

**Comparing the level of human disturbance in 2009 and 2018 at yellow-bellied marmot
(*Marmota flaviventer*) colonies**

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ABSTRACT

Natural areas and the animal communities within them are inevitably affected by human disturbance. Human disturbance can occur through tourism, ecotourism, and simply human presence. The effect of a human on an animal can be detrimental, and has even been shown to cause increases of stress response, result in animals spending less time foraging and taking care of young and more time foraging, and influence development of habituation, or decreased sensitivity, to human presence (Frid & Dill, 2002; Maréchal et al., 2016, Knapp et al., 2013). In order to understand any effects human disturbance may have on yellow-bellied marmot colonies (*Marmota flaviventer*), human disturbance must first be documented. In 2009, a study documented the level of human disturbance occurring within 300m of five marmot colonies along the East River Valley in the form of light and heavy vehicles, bicycles, dogs, and pedestrians. By revisiting those methods of disturbance documentation, we produced a dataset measuring the level of human disturbance at the same five marmot colonies in 2018. Through comparison of the 2009 average rates of disturbance at each colony to the average rates in 2018, the correlation of rank order of total and light vehicles was significant, as well as the difference in average rates of heavy vehicles. This means that the colonies that experienced the highest vehicle traffic in 2009 still experience the most in 2018, while rates of heavy vehicles changed significantly from 2009 to 2018. Flight initiation distance of marmots did not change significantly in response to the beginning of the tourist season, indicating marmots may not change behavior for a short-term disturbance. Coupled with the documentation of human disturbance, this data can be used to further track human disturbance in the future and apply the documentation to studies that help understand the behavior and development of species in affected communities.

INTRODUCTION

The continuing expansion of the human footprint leaves extensive environmental change in its wake, both locally and globally (French et al., 2010). This includes destructive effects such as the complete devastation and habitat fragmentation of natural areas by urban development, as well as simple and more subtle influences; for example: the introduction or increase of human presence in natural areas. There are more than eight billion visits per year to terrestrial protected areas (Blumstein et al., 2017), and many of these seek to engage in ecotourism, a form of tourism intended to leave as little impact as possible on the environment it occurs in. Both ecotourism and recreational activities are common in natural areas, despite the fact that human land use inevitably causes an impact on the organisms within that environment (Maréchal et al., 2016). Since anthropogenic disturbance facilitates change in the environment and the natural populations that inhabit it, humans must be wary of their use of natural lands and take responsibility for its wellbeing (French et al., 2010). Understanding the impact that humans can have on a natural community is the first step to forming an effective method for conservation of that community. By documenting the level of human disturbance in 2018 in the East River

Valley and comparing it to the level of disturbance in 2009, the amount and growth of human disturbance in the area can be monitored and used to inform how human disturbance will affect the area in the future.

Detrimental effects that can result when animal communities are exposed to human presence are well documented and known to occur in a number of species (French et al., 2010; Knapp et al., 2013). Human disturbance is often interpreted as a predatory threat, which can elicit different responses or effects in animals. For examples, in a study of Barbary macaques (*Macaca sylvanus*) in a tourist location, the macaques increased aggressive behavior during interactions with tourists, suggesting the tourists were interpreted as a threat. Also, grizzly bears (*Euxoa auxiliaris*) were found to both decrease energy intake by 12 kcal/min and either fled or increased aggressive behavior when disturbed by hikers (White et al. 1999). In barren ground caribou (*R. tarandus*), body mass and population size were found to decrease with an increase of military jet flights over herds (Maier, 1996). Human presence can induce stress, as seen in the Galapagos marine iguana (*Amblyrhynchus cristatus*) which had significantly increased corticosterone concentrations in tourist's sites compared to iguanas in undisturbed sites (French et al., 2010). Animals may increase anti-predator vigilance in response to such a threat, and therefore spend more time engaged in anti-predator behaviors when exposed to a disturbance stimulus, meaning there is less time for important activities such as foraging or providing care for young (Frid & Dill, 2002; Lima et. al, 1985; Li et. al, 2011), which could negatively impact survival. Even occasional disturbance can interrupt the natural behavioral cycles, as shown in studies of waterfowl (Davidson & Rothwell, 1993), and can cause elevation of aggression, stress, or an increased sensitivity of immunological response (Maréchal et al., 2016; French et al., 2010). Animals may also become habituated, or less sensitive, to a human presence, which could potentially be detrimental should a human ever pose a threat to the organism (Knapp et al., 2013).

In addition to increasing exposure of wildlife to humans, ecotourism poses several threats to the environment, including creation of waste and use of natural resources (Bessa et al., 2017). While ecotourism is often considered and promoted as a low-impact activity and may be less invasive than recreational activities (Tablado & D'Amico, 2017), the fact that it still introduces human presence into areas where wildlife can be easily affected means it can still cause a significant impact on animals (French et al, 2010; Maréchal et al., 2016).

Many studies of human impacts are cross-sectional; quantifying impacts at a single time at multiple locations (French et al., 2010; Maréchal et al. 2016). These cross-sectional studies leaves open the question of how the level and type of anthropogenic disturbance fluctuates over time. We revisited a study conducted in 2009 which recorded human disturbance of vehicles, bicycles, dogs, and pedestrian passing by yellow-bellied marmot (hereafter, 'marmot') colonies. By doing so, we tested whether and how human disturbance varied temporally and spatially.

