# Carinthia II

Part 3

## Nature Tech

Published since 1811
214th Year of Carinthia

Volume 1

Issue 1

2024 Verlag des Naturwissenschaftlichen Vereins für Kärnten

# Improvement of accuracy of different automatic visitor counting devices to monitor cyclists in conservation areas

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**ABSTRACT**

Conservation area managers face increasing challenges in balancing nature-based tourism with environmental protection, as visitor activities diversify and tourism grows in recreational and protected areas. To address this, effective visitor monitoring is crucial for identifying spatial and temporal hotspots of use and potential conflicts that could threaten conservation goals. In this context, a field test on a mountain bike trail near Villach compared the functionality of two automatic visitor counting technologies: an infrared counter and a magnetometer. A wildlife camera recorded videos of passing mountain bikers, serving as the "ground-truth" for the experiment. The infrared counter, detecting infrared wavelengths emitted by people or animals, and the magnetometer, sensing metal parts of bicycles, were evaluated for accuracy. Over 28 days, the wildlife camera recorded 4,004 cyclists. The magnetometer undercounted by 9.6%, while the infrared counter undercounted by 32.8%, with increasing inaccuracy on busy days. A linear regression model provided correction factors, with the magnetometer showing higher prediction accuracy. The study suggests that the magnetometer is more reliable for counting cyclists, but both technologies suffer accuracy issues with higher visitor traffic. Wildlife cameras, while useful, require careful data management and privacy considerations. Future tests could focus on differentiating between hikers and cyclists using these technologies on shared trails.

## Verbesserung der Genauigkeit unterschiedlicher automatischer Besucherzählgeräte zum Monitoring von Radfahrer:innen in Schutzgebieten

**ZUSAMMENFASSUNG**

Manager:innen von Schutzgebieten stehen vor zunehmenden Herausforderungen, Besucheraktivitäten sowie den Schutz von sensiblen Gebieten in Einklang zu bringen. Dies liegt einerseits an einer Diversifizierung von Besucheraktivitäten sowie andererseits an einer generellen Zunahme des Tourismus in Freizeit- und Schutzgebieten. Um dem entgegenzuwirken, ist ein effektives Besuchermonitoring entscheidend, um räumliche und zeitliche Hotspots sowie potenzielle Konfliktbereiche zu identifizieren, die die Naturschutzziele gefährden könnten. In diesem Zusammenhang wurde in einem Feldtest auf einem Mountainbike-Trail in der Nähe von Villach die Funktionalität von zwei automatischen Besucherzähltechnologien verglichen: einem Infrarot-Zählgerät und einem Magnetometer. Eine Wildkamera zeichnete Videos von vorbeifahrenden Mountainbikern auf, die als „Ground-Truth" für das Experiment dienten. Der Infrarot-Zähler, der Infrarotwellen erkennt, die von Menschen und Tieren ausgestrahlt werden, und der Magnetometer, der Metallteile von Fahrrädern detektiert, wurden auf ihre Genauigkeit getestet. Über einen Zeitraum von 28 Tagen zeichnete die Kamera 4.004 Radfahrer auf. Der Magnetometer zählte 9,6 % weniger, während der Infrarot-Zähler 32,8 % weniger Radfahrer erfasste, wobei die Ungenauigkeit an stark frequentierten Tagen zunahm. Ein lineares Regressionsmodell lieferte Korrekturfaktoren, wobei der Magnetometer eine höhere Vorhersagegenauigkeit zeigte. Der Versuch legt nahe, dass der Magnetometer zuverlässiger für die Zählung von Radfahrern ist, jedoch beide Technologien bei höherem Besucheraufkommen Genauigkeitsprobleme aufweisen. Wildkameras, obwohl nützlich, erfordern ein sorgfältiges Datenmanagement und Berücksichtigung von Datenschutzaspekten. Zukünftige Tests könnten sich darauf konzentrieren, Wanderer und Radfahrer auf gemeinsam genutzten Wegen mit diesen Technologien zu unterscheiden.

