Monitoring Domestic Canine (*Canis familiaris*) Activity on Wildcat Creek Bootleg Trails via Camera Traps

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ABSTRACT

Riparian ecosystems are disproportionately affected by anthropogenic influences because they are often centers of human recreation and are home to a diversity of flora and fauna. Domestic canines exacerbate these changes if their behavior is not properly regulated. To provide recommendations to protect the sensitive riparian ecosystem I made both quantitative and qualitative observations of domestic canine activity on bootleg trails along a particularly high traffic section of Wildcat Creek. To examine canine activity along Wildcat Creek, three camera traps were installed along the study site and continuously collected data from December 17, 2017 until April 17, 2018. I examined variables to determine temporal trail use patterns as well as variations in human presence and the number of dogs in a group as related to duration of visit. Results suggest that past dissuasion measures employed by East Bay Regional Park Department (EBRPD) have been somewhat successful but that there is an opportunity for further protection measures to take place based on very clear and consistent temporal patterns of canine trail use.

KEYWORDS

riparian ecosystems, habitat alteration, human recreation, temporal analysis, ecosystem management

INTRODUCTION

Habitat alteration inhibits the survivorship of sensitive aquatic species (Wilcove et al. 1998). Human recreation can be an especially significant cause of habitat alteration in riparian zones, these ecosystems exist in transition zones between terrestrial areas and freshwater habitats along flowing waters, and represent areas of maximum potential conflict between human recreation, water, and wildlife resources (Kindschy et al. 1982). Although less 1% of the western landscape of the United States is covered by riparian vegetation, the ecosystem has a profound ecological effect on surrounding areas because of both the ecosystem's support of a wide diversity of species pools and the disproportionate level of anthropogenic influence often occurring in these habitats (Sabo et al. 2005). Human activities are often centered along rivers and riparian zones because of their position in the landscape, historical value as a water source for agriculture which caused the centering of cities around this ecosystem, and their value in recreational activities including hiking (González et al. 2017). Unfortunately, the excessive human interaction with these ecosystems can result in adverse changes in thermal and flow regimes and increased input of sediment into the water, both of which can result in disturbances to native species (Naiman and Décamps 1997). Thus, anthropogenic changes to riparian ecosystems can have detrimental effects that extend beyond the confines of the terrestrial-freshwater interface.

Studies of the relationship between recreation and natural spaces show that although allowing humans limited access to sensitive environments does not necessarily disproportionately harm the natural environment, enforcement of park rules and close relationships with ecologists and conservationists is crucial in order to maintain a (Budowski 1976). Persuading participants to respect authorities on sustainable recreation can be difficult especially when they organize, forming groups such as the San Francisco based "Save Our Recreation," which advocates for the preservation of recreation in Golden Gate Park (Buffa 2017). These organizations can inhibit the effectiveness of conservation efforts by promoting the individual choice to disperse opposition and forestall regulation (Buckley 2012). Additionally, the "attitude-behavior gap" demonstrates that people's intentions and education do not always necessarily correspond to environmentally beneficial actions further necessitating the need for enforcement of protective rules (Vermeir and Verbeke 2006). Further exacerbating the problem, dogs, which act as recreational partners similar to small children, have an inability to identify the problem that their presence causes and are

ignorant to informational campaigns and logical reasoning, placing an additional burden on their human companions to recognize their potential to cause ecosystem disturbances and then regulate behavior responsibly (Mills 2017). Therefore, to completely understand the ecological disturbances caused by domesticated canines the problem must be investigated as both a subset of the larger problem of anthropogenic disturbance of natural spaces and also as a unique problem.

To mitigate the adverse effects that humans and canines have on protected spaces it is important to examine the case more specifically, taking into account factors such as location and ecosystem type. Humans and canines both have well documented adverse impacts on riparian and other freshwater ecosystems (Collins 2001, Gifford et al. 2017, Capps et al. 2017). There is a positive correlation between an increase in human recreation and tourism at water-land interfaces and both the amount of near-water land erosion and the amount of sediment deposited into the water (Rangel-Buitrago et al. 2018). The introduction of domestic canines into the protected areas can put the conservation of native species at risk by eroding riparian banks and harming native species (Whiteman et al. 2008). Canines can also contribute to fecal pollution, which has been found to be positively correlated with turbidity (Harmon et al. 2014). This series of factors suggests that the disturbances caused by canines and humans along the terrestrial-freshwater interface may be harmful to freshwater ecosystems beyond the influx of sediment, there may also be an increase in levels of harmful bacteria.

To ascertain a more complete picture of the impacts of humans and canines this study combines methods used to analyze anthropogenic disturbances in protected areas with methods used to monitor animal behavior over long spans of time. It is essential to look at visitation patterns that are often analyzed in feral populations such as diel variations, the availability of bootleg trail access, number of animals in each group, and the duration of the animal's visit (Ikeda et al. 2016). Thus, to determine the extent of canine interactions with bootleg trails this study analyzes differential access at different places in the trail, frequency and timing of trail use events, and whether the canine is accompanied by a human or in a group with other dogs. In summary, I fill the gap in existing research by applying a temporal analysis of the data using various resolutions coupled with additional variables that may influence the behavior of my study population.