Marmots are well-suited to this study for a variety of reasons. They live in burrows excavated under rocks, and spend large amounts of the day near the entrance of the burrow to look for predators and sun on rocks (Armitage, 1975; Svendsen, 1974). Marmots hibernate during the winter season but are active in the summer when the tourist season occurs for the breeding season and to prepare to hibernate again (Kilgore, 1972). Due to their fixed locations, it is possible to observe marmot colonies and the nearby roads and trails that humans use at the same time, which allows for the ability to measure a constant distance between location of approaching stimuli and the colony. Marmot colonies in the East River Valley of Gothic, Colorado, are distributed throughout the sub-alpine terrain amid well-marked and accessible trails and roads that are open to tourists, which allows humans to travel within 300 meters of the colonies (Blumstein et al., 2006). With human disturbance recorded, future studies on marmots will be able to compare physiological or behavioral marmot data to the amount of disturbance experienced in order to best understand how humans can impact animals directly. We hypothesize that human disturbance from 2009 to 2018 will remain distributed the same across sites, while actual levels of disturbance will increase from 2009 to 2018.

METHODS

Data collection

We replicated the methods of a previous study recording the level of human disturbance passing by marmot colonies in the East River Valley of the Rocky Mountain Biological Laboratory (RMBL) in 2009 (Li et al., 2011) were revisited in order to collect a dataset that could be compared to the Li et al. data, but revised to allow for collection of human disturbance data with the least amount of bias and uncontrolled variables possible. This involved three researchers observing seven marmot colonies and recording the number of light vehicles, heavy vehicles, cyclists, dogs, and pedestrians that passed within 100 or 300 m of each colony. The number of light vehicles and heavy vehicles was combined to become total vehicles once data were collected.

Data collection of human disturbance stimuli took place during the peak tourist season from 1 – 22 July 2018, during the hours when marmots are most active, 07:00-11:00 and 16:00 – 18:00 daily, except Saturdays, at seven different marmot colonies spread from low to high elevation throughout the East River Valley: Bench, River Mound, Town, Marmot Meadow, Picnic, North Picnic, and Stonefield. Counts of disturbance within 300 m of Picnic were used for counts within 300 meters of North Picnic, due to the close proximity of the colonies. The Horse Mound colony observed in 2009 is now extinct and was included in 2018. We improved upon the schedule of Li et al (Li et al., 2011) such that the amount of time spent at each site throughout the week was the same, and observations occurred only during the peak times of marmot activity.

Only the five colonies Marmot Meadow, North Picnic, Picnic, Stonefield, and Town were observed both in 2009 and 2018, and therefore were the colonies used to compare disturbance data between the two years.

The Crested Butte Chamber of Commerce shared data of total visitation collected at the visitor's center for 2010 to 2017, which documents tourism in areas near Gothic, Colorado, that may have implications for how many people may be visiting Gothic each tourist season.

Definition of variables

Distances were categorized with respect to the location of main burrows at each colony. If a path was within 100 m, the disturbance on that path would be recorded as within 100 m of the colony. This method was repeated to measure disturbance 300 m away.

The five types of human disturbance collected were light vehicles, heavy vehicles, bicycles, dogs, and pedestrians. Light vehicles included any vehicle no more than two-axes, including all-terrain vehicles (ATVs) and motorcycles. Heavy vehicles included any vehicles with more than two-axes, or a two-axle vehicle pulling a trailer with wheels. Bicyclists were counted even if the rider was walking with the bicycle. Dogs were counted only if the dog was walking on the ground (i.e., not riding in a car). Pedestrians included anyone walking or running along the designated paths. Counts were based on the number of times the stimuli passed the colony, therefore a single individual or vehicle could be counted multiple times if they passed back and forth.

Flight Initiation Distance

To explore if marmots quickly change behavioral response to human approach in correlation with the influx of tourists during the peak tourist season, we analyzed previously collected data of flight initiation distances (FIDs) for marmots from June, before the tourist season, and during July, at the peak of the tourist season using a linear mixed effects test in R (R Core Team, 2013). These FIDs were collected by approaching a relaxed marmot at a consistent velocity of 0.5 m/s in a straight line until the marmot become alert and then fled. The distance at which the marmot fled, first became alert, and starting distance from the marmot where a researcher first began the approach were also recorded, in addition to the number of other marmots in the vicinity as well as slope of initial substrate, slope of escape substrate, amount of vegetation present, and distance to burrow from the marmot's original location in order to best inform interpretation of the flight initiation distance results.

Statistical analysis

To understand whether the level of tourism has changed from 2009 to 2018, we compared average rates of human disturbance at each colony using non-parametric Wilcoxon

matched pairs signed rank tests. To see whether the levels of disturbance were similar across sites across years, we calculated Spearman rank order correlation coefficients. All tests were conducted in SPSS v. 21 (IBM Corporation, 2012), and we set our alpha to 0.05.

RESULTS

We revised the method of colony observation used by Li et al (2011) in 2009 in order to ensure each colony was observed for an equal amount of time and over multiple different days of the week. The days and hours that observations at focal colonies (Figure 1) took place are depicted in Figures 2 and 3.

Crested Butte recorded total tourist visitation through the visitor's center from 2010 to 2017 and will continue counting in the future. The visitation rates vary by the thousands, with 2015 exhibiting the highest visitation of 12,049 tourists in July, and 2016 and 2017 decreasing from there, with only 7,663 visitors and 6,247 visitors in July, respectively. Since 2010, the Crested Butte visitors center has recorded visitation data to estimate tourism. From Figure 4, it is clear 2015 had the highest visitation so far, with 2016 and 2017 visitation appearing more similar to 2010 visitation. 2017 had only 6,247 visitors, just over half of the 12,049 visitors recorded in 2015 (Table 2).

Table 3 depicts the hourly rates of disturbance for each type within 300 meters of the focal colonies, where TV = total vehicles, LV = light vehicles, HV = heavy vehicles, B = bicycles, D = dogs, and P = pedestrians that were collected in 2009 and 2018. The colonies were assigned rank orders from 1 to 5, 5 indicating the highest level of disturbance, and 1 indicating the lowest level of disturbance, for each type.

