

Research Note

Is Electric Loud? Comparing Noise from Traditional and Electric Bicycles in a Quiet Setting

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Abstract

Electric bicycle use in parks and recreational trails throughout the United States has been increasing in popularity, requiring management considerations. One of these considerations is the noise associated with e-bikes, yet little is known about how this noise may differ from traditional bikes and influence the acoustic environment. This study sought to measure and compare the extent and amount of noise that both traditional and e-bikes can contribute to an environment. Results show a range from no perceptible difference to a readily perceptible difference based on bicycle type (traditional, Class I e-bike, and Class II e-bike) and speed, with the largest difference being between a traditional bicycle and Class II e-bike at lower speeds. Understanding disturbances to the acoustic environment will provide decision makers with information on how to minimize impacts to acoustic resources and visitor experience, while maintaining access to recreation to park visitors.

Keywords

E-bikes, acoustics, acoustic environment, soundscape

Introduction

An electric bicycle, also known as “e-bike,” is defined as a two- or three-wheeled vehicle with operable pedals and an electric motor that assists with propulsion of the device. They are often divided by class, which are sometimes used to determine where they are allowable for use (Department of Interior, 2019). These classes are differentiated by ability to offer pedal assistance and maximum speed:

Class I: Equipped with a motor that provides assistance only when the rider is pedaling, and that ceases to provide assistance when the bicycle reaches the speed of 20 mph.

Class II: Equipped with a motor that may be used exclusively to propel the bicycle, and that is not capable of providing assistance when the bicycle reaches the speed of 20 mph.

Class III: Equipped with a motor that provides assistance only when the rider is pedaling, and that ceases to provide assistance when the bicycle reaches the speed of 28 mph.

Management of E-Bikes in Parks and Trails

A literature review of the wide-ranging social aspects of e-bikes found that most studies address at least one element of managerial, resource, or social considerations; yet also found that only 2.2% of published studies represented e-bike use on public lands (McCurdy et al., 2024). Rodman (2023) discusses the post-2020 boom in visitation and recreational use of trail systems in National Parks. Cumulatively, this use and trail way congestion has led to concerns about trail degradation, rider safety, recreational conflicts, and noise. Xiong (2022) explores previous studies on various attitudes between e-bikers and traditional bikers, which include hostility toward the newer hobby and traditionalists' resistance to accept e-bikes into their spaces.

These concerns have led to management strategies that segment bicycle usage by type of surface, for example paved road or dirt trail, and bicycle type or class (Nielson et al., 2019). Management strategies also vary by jurisdiction. The City of Loveland, Colorado allows Class I and Class II e-bikes on trails where traditional bicycles are allowed but prohibits the use of Class III e-bikes. This allowance excludes a single park, which focuses on wildlife viewing where only traditional bicycles are authorized, while all classes of electric are prohibited (City of Loveland, 2024). In 2020, the U.S. National Park Service updated regulations of e-bikes (36 CFR Parts 1 and 4) to manage traditional and e-bikes the same yet also giving superintendents the authority to limit or restrict e-bike use (including by class) after taking into consideration public health and safety, natural and cultural resource protection, and other management activities and objectives. The U.S. Bureau of Land Management (43 CFR 8340.0-5) and U.S. Forest Service (36 CFR Part 212) have taken a similar approach. The concerns and inconsistency among management strategies continues to suggest a need for additional research into the potential impacts of e-bike use in parks and recreational trails.

Noise in Parks

Generally, noise pollution refers to the elevation of sound levels due to noise-generating human activities that do not contribute to intrinsic sound resources. Decades of increased levels and types of human activity have rapidly increased the distribution of noise pollution in parks and protected areas including once remote wilderness sites (Barber et al., 2010). Anthropogenic noise sources have the potential to mask wildlife communications and directly influence human and wildlife behavior through cognitive impairment, distraction, stress, and altered physiology (Basner et al., 2014; Francis & Barber, 2013; Shannon et al., 2016). A 2024 analysis identified changes in animal behavior, such as increased vigilance and fleeing, due to recreational noise such as hiking and mountain biking (Zeller et al.). This had an increased effect when the person or persons were vocal during their activity. Noise is particularly concerning in parks and protected areas that are required to protect natural and cultural resources and the visitor experience. Recent research supports the notion that natural sounds are an im-

portant part of the visitor experience, and anthropogenic noise can detract from that experience (Ferguson et al., 2024; Rapoza et al., 2015).

