Counting visitors in alpine areas: how sensor range, clothing, air temperature and visitor volume affects passive infrared counter accuracy

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Terrestrial ecosystems at higher elevations and latitudes tend to be more sensitive to human impact and slower to recover than tempered or more nutrient rich ecosystems (Forbes et al. 2001; Müllerová et al. 2011). Yet such landscapes are also popular tourist destinations, particularly in the mountains. Sustainable tourism in sensitive natural areas demands that managers have accurate estimates of the number of human visitors such areas receive. Here we investigate the effect of technical errors on the accuracy of an automated pyroelectric counter commonly used to record visitor numbers in natural settings. Our tests assessed areas of potential counter error, and offer suggestions for how area managers in various settings can deploy and maintain counters to limit the effect that such errors can have on visitor number counts.

The Eco-Counter Eco-Twin, with a middle range Pyro lens, is a model widely used worldwide for counting visitor numbers by detecting body heat emitted by passing pedestrians. While these counters are often deployed in natural and mountain settings, results accuracy tests published in the scientific literature were from tests conducted in urban settings. We conducted four trials that investigated counter accuracy with respect to visitor attire, ambient temperature, visitor passing distance and visitor volume. Individual counter error rates exceeded manufacturer stated accuracy (± 5 %), but group means were not significantly different from manufacturer's claims (Figure 1). In general, counters under counted visitors at below freezing temperatures and over counted visitors at temperatures above 0 °C. Counter accuracy was also less at greater distances to the counter lens (up to 4 m) in both warm and cold conditions, but group means again did not significantly exceed manufacturer claims. One notable concern is that counters only detected the passing subject at -18 °C when she was wearing a fleece jacket, and did not detect her at all when she wore attire that was more appropriate for such temperatures.

Variation among counters was low at both 2 and 4 m distances for trials conducted both indoors and outdoors. Only at a 4 m distance did one counter deviate significantly from the others ($F_{6,77} = 4.637$, $p = 0.001$), but its mean error rate was still within manufacturer claims. We used the Norwegian Birkebeiner cross country ski race in the trial that investigated the effect of varying visitor volume, and recorded 5574 skiers passing counter sensors over a 2 hr period.

This frequency range is the equivalent of one visitor passing every 1 to 1.7 seconds, and is far beyond visitor volume where this type of counters are used in Norwegian natural settings but certainly relevant for urban environments. Variation among counters was minimal, and we observed a significant ($F_{1,71} = 8.60$, $p = 0.005$), and weakly negative ($r^2 = -0.331$) relationship between increasing visitor volume and error rate.

Our tests demonstrated that air temperature, distance to the counter, type of clothing and visitor volume can all affect counter accuracy within the range of conditions in which they are used for monitoring visitor numbers in Norwegian natural areas. However, these results also provide guidance for how counter accuracy can be improved when planning site location, installation, and monitoring and we believe these principles are applicable to other counting systems. Counter accuracy was acceptable when visitors pass within 2 m of counter sensors. The accuracy diminished dramatically at 4 m distances in tests when the counters' sensor sensitivity was manually decreased (-1 setting) as suggested by manufacturer: an effect further compounded by cold temperatures. In tests where sensor sensitivity was set to "Standard," however, we obtained counter readings that were within five perfect of true values. Counter installation should therefore be as close to the trail as possible to ensure that people pass within short range. In situations where this is not practical, sensor sensitivity should be adjusted to match the distance between visitors and counters.

Infrared sensor accuracy should increase with decreasing air temperatures, because colder air generates a greater contrast between ambient temperature and body temperature of passing subjects. For tests within moderate winter temperatures (between 0°C and -20°C), counters over reported visitor numbers – even at a reduced sensor sensitivity setting – but within manufacturer's claimed accuracy. The variation in accuracy levels and the systematic way in which counters deviated from actual visitor numbers indicate that sensitivity settings need to be tailored to the specific settings and uses. Colder temperatures may require decreased sensor sensitivity to avoid over reporting visitor numbers, but not if counter sensors cannot be mounted within 2 m of where visitors will pass. Warmer temperatures (> 10°C) should not require decreased sensitivity. Counters should also be tested at their installation sites to fine tune sensitivity settings to match site layout and microclimate and establish correction coefficients when necessary.

Counters sensitivity should also be refined seasonally if they are deployed for long periods so that sensitivity reflects changing temperature and visitor attire. It is also important to install the lens parallel to the ground surface and directed towards a background (e.g. open air or cliffs) at a sufficient height (1 m) that eliminates the risk of counting non-human activity in the background of the counting location. We recommend exercising caution when using this kind of counters in wintertime, especially in very low temperatu-

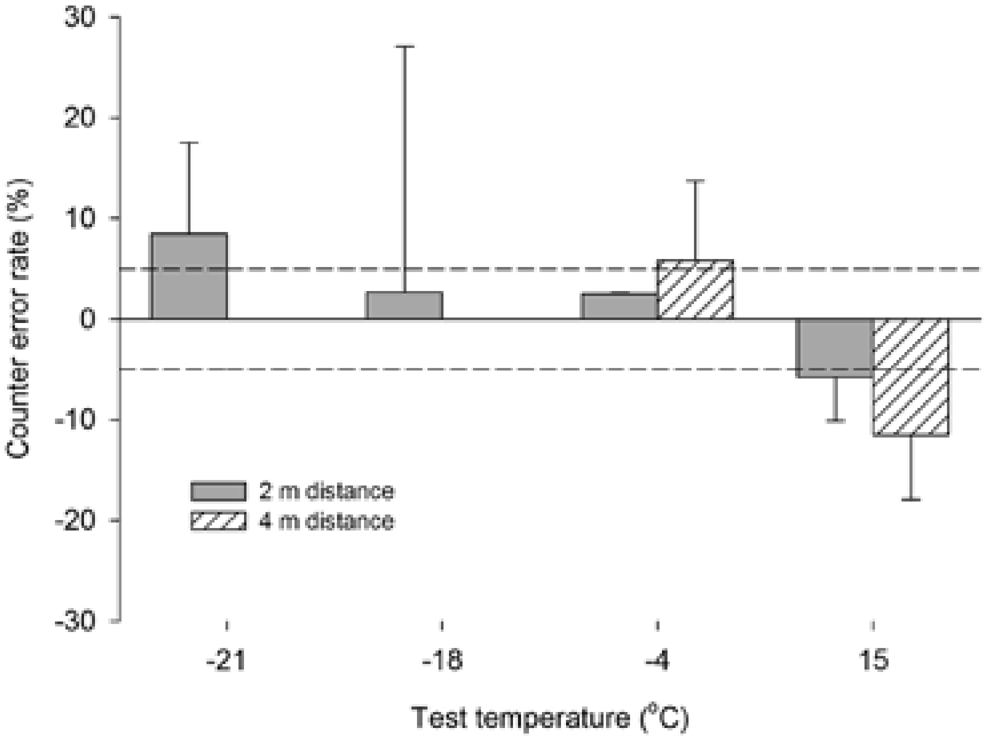

Figure 1. Mean error levels (%) from tests of visitor counter accuracy in varying air temperatures and distance from sensor. Dashed lines indicate the manufacturer's claimed accuracy range (±5 %), and error bars represent 1 SE. The test at 15 °C was conducted indoors, while results for the remaining three temperatures were from an outdoor test.

res. It is crucial that efforts to count park visitors include consideration of potential sources of error in the planning, installation, monitoring of counters and calculating correction coefficients for each counter and site, regardless the counting system in use.

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