Factors affecting Avian Species Diversity and Vocalization Rate in Claremont Canyon, Berkeley, CA

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ABSTRACT

Claremont Canyon is a wilderness preserve in Berkeley, CA, USA used for human recreation. Studies have shown that human nature recreation has negative effects on wildlife. This study investigates the effects of human conversation on bird species diversity and vocalization rate. I collected data using an OpenAcoustic Devices AudioMoth and compared it to data from two previous studies. Data analysis was conducted using BirdNET software and Microsoft Excel. Over 40 hours of recorded audio, I found there to be a total of 33 human conversations, 10 unique bird species, and 481 bird vocalizations with a BirdNET confidence score of more than 0.95. Out of 10 bird species I found, only 7 were identified in previous studies. The 3 species that were not previously identified were oak titmouse, cedar waxwing, and western bluebird. I found that bird species diversity decreased from 1991 to the present by 72% and that human conversations did not have a significant effect on bird species diversity (r-squared = 0.03) and vocalization rate (r-squared = 0.06). I found that BirdNET was less effective at identifying bird species than point counts. However, BirdNET is practical for inexperienced birders or when field work is not a possibility. I conclude that researchers should carefully consider using cutting-edge software, like BirdNET, by considering all possible advantages and downsides. Human recreation and bird behavior in Claremont Canyon should continue to be monitored to ensure ecosystem health.

KEYWORDS

BirdNET, OpenAcousticDevices AudioMoth, human nature recreation, bird behavior, wilderness preserve

INTRODUCTION

Increasing development by humans has led to encroachment, including in the form of recreation, on previously undisturbed wilderness areas and as a result is affecting the ecology of these areas. Numerous studies found that human recreation in wilderness areas can affect animals negatively, such as by disturbing them, affecting their behavior, and causing physiological stress (Barros et al. 2014, Larson et al. 2016, Larson et al. 2018). It was also found that human recreation in wilderness areas causes alterations in species diversity (Larson et al. 2018). Furthermore, non-motorised recreation in wilderness areas has been found to negatively impact birds from a diverse range of habitats around the world (Steven et al. 2011). These studies show that human recreation in wilderness areas poses a nuisance to wildlife such as birds. This is significant and calls for more detailed studies to avoid bigger issues related to wildlife conservation.

One of the potential negative effects that human recreation in wilderness locations can have on birds is a decrease in species diversity. Locations near human developments have lower proportions of temperate migrant birds compared to undeveloped natural areas (Merenlender et al. 2009). One study found that recreation negatively affected bird and mammal abundance (Larson et al. 2019). Another study indicated that occurrence and composition of bird communities was affected by number of visits while no impact on total species richness was observed (Kangas et al. 2010). Dogs and carnivores were similarly found to decline in abundance with more human visitation (Reed and Merenlender 2010). A study noted a decrease in bird observation number compared to a similar study done 23 years earlier in the same region (Harding 2015). These studies provide evidence for negative effects of human recreation on animal abundance, particularly on birds. This is significant because it means that continued human recreation in wilderness zones could result in decreases in bird population sizes, an important conservation concern. Further studies should be conducted on this topic because it is still unclear what the effects of human recreation on bird species diversity are.

There is evidence that human recreation in wilderness locations also has an influence on bird vocalization frequency. Two studies found that human disturbance resulted in birds increasing the frequency of communications by over 500% (Swarthout and Steidl 2003, Fernández and Azkona 1993). Birds responded to an aircraft event at a site with relatively low aircraft noise with an increase in bird vocalization richness; they were also found to avoid masking by changing their vocalization frequency and timing (Vincelette et al. 2021). This may be important when considering hikers who engage in conversations while walking as this may similarly influence bird vocalization frequency. These studies show how anthropogenic auditory disturbances can affect birds and influence their vocalization frequency. This is an important topic to study because changes in bird vocalization frequency may have other ramifications for avian health.

We know that human activity can disturb birds and affect many aspects of their health, including abundance and vocalization rate. However, there are not any studies that have investigated these effects over the long term. I will investigate this by referring to previous studies by Harding (2015) and Dreher (1992); these studies present data on bird species diversity at the same study site during the years 2014/2015 and 1991/1992, respectively. My central research question seeks to understand the effects of human conversation on bird species diversity and vocalization rate. To answer this question, I will investigate 1) how human conversation count and bird species and vocalization count change throughout the day, 2) how bird species diversity and vocalization rate change with changing levels of human conversations, and 3) how bird species diversity has changed from 1991 to the present. For each of these questions, I hypothesize that 1) conversation count will have a normal distribution throughout the day with the peak at noon, 2) bird species diversity will decrease and vocalization count will increase with increasing human conversation count (Larson et al. 2018, Swarthout and Steidl 2003, Fernández and Azkona 1993), and 3) bird species diversity will have a decreasing trend from 1991 to the present (Harding 2015). By answering these three questions, I will be able to better understand how human recreation influences bird behavior and the implications for bird conversation.