Study Objectives

To study both natural and non-natural sounds, scientists collect acoustic measurements to quantify potential impacts to visitor experience, cultural immersion, and wildlife behaviors. The results of these studies assist decision makers and planners to assess consistency with management objectives and to inform future decisions regarding the protection of resources. Regarding bicycle noise, there has been little scientifically measured or peer-reviewed information available comparing e-bike and traditional bicycle noise (Nielsen et al., 2019). The purpose of this study is to systematically measure the noise of three different bicycle types to better understand the differences in their noise generation. By filling this gap, managers can make more informed decisions for managing bicycle use in traditionally quiet settings such as parks and protected areas.

Methods

Study Design

The study site was located outside of Fort Collins, Colorado in a quiet area with little traffic. An asphalt road was utilized that had an approximate 1% incline in the direction the bicycles were ridden. All passes were completed when no traffic was present at or near the site.

Bicycle selection was based on local availability (e.g., rentals), which limited the extent of bicycle types and tire treads measured for this study. Bikes had their own individual tire type but were similar in width and tread pattern. The three bicycles available were: Traditional Raleigh Mojave 2.0, Class I Trek Rail e-bike mid-drive, and a Class II Pedego e-bike hub-drive. No Class III bikes were evaluated due to a lack of availability. The two e-bikes were chosen specifically to have both a mid-drive and hub-drive motor.

Measurements were collected from the three different bicycles at three different speeds (10 mph, 15 mph, and 18 mph) that were chosen to represent a variety of speeds that could be encountered on public trails. The rider in this study aimed for these speed brackets, but due to lack of cruise control and natural human error some received a higher number of passes than others. Generally, each speed had three to six passes by for each bicycle to establish a solid baseline. No throttles, braking, or gear shifting were utilized during the study. Pass by data were collected during nine second events with four seconds at the approach, one second at the pass and four seconds during the departure. Each pass occurred 1.5m from the microphone, which was set on a tripod 1.7m from the ground to mimic a general height of a human ear (Figure 1).

Data Collection & Equipment

A Larson Davis 831 sound level meter (SLM) was used to record the sound pressure level and 1/3 octave band data according to American National Standards Institute (ANSI) S1.4 Type 1 acoustic requirements. These standards define methodologies in the measurement of sound levels and are developed by the Acoustical Society of America (ASA). Sound levels are represented in decibels (dB), which is a logarithmic measure representing the perception of the volume of a source. Sound levels were measured over narrow (1/3) frequency bands to represent how humans can distinguish between the frequencies (pitch) of a sound between 12.5 hz and 20 khz. Measurements

Figure 1
Sound Level Meter Setup and Pass by Distance Marked by Red Chalk on the Road



were A-weighted to match the sensitivities of the human ear, which is often applied in environmental monitoring. The sample rate was set to 50ms, to accurately measure the rapidly varying sounds of each pass by event. Metadata recorded on site included the time at pass by, speed, and bicycle type or class. Time was logged directly from the SLM screen and speed was measured by the display on each bicycle's speedometer and recorded at the point of closest approach.

Metrics

The metrics chosen for this study are as follows and were calculated over the 9 second measurement period for each pass by.

- **Percentile Sound Levels ($L(X)$):** Sound pressure levels exceeded (x) amount of the measurement period.
 - $L_{A90, 50ms}$: The approximated residual background ambient sound level. LA90 represents the lowest 10% of ambient sounds during the sample period (ANSI-ASA S12.100-2014).
 - $L_{A05, 50ms}$: Measure of peak sound level, which shows sounds exceeded 5% of the event period.
 - **Existing Ambient Sound Level ($L_{A50, 50ms}$):** Median sound level, or sound level exceeded 50% of the time.
- **Energy Equivalent Sound Level ($L_{Aeq, 50ms}$):** The averaged sound energy level.
- **Sound Exposure Level (SEL):** The sum of all energy across an event.