BACKGROUND

In Wildcat Creek, rainbow trout (*Oncorhynchus mykiss*) is the species best for modeling the effects of disturbance stressors because they are likely to be affected by both thermal and flow regime changes as well as changes in turbidity (Wenger et al. 2011). A reduced flow regime can negatively affect the sediment transport regime by diminishing flushing flows and exacerbating problems associated with fine sediment in the habitat of *O. mykiss*. Sediment finer than 2mm is a limiting factor in rainbow trout survivorship and reduced flows further inflame the problem (Adams et al. 2008). Sediment inputs from riparian banks often falls below this threshold, when particles of this kind exceed 30% of the spawning gravel, low survival of embryos and fry is expected (Raleigh et al. 1984). Thus, it is crucial that sediment deposition is monitored and reduced as much as possible in order to ensure the survival of the species. Their sensitivities to the sediment stressors can provide useful information about the health of the ecosystem as a whole.

Historically, *O. mykiss* was prevalent in Wildcat Creek until their eradication soon after World War II (Collins 2001). They were reintroduced by East Bay Regional Park Districts' (EBRPD) Fisheries Department in 1983 by relocating a subset of the population from Redwood Creek in Marin County, California. The population of *O. mykiss* has been monitored consistently since that time, fluctuating initially and remaining relatively stable for the last decade. The period of stability coincides with consistent efforts by EBRPD both to study the causes of the fluctuations and to maintain the population at current levels. In 2001, EBRPD began employing interns to both monitor the trout populations and to determine the causes of *O. mykiss'* population fluctuation. As a result of multiple studies over the years EBRPD has been able to determine that the most concerning cause of the unstable population is sedimentation input and resulting increased turbidity of pools. The most actionable cause of this turbidity is the activity of humans and their domesticated canine companions who erode riparian banks and increase sediment input to these pools by attempting to enter Wildcat Creek via "bootleg" trails that lead from the main trail to the creek itself (Podvin 2014).

Since the advent of this discovery EBRPD has employed both informational measures and physical barriers to dissuade the public from using these bootleg trails. These measures include twelve signs erected in 2002 and two-rail split fencing installed in 2003 along the most sensitive and heavily trafficked areas of the trail (Podvin 2014). After these dissuasion methods were

implemented there were several studies conducted monitoring the measure's effects. All of the studies following implementation of these methods were centered around Nook Pool (37°53'38"N, 122°15'14"W), as its depth makes it an ideal place for trout to spawn and its adjacency to a trail entrance put the pool at particular risk for anthropogenic disturbances. Studies conducted by EBRPD have found that the percentage of canines that enter the pool has decreased over time (Wise 2003, Graul 2004, Podvin 2014). Although the monitoring and creation of deterrence methods around Nook Pool continues to be important because of its sensitivity, there is a need for both a temporal and physical expansion of the previously used monitoring techniques in order to more fully understand the patterns of both canine and human use of the bootleg trails.

METHODS

Study Site

This study was conducted immediately adjacent to Wildcat Canyon Creek in a portion of Tilden Regional Park in Berkeley, California, on 3 bootleg trails, located at 37°54'3"N, 122°15'12"W, 37°53'58"N, 122°15'10"W and 37°53'38"N, 122°15'14"W, that stem off of Wildcat Gorge Trail. Wildcat Creek is approximately 10 miles long with a watershed encompassing about 4,500 acres with an elevation ranging between 5 meters at its mouth in Richmond, CA and 262 meters at its source in Berkeley, CA (Hassler 2002). Between Berkeley and Richmond, the creek is highly exposed to anthropogenic activities passing through 2 reservoirs (Lake Jewell and Lake Anza), many high traffic areas of Tilden Regional Park, a golf course, a working farm, and residential areas. The area is characterized by a Mediterranean climate with cool and relatively moist winters, the season in which most of our data collection took place. Although previous studies of this area have focused on the interactions between domesticated canines and *O. mykiss* along the freshwater-terrestrial border (Podvin 2014), the area is home to many other species that also have access to the bootleg trails, including mule deer, wild turkeys, coyotes, and mountain lions.

With assistance from EBRPD staff, I placed three camera traps in positions where they were able to monitor bootleg trails where some deterrence measures are already in place but access is still possible. The entrance to the bootleg trail monitored by camera 1 is covered by a partially

collapsed, easily passable wooden fence that was built by EBRPD staff. This is the first bootleg trail that is accessible to both humans and canines when proceeding down the trail from the Brook Pool entrance. Camera 2 monitored the most accessible bootleg trail of the three. The slope is the least steep on this bootleg trail at an angle of about 45 degrees with no signage or physical barriers preventing use of the trail. It is the most centrally located of the three locations, fairly removed from either entrance. Camera 2 is also the longest bootleg trail, with the largest distance from the main creek to the creek. The last camera trap, labeled Camera 3, is nearest to Nook Pool and has the most methods of deterrence around the entrance to the corresponding bootleg trail.