## INTRODUCTION

Land managers experience an increasing popularity of nature-based tourism in recreational and conservation areas (CAs). With the increasing demand and diversification of visitor activities, keeping the balance between touristic destination development and environmental protection is a difficult challenge [1]. Visitor monitoring has become an important management activity to understand spatial and temporal hotspots of activity and to identify conflict areas where visitor activities may compromise conservation objectives. Diverse methods and data sources are being used to understand visitor movements. These include traditional methods like manual counting, visitor surveys as well as the use of indirect data and more technology-based methods. Such methods include the use of automatic visitor counters, GPS loggers, and the analysis of digital data, for example from outdoor and fitness apps or passive mobile data from mobile network providers [2].

A variety of automatic visitor counter technologies are deployed to count the frequency of visitors. For example, infrared sensors detect the body temperature of visitors passing by. Pressure mats detect pedestrians walking over them. For the monitoring of bicycles, electromagnetic bands or pressure tubes are buried in the ground. Magnetometers, which detect changes in the electromagnetic field when a bicycle passes, are another type of visitor counting technology. Some devices are equipped for bidirectional counting, and combinational sensors aid in distinguishing between hikers and cyclists. Moreover, cameras, supplemented with algorithms for counting, find application in monitoring visitors within CAs. The process of data retrieval varies widely: some devices send data via GSM or satellite connection in real-time to desktop apps or transmit data via Bluetooth in the field. Others require physical connection to portable docks for data transmission [3], [4].

Ryus et al. [5] and Ozan et al. [3] evaluated currently deployed visitor counter technologies for counting pedestrians and cyclists in urban contexts. They analyzed the benefit-cost-ratio of various devices and pointed out given limitations as well as operational requirements of these devices. Ozan et al. [3] provided a list of state-of-the-art technologies, with products from companies like Chamber Electronics, Eco-Counter, MetroCount, and TRAFx .

Prior to the selection of the most suitable counter technology for a specific site, CA managers are advised to clearly outline the scope (i.e., location, data transmission, etc.) of their objective and desired product features [6]. Factors like practicality and ease of use of the device and accompanying software, precision and reliability of data, compatibility with already existing technology and cost-effectiveness play a pivotal role [3]. When the selection process is complete Andersen et al. [7] advise testing the counter devices to get familiar with its functionality and to determine the accuracy and consistency of data derived at the individual location. For most devices the delay time as well as the sensitivity of sensors can be adjusted to meet the on-site requirements. Additionally, correction factors can be used to diminish undercounts or overcounts.

Factors that influence the accuracy and consistency of the data and may require calibration or the use of a correction factor include: 1) the location; 2) the time interval between passersby and group sizes; as well as 3) air temperature [7], [8]. For infrared counters, Andersen et al. [7] recommend choosing locations that enable only one person to pass the counter at a time to improve the counting accuracy. If not, there may be a significant undercount if one person blocks the sensor while other people walk by.

In this article we investigate the use of different monitoring technologies for counting bicycles along a mountain bike single trail near Villach. The aim of the test is to get familiar with the devices and to assess their accuracy at the selected location. With the results we calculate correction factors to improve the accuracy of the tested devices.

## METHODS

Two counter technologies were tested in an on-site field test at a popular mountain bike single trail in the region of Villach: TRAFx (TRAFx Research Ltd., Canmore, AB, Canada) Infrared Trail Counter, which is triggered by the infrared radiation emitted by people and animals that pass by, and TRAFx Vehicle Counter, which is a magnetometer that detects


**Fig. 1**

**Figure 1:** Counting device locations on mountain bike single trail and snippet of wildlife camera capture with marked positions of counter devices. Source: own figure

***Abbildung 1:*** *Standorte der Zählgeräte auf der Mountainbike-Strecke und Schnappschuss der Wildkamera mit markierten Positionen der Besucherzählgeräte. Quelle: eigene Abbildung*

passing objects through sensing changes in the magnetic field. Videos taken of the mountain bikers from behind with a wildlife camera (Patriot model, Browning Arms Co., Morgan, UT, USA) were manually evaluated and served as the "ground-truth" data of the experiment.

The first tested sensor, the infrared counter, detects the infrared wavelength that people emit. According to the producer it can be used for purposes of counting visitors who do activities like hiking, jogging, inline skating or biking [9]. The second sensor, the magnetometer, detects passing cyclists and vehicles by recognizing their metal parts such as pedals or chains [10], [11].