Analysis

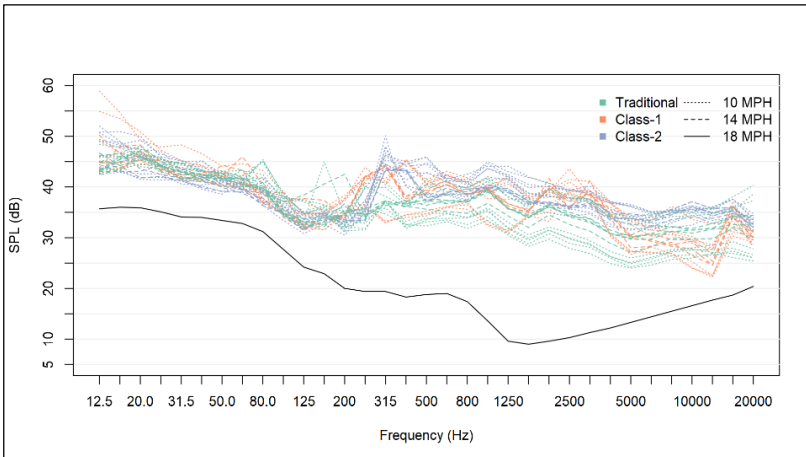
The data were analyzed using a script written in R Statistical Software (v4.3.3; R Core Team 2024). Data were split into event windows, centered around the pass by time, creating individual 9 second events at a 50ms sample rate for a total of 180 samples per event. For each of these windows, a single L_{eq} was calculated for both the 1/3 octave spectra and the $L_{Apeak, 50ms}$ broadband value. All data from each speed/bicycle class combination were binned into an aggregate SEL, L_{50} , and L_{05} before analysis. We did not take the L_{A50} from each pass by separately, and then averaged across all events. The L_{A50} for the Class-2 e-bike at 18mph is the L_{A50} of all samples for the multiple pass by for that bicycle/speed, rather than an average of the L_{A50s} of the pass by events. This approach negates any differences in the number of pass by events per speed category. The residual background acoustic environment was measured to be 27.0 dB ($L_{Apeak, 50ms}$) by calculating the L_{A90} of the entire measurement period. This included the acoustic recordings of each event in their entirety for a total of 2,000 seconds.

Noise attenuation, the reduction or loss of energy in sound waves through distance, was also considered during analysis. For this study, we extracted the L_{A05} and calculated the attenuation by a factor $-20 \cdot \log_{10}$ to estimate what the noise would be at 25 feet and 100 feet from its source. Each of the metrics listed above were used to determine differences.

Results

The results of this study reveal interesting and relatively consistent patterns across bicycle type and speed levels. Figure 2 displays the overall results of the study regarding sound pressure levels. Lower-level frequency sounds were similar between all bicycle types and speed until around 200 Hz. Visually, there is a trend where the traditional bicycle is producing lower levels of noise with Class II producing the higher level. All the pass by events were well above the residual ambient background levels, meaning all bicycle types at all speeds were clearly audible.

Figure 2
Overall Unweighted Sound Pressure Levels for All Pass by Events Across Frequency Levels. Solid Black Line is the Residual Background Ambient of the Site during the Measurement Periods



Examining the results in greater detail, Table 1 represents results organized by the different sound pressure level metrics with the associated delta (Δ) between bicycle types. Differences of 3 dB and above are notable differences, as an increase of 3 dB is a doubling of the sound energy, while an increase of 10 dB increases the sound tenfold. An increase of 3 dB is typically audible to the human ear, while 10 dB is a doubling of perceptive loudness (Barber et al., 2010). The clearest trend across all bicycle types is that an increase in speed results in increased sound pressure levels. Also, the changes in sound level decreases as speed increases between bicycle types in all metrics except the SEL values. The most discernible sound level difference between bicycles was observed at the L_{A05} metric with the largest difference between the traditional and Class II (8.0 dB). L_{Aeq} metric produced results showing that, like L_{A05} , the largest difference between bicycle types is seen in the lower speeds, with the highest also being between the traditional and Class II (6.7 dB). L_{A50} analysis produced results showing the lowest differences between traditional, Class I, or Class II bicycles during their 9 second events, while SEL produced unique results showing a highest difference in sound energy from the traditional and Class II bicycle occurring at the highest speed (18 mph) followed then by the same types at the lowest (10 mph).

