Visitor Counting with Acoustic Slab Sensors in the Swiss National Park

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Keywords: Visitor counting, acoustic slab sensor, Swiss National Park, walking experiments.

Introduction

Monitoring of visitor flow in recreational parks is important to various tasks of management, e.g. to assess the impact of visitors to the nature, to get information about the signification to the regional market or to estimate the demand trends for the future (Cessford & Muhar 2003). However, data acquisition is a very time-consuming and money-intensive assignment. There are three main categories of data collection methods: self-counting, direct-counting and indirect counting (Hollenhorst et al. 1992). Depending on the goal of visitor monitoring, different data collection types are used. Self-counting methods are quite uncertain because their backflow is low. With direct-counting methods a lot of information, such as visitor characteristics, visitor behaviour and visitor numbers can be collected. The disadvantage of these methods is their big costs. A lot of human resources are needed to collect data. Indirect-counting systems generate simple estimations of recreational use, which are quite accurate after calibration (Hollenhorst et al. 1992).

The Swiss National Park (SNP) is situated on the extreme south east of Switzerland, on the border to Italy. The Park was established in 1914 as the first national park of the Alps and of central Europe. Its aims are total protection of nature and research. It covers an area of 172 km2 and has 80 km of public accessible hiking trails. Many research programs concerning various themes of natural environment without direct influence of humans are taking place in the area. So far, there was only little research of visitor use and distribution. Any use of the park, except hiking, is prohibited and it is strictly forbidden to leave the trails. That makes it easier to use an indirect-counting system. The last visitor counting in the Swiss National Park originates from the years 1991-1993 (Lozza 1996). However, since these investigations, some outer circumstances changed (e.g. new direct railway-line into the region) and the technological development progressed. In summer 2005 the SNP started a new visitor monitoring experiment with a pilot project. At four places in three different valleys of the park indirect-counting systems with acoustic slab sensors were installed. For two days in July, human observers counted the visitors who passed the sensors on every counting site. This data was used for checking and calibrating the counting system.

Main questions

In this survey the calibration process of the automatically collected data will be presented. Furthermore, main problems of miscounting will be figured out to improve the application and the handling of such acoustic slab sensors. Recommendations to get more exact data will be elaborated. Furthermore the number of visitors of the SNP during the year 2005 was estimated and will be discussed on the basis of the collected data.

Methods

Four acoustic slab sensors were installed in the first days of July at Mingèr and Margunet Valley and two at Trupchun Valley. The sensors consist of two pressure sensitive slabs. According to the manual of the manufacturer they are buried under an 8 to 10 cm thick layer of soil. Each slab has a socket on which it is connected to a data logger. The system registers the visitors hourly. To calibrate the sensors and check the accuracy of the automatically collected data, simultaneous counting by man during two days was performed, on Monday and Tuesday the 18th and 19th of July 2005. Each day there were observations from 8 a.m. until 6 p.m. The observers counted people who passed the system and kept an eye on their passing behaviour.

To estimate the number of visitors in the SNP, the automatically imposed data must be calibrated. For that reason the number of visitors observed was divided by the number of automatically registered visitors. This factor is used as a calibration factor (Ross 2005). To calculate a consistent calibration factor, the mean of every hour can be used (Formula I). As there were no evident reasons to explain the outliers with an index bigger than 1, they were also used to calculate the calibration factor.

a: automatically collected data with acoustic slab sensors

cf: calibration factor

m: manually collected data

$$\text{I.} \quad cf = mean\left(\sum \frac{m}{a}\right)$$

Based on the data of the counting days and estimations about visitor distribution in the SNP for the year 1993 (Lozza 1996) the total number of visitors for the whole year 2005 (with the assumption of a similar visitor distribution) was calculated. The sensors were located near the four main entrances of the SNP. On the counting days more sites and directions were observed than the sensors covered. On each site the total number of visitors on these days was compiled. The comparison between the estimated persons on the site and the number of people that passed the counter leads to another correction factor. It is described in Formula II.

a: automatically collected data with acoustic slab sensor

cf: calibration factor

s: number of visitors that passed the sensor site

t: total number of visitors in the valley on counting days

T: estimated total number of visitors

$$\text{II.} \quad T = cf * a + \left(\frac{t-s}{s}\right) * cf * a$$

Lozza (1996) figured out that the four sites cover about 65% of all visitors in the SNP. So the visitor numbers as calculated in Formula II were divided by 0.65.