METHODS

Study site description

My study site is in Claremont Canyon, a 208-acre preserve located in the Berkeley and Oakland hills of California, USA and managed by the East Bay Regional Parks District (Figure 1). Other portions of the canyon are managed by the University of California, East Bay Municipal Utilities District, and the City of Oakland (East Bay Regional Parks District 2022). Claremont Canyon is an ecological corridor on an urban fringe which supports a range of vegetation types including grassland, coastal scrub, oak/bay woodland, and eucalyptus plantation. Claremont Canyon is home to a variety of wildlife including black tailed-deer, coyote, western terrestrial garter snake, red-tailed hawk, and gray fox (ibid). The numerous bird species residing in Claremont Canyon are of particular interest to this study. Claremont Canyon is popular for its network of dirt paths which are frequently used for recreational hiking by locals. There is no bicycle or motorized vehicle traffic permitted on the preserve (East Bay Regional Parks District 2022). In my study, I sought to investigate the effects of human nature recreation on birds residing in Claremont Canyon.

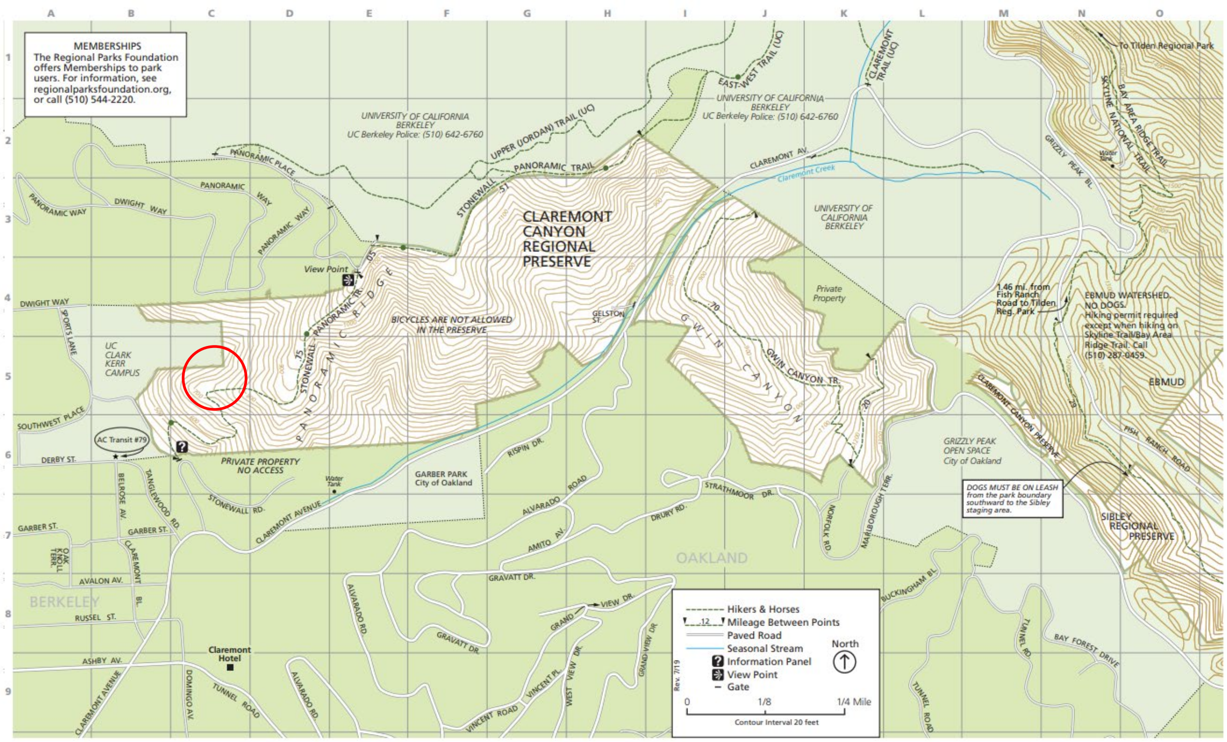

Figure 1. Map of Claremont Canyon area. The approximate location of my study site is circled in red. The map was retrieved from the East Bay Regional Parks District website (retrieved 5-5-22).

I selected a single study site, out of three sites I examined in a pilot study, to conduct my experiment (Figure 2). The GPS coordinates for this location are 37º 51' 53.648" N 122º 14' 33.344" W. The site is characterized by a densely wooded area along a narrow, packed-earth path carved into a moderately steep hillside. This forested area provides plenty of space for birds to roost and is at the same time a path frequented by hikers due to its proximity to one of the trailheads leading into the preserve. Nevertheless, my study site is separated from roads and other significant disturbances by at least 200 meters distance (Figure 2).

