A REVIEW AND ANALYSIS OF NOISE LEVELS AND ARTIFICAL LIGHT DISTURBANCES FROM MOTORSPORT EVENTS ON WILDLIFE

by

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DEDICATION

This paper is dedicated to my partner Christian. Christian, I could not have done this without your constant love and support. Thank you so much for everything you do.

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I thank my professors for their guidance and knowledge during my time in the LRES program. I would specifically like to thank Scott Powell, my advisor through the program and this project. His support, ideas, feedback, and motivating words were crucial to my success.

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ABSTRACT

Motorsport is a growing automotive sector continuously expanding during a time when human activities are increasing noise and light pollution. Anthropogenic noise and artificial light at night can alter an animal's behavior, communication, and physiology. However, research on the impact of anthropogenic noise and artificial light from motorsport on local wildlife is limited. Therefore, my goal was to provide a critical analysis of the effect of anthropogenic noise and artificial light at night from motorsport events on wildlife. I accomplished this goal through a literature review and two case studies on Albert Park in Melbourne, Australia, and the Singapore Grand Prix. I then synthesized published evidence of wildlife responses to light and noise with motorsport noise and lighting data through a discussion to draw conclusions about the effect of motorsport on wildlife. I found that although motorsport is not a sector as large as other sporting industries or other transportation industries such as aviation, the noise level and light intensity are far higher. The noise level and artificial light emitted from motorsport exceeds the minimum level for behavioral and physiological responses in terrestrial wildlife and it is highly likely that surrounding wildlife exhibit behavioral and physiological responses, though responses may vary by species. It is crucial to increase research efforts that address knowledge gaps associated with motorsport's impact on wildlife. The variability among circuit types, locations, and racing categories makes definitive research on the overall impact of motorsport on wildlife difficult, however this variability can be overcome by integrative track-specific research focused on the surrounding wildlife and habitat at each venue.

INTRODUCTION

High-performance motorsport is a global sport that combines high fuel consumption, extensive engineering, and complex logistics to race motorized vehicles, such as cars or motorcycles, at extreme speeds around a course ("Motorsport," n.d). Although the land-use footprint of motorsport is small on a national or global scale, fan engagement with motorsport is steadily rising. By 2034, the global motorsport market size is expected to rise from its current valuation of 6.8 billion USD to 16.7 billion USD (Pangarkar, 2025). Aside from market value, the annual gross output of motorsport in 2021 was approximately 185 billion USD ("A report on the Global Contribution of Motor Sport to Economy and Community Development," 2021). This growth has sparked investments in racing infrastructure worldwide, with governments and investors focused on tourism and technological advancement (Pangarkar, 2025). Motorsport events, however, emit intense noise levels greater than 120 decibels (dB) during peak hours and intense artificial light from floodlights and other trackside lighting as bright as 3000 lux (Payne et al. 2011; "The first Formula One night race," n.d.) Both anthropogenic noise, which is increased ambient noise levels caused by human activities, and artificial light at night (ALAN) are well-researched environmental issues that can cause behavioral and physiological responses in wildlife, raising concern over the effect of motorsport events (Shannon et al., 2016; Wise, 2007; "Save Albert Park," n.d).

Despite its complexity and growing popularity, motorsport and its relationship to local ecosystems remain understudied in environmental science. Available research on the topic focus on broad sustainability, or Formula One's Net Zero goals, or how climate change itself affects the sport, rather than the effect of motorsport on the climate (Robeers et al., 2023; Wood, 2011; Orr et al., 2025).

Project Goals, Objectives, and Methods

My project provides a critical analysis of the effects of anthropogenic noise and artificial light at night from motorsport events on wildlife. Through this analysis, I synthesize information from available sources to draw conclusions. I provide suggestions of alternative operations for motorsport venues and offer research recommendations to foster sustainable common ground that addresses both environmental pressures and the goals of motorsport. I also provide insight to the current effects of motorsport on local environments and contribute to the vastly understudied link between motorsport and environmental science.