Between the two years, only the rate of total vehicles and light vehicles were found to be correlated using Spearman rank order correlation coefficients (Figure 6). Thus, marmot colonies that ranked highly in these disturbances in 2009 also ranked highly in these disturbances in 2018. While heavy vehicular disturbance and pedestrian disturbance were both highly correlated, given only five colonies, we had insufficient power to assert that they were significantly correlated. Dog, pedestrian, and bicycle disturbance rates were not correlated across years.

The median of the rates of disturbance are depicted in the boxplots of Figure 7 by the line within the box, which defines the portion about the median as the 75th percentile, and the portion below the line as the 25th percentile. The box represents 50% of the data of average rates of disturbance, while the extending whiskers encompass the range of 95% of the data. Extreme outliers are depicted by the asterisks. There are extreme outliers for all types of disturbance except bicycles (Figure 7). Non-parametric Wilcoxon matched pairs signed rank tests on average rates showed that there was a significant difference in average disturbance between 2009 and 2018 only in the rate of heavy vehicles, with fewer heavy vehicles observed in 2018 than in

2009, while total vehicles, light vehicles, bicycles, dogs, and pedestrians did not change significantly between years (Figure 7).

In the data collected by Li et al., the counts of pedestrian disturbance in Town were abnormally high on 7 July, 2009. We tested the effect of removing the counts for that day by repeating the Spearman rank order correlation coefficient and non-parametric Wilcoxon matched pairs signed ranks tests for all of the average rates with 7 July removed, and we found that it did not change the results of any of the statistical tests.

Analysis of flight initiation distances in June and July using a Linear Mixed Effects Model did not result in a significant impact of month on human approach distance tolerated by marmots before fleeing ($p = 0.6627$).

DISCUSSION

By quantifying the level of human disturbance that each marmot colony is subjected to both in 2018 and 2009, we determined that there has not been a significant change in pressure of tourism near marmot colonies over the past nine years. This is shown by the significant correlation of rank order of total and light vehicle disturbance (Figure 3), the most prevalent disturbance type (Table 3) between years. The significant correlation of rank order means that the sites that experienced the most vehicular disturbance in 2009 still experience the most in 2018, which supports our hypothesis that the patterns of human disturbance throughout the valley would be predictable. Since the average of heavy was the only disturbance to change significantly between years, with a slight decrease from 2009 to 2018, it is more evident that there was not a significant change in tourism level between 2009 and 2018. While the raw numbers did increase overall in total vehicles from 2009 to 2018 (Table 3), it was not large enough to cause a significant difference between years. The visitation counts at Crested Butte and Mount Crested Butte, both within ten miles of Gothic, fluctuate from 2010 to 2017, but both increase from 2016 to 2017. Since our study only compared 2009 to 2018, it is possible that the level of human disturbance occurring in Gothic in years such as 2014 and 2015 where visitation was the highest recorded so far in Crested Butte and Mount Crested Butte, could be significantly different from the disturbance recorded in Gothic in 2018, where the nearby towns show lower levels of visitation, more similar to what was recorded in 2010 (Figure 4 and 5).

Vehicular traffic, as the most prevalent disturbance recorded in our study (Table 3), is important to monitor as was done in this study, as it can pose a large threat to marmots. Vehicle caused threats include mortality from vehicular collisions or even familial separations due to attempts to successfully cross a road while avoiding cars (Tablado & D'Amico, 2017). Road traffic can also disrupt an animals' normal behavioral cycle, as has been shown in studies of cinerous vultures (*Aegypius monchus*) that exhibit decreased nest success in nests closer to roads. The danger of vehicular traffic is pertinent to the East River Valley wildlife communities, as the main road cuts straight through the valley and may separate sides of valuable habitat from each

other. All of the human visitation to the valley must begin on that road, as it is the only road coming from Crested Butte and Mount Crested Butte into Gothic. Town and Marmot Meadow experienced the highest amount of vehicular traffic both in 2009 and 2018, and therefore are the marmot colonies that experience the most threat from vehicles (Table 3).

Bicycles, dogs, and pedestrians were not significantly correlated by rank order but did not have significant differences in means between 2009 and 2018, meaning the level of disturbance that occurred was relatively similar between years, while the locations that experienced the most disturbance changed between years. The colonies that previously did not experience the most disturbance of these types may be more vulnerable to the danger of an increase in disturbance, for example, in 2009 Town was ranked lowest for level of bicycle disturbance, while in 2018 it was ranked as 4, or the second highest level of bicycle disturbance (Table 3). An increase of potentially threatening human disturbance could put pressure on behavioral changes in order to best survive living in close proximity to the danger.

Since marmots did not exhibit significantly different flight initiation distance behavior after an increase of tourists, they may not habituate in response to short term changes in human disturbance. In order to understand how marmot behavior may be influenced after a longer amount of time, flight initiation distance data should be collected in the same method each year in order to be analyzed in the future in pairing with levels of human disturbance. In the future, levels of human disturbance on these five marmot colonies could continue to be recorded in the same method and compared to this study as well as the study conducted in 2009 in order to understand the possible fluctuation of human disturbance over an even longer period of time.

Ultimately, understanding the rate and fluctuation of human disturbance over time is necessary to inform the best possible protocol to protect natural lands in order for wildlife and humans to coexist effectively within them (Li et al., 2011). While this study focuses on marmot colonies, the East River Valley is a popular destination for mountain biking and hiking and the human disturbance recorded in this area could potentially be applied as a general reference point for other similar areas and the organisms within them. Since ecotourism and recreational land use inevitably cause human-induced responses in animals that can impact survival and fitness, documenting the development of human use of natural lands through time is pertinent to protecting wildlife in such sites in the future (French et. al, 2010; Villanueva et al. 2011). In order for ecotourism to be sustainable in respect to the health of the environment, human disturbance must be quantified and used to inform future management to prevent detrimental effects as efficiently as possible (Ellenberg, 2017).