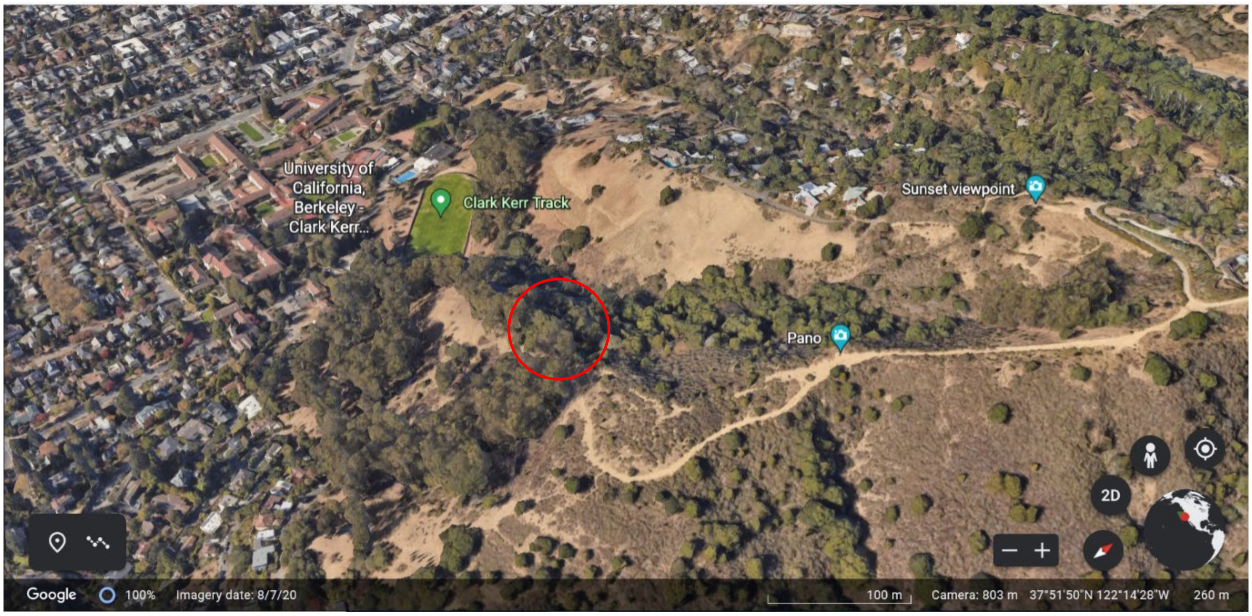

Figure 2. Ariel view satellite image of Claremont Canyon study site area. Shown is a lower west section of Claremont Canyon preserve with an urban area south of the UC Berkeley campus to the left. The approximate location of my study site is circled in red. The image was retrieved from Google Earth (retrieved 4-18-22).

Human and bird activity daily trends

To determine trends in count of bird species, bird vocalizations, and human conversations, I deployed an automated recording device, specifically an Open Acoustic Devices AudioMoth, to collect sound data. Before deploying the AudioMoth, I programmed it to record for 5 minutes at the top of each hour from 6am to 6pm PST. The settings I used were Sleep duration = 3300 s, Recording duration = 300 s, and Recording period from 6:00 to 18:00 "local time", which was UTC-8. All other settings were default. I set the AudioMoth to record from Saturday to Tuesday starting on February 5, 2022 and repeated this schedule weekly until February 22, 2022. Starting on February 23, 2022, I began recording all week long until the weekend of March 12, 2022. This was done purposely to avoid complications set forth by the beginning of daylight saving time on March 13, 2022.

To deploy the AudioMoth, I switched the device to CUSTOM, placed it inside a resealable plastic bag along with a desiccant packet, sealed the bag, then tied the bag with its contents to a relatively narrow tree trunk using about 6 feet of twine. I secured the bag about 6 feet above the ground on a slope about 20 feet above the trail and facing away from the trail. This inconspicuous location was chosen to prevent tampering while still obtaining effective human and bird recordings. After completion of each recording period, I collected the device and uploaded the recorded data files to my computer.

To conduct my analysis, Kendall Calhoun (University of California, Berkeley) helped me input each recording into BirdNET software to identify the bird species found in each recording. BirdNET is a computer program for Microsoft Windows which automatically identifies bird species from bird audio recordings. BirdNET includes relevant information including confidence score, audio file name, and time stamp of each identification. To ensure that all BirdNET data points were accurate, I only used results with a confidence score more than or equal to 0.95. To determine the human conversation count, I listened to relevant recordings and counted how many times I heard a distinct human conversation. To determine bird species diversity and vocalization rate, I used Microsoft Excel to count the number of unique bird species and individual vocalizations for every hour. Finally, I organized my data by hour and used these values to create figures for presenting my data.

Human conversation effects

To determine the effects of human conversation on bird species diversity and vocalization rate, I made two linear regression graphs. Using Microsoft Excel, I made one scatter plot using my data for human conversation count vs. bird species count and another one for human conversation count vs. bird vocalization count. I then added a trendline to each plot and noted the line equation and r-squared value for each.

Bird species diversity trends

To determine historical trends in bird species diversity, I compared my findings with data from Harding (2015) and Dreher (1992) (Table 1). Using Microsoft Excel, I organized my data and placed it alongside the bird species diversity data taken from Harding (2015) and Dreher (1992). I then created a table and graph to present my findings.