According to the passing behaviour of the visitors and the results of visitor monitoring in SNP, hypotheses were formulated and tested with walking experiments. The loggers are assumed to work correctly. The hypothesis concerned the following questions:

- What is the sensitive area of the counter?
- How does step length affect the counting?
- How must groups pass the sensor to be counted correctly?
- Does composition of covering material affect the sensors counting?

For the experiments the sensors were installed on three different locations covered with different material. Before covering, the exact position of the panels was flagged to test the stepping sensitivity on the edge and near the counter. To test the sensitivity for groups, the group sizes and distance between the hikers were varied. The test persons carried a stick of a given length to keep the distance between them constant. In another experiment artificial boundaries were constructed to force the hikers walk in line. The experiments consisted of 10 repeated exceedances. Experiments of bigger groups were not repeated 10 times, but read off after every exceedance.

Results

Visitor counting in the Swiss National Park

To calibrate the sensors counting visitors in SNP, the automatically and manually counted data were compared. The results show quite a big deflection and data is not very constant. On the x-axis in Figure 1 the number of manually counted visitors is shown. On the y-axis is an index that represents the division of automatic counts by manual counts. An index below 1 indicates sensor under-count and indices above 1 represent sensor over-count.

Except for some over-estimates, when there were few visitors, the counting sensors always measured fewer visitors than really passed. Particularly when a lot of visitors passed the system the counting seems to be constant by an index of about 0.5. Causes of under-estimates could be visitors with very long stride who step over the sensors, visitor passing in groups even side by side or with very small distance among each other, or the counter can become less sensitive if the soil above is frozen or very compact (Ross 2005). If the path is too wide, visitors can miss the sensors and are not recorded. Another problem may be caused by the time synchronisation. The sensors count people hourly. Hikers who pass the system on clock hour may be counted manually for the previous and by the sensors for the following hour. Probably this was the problem on site Trupchun 1, where an index greater than 2.5 was calculated (Figure 1). There was a quite big over-count from 3 to 4 p.m. and an under-count during the hour before. When there are more visitors per hour this problem cannot be figured out. Other reasons for over-counting by the sensors may be people crossing the slabs very slowly, or even turning over. As the sensors were placed near crossings, tourists who are not sure where to go may act as described. Walking experiments in the following section will give more information about the counting problems.

In Table 1 the difference between the two data collection methods are shown. On site Mingèr and Trupchun 2 the mechanical under-estimate was very high. Less than 50% of the actual visitors were counted by the sensors. Causes of miscounts are described above.

The calculated correction factors range between 2.28 and 1.63 on the four observation places. The quite big (but not significant) differences on the four sites show that the under-estimates are not a bias of the sensors itself, but are specific for the sites. There must be differences in outer circumstances or in the composition of visitors. Outer circumstances could be wrongly installed sensors, the depth in which the sensor is buried, the path width or the sort of the material that covers it (Muhar et al. 2002).

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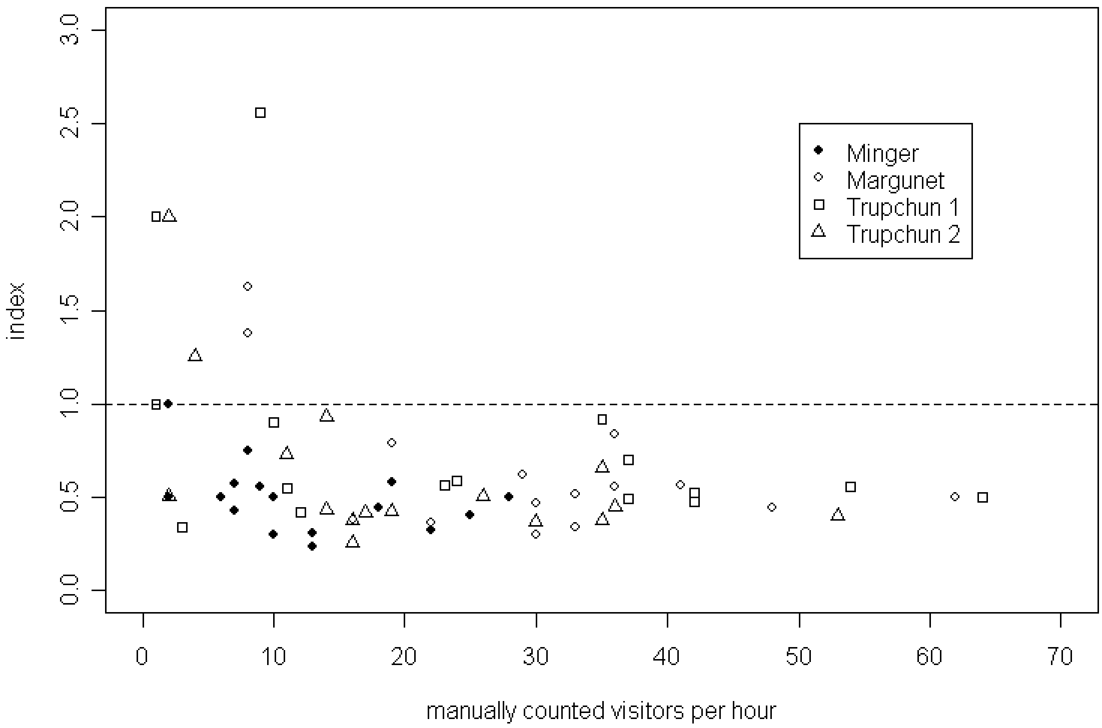