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TABLES & FIGURES

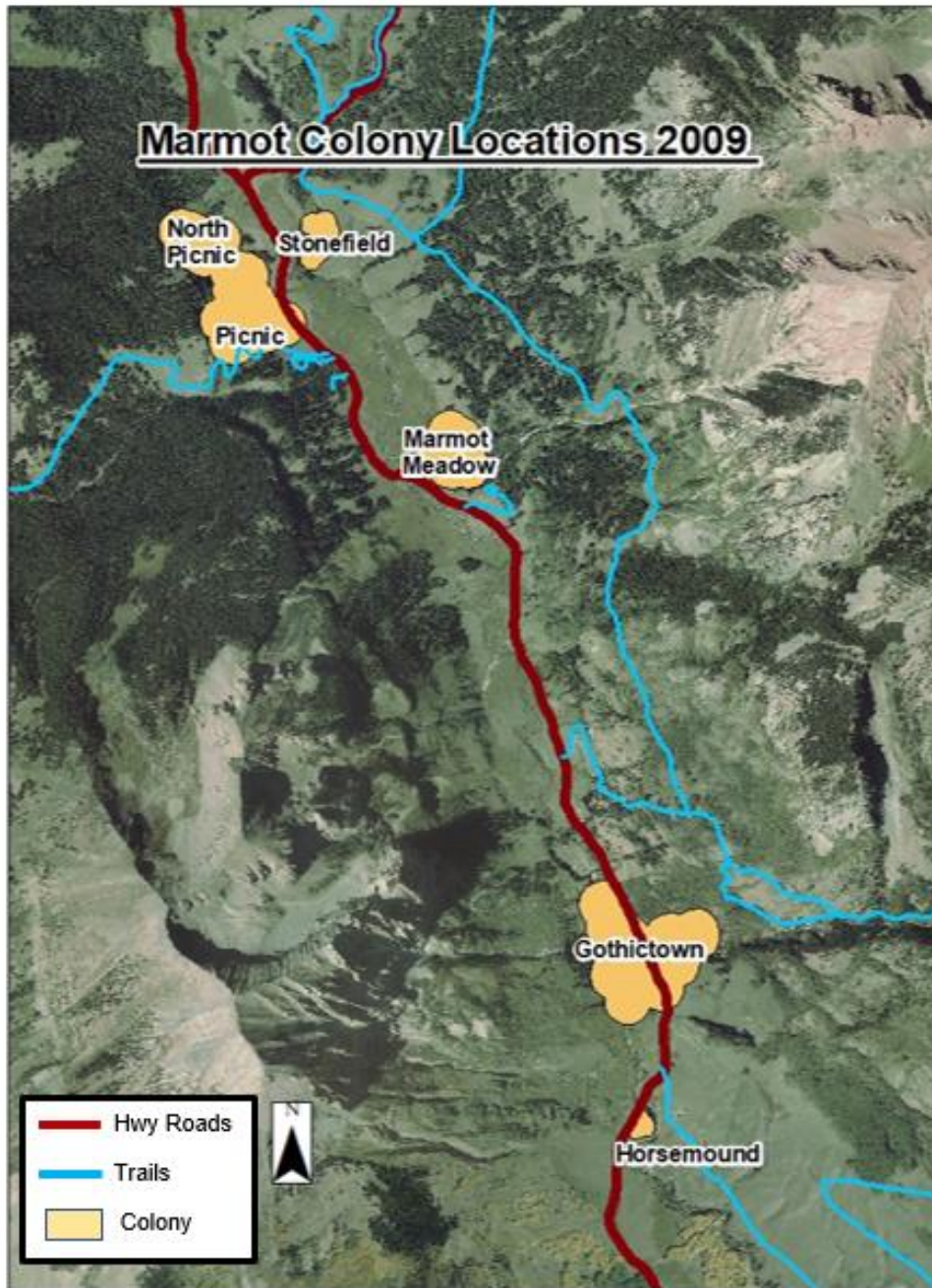


Fig. 1. The six colonies observed in 2009 by Li et al. (2011), with all colonies observed again in 2018 except Horsemound.