Table 1. Comparison of Dreher (1992), Harding (2015), and my study. Included are relevant details of the studies used to determine historical bird species diversity in Claremont Canyon. Upper Claremont Canyon is managed by the University of California.

Study	**Years**	**ID methods**	**Data collection period**	**Exact site**	**Survey schedule**	**Total survey time**
Dreher 1992	1991-1992	Personal censusing method (Stebbins 1990)	Late Oct. 1991 – late Feb. 1992	Upper Claremont Canyon	2 hours after/before sunrise/sunset	30 hours
Harding 2015	2014-2015	Personal censusing method (Stebbins 1990)	Nov. – Feb.	Upper Claremont Canyon	2 hours after dawn	30 hours
My study	2021-2022	BirdNET software with AudioMoth	Feb. 5 – Mar. 14	Lower west Claremont Canyon	All-day	40 hours

RESULTS

Human and bird activity daily trends

After completing my data analysis, I found there to be a total of 33 human conversations over all recordings. The average number of human conversations for each hour was 2 with a minimum of 0 during hours 6, 7, and 19 and a maximum of 10 during hour 11. Conversation count for each hour appears to have had remained relatively consistent between the hours of 8 and 18 with a sudden peak at hour eleven (Figure 3).

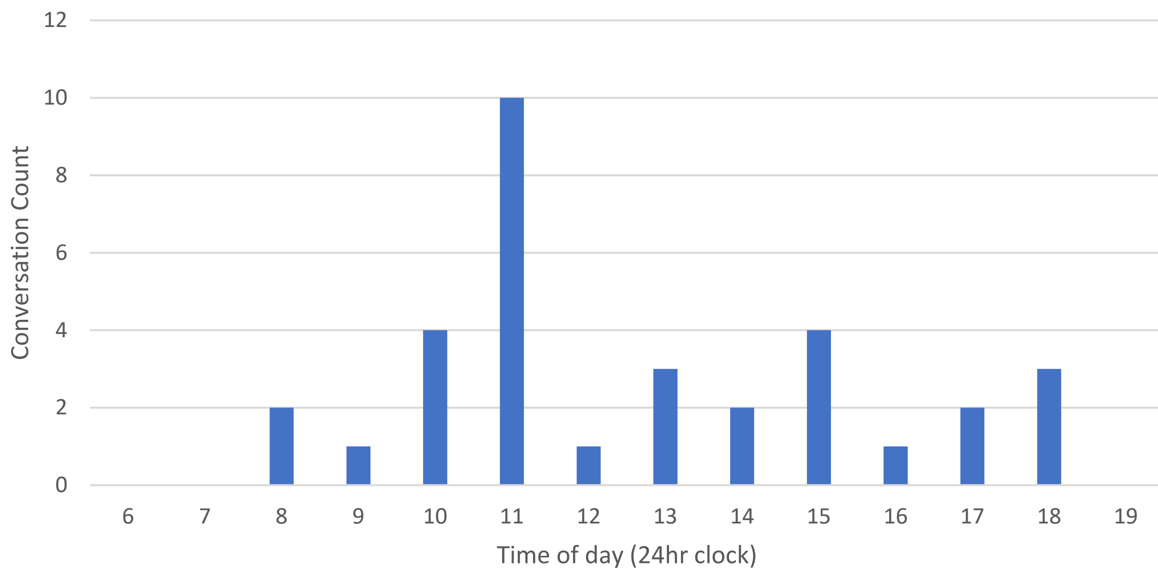

Figure 3. Conversation count throughout the day. Conversation count is cumulative for each hour over the entire 30-day data collection period. Peak conversation count clearly occurs at hour eleven. Time of day is measured using a 24 hour clock.

I observed a total of 10 unique bird species over all recordings. The average number of unique bird species for each hour was 3 with a minimum of 1 during hours 6 and 19 and a maximum of 4 during hours 7, 8, 9, 10, 12, 13, and 14. Species count for each hour appears to have remained relatively constant between the hours of 7 and 14 with a drop off beginning at hour 15 (Figure 4).