I used Google, Google Scholar, and JSTOR search engines to locate peer-reviewed literature. I compiled the information from reviewing literature and compared sources that measured noise levels and light pollution from motorsport events to studies that measured the thresholds of noise and light and investigated the impact on different wildlife species. I also used the information collected to highlight case studies on Albert Park in Melbourne, Australia, and the Singapore Grand Prix. Last, I used ChatGPT 4o to brainstorm key questions and information, edit for brevity, and, periodically, to find sources that were otherwise difficult to locate using the search engines mentioned previously. Although the connection between environmental science and motorsport remains relatively understudied, literature was the most accessible avenue to research this topic. Most motorsport series capable of evaluating the environmental effects of their series and the courses on their annual racing schedule are inaccessible to the public. Any information that is made accessible to the public regarding this topic remains vague.

In my project, the term “wildlife” refers to non-domesticated animal species that occupy natural or semi-natural environments. The term “wildlife habitat” refers to natural or semi-natural areas such as green spaces or other landscapes that sustain high concentrations of wildlife populations.

BACKGROUND

Motorsport

In Germany in 1885, Karl Benz built the first gas-powered vehicle. This marked the beginning of an industry that has continually expanded, captivating the world through innovation and power (Parissien, 2014). Motor racing followed soon after, with the first organized competition taking place in 1894 between Paris and Rouen, France. Grand Prix racing, or a high-level international competition, emerged and a governing body called the Fédération Internationale de l'Automobile (FIA) soon followed (Li et al., 2023). The 1930s saw the origins of stock car racing like NASCAR, sports-car racing, and hot-rod racing. Kart racing emerged in the 1950s alongside Formula One, the most well-known form of grand prix racing and the highest class of international single-seater automobile racing sanctioned by the FIA (“Automobile racing”, 2025; Li et al., 2023). Today, standard motorsport events generally take place over three days (“The Beginner’s Guide to the F1 Weekend,” n.d.).

There are an estimated 103 to 145 active circuits in the United States, and 350 to 520 active circuits worldwide (“USA,” n.d.; Magazine, n.d.) (Figure 1) (Table 1). This estimate varies among sources due to different definitions of what is classified as a large motorsport venue and the inclusion of all circuit types. As the motorsport industry expands, new circuits are continuously under construction. For Formula One alone, a new circuit in Saudi Arabia is set to join the race calendar in 2028, and a new track in Madrid has been constructed to begin racing in the 2026 Formula One season (Haldenby, 2024).

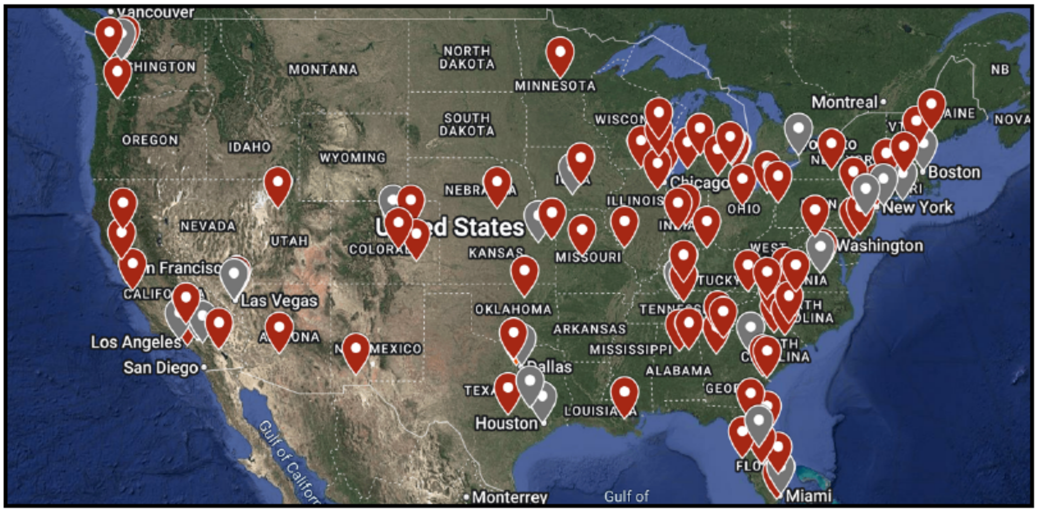

Figure 1. Circuit locations in the United States. Active circuits are red pinpoints, while historic circuits are grey pinpoints (“USA,” n.d.).