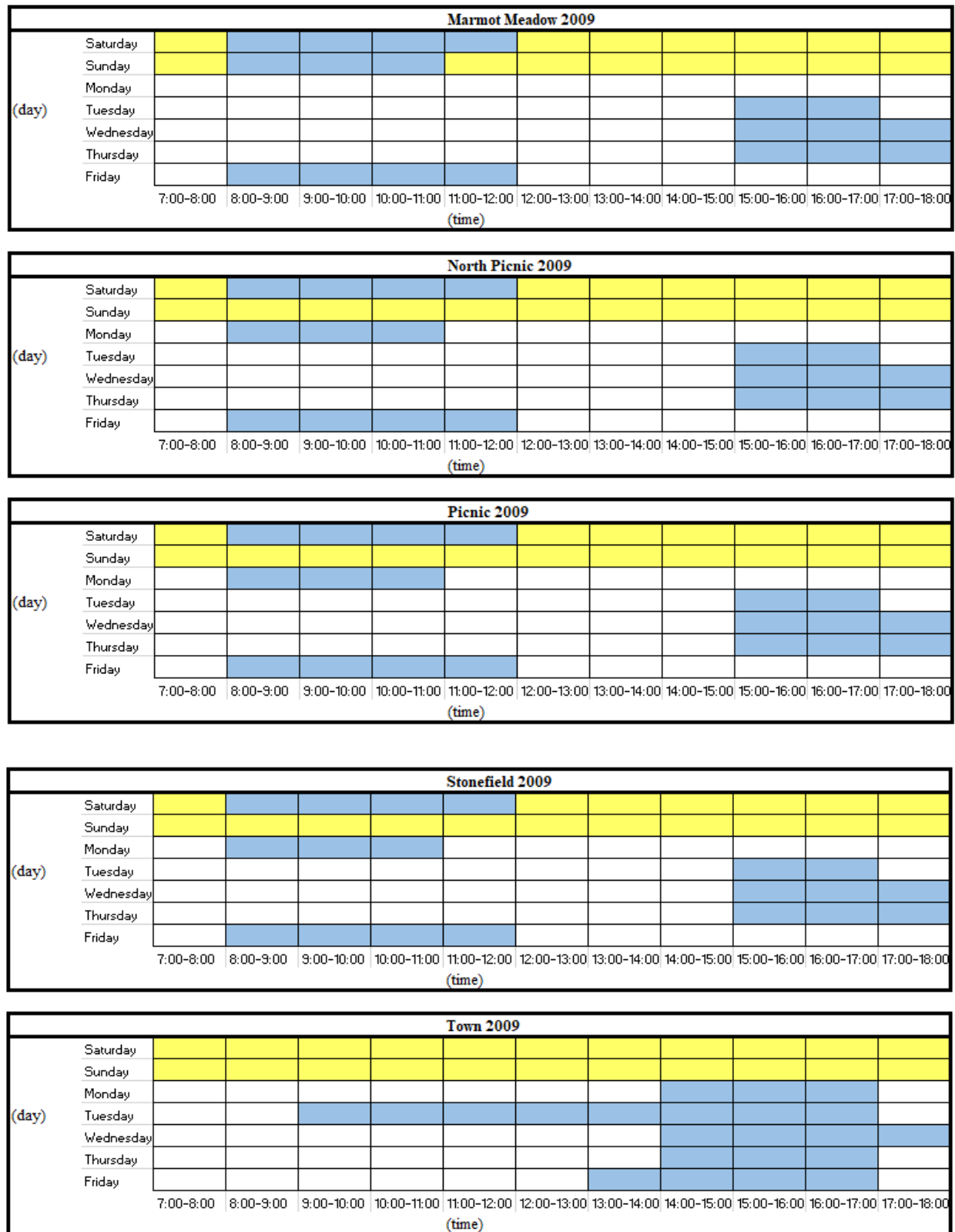


Figure 2. The times and days marmot colonies were observed by Li et al (2011).