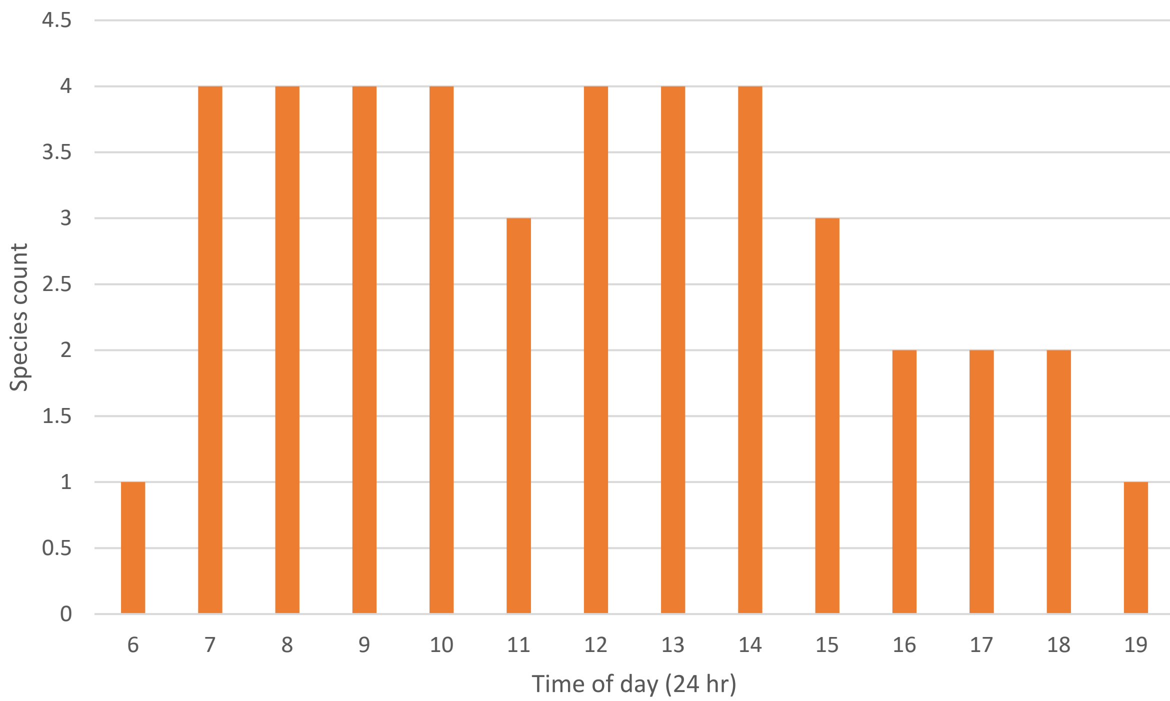

Figure 4. Bird species count throughout the day. Species count refers to the number of unique bird species present. Species count is cumulative for each hour over the entire 30-day data collection period. Time of day is measured using a 24 hour clock.

I observed a total of 481 individual bird vocalizations with at least a 0.95 confidence score over all recordings. 4,104 BirdNET identifications were not included in the study because they had a confidence score less than 0.95. The average number of bird vocalizations for each hour was 34 with a minimum of 4 during hour 18 and a maximum of 90 during hour 7. Vocalization count for each hour appears to have had a decreasing trend over the course of the day (Figure 5).

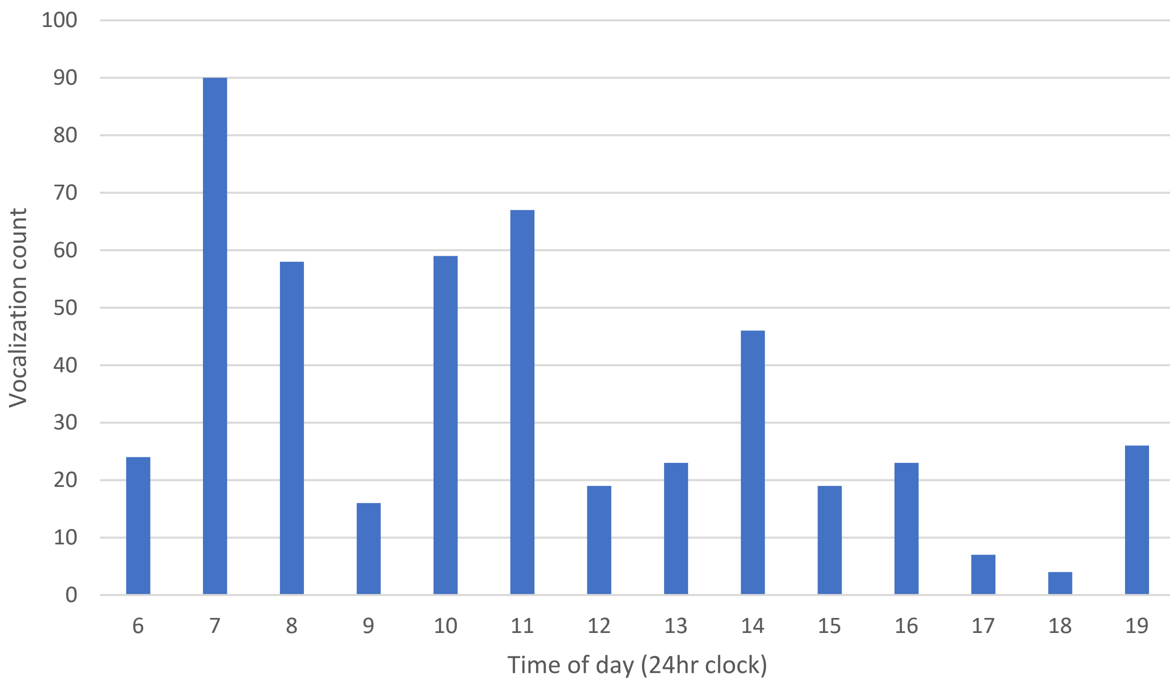

Figure 5. Vocalization count throughout the day. Vocalization count is cumulative for each hour over the entire 30- day data collection period. Peak vocalization count clearly occurs at hour seven. Time of day is measured using a 24 hour clock.