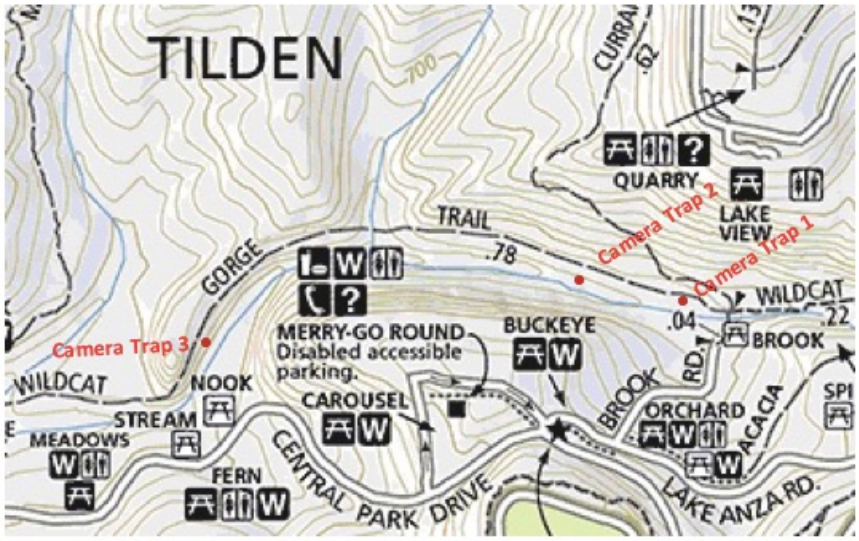

Figure 1. An aerial view of Wildcat Creek, with the 3 camera trap sites shown in red. Map source: East Bay Regional Parks Department

None of the three cameras were able to capture the entire bootleg trail. Thus, to get a more complete picture of canine and human behavior I filled in these blind spots with participant observation. I attempted to be covert in my observations by posing as a dog walker so as not to influence the behavior of humans by overtly recording their behavior (Acevedo-Gutierrez et al. 2011). On 6 random dates throughout the period of observation (12/17/17, 12/31/17, 1/15/18, 2/4/18, 3/14/18 and 4/17/18) I spent a minimum of 2 hours walking the trail and observing both human and canine behavior that was outside of the scope of the camera traps' view.

Study Population

The population of interest is domesticated canines (*Canis familiaris*), also known as pet dogs, that come to our study site as companions to humans. The appearance of this population is widely varied with individuals varying in weight from 3 pounds to upwards of 150 pounds, in height from 6 to 33 inches at the shoulder, with similarly wide variation in coat color and texture. *Canis familiaris* retains many behaviors of their wild relatives, which include coyotes (*Canis latrans*) which are native to this study site. Some of these behaviors include marking territories by urinating on trees, digging, and chasing after smaller animals. Although *C. familiaris* is by nature a social, pack oriented animal most human caretakers have one or two domesticated canines at a time; thus, we often see *C. familiaris* appearing alone or in groups of 2 or 3.

Data Collection

Equipment

To perform a more extensive study of the behavior of *C. familiaris* than have previously been attempted at Wildcat Creek by EBRPD, 3 camera traps were installed throughout the study area aimed at accessible bootleg trails. The camera models used were the Moultrie A-30 Game Camera (Camera trap 3) and the Bushnell Bandit Trail Camera (Camera Trap 1 and Camera trap 2). The Moultrie A-30 has a 12-megapixel resolution, a trigger speed of 0.7 seconds, and a flash range of 70 feet. The Bushnell Bandit Trail Camera has a 14-megapixel resolution, a trigger speed of 0.3 seconds, and a flash range of 100 feet. Both camera models were set to high sensitivity, no delay, continuous operation, and one photo per trigger, which capture one photo every other second if an animal was in sight and moving so that we could determine if there were multiple dogs in the group or if a human accompanied the dog down the bootleg trail. Both camera models also recorded the date, time, and temperature for each photo. The cameras were secured to trees about 1 meter above the ground and at least 2 meters away from the bootleg trail of interest so as to capture a wider area of movement along the trails.

Image Cataloging

I uploaded the photographs captured during the study period using Macintosh Preview to examine each one individually. The camera traps continuously record data from December 17th, 2017 to April 17th, 2018 and I downloaded and analyzed the pictures approximately once per month. For each photo I noted the time, day of the week, temperature, if a human was photographed using the trail alongside the canine, the duration of the canine's visit, which camera trap the photo was from, how many inches of precipitation occurred on the day, and how many dogs were in the group. If there was no dog present in the frame the photo was discarded and not included in the data set. Visits were defined as one dog's use of an individual trail (i.e. if a single dog was pictured on multiple cameras within a small amount of time they were counted as individual visits). Because the Moultrie camera only returns temporal accuracy up to the minute, it is impossible to determine exactly how long the canine stayed on the trail adjacent to camera trap 3. Because of this limitation, and to maintain consistency between cameras, we rounded the duration of each visit to the nearest minute.