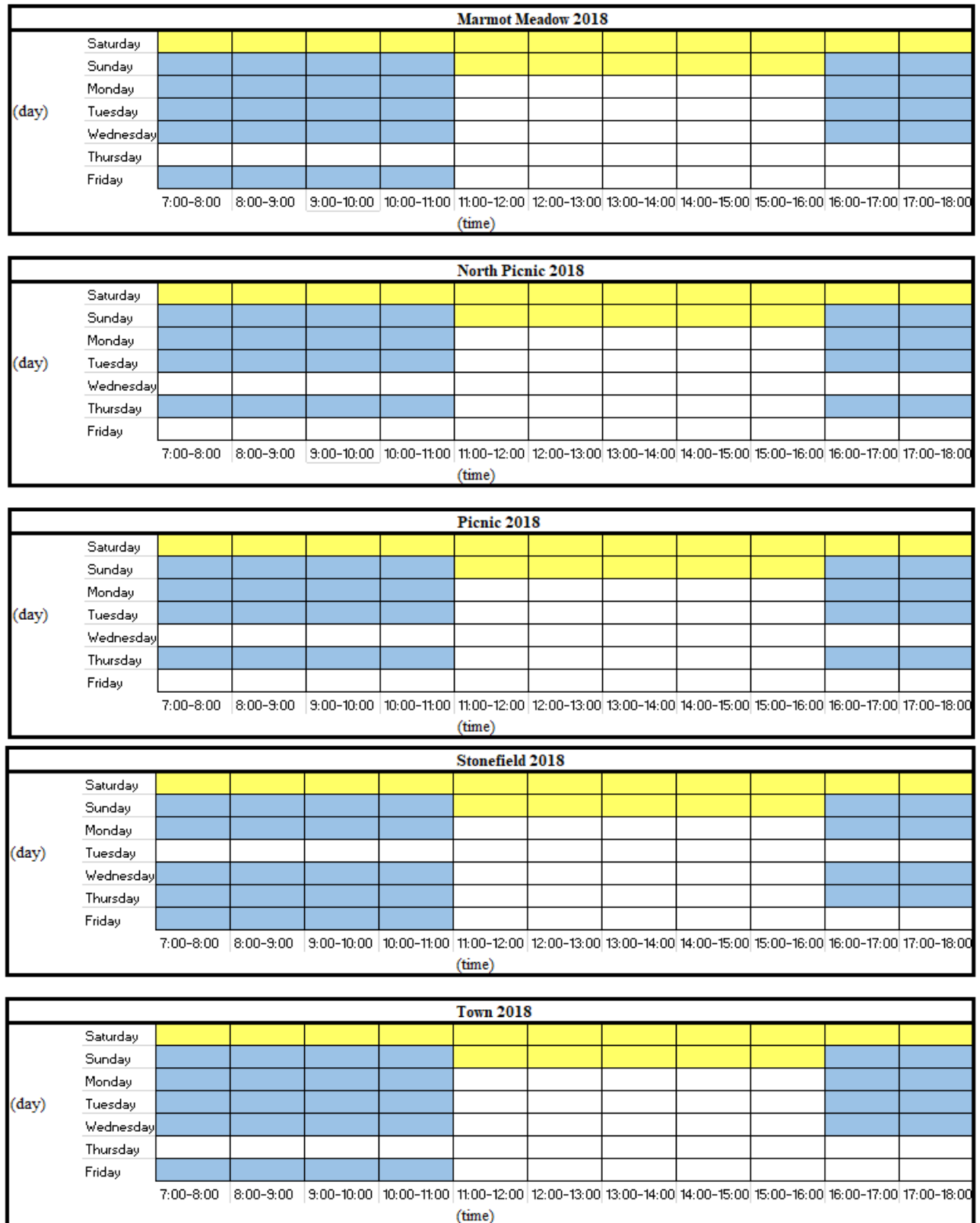


Figure 3. The times and days marmot colonies were observed in 2018.

Table 1. Crested Butte visitors center counts of total visitation for the month of July

	2010	2011	2012	2013	2014	2015	2016	2017
July	8650	10161	7811	9878	10945	12049	7663	6247

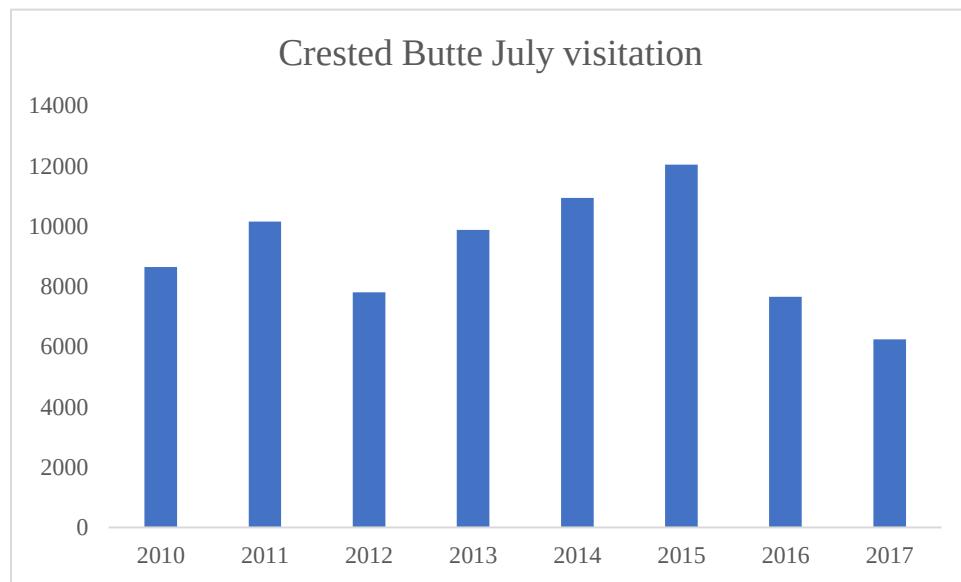


Figure 4. counts of tourists in July as recorded by the Crested Butte visitors center

Table 2. Mount Crested Butte visitation in July from 2010 to 2017.

	2010	2011	2012	2013	2014	2015	2016	2017
July	949	1539	1081	888	2409	2126	1788	2172

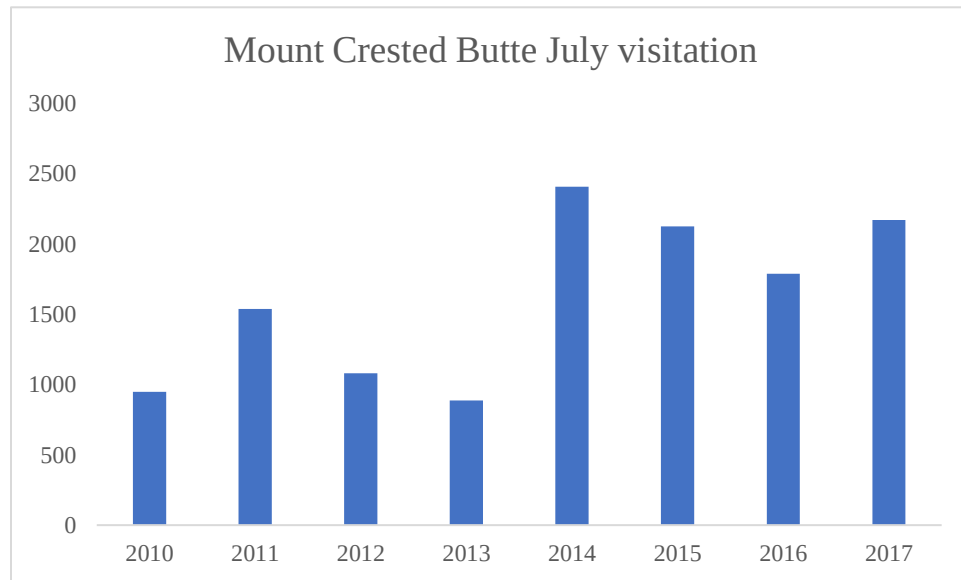


Figure 5. counts of tourists in July as recorded by the Mount Crested Butte visitors center

Table 3. the average hourly rates of disturbance types at each colony recorded in 2009 and 2018.