Human conversation effects

After determining daily trends in human and bird activity, I was able to compare human conversation count to bird species and vocalization count. I created a linear regression for human conversation count and bird species count and found an r-squared value of 0.03 with line equation $y = 0.0803x + 2.8108$. Therefore, there was not a significant correlation between human conversation count and bird species count. I also created a regression for human conversation count and bird vocalization count and found an r-squared value of 0.06 with line equation $y = 0.025x + 1.4991$. Therefore, there was not a significant correlation between human conversation count and bird vocalization count.

Bird species diversity trends

The 10 bird species I observed in my study were Anna's hummingbird, Bewick's wren, California towhee, cedar waxwing, chestnut-backed chickadee, common raven, great horned owl, northern flicker, oak titmouse, and western bluebird. Out of these species, 7 of them appeared in Dreher (1992) and Harding (2015); these were Anna's hummingbird, Bewick's wren, California towhee (appears as brown towhee), chestnut-backed chickadee, common raven, great horned owl, and northern flicker (appears as red-shafted flicker) (Table 2). The 3 species not identified in Dreher (1992) and Harding (2015) were oak titmouse, cedar waxwing, and western bluebird.

Table 2. Bird species comparison of Dreher (1992), Harding (2015), and my study. Only BirdNET data with a confidence score over 0.95 were used for the Present column. TRUE indicates one or more birds of the given species were observed and FALSE indicates the bird species was not observed in the study. Cells with TRUE have been highlighted to make the table easier to read.

Common name	Latin name	1991-92	2014-15	Present
Cooper's hawk	*Accipiter cooperii*	TRUE	FALSE	FALSE
Sharp shinned hawk	*Accipiter striatus*	TRUE	FALSE	FALSE
Rufous-crowned sparrow	*Aimophila ruficeps*	FALSE	TRUE	FALSE
Scrub jay	*Aphelocoma coerulescens*	TRUE	TRUE	FALSE
Oak titmouse	*Baelophus iornatus*	FALSE	FALSE	TRUE
Cedar waxwing	*Bombycilla cedrorum*	FALSE	FALSE	TRUE
Great horned owl	*Bubo virginianus*	TRUE	TRUE	TRUE
Red tailed hawk	*Buteo jamaicensis*	TRUE	TRUE	FALSE
Swainson's hawk	*Buteo swainsoni*	TRUE	FALSE	FALSE
Anna's hummingbird	*Calypte anna*	TRUE	TRUE	TRUE
Turkey vulture	*Cathartes aura*	TRUE	FALSE	FALSE
Hermit thrush	*Catharus guttatus*	TRUE	FALSE	FALSE
Wrentit	*Chamaea fasciata*	TRUE	TRUE	FALSE
Red-shafted flicker	*Colaptes auratus*	TRUE	FALSE	TRUE
Band-tailed pigeon	*Columba fasciata*	TRUE	FALSE	FALSE
Common raven	*Corvus corax*	FALSE	TRUE	TRUE
Steller's jay	*Cyanocitta stelleri*	TRUE	TRUE	FALSE
Townsend's warbler	*Dendroica townsendi*	TRUE	FALSE	FALSE
Black-shouldered kite	*Elanus caeruleus*	TRUE	FALSE	FALSE
Pacific slope flycatcher	*Empidonax difficllis*	FALSE	TRUE	FALSE
Brewer's blackbird	*Euphagus cyanocephalus*	TRUE	TRUE	FALSE
Varied thrush	*Ixorus naevius*	FALSE	TRUE	FALSE
Dark-eyed junco	*Junco hyemalis*	TRUE	TRUE	FALSE
Lincoln's sparrow	*Melospiza lincolnii*	TRUE	TRUE	FALSE
Song sparrow	*Melospiza melodia*	TRUE	TRUE	FALSE