Table 1
Results at L_{A05} , L_{Aeq} , L_{A50} , SEL at Various Speeds (mph)

L_{A05}	Traditional	Class I	Class II	T Δ C I	T Δ C II	C I Δ C II
10	49.6	53.9	57.6	4.3	8	3.7
15	54.3	57.4	57.4	3.1	3.1	0
18	58.3	59.3	60	1	1.7	0.7
L_{Aeq}						
10	42.8	46.6	49.5	3.8	6.7	2.9
15	46.7	49.4	49.3	2.7	2.6	-0.1
18	49.8	51.1	52.1	1.3	2.3	1
L_{A50}						
10	37.7	38.2	39.4	0.5	1.7	1.2
15	38.7	40.2	40.8	1.5	2.1	0.6
18	39.7	41.1	40.9	1.4	1.2	-0.2
SEL						
10	59.3	60.9	63.8	1.6	4.5	2.9
15	63.2	65	64.9	1.8	1.7	-0.1
18	64.1	66.7	69.4	2.6	5.3	2.7

The attenuation of noise from each bicycle was also calculated based upon the L_{A05} results estimated at 25 feet and 100 feet from the noise source. In a quiet environment, such as the one where data were collected, the analyses suggest that all bicycle pass by events would still be audible at 25 feet and 100 feet away. At 100 feet, these pass by event sound pressure levels would be nearing the background ambient, especially at slower speeds. In louder environments, pass by noise could reasonably be inaudible at these levels.

Table 2
Attenuation of L_{A05} at 25 feet and 100 feet

Speed	Traditional L_{A05}	Traditional L_{A05} at 25ft (100 ft)	Class I L_{A05}	Class I L_{A05} 25ft (100 ft)	Class II L_{A05}	Class II L_{A05} 25ft (100 ft)
10 mph	49.6	35.4 (23.4)	53.9	39.7 (27.7)	57.6	43.4 (31.4)
15 mph	54.3	40.1 (28.1)	57.4	43.2 (31.2)	57.4	43.2 (31.2)
18 mph	58.3	44.1 (32.1)	59.3	45.1 (33.1)	60.0	45.8 (33.8)

Discussion and Conclusions

During this study, three types of bicycle noise were examined, specifically between a traditional bicycle, Class I, and Class II e-bikes at varying speeds (10, 15, 18 mph). Taken collectively, the higher the speed, the more noise emitted by all bicycle types. This finding was consistent for all four metrics analyzed. The results of the acoustic measures collected also suggest that the e-bikes studied emit more noise than the traditional bicycle, especially at lower speeds. Another consideration is when humans can perceive differences in sounds. Generally, a 3 dB increase is perceptible to the human ear, a 6 dB increase is readily perceptible, and a 10 dB increase is an overall doubling of loudness. From these, we can examine the results of each metric and identify when differences have the potential to affect the acoustic environment.

The metrics L_{A05} and L_{Aeq} both display observable increases for the e-bikes when compared to the traditional bicycle with emphasis on the Class II. These findings were most prominent at the lowest (10 mph) speed with the smallest change observed at the highest (18 mph). As previously mentioned, L_{05} quantifies only the highest 5% of sound pressure level during the measurement period, while L_{Aeq} quantifies the average sound pressure level of the measurement period. These two measurements are best suited for identifying noise that would be most perceivable to humans and wildlife. The L_{05} amounts to the loudest noise that would be noticeable, and thus, the point in the noise event most likely to draw the attention of someone or something. For an event based metric, especially one that is limited to only 9 seconds, the L_{Aeq} is the better measure of central tendency than the L_{A50} , because the L_{eq} is more sensitive to the higher levels of noise, which are more noticeable to listeners (Anderson et al., 2011).