Table 1. The number of motorsport circuits worldwide, as estimated on the lower end of the range

WORLDWIDE MOTORSPORT CIRCUITS	
LOCATION	**Count**
AFRICA	6
ASIA	55
AUSTRALIA/OCEANIA	33
EUROPE	87
NORTH AMERICA	103
SOUTH AMERICA	66
TOTAL	**350**

Types of racetracks

Different racetrack types require different land use, in both size and development. Venues must not only account for the physical racetrack or circuit, but also facilities for participants, teams, and guests as well. Texas Motor Speedway, an oval track, uses 1500 acres for the oval and all facilities, including parking ("Track Facts | Media | Texas Motor Speedway," n.d.). Similarly, different events bring in varying participation numbers and noise decibels levels. A Formula One race, when all cars participating are at full throttle, produces 147 dB of sound, 72 decibels above the safe level considered unlikely to cause hearing loss ("Formula 1 and Noise-Induced Hearing Loss | Beltone," n.d). Certain tracks may run events at night, while others do not. Bright lights are necessary to maintain safety for drivers, event staff, and spectators at nighttime motorsport events. Different regulations proposed by the governing body of the motorsport category determine the level of light necessary for different circuits and cars (“Lighting the Racetrack for Speed and Safety,” 2025).

Each type of racing uses different tracks and circuits. Stock cars, such as NASCAR or single-seater IndyCars, take place on oval courses, which are purpose-built circuits with banked turns. Road courses are permanent circuits that have either been purpose-built or converted from other venues such as airfields and are generally used with Grand Prix racing. The Indianapolis Motor Speedway is a well-known oval course, and Silverstone is a famous road course that was converted from an airfield (Figure 2). Street circuits are temporarily built circuits, which means facilities are assembled before the event and taken apart afterwards, utilizing existing roads and closing them off to general traffic during events. Other types of courses include parkland circuits, utilizing the road network of public parks, and car park circuits, which adapt parking areas to create a course (“Circuit configuration,” n.d).

Figure 2. [Left] Indianapolis Motor Speedway, Oval Course. [Right] Silverstone, Road Course (“109th Running of the Indianapolis 500,” 2025; Parkes, 2019).

<u>Proximity to wildlife.</u> Land use, noise, light pollution, and wildlife proximity vary by circuit type (Table 2). Street circuits use existing public streets, and are generally located in

large, dense, urban areas, making them less likely to be near wildlife habitat. Circuit de Monaco is an example of a street circuit ("Circuit configuration." n.d.) (Figure 3).

Table 2. Land use, noise, light pollution, and wildlife proximity by circuit type.

CIRCUIT TYPE	LAND USE (ACRES)	PEAK NOISE LEVEL (DB)	ILLUMINANCE (LUX)	ESTIMATED WILDLIFE PROXIMITY	EXAMPLE
OVAL CIRCUITS	700 – 1,500	110 – 130	1,000 – 2,500	Moderate	Indianapolis Motor Speedway (Indianapolis, USA)
PERMANENT ROAD COURSES	600 – 800	110 – 150	1,250 – 3,000	Moderate	Silverstone (Towcester, England)
STREET CIRCUITS	N/A	110 – 150	3,000	Low	Circuit de Monaco (Monte Carlo, Monaco)
PARKLAND CIRCUITS	500-600	110 – 150	N/A	High	Albert Park (Melbourne, Australia)

Parkland circuits use the roads of large park areas and are more likely to be closer to wildlife habitat than streets circuits, as they are in large greenspaces. These circuits, however, are generally in urban areas as well. Albert Park in Melbourne, Australia is an example of a parkland circuit ("Circuit Configuration," n.d.) (Figure 3). Another well-known parkland circuit is the Circuit Gilles Villeneuve in Montreal, Canada. In June 2025, a groundhog was struck when attempting to cross the racetrack during a Formula One race in Montreal. This is not an uncommon occurrence at the Montreal Grand Prix, with similar incidents occurring in previous years (Edmondson, 2025).

Figure 3. [Left] Circuit de Monaco, Street Circuit; [Right] Albert Park, Parkland Circuit ("Circuit de Monaco," 2023; Albert Park Grand Prix Circuit," 2023).

Purpose built circuits, including ovals and some road courses, are typically built farther from urban areas. Most oval racetracks were built in the 1950s and 1960s, and, at the time, were built farther from town centers to limit noise disturbance for city residents. Growing urbanization has brought these circuits closer to denser, suburban areas ("Racing towards Sprawl: How Urban Sprawl Impacts Motorsports and You," 2025). In 2025 alone, three animals, a rabbit, a bird, and a squirrel, were struck by racecars on tracks at NASCAR events (Duncan, 2025).