Figure 1: Comparison of manually collected data with automatic data collection. The index is calculated by the division of automatically and manually collected data. An index below 1 represents an under-count by the sensor.

Table 1: Collected data, deviance and calibration factor on 2 observation days in July.

Observation Sites	Total of manually counted visitors	Total of automatically counted visitors	Percentage of automatically counted visitors	Calibration factor (cf)
Mingèr	201	90	44.8%	2.28
Margunet	469	255	54.4%	1.81
Trupchun1	405	254	62.7%	1.63
Trupchun2	330	159	48.2%	1.96

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Total of visitors for the year 2005

The calculation of 110‘000 visitors for the year 2005 is lower than the last estimations (Figure 2). It must be considered that the bases of the estimations are different for the 3 years. In 1991 the estimation of 250‘000 visitors per year based on just two counting days in August. Possibly the good weather on these days resulted in an over-estimation. Already Lozza (1996) could not approve a visitor number of 250‘000. In 1993 the visitors were counted on 15 days (Lozza 1996). Lozza estimated 150‘000 visitors for the year 1993. Counting over the whole period gives lower visitor numbers than extrapolation of some test days. A peculiarity of the observed data in the year 1993 is the fact that a very popular program to settle bearded vultures in the SNP has been carried out. Also in 2005 there was a bear as special attraction that may have increased visitor numbers. The error bar of the estimation in 2005 describes the confidence interval of the correction factor (cf).

Comparing the observations of the year 1993 with 2005, a trend for future attendance could be ventured. Because the type of data collection differs for 2005 it is difficult to give a secure statement. Highly decreasing visitor numbers are not expected. As the insecurity of the calculation reaches the number of 150‘000, the visitor numbers are expected to be slightly decreasing or to remain constant for the last decade.

Experimental sensor tests

The sensitivity of the sensors was tested with walking experiments. The main results of the experiments are listed in Table 2.

The experiments of stepping on the slab border demonstrate that the sensor can not detect every passing hiker. The deviance is not very big. The sensor is less sensitive on the side with the sockets, where it missed 10 hikers out of 100. On the opposite side without sockets, the miscount is just half as big.

Big step length may cause problems for the counter but only for very long strides (Ross 2005). For a step length of 80 cm the deviance is 4 percent. Short steps do not cause any deviance. Stepping between the two slabs did not provoke any miscount either.

The manufacturer declares that children heavier than 10 kg trigger counting. Our experiments with two children approve this information only partly. A child that weighs 14 kg provoked an under-counting of 13 percent, which is a significant miscount. A child of 22 kg was always counted accurately.

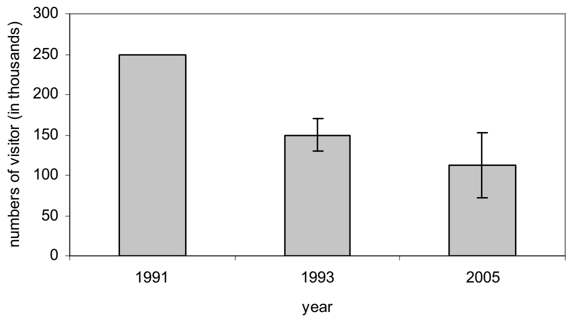

Figure 2: Estimations for visitor numbers in the SNP. The data is based on two observation days in 1991, 15 days in 1993 and 4 months of automatic counting in the year 2005.