2009	TV Rate	LV Rate	HV Rate	B Rate	D Rate	P Rate
Marmot Meadow	29.54	28.01	1.53	6.94	0.53	3.08
North Picnic	23.85	22.59	1.26	7.10	0.63	1.62
Picnic	26.35	25.09	1.26	6.89	1.10	4.36
Stonefield	23.58	22.53	1.05	6.83	0.63	1.47
Town	52.54	45.63	6.92	6.74	0.38	111.19
2018	TV Rate	LV Rate	HV Rate	B Rate	D Rate	P Rate
Marmot Meadow	36.82	36.38	0.44	8.85	0.03	2.82
North Picnic	27.06	27.03	0.03	6.74	0.00	0.68
Picnic	27.68	27.62	0.06	6.26	0.00	2.44
Stonefield	21.06	20.85	0.21	6.88	0.09	2.00
Town	82.38	79.32	3.06	7.74	0.41	75.50
2009	TV Rank	LV Rank	HV Rank	B Rank	D Rank	P Rate
Marmot Meadow	4	4	4	4	2	3
North Picnic	2	2	2	5	3	2
Picnic	3	3	2	3	5	4
Stonefield	1	1	1	2	3	1
Town	5	5	5	1	1	5
2018	TV Rank	LV Rank	HV Rank	B Rank	D Rank	P Rate
Marmot Meadow	4	4	4	5	3	4
North Picnic	2	2	1	2	1	1
Picnic	3	3	2	1	1	3
Stonefield	1	1	3	3	4	2
Town	5	5	5	4	5	5

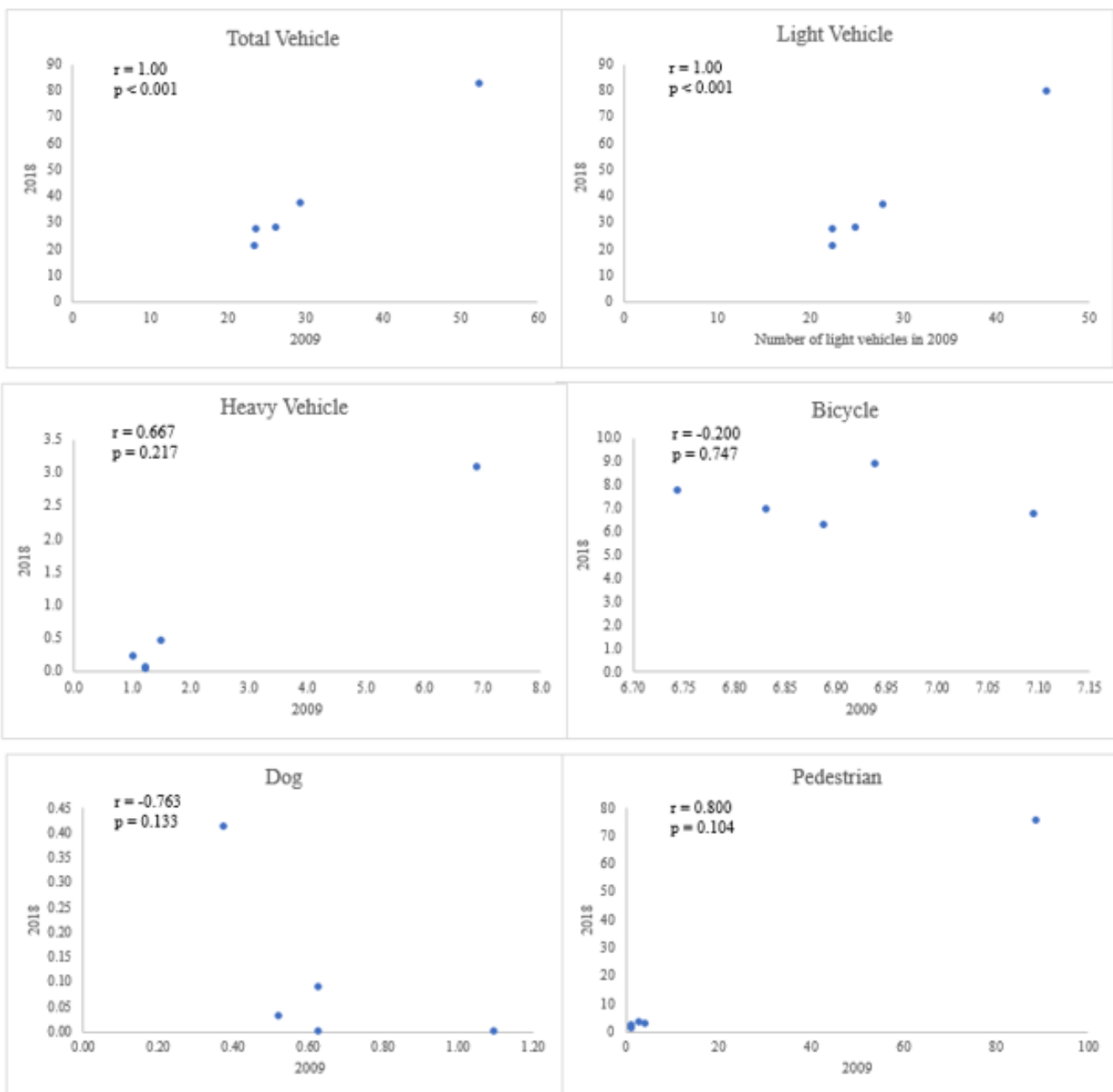


Figure 6. Human disturbance caused by the recorded disturbance types, with the Spearman rank order correlation coefficients and the associated p-values included.