Scientific Background

Many species use sound to communicate, forage, avoid predators, navigate, and reproduce. When sound is masked by anthropogenic noise, wildlife's ability to detect or recognize sounds by members of their community is degraded, which can lead to suppressed reproduction, decreased foraging, and increased stress levels (Shannon et al., 2016; Wise, 2007; Tellac et al., 2013). In some cases, increased anthropogenic noise will cause animals to avoid areas, disrupting navigational patterns (Leone and Warren, 2024). Artificial light at night can cause similar responses, as it alters perceived day/night cycles for many species (Tellec et al., 2013). Even low levels of light pollution can lead to behavioral responses. For migratory birds, light pollution can disrupt flight routes, drawing them off their original course ("Threats to Birds: Collisions (Nighttime Lighting)," 2023). In amphibians such as the common toad *(Bufo bufo),* increased light levels at night affects their activity levels, leading to decreased calling to other members of their community (Wise, 2007). For nocturnal species, such as the grey mouse lemur (*Microcebus murinus*), light pollution affects nocturnal activity, such as locomotion and body temperature, through the modification of daily rhythms. The consequences of anthropogenic noise and light pollution can have serious impacts after long periods of time when core behavioral patterns are modified, potentially leading to a loss of fitness and inability to adapt (Tellac et al., 2013).

Land use and degradation, habitat fragmentation, pollution, anthropogenic noise, and artificial light at night are issues undermining healthy ecosystems (Intergovernmental Panel on Climate Change, 2022; Olsson et al., 2019; Intergovernmental Panel on Climate Change, 2023). Since the Industrial Revolution, anthropogenic noise has increased substantially (Leon and Warren, 2024). Similarly, artificial light at night has also grown, following increasing use of electricity. Some studies estimate that brightness in the visible spectrum has increased approximately 270% worldwide (Gaston and Sanchez de Miguel, 2022). In the United States, Buxton et al. (2017) found that anthropogenic noise caused background sound levels to double in 63% of protected areas and increase 10-fold in 21% of protected areas. They focused on noise exceedance, or the amount that anthropogenic noise raises sound above natural levels. For critical habitat, or designated habitat for species listed under the U.S. Endangered Species Act, there was noise exceedance of at least 3 dB in 57.8% of protected areas and at least 10 dB increase in 13.7% of protected areas (Buxton et al., 2017) (Figure 4).

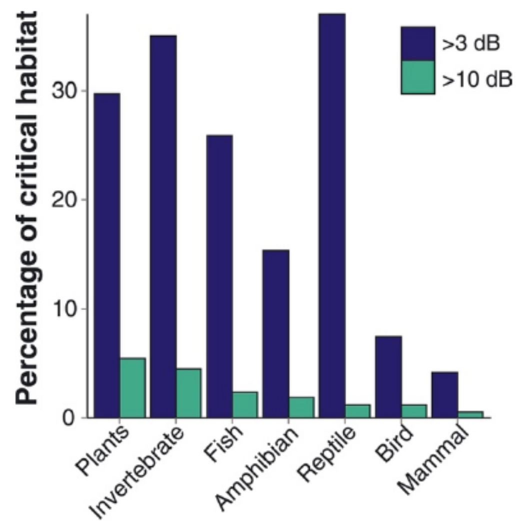

Figure 4. The percentage of critical habitat where anthropogenic noise increased natural sound levels by at least 3 and 10 dB, for each taxon of species under the U.S. Endangered Species Act (Buxton et al., 2017).

ANTHROPOGENIC NOISE

Noise is measured in units of decibels (dB), which is a measure of sound intensity. Noise can also be described using dBA, which weights the sound intensity based on how a human ear responds to frequency. There is not a universal "conversion" for dB to dBA, however a general thought process is that low-frequency noise results in a lower dBA than dB; a high-frequency noise results in a slightly higher dBA than dB; and broadband noise remains relatively similar between dBA and dB (Wallis, 2021; "Noise Control Concepts," n.d.). Using decibels to measure noise uses a logarithmic scale, rather than a linear scale which is a more familiar standard of measurement. An example provided by the National Institute on Deafness and Other

Communication Disorders describes a building 80-feet tall. If construction adds 10 feet to the top of the building, then the building is 12.5% taller using a linear scale. Using a logarithmic scale, adding 10 decibels to 80 decibels indicates that the sound is ten times more intense (“Noised-Induced Hearing Loss,” 2025). Different anthropogenic activities have different levels of sound intensity, ranging from normal conversation at 60 dB to fireworks at 140 to 160 dB (“Noise-Induced Hearing Loss,” 2025) (Table 3).