Statistical Analysis

I organized the raw data from the cameras in Excel in a tabular format and then imported into R. I analyzed the data based on temporal data, noting the day of the week, hour of the day, duration of stay, and the date, as well as by camera trap number, number of dogs in the group, and whether a human is present. To maintain consistency of results as the data set expands I looked at proportions of visits rather than raw numbers while creating the graphs of temporal trends of canine activity (Harrison et al. 2002). Because there was little difference in location between the sites, I pooled the data to access the significance of all variables expect for when it is specifically stated that the data is analyzed based on camera trap number. For the 2 statistical tests that I performed the data was not distributed normally, so I ran a Mann-Whitney U-test to compare the ranks of sums between two groups. If the same dog appeared on two different bootleg trails within a small period of time I did count each visit as a separate event.

RESULTS

The three camera traps recorded a total of 387 visits by canines over 122 trap-days. From this data, I was able to determine general activity patterns for canines and the impact that different variable have on those patterns.

Duration of Visit in Relation to Human Presence

There was a statistically significant difference between duration of stay in the two scenarios ($p = 2.2 \times 10^{-16}$). The mean stay duration is 1.34 minutes with a median and mode stay duration of 1 minute each. In 271 of the 387 canine trail use events there was no human accompaniment. In these events the vast majority of the canines, 209 out of 271, stayed on the bootleg trails for one minute or less. The longest stay duration recorded for this subset of the data is 6 minutes and this only occurred twice out of the 387 recorded events. My participant observation identified that in these unaccompanied scenarios the human companion often just kept walking along the trail without stopping for their dog. The dog would then run quickly back up the trail to stay near to their companion, often not even entering the creek, likely causing minimal damage to the streambank.

A human accompanied the canine in their use of the bootleg trail 120 times out of the 387 total canine camera events. When the human companion accompanied the canine down the bootleg trail it extended their stay time significantly. The most frequent duration of stay is 3 minutes, with a mean stay duration of 5.92 minutes, and a median stay duration of 4 minutes with a maximum duration is 24 minutes. My participant observation revealed that in these scenarios the human encouraged their canine to follow them down the trail at least half of the time, almost no one in this group verbally or physically attempted to dissuade their canine from entering the water. Some of the humans in this group even encouraged their dog to enter the water by throwing sticks or with verbal cues.

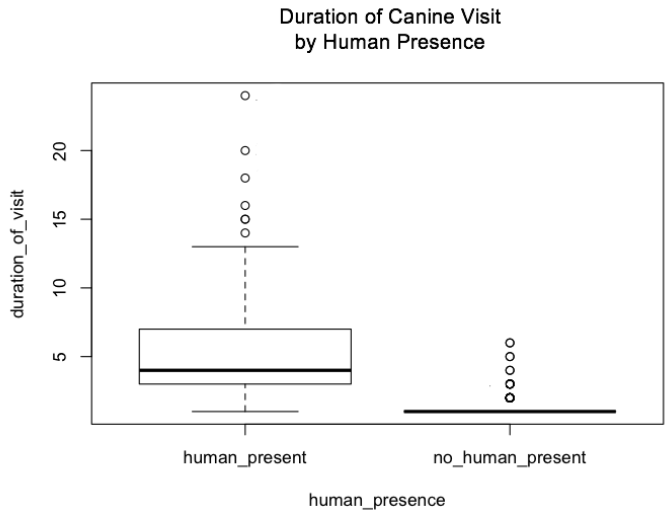

Figure 2. Duration of canine visit by human presence. The dogs tend to stay longer when their human companion follows them down the trail.

Duration of Visit in Relation to Number of Dogs in Group

The test returned a p-value of $3.815x^{-10}$ indicating that there is a statistically significant difference between duration of stay depending on if the dog is alone or in a group.

Out of 387 total visits the dog used the bootleg trail without other dogs 361 times. In 235 of these events the dog was on the trail for one minute or less (Figure 3). The mean duration of stay was 2.12 minutes with both a median and mode of 1 minute.

In 26 out of 387 total canine visits there was more than one canine using the trail at a time. Analysis of this data showed that this extended the duration of canine stay on trail significantly. For these visits, shown in Figure 3 as "Group", the mean duration of stay was 4.29 minutes, with a median and mode of 3 minutes each.

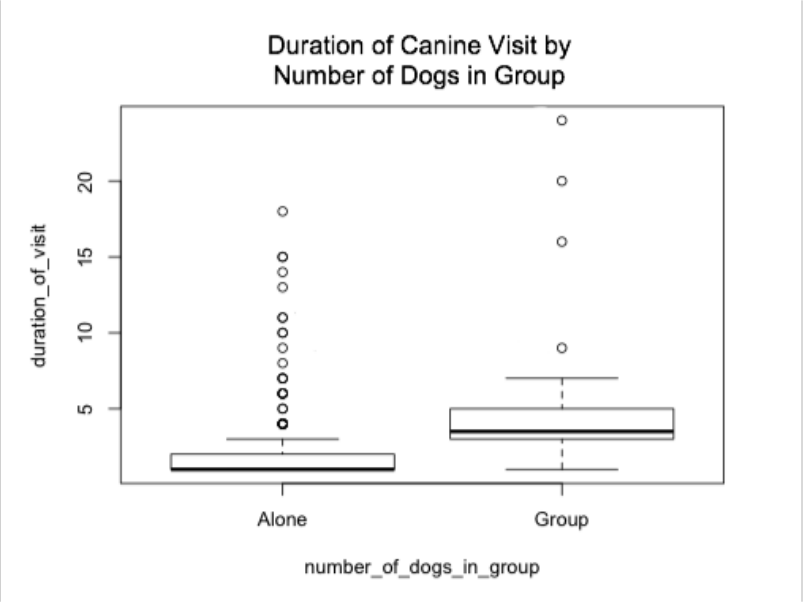

Figure 3. Duration of canine visit by number of dogs in group. Dogs tend to stay longer when there are more dogs in the group.