In August 2023 the devices were installed for a duration of 28 days. The magnetometer was buried next to the trail in a plastic box (80 cm distance to the opposite trail side) and the infrared counter was positioned on a tree 1 m above the trail surface (1.5 m distance to the opposite trail side). The wildlife camera was installed longitudinally to the trail and recorded 5-second videos with a line of sight of around 10 m along the trail (Figure 1). The camera recorded cyclists from behind which avoided the identification of individuals.

## RESULTS

During the test period (28 days) the wildlife camera recorded 2,826 videos, consuming a total of 81.7 GB of storage. The 8 AA batteries had to be changed two times during the test period with around 25 percent of battery capacity left when we changed them. The

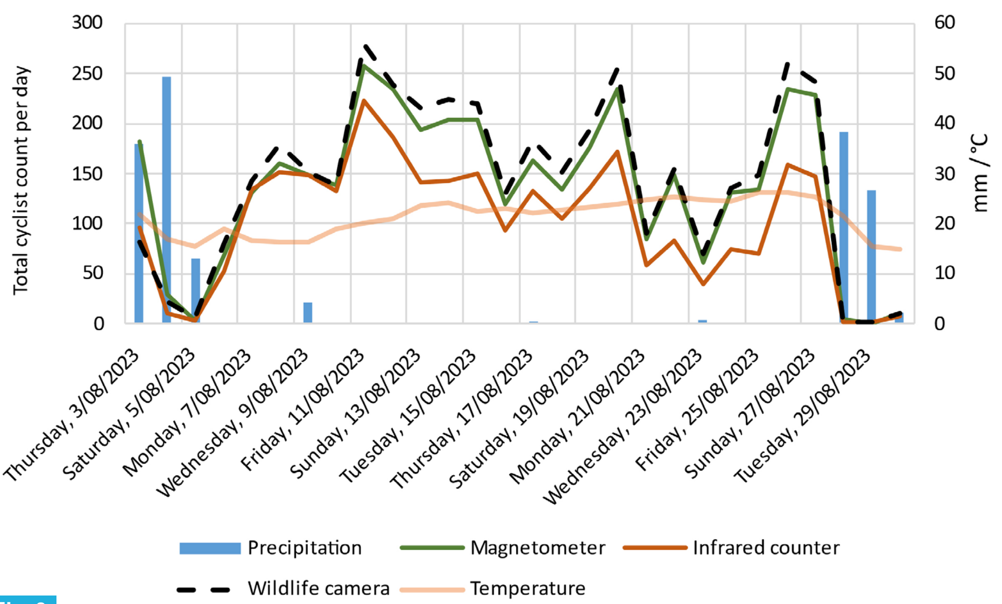


**Fig. 2**

**Figure 2:** Daily variation in cyclists' counts on the mountain bike single trail, as well as daily temperature and precipitation from Villach weather station. The comparison of daily counts with wildlife camera data shows the highest undercounts on highly frequented days. Source: own figure

***Abbildung 2:*** *Tagesgang der Besucherfrequenz auf dem Mountainbike Single Trail, sowie Temperatur und Niederschlagsdaten der Station Villach. Der Vergleich des Tagesgangs mit der Wildkamerazählung zeigt die höchste Unterzählung an stark frequentierten Tagen. Quelle: eigene Abbildung* data were manually evaluated by a trainee and considered as “ground-truth” data. In total, 4,004 cyclists, 10 pedestrians, 3 dogs, 1 deer and 7 e-scooters were recorded by the wildlife camera on the trail. The magnetometer undercounted 9.6%, and the infrared counter undercounted 32.8% of cyclists with an increasing undercount with higher visitor numbers.