Table 3. Noise level (decibels) of different sources of anthropogenic noise.

Noise origin	**Intensity (dB)**
Whispering	30
Normal conversation	65
Busy traffic	80
Lawn mower	100
NASCAR RACE	100-105
Formula One Race	147
Jet Takeoff	150

Anthropogenic noise refers to increased ambient noise levels caused by human activities. Throughout history, humans have altered the natural soundscape in many ways, gradually increasing over time. It began with the use of stone and metal for construction, evolved to using gunpowder, and continued evolving through the industrial revolution to our current time period. Today, aviation, roadways, and other vessels of transport are a common source of anthropogenic noise. Small activities such as playing music and using generators also contribute to anthropogenic noise (Slabbekoorn, 2019).

Anthropogenic noise from motorsport

Although workplace environments and other areas with close range noise exposure to humans are well studied, there are limited studies assessing the noise level of motorsport events, specifically at a distance farther away than trackside. MotoGP bikes, a popular motorcycle racing series, can produce a trackside noise level of 130 dB. A Formula One race can produce a noise level of 147 dB ("Why Do MotoGP Riders Wear Earplugs?" 2025; "Formula 1 and Noise-Induced Hearing Loss | Beltone," n.d.).

Available noise exposure assessments for motorsport spectators at six events across multiple motorsport categories found that average noise levels for spectators ranged from 75 to 92 dB, with a maximum of 105 dB (Oluaderoumnu et al., 2018) (Table 3). An assessment that focused on farther distances from trackside found that during a NASCAR event, noise levels reached 104 dBA 150 feet from the track (Rose et al., 2008).

Effects of anthropogenic noise on wildlife. Across taxonomic animal groups and diverse environments, animals' response to anthropogenic noise varies, as does their sensitivity level. This variability makes quantifying the effects of noise pollution difficult, as does the way each species perceives noise (Shannon et al., 2016).

When isolating noise from confounding variables, noise alone can alter an animal's behavior, alter habitat use, and cause physiological changes. Terrestrial animals begin responding to noise at 40 dB. Noise can also distract animals from other stimuli. For example, disturbance-sensitive predators will be less likely to hunt in disturbance prone areas. Increased noise also acts as an environmental stressor which can increase stress and hormone levels. Wildlife started exhibiting physiological effects at noise exposure levels as low as 51 dB, but the reviewed studies included a range of up to 68 dB, depending on the species (Shannon et al. 2016).

Although acute noise can degrade auditory cues, communication, and orientation, chronic noise can have similar effects. Continued responses to increased noise levels can impact the structure of communities longer term, and when combined with other environmental stressors, there can be larger effects on the species overall health and population (Shannon et al., 2016; "Effects of noise on Wildlife," n.d.).

ARTIFICIAL LIGHT AT NIGHT

ALAN is the acronym used to describe artificial light visible during nighttime. In the past 100 years, with the increased use of electricity, ALAN has grown substantially. Artificial lights, especially in large quantities, emit light upward into the atmosphere, which reflects off of particles and scatters the light. This is called skyglow and is the reason light can be seen in the sky and on the horizon, miles from the actual source of light (Gaston and Sanchez de Miguel, 2022). Light pollution caused by increased ALAN is most severe in urban environments and is continuing to expand (Candolin, 2024).

ALAN originates from mobile lighting, such as cars and other modes of transport, and static lighting, which are lights associated with housing, businesses, and sports hubs (Gaston and Sanchez se Miguel, 2022). Nighttime sporting events use and emit a large quantity of light during events. Event lighting is generally measured using lux, the measurement for illuminance. Lux quantifies how bright a surface appears when one lumen is evenly distributed over one square meter ("Lux," n.d.) Recreational sporting events require 200-300 lux, while more competitive events, such as professional soccer and football games can require around 800 lux for regular games and nearly 2000 for games such as the FIFA World Cup ("What are the lighting requirements for a football field?" 2025).