Diel Activity

Canine visits on the monitored trails occurred entirely between the hours of 7:00 and 19:00, with 15:00 being the most frequent hour of canine visits. There were no visits at all between 20:00 and 6:00.

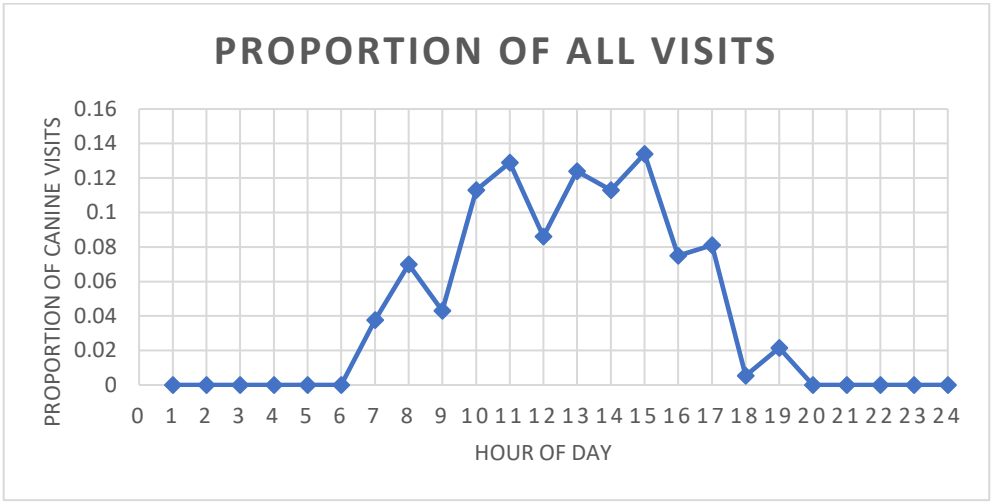

Figure 4. Proportion of canine visits that occurred at each hour of the day. The values are connected with lines to better show overall trends.

Visitation by Day of the Week

Saturday and Sunday (weekend days), were by far the two days that attracted the most canine visits with visitation proportions of 26.3% and 22.5% respectively. Out of 347 canine visitation events 189 (48.8%) occurred on weekend days. No other day reached a proportion above 15.6% with an average proportion of visits for non-weekend days of 10.2%. Thus, we saw a large disparity is proportion of visits for weekend days versus non-weekend days.

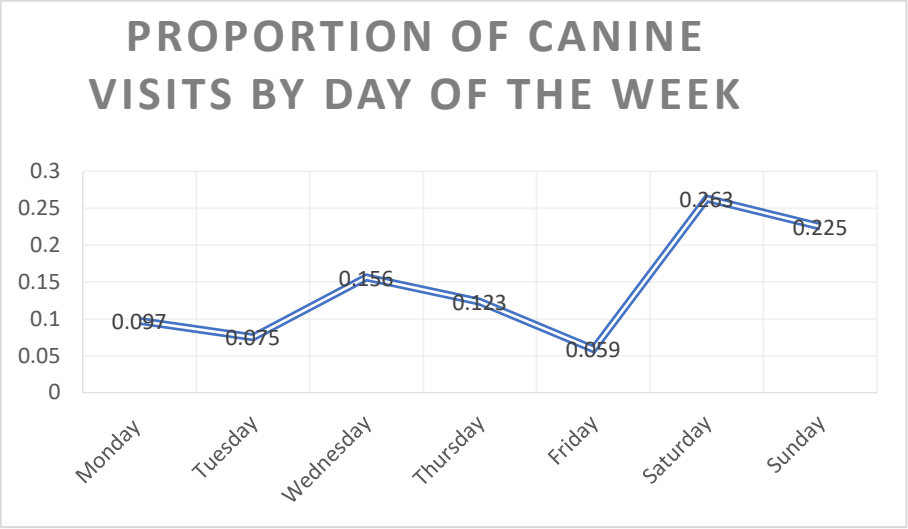

Figure 5. Proportion of canine visits that occurred on each day of the week. The values are connected by lines in order to better show overall trends.

Visitation Variation by Camera Trap Number

Because the canine's human companion's use of the trail has a statistically significant impact on the duration of the canine's stay on the bootleg trail, we also determined the efficacy of different deterrence measures at each bootleg trail. There was human accompaniment of 53.6% at camera trap 1, 36.4% at camera trap 2, and 8.8% of the time at camera trap 3. This difference is reflected in average visitation lengths on 3.88 minutes at camera trap 1, 2.14 minutes at camera trap 2, and 1.82 minutes at camera trap 3. Additionally, the number of visits were 85 at camera 1, 119 at camera trap 2, and 183 at camera trap 3 over the data collection period.