For the statistical analysis, SPSS software (IBM Corporation, Armonk, NY, USA) was used. Zero values of the wildlife camera and outliers from the counters were removed from the data set. The daily counts were compared with meteorological data (temperature and precipitation) from a nearby weather station (Villach). While the infrared counter varied

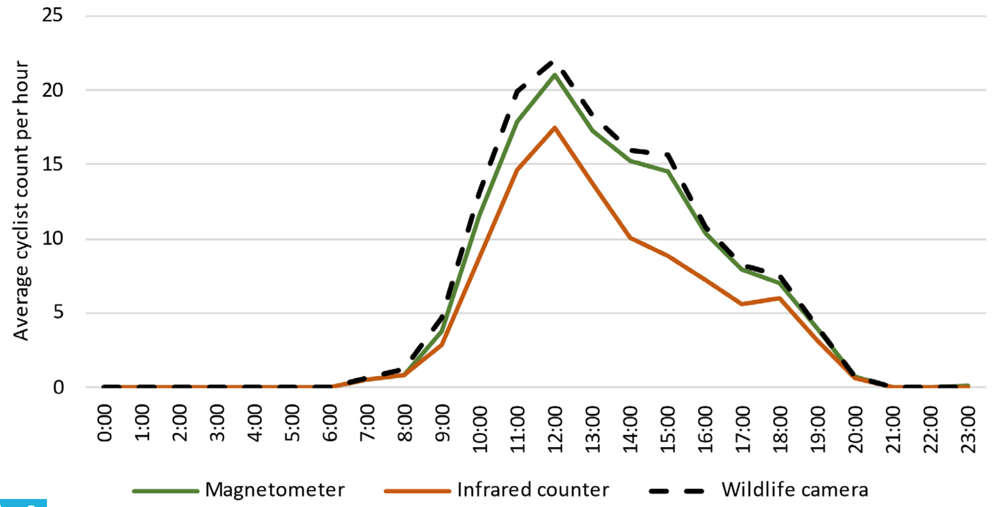


Fig. 3

**Figure 3:** Average count of mountain bikers in the course of the day. The average hourly counts show a similar trend as the daily variations with highest undercounts around the highly frequented midday hours.
Source: own figure

***Abbildung 3:*** *Durchschnittliche Zählung von Mountainbikern im Tagesverlauf. Die durchschnittliche Anzahl zeigt einen ähnlichen Trend wie der Tagesgang mit der höchsten Unterzählung an den stark frequentierten Stunden um die counts.*
*Source: own figure*

