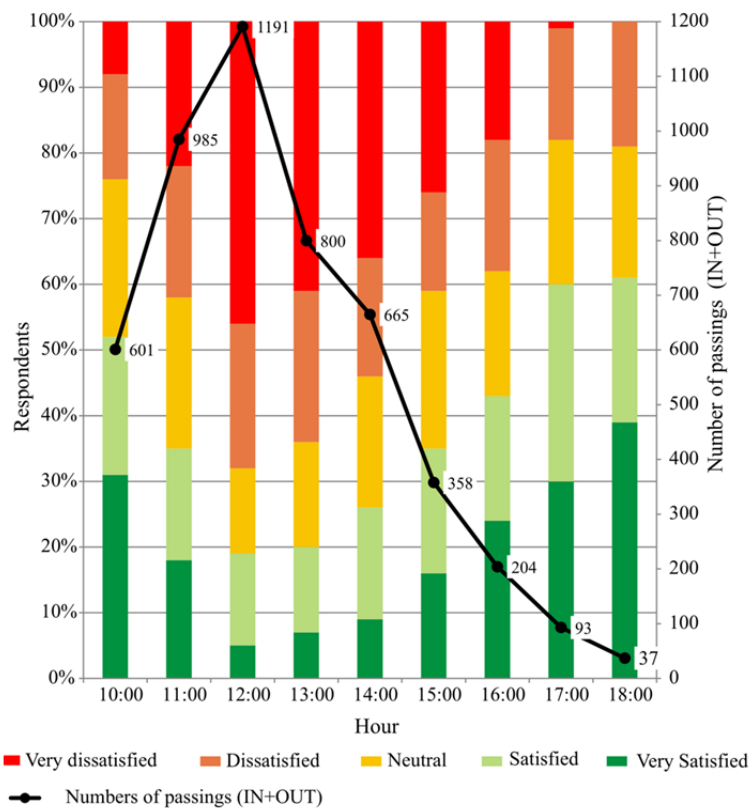


Figure 5 The relationship between the number of passings (IN+OUT) of the trail in Szczeliniec Wielki and the degree of tourist satisfaction. Additionally, the median number of monthly visitors is shown. (Source: Rogowski 2019)

electric sensor.

The pyroelectric sensors were not free from the measuring errors. According to auto-calibration works performed, conducted however in the Karkonosze National Park (Rogowski 2018b), the mean sensor error rate can be estimated at 10%. In the frame of the MSTT on-site calibration of pyroelectric sensors was performed. The results of on-site calibration conducted in the SMNP have revealed similar error rate. The highest differences between manual and automated pyroelectric counts have occurred in the periods characterized by the highest visitors flow. Erroneous counts were observed during groups passing when intervals between single visitors passing were shorter than 2 seconds. Among the 428 visitor's passes recorded during on-site calibration 44% have revealed errors. The maximum error, considering both over- and underestimations, has reached from 15% to 18%. The mean error rate was at a level of 10%. The visitors counts errors were not recorded for visitor's passes that occurred at the intervals longer

that 2 second as well for the groups smaller than six persons. The detailed description of on-site calibration results will be presented in separate study. The result of on-site calibration will help to verify error rate of visitors counts in the MSTT.

3 Discussion

The MSTT has provided comprehensive results on visitors flow in the SMNP. The advantage of the system is that it operates throughout the entire calendar year. Six stages of the creation of the MSTT were taken into account in the study. The most optimal methods, among those presented by previous authors (Cessford and Muhar 2003; Kajala 2007), were selected and applied in the MSTT. The combination of two main measuring techniques, i.e. monitoring by use of pyroelectric sensors and PAPI surveys, enabled a robust description of visitors flow in the SMNP. The author believe that presented methodology can be applied to other mid-mountain areas as a useful tool in the tourism management of the national park.

By juxtaposing individual entrances, one can determine the popularity of park attractions or indicate the spatial distribution of visitors in a national park and changes therein over time. The number of visitors according to MSTT application can be calculated based on monthly, daily, and hourly entries. This allows to produce a visitor entry model for park attractions of high, medium, and low popularity. Moreover, it is also possible to indicate the susceptibility of tourist traffic to seasonality with respect to particular attractions, distinguishing attractions with a high, medium and low degree of susceptibility to seasonality. Interpolating numerical data for trail sections one can determine the intensity of visitors flow, indicating sections with high, medium and low intensity of visitors flow.

The SMNP is a suitable destination for short breaks leisure visits in wilderness. Almost 2/3 of the total visitors (511,303) were recorded in summer. From 19% to 64% of the monthly number of visitors were recorded during holiday periods. The duration of high tourist season was established by monthly and daily visitor's counts and assigned to the period from May 1 to August 31. During

these periods the study area is subjected to masstourism. This was confirmed in PAPI surveys. Indeed, the problem of masstourism in the SMNP is increasing. In 2018 a total increase of 22% in visitors flow was noted in the park, whereas at Szczeliniec Wielki the increase of 32% was reported. The problem of overtourism in national parks is increasingly reported (Meziane 2018; Peeters et al. 2018; Kruczek and Przybyło-Kisieleska 2018; Simmonds et al. 2018; Milano et al. 2019).