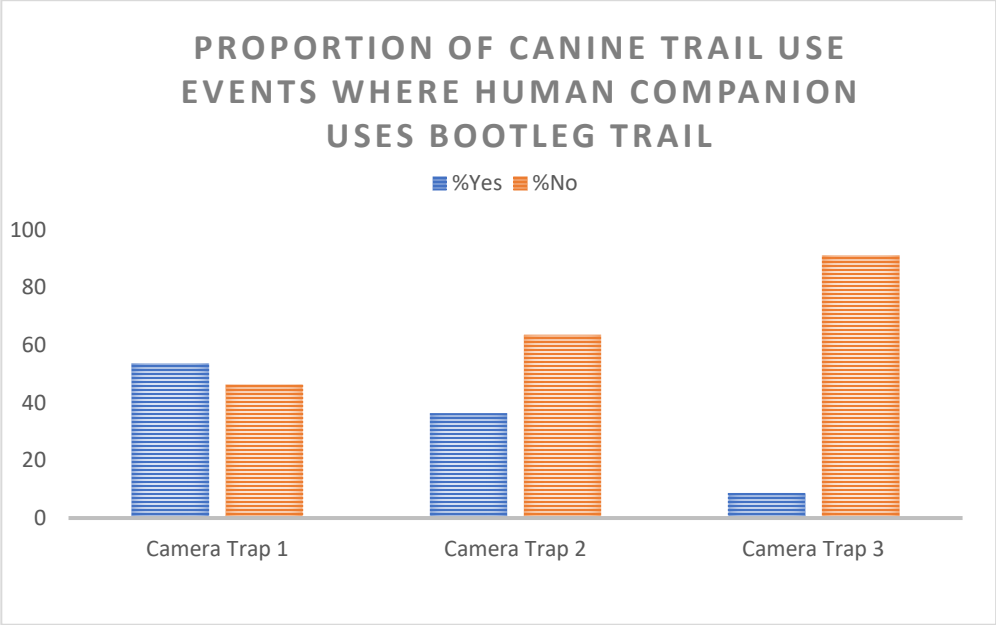

Figure 6. Proportion of canine trail use events where human companion uses bootleg trail. This clustered column shows the percentage of canine trail use events in which the human companion accompanied the canine down the trail, clustered camera trap number.

DISCUSSION

The goal of this study was to determine long-term trends in domestic canine activity on Wildcat Creek bootleg trails to evaluate past dissuasion measures and make recommendations for future dissuasion measures. Through the use of camera traps and participant observation, I was able to provide the most detailed study to date of canine activity patterns on Wildcat Creek bootleg trails to date. My findings were consistent with typical temporal trends in human recreation patterns but the canines are able to access the environment in a way that humans can not (Kitchen et al. 2000). Specifically, the canines could get through relatively small gaps in the fences, ran down the bootleg trails at increased speeds, and entered the creek at far greater rates than humans (Podvin 2014). Thus, it is essential for future recommendations for deterrence measures to account for both the instinctive animal behavior of the canine as well as the human influence on these behaviors.

Temporal Patterns

The temporal trends observed in this study site were consistent with trends observed in studies of human recreation and tourism in protected areas (Patten and Burger 2018, Ladle et al. 2018). The results for day of the week shows a significant uptick in the proportion of visits that occur on weekends, opposite to the general pattern of the typical American work week (Bell et al. 2012). This increase in visits aligns with our classification of Wildcat Creek as a recreational space. The canine trail use events also fall entirely between the hours of 7am and 7pm which is consistent with the diurnal sleep pattern of humans (Czeisler et al. 1980) and the limitations on public access to the park by East Bay Regional Parks. These results confirm that the temporal trends of canine visitation mirror temporal trends of human recreation, suggesting that the most damage occurs on the trails on Saturdays and Sundays and entirely between the hours of 7am and 7pm. These patterns are in direct contrast with typical trends for other species in the genus *Canis* such as coyotes (*Canis latrans*) who have been known to shift away from diurnal activity patterns when humans begin to infiltrate their habitats (Kitchen et al. 2000).

Duration of Stay

It is critical to consider the length of time that the canine is traveling on the bootleg trail because as the amount of time spent on the trail increases so does the impact on the sensitive riparian environment (Harrison et al. 2002). Although it may be impossible to completely prevent all canines from using the bootleg trails, reducing the amount of time that they spend on the trails will greatly reduce the amount of harm that the canines are doing to the banks.

Influence of Group Size

Dogs who used the bootleg trails in groups spent significantly more time on the trail than dogs who used the trails alone with a difference in mean of over two minutes. Based on participant observation this increased time over single dogs is likely because it is harder to physically control and influence the behavior of more than one dog at a time and because dog walkers who do not own the canine may feel less responsibility for the dog's behavior. Additionally, canines in groups

often engage in play activities such as chasing or wrestling with each other when using the bootleg trails together. These interactions can increase soil compaction and erosion and decrease vegetative cover further (Ballantyne and Pickering 2015). This is consistent with findings on other multi-use trails (Wolf et al. 2018) and has occasionally resulted in bans on walking large numbers of dogs at one time (Jamieson 2017). When canines use the trails alone, these effects are mitigated.