Table 2: Mean deviance between sensor counting and passing experiments.

Number of repetition	Total observations	Experiment	Mean deviance
10	100	step on border of sensor (socket side)	10%
10	100	step on border of sensor (opposition side)	5%
10	100	step on border of sensor (both sides)	8%
10	100	step length 80cm	4%
10	100	step length 30cm	0%
10	100	step between two sensors	0%
10	100	hiker with sticks	0%
5	50	children (22kg)	0%
5	50	children (14kg)	14%
10	200	2 persons 100cm distance	0%
10	200	2 persons 80 cm distance	42%
10	200	2 persons 60 cm distance	32%
10	300	3 persons 80 cm distance	16%
10	400	4 persons 80 cm distance	13%
10	60	6 persons in group	53%
10	60	6 persons in line	13%
10	70	7 persons with boundaries	6%

If the distance between two persons is one meter and more, the counting is correct. With less space between hikers there is a quite big deviance of up to 40 percent. Walking in line with less than 80 cm distance is not very comfortable. But if the path is wide enough for hikers to walk at least partly side by side it is very probable that they walk closer. If the distance between persons is too small for the counter it does not matter how close they walk. Groups of three and four persons with small distance provoke fewer miscounts than groups of two persons. Probably it is more difficult to keep the distance constant. Furthermore, a group of three and more persons triggers at least twice. If a group passes the sensor side by side the counting is not correct. A deviance of over 50% was measured for a group of 6 people. If the same group walks in line as close as possible, the deviance is much smaller. It is very interesting that the experiment with 7 persons walking as close as possible with boundaries is quite correctly counted by the sensor. That means, with boundaries people can not walk closer than one meter, neither do they step beside the slabs. A problem for recreational areas such as the SNP is that the boundaries must be natural or designed inconspicuously, in a way that neither tempts children to play and provoke an over-count nor allows people to walk closely together or side by side to provoke under-counts.

Table 3: Experiments with different type cover material.

Number of repetition	Total observations	Cover material	Experiment	Mean deviance
5	50	Soil and gravel	Normal walking	0%
5	50	Soil and gravel	Step on border of sensors (side without socket)	2%
10	100	Soil and wood chips	Normal walking	0%
10	100	Soil and wood chips	Step on border of sensors (side without socket)	46%
5	100	Gravel	Normal walking	4%

Further research

It is important that the sensors always work properly during the whole season. They must be checked regularly. Ross (2005) mentioned the problem of frozen ground that can provoke under-counts with such sensor systems. In the test period it was not possible to check this situation. Another question concerns the verification of the 65% (Lozza 1996) of total park visitors that can be reached with the four test sites. For further calibration work a proper observation of the time synchronisation between the observers and the sensors is recommended.

Conclusion

For every sensor on each site calibration must be performed (Ross 2005). The calibration may be realized together with visitor interviews to perform visitor surveys at the same time. For the calibration, special regard should be spent on the time synchronisation between the observers and the sensors.

In the year 2005 there were 110'000 estimated visitors in the SNP, which is less than the number of visitors in the year 1993. The data collection was different. Nevertheless, the total number of visitors slightly decreased or remained constant over the last decade.

The results of walking experiments with acoustic slab sensors showed that they perfectly count single persons who step in the centre of the sensors. Under covering material of soil and gravel the sensor detects persons passing on the border of the slab. But the sensor is less sensitive on the sides of the sockets. Long steps may affect the counting accuracy (Ross 2005), but with steps up to 80 cm there are no incisive problems, even if the hikers step only in the middle of the two slabs. Children lighter than 15 kg may not be counted correctly. Groups affect the counting most. If persons are walking very close together, with a distance under 1 meter, they are often counted as just one person. The hikers must be forced to walk in line. If there is not enough space to walk side by side, their distance normally is in the sensitive band of the counting system. It is recommended using even natural boundaries or, if such obstacles are not available, to construct light artificial railings that do not encourage to be played with. For example, such railings could be wire fences.

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