Brown-headed cowbird	*Molathrus ater*	FALSE	TRUE	FALSE
Chestnut-backed chickadee	*Parus atricapillus*	TRUE	TRUE	TRUE
Black-capped chickadee	*Parus pubescens*	TRUE	TRUE	FALSE
Fox sparrow	*Passerella iliaca*	FALSE	TRUE	FALSE
Black-headed grosbeak	*Pheucticus melanocephalus*	FALSE	TRUE	FALSE
Downy woodpecker	*Picoides pubescens*	TRUE	TRUE	FALSE
Hairy woodpecker	*Picoides villosus*	FALSE	TRUE	FALSE
Rufous-sided towhee	*Pipilo erythrophthalmus*	TRUE	TRUE	FALSE
Brown towhee	*Pipilo fuscus*	TRUE	TRUE	TRUE
Spotted towhee	*Pipilo maculatus*	FALSE	TRUE	FALSE
Blue-gray gnatcatcher	*Polioptila caerula*	FALSE	TRUE	FALSE
Bustit	*Psaltriparus minimus*	FALSE	TRUE	FALSE
Ruby-crowned kinglet	*Regulus calendula*	TRUE	FALSE	FALSE
Black phoebe	*Sayonoris nigricans*	FALSE	TRUE	FALSE
Rufous Hummingbird	*Selasphorus rufus*	FALSE	TRUE	FALSE
Allen's hummingbird	*Selasphorus sasin*	TRUE	FALSE	FALSE
Western bluebird	*Sialia Mexicana*	FALSE	FALSE	TRUE
Red-breasted nuthatch	*Sitta canadensis*	TRUE	TRUE	FALSE
Pygmy nuthatch	*Sitta pygmaea*	TRUE	FALSE	FALSE
European starling	*Sturnus vulgaris*	TRUE	FALSE	FALSE
Bewick's wren	*Thyromanes bewickii*	TRUE	TRUE	TRUE
House wren	*Troglodytes aedon*	FALSE	TRUE	FALSE
American robin	*Turdus migratorius*	TRUE	TRUE	FALSE
Common barn owl	*Tyto alba*	TRUE	FALSE	FALSE
Hutton's vireo	*Vireo huttoni*	TRUE	FALSE	FALSE
Solitary vireo	*Vireo solitarius*	TRUE	FALSE	FALSE
Mourning dove	*Zenaida macroura*	TRUE	TRUE	FALSE
Golden-crowned sparrow	*Zonotrichia atricapilla*	TRUE	TRUE	FALSE

I found that from 1991 to 2022, bird species diversity had a decreasing trend. The Harding (2015) dataset reported 34 different species out of 242 total bird observations with 61 unidentified observations. The Dreher (1992) dataset reported 36 different species out of 455 total bird observations, and 104 observations were not identified. Compared to the Harding (2015) census, I observed a decrease in the bird species count from 2014-15 to 2022. Harding (2015) observed a small decrease in bird species count from 1991-92 to 2014-15. Therefore, I observed a continuous decrease in bird species count from 1991 to the present (Figure 6).

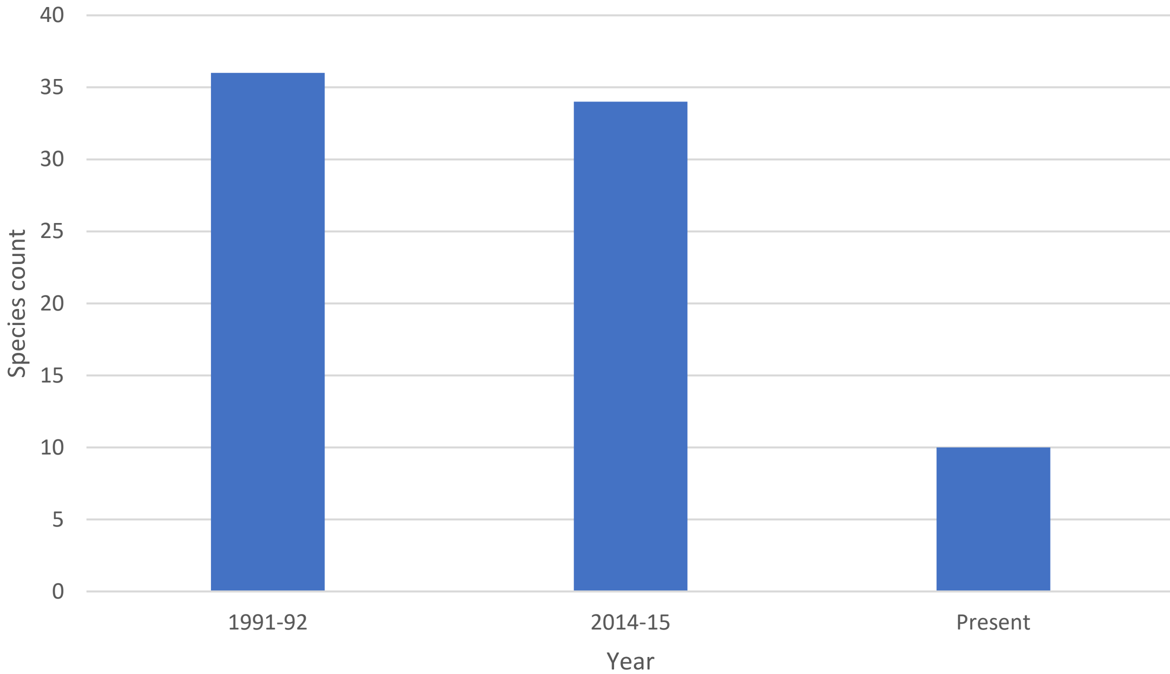

Figure 6. Species count from 1991 to present. Species counts for 1991-92, 2014-15, and Present are taken from Dreher (1992), Harding (2015), and my study, respectively. Species counts are cumulative over the entire data collection period for each study.