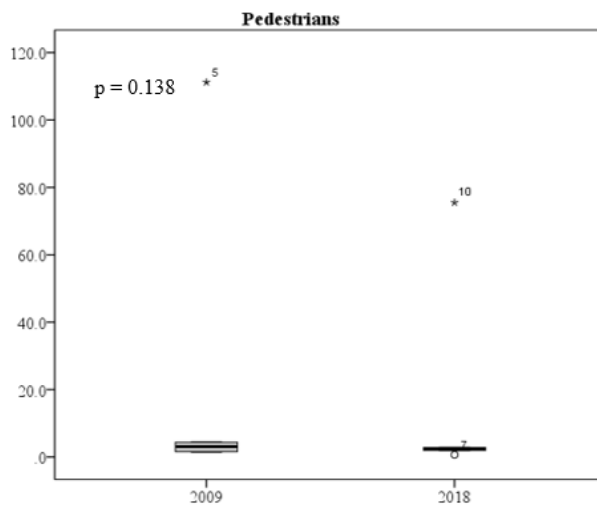
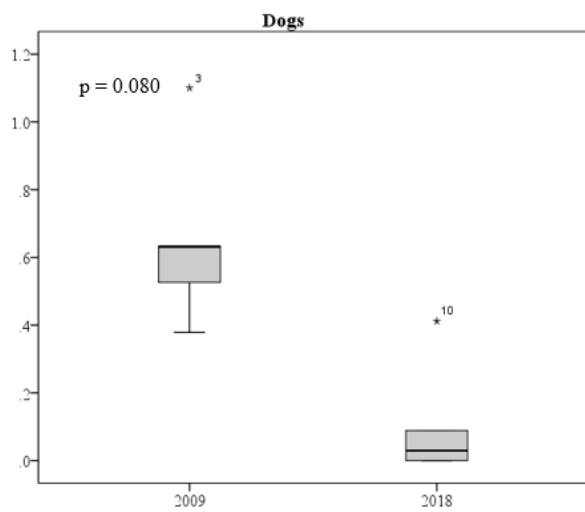
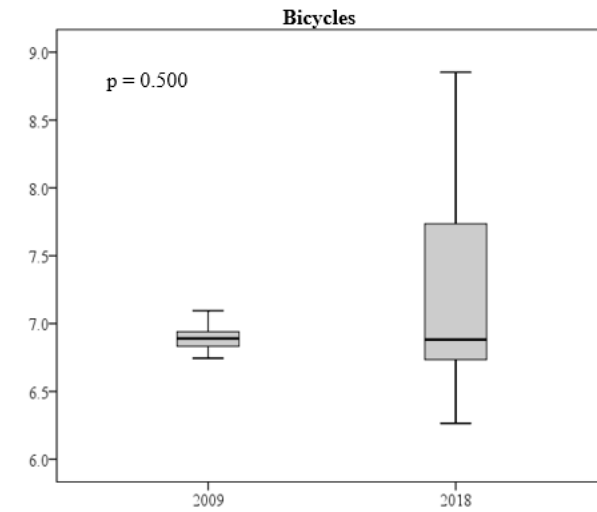
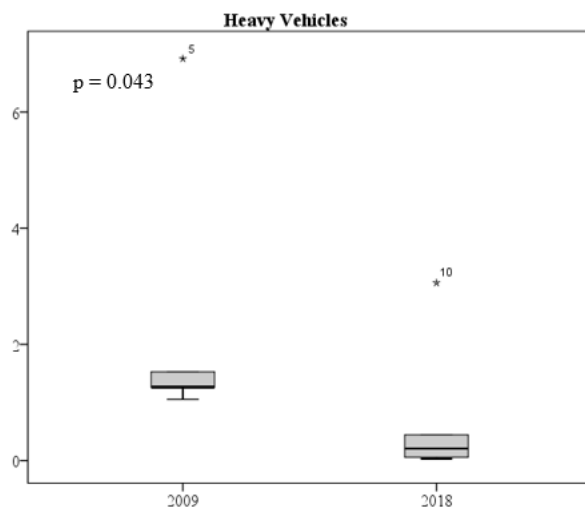
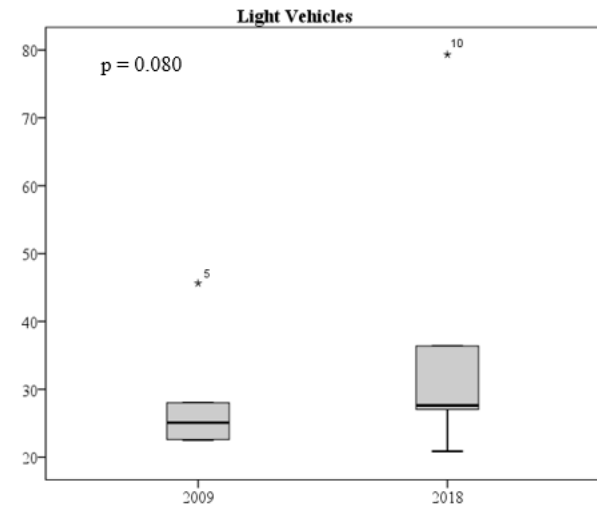
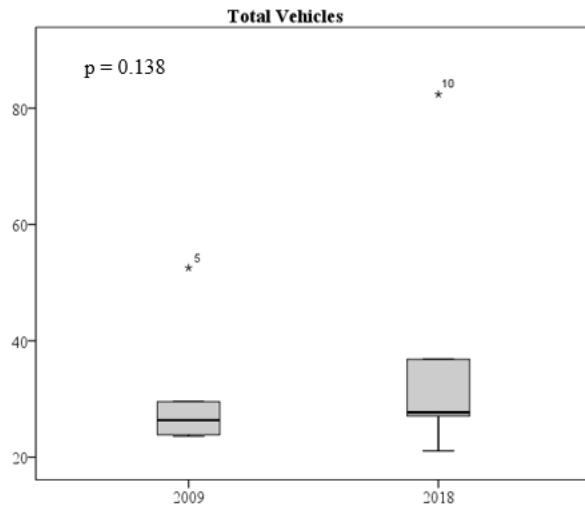


Figure 7. Box plots of average rates of disturbance in 2009 and 2018 with significance of the difference between averages tested with a Wilcoxon matched-pairs signed rank test.