Influence of Human Presence

There was a clear relationship between the presence of a human on the trail with the canine and the amount of time they spent on the trail. For this variable, I saw a maximum stay of 24 minutes when the canine was accompanied by a human. This extended duration of stay means that canine and human spent 24 minutes off of the allowed trail, eroding the delicate riparian bank, and creating sediment runoff. These behaviors can disrupt the habitat of the trout that EBRPD is attempting to protect (Podvin 2014). If the human continues on the main trail without venturing onto the bootleg trail, the canine's average time spent disrupting the riparian bank and freshwater habitat below will be significantly reduced, the data showed a maximum stay duration of 6 minutes when humans exhibited this behavior pattern. This difference is not surprising because dogs likelihood of mirroring their owners' movements and reactions can be used as a tool to manage pets in public areas, a principle call behavioral synchrony (Duranton et al. 2018).

Variation by Camera Trap

Due to the influence of human presence on duration of stay, I analyzed the variable by camera trap to produce more clarity about the dissuasion measures already in place. Although camera trap 3 still had the most visits over all with 183 total visits, it also had the lowest proportion of humans accompanying the canine on the bootleg trail at 8.8% and the shortest average duration of stay at 1.82 minutes. Because of its potential for recreational use and its past reputation for being the most commonly used area in the study site it makes sense that it had the highest number of visits of the three camera traps (Podvin 2014). Despite having the highest number of visits, based on my participant observation over the study period, this shows that per trail use event, the least amount of damage occurred at camera trap 3. Out of the trails monitored by the camera traps, this

trail had the most management practices proven in previous studies to be effective including the creation of physical barriers from native vegetation, here in the form of willow fascines (Jamieson 2017), educational campaigns (Boon et al. 2008), replanting native vegetation (Buckley 2012), the installation of fences, and the maintenance of a buffer zone between the trail and the creek (Gumiero et al. 2015).

Camera trap 2 monitored a bootleg trail in an area where the buffer zone between the trail and the creek was within the recommended 10-50 meters but had no other dissuasion measures (Osborne and Kovacic 1993). Although this camera documented less visits overall than camera trap 3, the proportion of canine visits that were accompanied by humans was higher at 36.4% with an average duration of stay of 2.14 minutes, causing more damage per visit. Finally, camera trap 1 had the longest average duration of stay at 3.88 minutes with 53.6% of the canines accompanied by a human. These stats show the importance of maintaining the physical barriers, as the camera monitors a bootleg trail with a broken fence that is easily traversable. Additionally, the buffer zone was much less robust, with less vegetative cover, and a width less than the recommended 10 meters. Neither camera trap 1 nor camera trap 2 had sufficient fencing, adequate vegetative barriers, or educational campaigns. Overall, the combination of the dissuasion measures already employed by EBRPD did seem to decrease the time spent on the trail by canines and the overall trail presence by humans. The statistics for camera trap 1 demonstrate the need for continued maintenance of fences for them to be effective. If the fences do not block the entirety of the bootleg trailhead and do not have wire fencing preventing canines from easily getting through, the data shows that they do little to nothing to deter canines from entering and using the trails. This maintenance is especially crucial in locations like camera trap 1 where the vegetative buffer has a width less that literature recommends.

Limitations and future directions

Although this study took place over the longest period of time of any study in this area, there was very little seasonal variation over the four-month long study period. To fully understand temporal trends, I would recommend that a future study that examines trail use over the course of an entire year to determine if there are variations in use patterns between seasons or as temperature differences become more extreme. Although there was very little variation in these variables over

the course of this study, it is entirely possible that as the year goes on intraannual trail use patterns would emerge. Also, because our study only had 3 camera traps, replication of the type of bootleg trail monitored was not possible. The lack of replication combined with time limitations resulted in our inability to conclusively determine which of the dissuasion measures at camera trap 3 were actually the most effective. In future experiments, I would recommend attempting to test each of the recommended dissuasion measures separately on different bootleg trails throughout the study site and monitor each with a camera trap.

I would also recommend a separate future study that attempts to determine bootleg trail use trends by native species such as deer, raccoons, and coyotes to determine how much the bootleg trails are used by canines versus native species. This study did capture photographs of the aforementioned native species mostly between the hours of 8pm and 6am, indicating a nocturnal visitation pattern but I did not fully analyze the differences in patterns by species or by camera trap so I cannot give adequate recommendations for how to address this variable. Capturing this information would help EBRPD to employ dissuasion measures that take a more holistic view of the riparian ecosystem in order to ensure the health of the ecosystem in its entirety (Gurnell et al. 2016). For instance, if native animals need access to the trails to effectively interact with this ecosystem, EBRPD may have to more employ non-physical dissuasion measures so that native animals can still access the trails.

Last, an analysis of the dogs' breeds or sizes may be helpful in creating a complete picture of how the riparian ecosystem is damaged by canines. Through my participant observation I saw that larger dogs seem to use the bootleg trails and enter the creek before their human companions are able to stop them. However, I was unable to effectively analyze this trend because it is difficult to determine the size and breed in the camera trap photos as the photos are often blurry or the entire dog isn't captured. Thus, this variable will likely have to be analyzed in person using methods similar to previous studies of this site but paying attention to this variable and over a longer period of time (Podvin 2014).