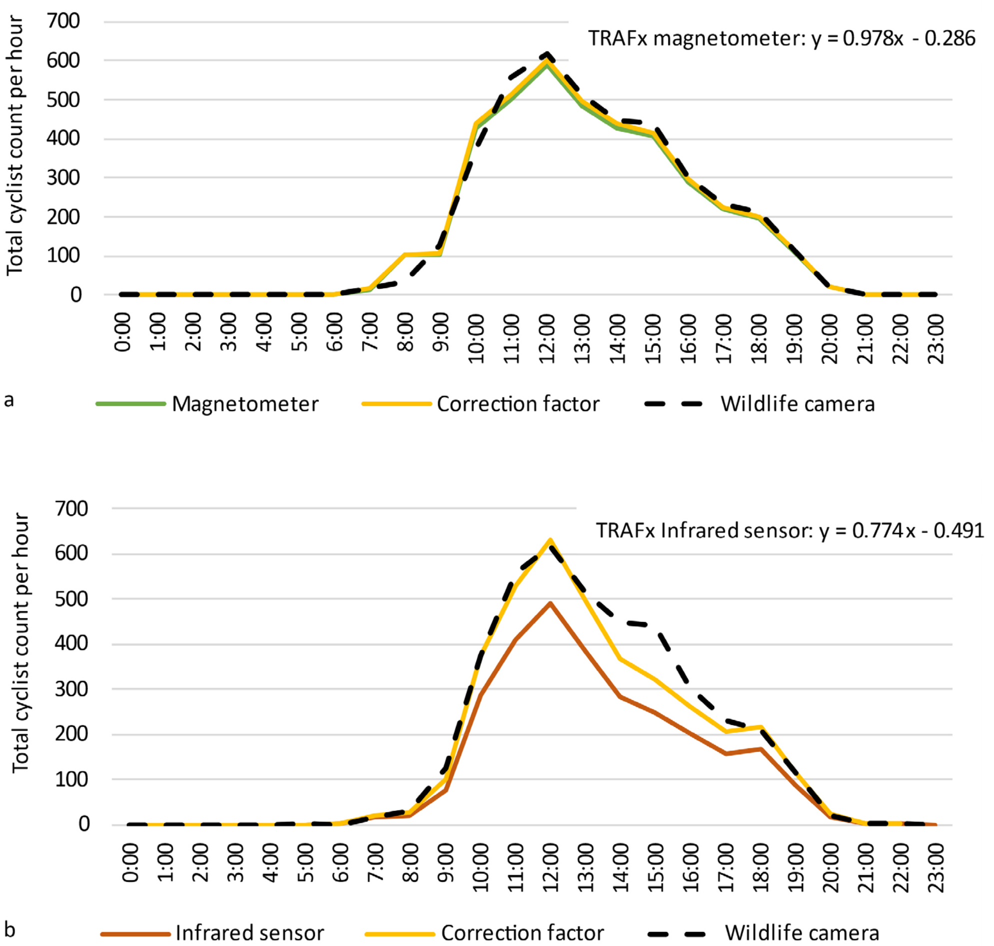


Fig. 4

**Figure 4:** Total daily count of mountain bikers using the correction factor of the linear regression: for the magnetometer (a); for the infrared counter (b). The yellow lines represent the corrected hourly counts.
Source: own figure

***Abbildung 4:*** *Gesamtzahl der Radfahrer pro Stunde mit Verwendung des Korrekturfaktors der linearen Regression: für den Magnetometer (a); für den Infrarot Zähler (b). Die gelbe Linie repräsentiert die korrigierten Stundenwerte.*
*Quelle: eigene Abbildung*

strongly on highly frequented days, the magnetometer only showed slight deviations (Figure 2).
Regarding the average hourly counts of the test period, the highest visitor numbers were counted between 11:00 and 14:00. While the magnetometer only showed a slight undercount compared to the “ground-truth” data, the infrared counter showed the highest deviations during the afternoon hours (Figure 3).

A linear regression analysis was performed to calculate a correction factor for the visitor counters. The magnetometer model [$y = 0.978x - 0.286$ ($R^2 = 0.973$, $\sigma = 1.348$, $p < 0.001$)] can better predict the actual visitor numbers than the infrared counter model [$y = 0.774x - 0.491$ ($R^2 = 0.867$, $\sigma = 2.521$, $p < 0.001$)] (Figure 4).

## DISCUSSION

The findings of our investigation are consistent with the results of other test studies [3], [8]. They show that automatic visitor counting devices undercount the number of visitors. We could see a decreasing accuracy of both the infrared counter and the magnetometer with increasing visitor numbers. To improve visitor number predictions a linear regression model can be used to address this shortcoming.
Depending on the visitor activity different counter technologies can be considered. The infrared counter was not ideal for counting mountain bikers. The magnetometer performed well in our test setting. According to the producer it has the limitation not to be used in close proximity to roads, as bypassing cars or other motorized vehicles may lead to a high overcount due to the sensitivity of the sensor. This limits its scope of application and points out that CA managers must clearly define the necessary product features prior to selecting the suitable technology. Further tests could focus on testing infrared counters and magnetometers on a shared trail to differentiate between hikers and mountain bikers. Manually counting passers-by from wildlife camera recordings demands significant time investment. Additionally, collected data necessitates careful data handling regarding privacy considerations. When using cameras on a bi-directional trail it is recommended to use a low-resolution image setting or an algorithm that pixelates people before manually evaluating the data. Additionally, the use of cameras alongside trails should be communicated to the public. The utilization of wildlife cameras for verifying the accuracy of visitor counters requires thorough preparation. The choice of installation site is crucial. Hanging branches in the image can significantly impact data storage and battery lifetime, due to a high number of falsely recorded videos. It needs to be considered that undercounting can also occur with wildlife cameras despite manual evaluation. However, aligning the camera longitudinally to the trail opens up a larger time window in which objects move past the motion sensor and trigger the recording, which increases the probability of counting. Depending on the number of recorded videos, the data storage and battery life of the wildlife camera requires regular on-site visits to check and replace SD cards and batteries.

## ACKNOWLEDGEMENT

The study was possible in the frame of the INTERREG Central Europe project “HUMANITA - Human-Nature Interactions and Impacts of Tourist Activities on Protected Areas” The project is supported by the Interreg CENTRAL EUROPE Programme 2021-2027 with co-financing from the European Regional Development Fund (ERDF) – the project total budget is 2,396,346.70 EUR, of which the ERDF funding amounts to 1,917,077.36 EUR.

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