Additionally the outcomes the MSTT were incorporated into Tourist Carrying Capacity (TCC) estimation. The TCC estimation was computed for two hiking trails including Szczeliniec Wielki and Błędne Skały (Rogowski 2019). The TCC estimations incorporated trail width measurements, plant habitats neighbouring the trail and tourists satisfaction (Figure 5). Finally, the optimal distance between the visitors on a trail was determined. The TCC estimations were compared with visitor number in hourly resolution obtain from MSTT i.e. pyroelectric sensors data. As a result periods exceeding TCC were distinguished together with interim limits in the park (Rogowski 2019). Propose limits will be tested in 2020.

4 Conclusion and Perspectives

The data collected by the MSTT enabled multilevel and robust characterization of tourist traffic in the SMNP. The MSTT data are continuously transferred to the national park managers allowing for adequate reaction in order to effectively manage tourism in the park area. Application of homogeneous measurement techniques across three years, enabled a data comparison between years and determination of tourist traffic trends.

The current functioning of the studied system requires a continuous monitoring of the condition of pyroelectric sensors and continuous reading of data.

The presented methodology of the MSTT could be applied to other mid-mountain national park areas. In order to sustain the MSTT methodology in the long-run the following guidelines and workload estimates should be taken into account:

- before selecting the monitoring techniques, landscape type and organization of tourist traffic in

the study area need to be analyzed. Both factors determine to the greatest extent the monitoring techniques and tools that will make the system more effective in providing reliable data;

- Visitors data acquisition from pyroelectric should be performed once per month, not less frequent;
- During each data acquisition campaign the sensors should be maintained, this mainly includes detectors cleaning and verification of potential wildlife and human impacts;
- Considering 39 pyroelectric sensor used in this study, the visitors data acquisition and maintenance of pyroelectric sensors required ca. 36 mandays, i.e., 288 hours of field work annually;
- Additionally, time required for trouble-shooting activities has to be taken into account (i.e., sensor replacement and mitigation of unexpected wildlife and human impacts). In this study this consumed in average 10 mandays, i.e., 80 hours annually;
- Visitors data calibration is highly recommended. On-site calibration campaigns should be performed in a first measuring year at least three times, i.e., once per high, mid- and low season. The calibration should encompasses at minimum two pyroelectric sensors, for e.g. those mounted at heavily loaded and less loaded trail. In this study the on-site calibration was performed on two trails and consumed 6 mandays, i.e., 48 hours;
- All estimates of required workload in relation to system maintenance have to consider the average access time between the pyroelectric sensors. In this study this time was very short and equaled 30 minutes;
- it is recommended that well-trained and the same person is delegated to system maintenance in a long-term;
- Visitors data processing require statistical tools. Data analyses should be performed in close collaboration between research sector or academia and park managers.

Major limitation of the MSTT could consider financial aspect of the system, specifically the costs of high replication of pyroelectric sensors. Additionally, for some park managers required mandays for MSTT maintenances and data acquisition might be consider as limitation. Both

limitations could be potentially overcome by long-term planning of the MSTT application in a given area, including external grants contribution.

In total 39 pyroelectric sensors were used in this study. High replication of measuring devices allowed for continuous visitors monitoring performed on each trailhead. To my knowledge this might be the first application of such high number of pyroelectric sensors being used in a single study area. Giving a large number of devices used, the results of the MSTT could be useful in the follow up-studies, such as:

- Spatio-temporal characteristic of visitor flow in various temporal resolutions, such as annual, seasonal, monthly, daily and hourly;
- Identification of visitor types in national park including socio-demographic characteristics, visitors motivation and behaviour. The visitors trends can be analysed among years. As a product, list of recommendations for local tour operators and policymakers can be provided in order to create a more sustainable tourist offer for the Stolowe Mts. cross-border region;
- Modelling and forecasting visitors flow using correlation matrix between daily pyroelectric sensors data. Both studies can be helpful in detecting incorrect data and/or imputing the missing values;
- Estimation of economic impact of tourism in a given region and role of visitors types in local economy for example: accommodation and gastronomy sectors, local air-crafts businesses,
- Calculation of Tourism Carrying Capacity (TCC) of trails network in the national park in order to monitor the masstourism and potential of overtourism.

Further work on the development of the MSTT should be connected with the monitoring of other forms of tourist activity in the national park, i.e. climbing, cycling, cross country skiing. This will provide a holistic characteristic of tourist traffic in the study area. In addition, the MSTT should also aim to monitor illegal tourism, determined its magnitude, structure and spatial patterns. This is especially the case of unmarked paths, where trespassing remains a recurring problem. Considering a multilevel aspect of the MSTT, the system provides powerful tools for tourism management in national parks.

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