Quantifying effects of signs on visitor flow in NP Krka

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Krka National Park is the second most visited National park in Croatia. It covers an area 109 km^2 centered on the Krka river, a natural and karst phenomenon, and the lower course of the Čikola River. The Krka river has seven travertine waterfalls, which are fundamental phenomenon of the park. The Park is visited by about a million people every year, with 95% of them visiting the most popular waterfall, Skradinski buk, with an an area of only 0.3 km^2. Consequently, crowding has become a problem there.

The area of Skradinski buk can be traversed by a roughly circular path with two entrances. Historically, conuterclockwise (CCW) direction of visitor movement has been dominant. Previous research suggested that visitors taking the clockwise (CW) direction are more dissatified than those taking the CCW direction, and suggested that this is because visitors moving CW experience much more opposing traffic than those moving CCW. It was suggested that installing signs reinforcing the dominant (CCW) direction would decrease the proportion of visitors taking the CW direction, thus decreasing the proportion of visitors experiencing high traffic against their movement and, consequently, improving the visitor experience. In 2017 signs with permissible direction reinforcing the CCW movement were set at key places. Signs forbidding CW movement were placed at the end of the footpath and at a point mid-way between the two entrances asking visitors to turn around if going CW towards the bridge, while signs suggesting CCW movement were placed at the beginning of the footpath. No signs were installed near the main bridge facing the waterfall. Other than sign installation, no other enforecement was undertaken.

To quantify the ensuing effects on visitor movement, data on visitor movement before (2015) and after (2017) sign installation were analyzed. Data were collected using an app written for Android where each visitor (time of passage and direction of movement) was recorded on two locations at Skradinski buk - near the bridge and on the footpath in both years. Measurements were carried out in August during the summer season, when crowding is highest.

In total, 80633 digitalized records of time and direction of visitor movement were collected: 39266 in 2017, and 41367 in 2015. Using the records of visitor movement, binomial parameter estimates were determined and visitor flow in each direction (CW and CCW) was calculated. Binomial parameter estimates with the 95% confidence intervals were obtained using *binofit* function in Matlab Software. Visitor flows were calculated (Figure 1) as the number of visitors per minute averaged over a ten-minute intervals of data on passage time and direction of movement.

There is a noticeable drop in CW movement following the installation of the signs. CCW movement has increased from 77% in year 2015 to 90% in 2017, suggesting a marked efficiency of signs even without additional enforcement. The number of visitor moving in the suggested (CCW) direction, however, is much higher on the footpath than it is near the bridge for both years. In 2015, 83% of visitor were moving CCW on the footpath, while only 73% did so at the bridge. After the signs were installed, the number of visitors moving CCW

increased to 97% on the footpath, and to 85% near the bridge. Therefore, even though the CCW movement over the bridge was lower than on the footpath, the signs resulted in similar increase in percentage points (pp) of CCW movement at both locations: 14 pp on the footpath, and 12 pp over the bridge. Higher CW flow over the bridge than on the footpath could be a consequence of several factors: i) positioning of the signs, ii) infrastructural considerations (e.g. placement of free toilets and water fountain), and iii) additional activities (e.g. swimming) in which the visitors near bridge are involved.

Even though the ratio of visitors moving in opposite directions differs before and after the sign installation, the mean total visitor flow (CW+CCW) does not. The total visitor flow near the bridge in 2015 varied from 1.2 to 62 visitors per minute, with a mean of 24.34 (std 12.26), while in 2017 it varied from 3.1 to 44.70 visitors per minute, with a mean 24.07 (std 11.69). The mean total visitor flow on the footpath is lower compared to the total visitor flow near the bridge for both years. The total visitor flow on the footpath in 2015 varied from 0.3 to 69.87 visitors per minute, with a mean of 20.21 (std 12.77), while in the 2017 the flow varied from 0.9 do 87.1 with the mean of 20.09 (std 15.68).

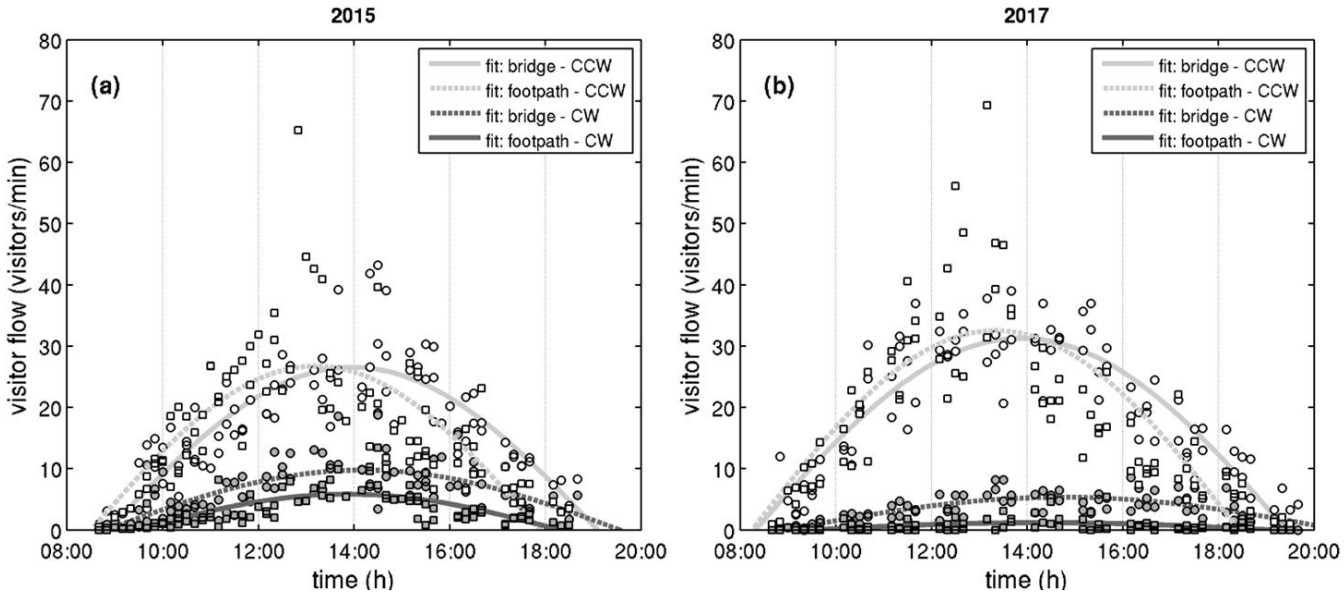

Figure 1: Difference in visitor flow and it's direction (counterclockwise - CCW and clockwise - CW) on two location during working hours in NP Krka: panel (a) in August 2015, and panel (b) in August 2017. The symbols represent the visitor flow expressed as a number of visitors in a minute calculated as the average of 10 minute intervals. The flow was monitored on two locations: near main bridge (circle symbols) and on footpath (square symbols) in counterclockwise (white symbols) and clockwise (dark symbols) direction. Lines represent the sine fit on the visitor flow data. Lines were included for illustration purposes only, and represent fits of one-term sine model.

The increase in CCW movement indicate the signs are an effective management tool. Additional enforcement would increase the desired direction movement, but may not be advisable as it could create an environment uncharacteristic of protected areas. Further research will focus on testing whether the changes in movement patterns decreased perception of crowding as expected, and how overall visitor satisfaction has been affected.