Two other metrics were considered and were found to be less consistent. The L_{50} , a median measure, displayed only small differences between each bicycle type. However, it did follow a similar trend in that the e-bikes do emit more noise, though indiscernible in an auditory sense. SEL, an overall energy production measure, also showed a higher noise level from the e-bikes, though the results suggested differences at both lower and higher speeds. As mentioned above, the L_{Aeq} is likely a better measure of central tendency for an event-based metric like bicycle noise than the L_{A50} ; yet the L_{50} is a better measure of ambience and longer duration noise events (e.g., a generator). We present the L_{50} here because in a very busy trail environment, where bicycles are consistently passing, the L_{50} could be a more important metric. Finally, SEL represents all the acoustic energy of an event compressed into a single second. This measure best captures the total amount of energy of an event, standardized to one second, and is

most effective when comparing events of different durations. Even though all of our events were 9 seconds, we present the SEL here to give a comprehensive summary of the pass by events.

With the continued popularity of e-bikes and the multiple management strategies for e-bike use across varying jurisdictional boundaries, more information is needed about the potential impacts of e-bikes to the natural and cultural resources and visitor experience in parks and recreational trails. This study helps fill a critical gap in the literature around the noise differences between traditional bicycles and e-bikes.

Study Limitations and Future Study Considerations

As discussed above, there were some limitations to this study. First, due to availability, only three bicycles and their individual tire treads were tested. There is a wide variety of both traditional and e-bikes on the market, all that undoubtedly produce varying amounts of noise as well as can be fitted with an uncountable number of tires. Maintenance history of a bicycle also likely plays a role on a bicycle's sound energy, which could not be controlled for here. The second limitation was the research was conducted on a flat, asphalt road (approximately 1% incline). Park roads and bicycle paths often undulate, which requires different pedaling energy needs, and vary by surface type—neither characteristic is captured in this study.

This study specifically focused on the noise within human hearing range and its effects on the natural acoustic environment and park visitors. This study also only measured single pass-bys where future consideration could quantify the cumulative effects of busy trails with higher visitor traffic. Further studies could include the analysis of frequency ranges to explore wildlife and species-specific responses and behavior. Examination of how each bicycle produces noise at different frequency ranges could give a deeper insight into how particular species could react to the presence of each bicycle type in a trail or park settings.

Management Implications

The analysis presented here provides additional information for decision makers to consider when designing rules, regulations, or site-specific management plans. The results of this study suggest that e-bikes emit more noise than traditional bicycles, especially at lower speeds. These differences range from not perceptible to the human ear (below 3 dB) to readily perceptible (6 dB or higher). Another consideration is that a 3 dB increase for a sound source represents a doubling of acoustic energy, therefore, even small changes in noise emissions between bicycle types could affect the acoustic environment. For instance, if two bicycle types differ by 3 dB, the noise output from a single pass by of the louder model is equivalent to two pass bys of the quieter model. Similarly, a doubling of the number of cyclists would increase a noise event by 3 dB. These could be regarded with other considerations when making management decisions for their use. This paper does not suggest any universal management action regarding e-bikes based on noise emissions found in this study due to varying context sensitive considerations. For example, for a recreational trail through a suburban/urban environment or adjacent to a road, the noise level from bikes may not be an important consideration; yet, for a trail that runs through a quiet, noise sensitive environment, the differences between e-bikes and traditional bikes may require more detailed consideration. A recent study found significant wildlife responses to recreation noises at levels between 55-59 dBA (Zeller et al., 2024), which are similar to the L_{A05} values reported here.

The sampling site was a quiet area, with a similar background ambient to many parks and protected areas. There are potential effects to the acoustic environment from the use of any kind of bicycle when compared to the natural environment. However, all of the acoustic measures found in this study were not overly “loud” for human recreation and are much less than other forms of transportation noise, such as vehicles (Miller et al., 2020). These results also revealed that all bicycle types emit more noise at higher speeds which, in addition to reasons of safety, is another reason for speed limits on recreational trails.

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