Educational Recommendations

The educational signs along Wildcat Creek emphasize *O. mykiss*' need for high water quality and ask humans to control their dogs and stay off creek banks (Podvin 2104). Our results

and the results of prior studies show that the signs were marginally effective in deterring canines and humans from using bootleg trails (Podvin 2014). However, the verbiage on the signs does not emphasize human connection to creek health as much as it could. Educational signage is most successful when it promotes a sense of belonging to the space and attaches it to personal meaning (Ramkissoon et al. 2018). Visitors are more receptive to educational campaigns when they either view themselves as part of the problem or see ways that the environment could negatively affect them and those close to them, involving a combination of appeals to both emotion and logic (Priskin 2003, Boon et al. 2008). Therefore, in order to fully access the potential of the educational signs, I propose that EBRPD emphasizes personal responsibility more on the signs that they have addressing the trout population and how they are harmed by erosion of the banks. Additionally, I would install signs that address the potential risk to canine health that is caused by algal blooms in Lake Anza which is located upstream from our study site (Freeman 2010, Podvin 2014). This will help to better appeal to human's emotions by showing them that there is a potential health risk to their canine companion's health and thus making the problem more personal. Additionally, I would recommend that more signs be placed at bootleg trail entrances along the trail. Based on the results of this study that would likely reduce the number of canine trail use events even if EBRPD keeps the signs as they are now.

Observation Recommendations

Prior studies have found that the percentage of groups in which official pro-environment policies are not followed is about two-thirds lower when an observer who looked to be affiliated with the protected area is present (Freeman 2010). The number of incidents of harassment was significantly reduced when the observer was present even if the observer did not speak to the tourists directly (Acevedo-Gutierrez et al. 2011). Because of the temporal trends that this study brought to light, I recommend that either EBRPD staff or volunteers be monitoring the trails between 7am and 7pm. I also recommend that a volunteer program be implemented to ensure that there is always someone supervising the trails on Saturdays and Sundays during the aforementioned times when most of the trail visits occur. These volunteers should be briefed on the detrimental effects of canine and human trail use and be asked to walk along the main trail while wearing official EBRPD clothing to make their presence known.

Physical Recommendations

In addition to the previously mentioned dissuasion measures, there are additional physical measures that make use of the environment and have proven to protect riparian ecosystems. For example, vegetated buffer strips (VBS) adjacent to riparian habitats may reduce the negative effects of human and canine trail use. These VBSs best retain sediment and nutrients, preventing runoff most effectively when they are between 10-50 meters in width (Osborne and Kovacic 1993). When native plant species are maintained in the VBSs they filter out the harmful sediment and other non-point source pollutants by detaining and processing them (Coleman and Kupfer 1996). Comparing our results for human presence on camera trap 1 versus camera trap 2 highlights the importance of maintaining robust VBSs. If the creek is farther away from the authorized trail canines spend less time on the trail and thus, cause less damage. To capitalize on this finding, I recommend that the width of the VBS be maximized wherever possible. If the VBS cannot be expanded to at least 10 meters wide, then it is important that sufficient native vegetation is planted in the space that is available along with other deterrents.

The fact that informal path systems cause significant environmental harm by substantially impacting sensitive habitats has been well established and is the reason for this study (Hamberg et al. 2008). These bootleg trails are especially harmful in riparian ecosystems when they lead directly to the water (Rangel-Buitrago et al. 2018). Thus, to mitigate as much of the ecosystem damage as possible I recommend diverting the trails that do lead straight into the water so that they loop back up to the authorized trail and planting native plants on the area of the bootleg trail near to the water. This method reduces the spatial extent of trampling impacts, by promoting the use of a limited number of well-established bootleg paths away from sensitive vegetation and protected habitats (Korpilo et al. 2018).

EBRPD has not yet definitively established bank stability requirements for Wildcat Creek. In riparian ecosystems in Wyoming prior studies have determined that ideal bank characteristics for rainbow and brown trout are greater than 55% vegetative bank cover and 0-9% erosion on banks (Adams et al. 2008). Assuming that rainbow trout in Wildcat Creek require similar cover and bank requirements, I recommend that EBRPD conducts a study to determine if the banks fall within the recommended ranges and begin restoration if they do not.

Broader Implications

It is important to expand conservation efforts beyond previous studies of the area that only focus on Nook Pool because freshwater systems are affected by any activity taking place within the ecosystem, especially those taking place upstream (Saunders et al. 2002). Thus, because of the continuous and reciprocal nature of riparian ecosystems, it is crucial that firstly, the efforts that EBRPD made to deter canines from entering Nook Pool be implemented at different access points throughout the study site (Naiman and Décamps 1997). Although some of the methods are implemented at various points throughout the trail, to maintain a healthy ecosystem that allows the trout population to thrive, EBRPD must consider the study site as a whole and make sure that they are doing all that they can to deter canines from disrupting the banks at every possible entrance point. This study addressed canine activity trends in a relatively small study site but it serves as an important step in a more comprehensive stream health management in Tilden Regional Park.

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