DISCUSSION

Bird species diversity and vocalizations have rarely been studied in relation to human nature recreation over the long term. Studies have shown that human nature recreation has negative effects on bird behavior (Barros et al. 2014, Larson et al. 2016, Larson et al. 2018). I investigated the effects of human conversation on bird behavior in Claremont Canyon preserve in Berkeley, California, USA. I found that human conversations did not cause an overall change in bird species diversity and bird vocalization rate. From the year 1991 to the present, I observed a decreasing trend in bird species count in Claremont Canyon. I conclude that bird behavior should continue to be monitored to ensure ecosystem health. I suggest that the use of cutting-edge software like BirdNET should be carefully considered before substituting it for direct field work.

Human and bird activity daily trends

I found that human conversation and bird species diversity and vocalization rate were not constant throughout the day. Human conversation had a sudden peak at hour 11 (Figure 3), bird species diversity had a declining trend beginning mid-afternoon (Figure 4), and bird vocalization rate had a relatively constant declining trend throughout the day (Figure 5). The sudden peak in human conversation suggests that recreational hikers prefer to go to Claremont Canyon during the late morning hours. The bird activity trends I observed provide evidence that the bird morning chorus occurs around hour seven during late winter in Claremont Canyon. This agrees with a previous study that found that morning acoustic activity in a Mediterranean landscape peaked around 30 minutes before sunrise (Farina et al. 2015). By accounting for these fluctuations in daily human and bird activity, I was better able to assess the precise effects of human conversation on bird behavior.

Human conversation effects

Human conversation influence on bird call rate and species diversity did not yield significant results. Although human conversation was not found to affect bird behavior in this study, significant effects on bird behavior could possibly be observed with different conditions and anthropogenic disturbances. For example, bird species diversity was found to significantly decrease in a forest with more noise and air pollution (Saha and Padhy 2011). Similarly, in another study, there was a significant increase in the vocalization rate of Mexican spotted owl when hikers were nearby (Swarthout and Steidl 2003). Vocalizations have also been found to play an important role in the reproductive habits of the New Zealand kiwi (Digby et al. 2014). Changes in bird species diversity and vocalizations could indicate impacts of bird health by anthropogenic stressors.

Bird species diversity trends and BirdNET effectiveness

I observed an overall decreasing trend in bird species diversity from 1991 to the present. Some new species appeared that were not recorded in Harding (2015) nor Dreher (1992), despite an overall decrease in species diversity. This result may be due to different experimental methods or differing vegetation between study sites (Dreher 1992, Harding 2015). Particularly, the combination of BirdNET and AudioMoth I used to collect data was significantly less effective than the point count methods used in Harding (2015) and Dreher (1992). Because I was confined to using BirdNET results with a confidence score above 0.95, many data points were left out of analysis. Despite the low accuracy of BirdNET, it can be a useful tool for researchers who have little experience with identifying bird vocalizations.

Studies evaluating AudioMoth performance tend to highlight improvements over traditional passive recording techniques but fail to mention the limitations of using this kind of monitoring for research (Hill et al. 2018, Hill et al. 2019). The static location of the AudioMoth cannot replicate point counts done by an individual walking down a transect. This can be alleviated by placing multiple AudioMoths several feet apart along a transect. I found the use of an AudioMoth to be time-efficient because it only needs to be mounted and collected and can record over weeks at a time. A potential solution when field work is not a possibility is to conduct point counts on audio recorded by several AudioMoths along a transect. These tradeoffs, in addition to the circumstances of each project, should be carefully considered when deciding on which bird identification method to use.

Human conversation effects on bird behavior

After investigating how bird behavior changes with increased number of human conversations, I was able to synthesize my findings about the effects of humans on birds in Claremont Canyon. First, I conclude that human recreational activity in Claremont Canyon should continue to be monitored for significant trends, especially during the late morning hours. Similarly, bird behavior should continue being monitored since changes in behavior could indicate a threat to bird health. Second, I conclude that human recreation does not significantly affect bird species diversity or vocalization rate. Still, it may be necessary to continue investigating human nature recreation effect on birds in Claremont Canyon due to evidence of negative effects from other studies (Steven et al. 2011). Third, I conclude that the tradeoffs of using software like BirdNET to conduct research should be carefully considered. Further investigation on bird species diversity in Claremont Canyon should be done year-round to better understand species diversity patterns.

Limitations and Future Directions

Some limitations to my study are that I used a single study location for my study which may not be reflective of Claremont Canyon as a whole or of other nature preserves. Also, I counted bird vocalization rate and species diversity using BirdNET while Harding (2015) and Dreher (1992) implemented adaptions of the point count method outlined in Stebbins (1990). Finally, because my data was only collected during the winter season, factors like migration and seasonal differences are not accounted for in my study. Future studies investigating year-round bird behavior may uncover additional beneficial findings for conservation.

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