Artificial light at night from motorsports

Motorsport events require similar levels of lighting to other sporting industries. Bright lights are necessary to maintain safety for drivers, event staff, and spectators at nighttime motorsport events. Lower racing categories or organizations may only require a minimum of 200 lux evenly lit around the racetrack. However, in 2010, the FIA recommended an average of 1250 lux at horizontal ground level ("Lighting the Racetrack for Speed and Safety," 2025; Plessis, 2010). The Singapore Grand Prix, which was Formula One's first night race in 2008 provides 3000 lux and is four times brighter than a typical stadium ("The First Formula One Night Race," n.d.) (Figure 5).

Figure 5. The Singapore Grand Prix at the Marina Bay Circuit during a Formula One event ("Preview: The 2025 Singapore Grand Prix – Presented by OKX," 2025).

Motorsport venues are far brighter than other industries. Airports vary depending on the area of the facility, ranging from 20 lux along the runways to 500 lux for indoor areas ("Airports and tarmac Road lighting Solar Street light design," 2025). Construction sites also vary, depending on the necessary work, however in areas where detail is crucial, illuminance is generally 100 lux ("How Much Lighting is Recommended for General Construction," n.d.) (Figure 6).

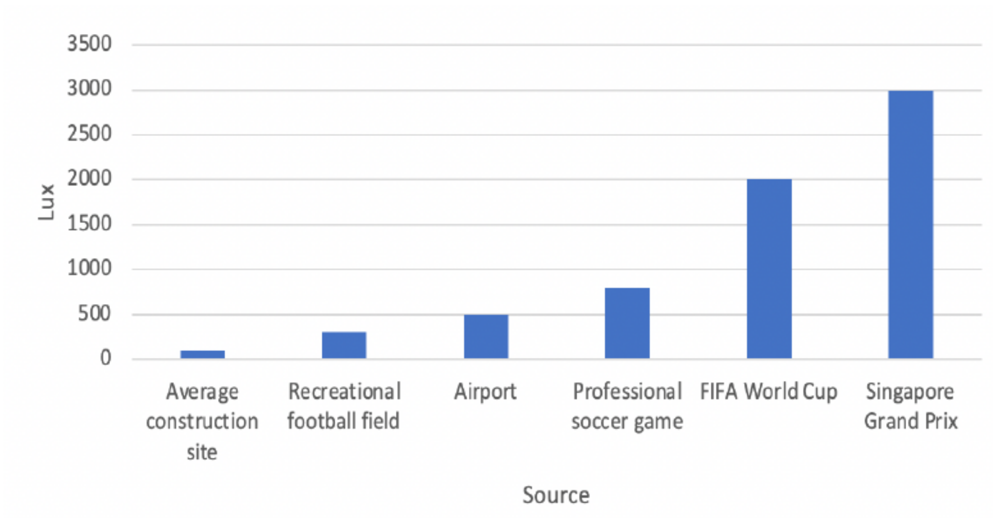

Figure 6. Illuminance from different anthropogenic sources

Although the light output of motorsport events is higher than an average professional sports stadium or the brightest area of an airport, these other sectors are larger than motorsport in terms of quantity and land use at a global scale. Worldwide, there are more than 40,000 airports, 9,000 of which are commercial airports (Roland, 2024). Sports stadiums are also ubiquitous, as there are around 2,300 stadiums with a capacity of at least 10,000 spectators, some of which are considerably smaller than the spectator count at motorsport events, which range from 90,000 at an average Formula One race to 350,000 at the Indianapolis 500, ("World of Stadiums," n.d.; Haldenby, 2025; Martin, 2025).

Effects of artificial light at night on wildlife. Many species are sensitive to artificial light, and it is well observed in migratory bird species, sea turtles, and insects. Data are lacking in regard to how other species respond to light pollution (Wise, 2007). For migratory birds, light from as far as 3.1 miles away can disrupt their migration route, especially on cloudy nights when light reflects off clouds (Threats to Birds: Collisions (Nighttime Lighting)," 2023). For amphibians, even brief exposure to artificial light reduced calling between male and female toads and caused disrupted movement and foraging patterns in both toads and redback salamanders (*Plethodon cinerus*). Long term exposure to light levels higher than 5 lux affects the activity and energy level of the common toad (Wise, 2007). Changes in behavior can affect population viability through their impact on a species' habitat occupancy, reproductive success, and survival (Steidle and Powell, 2006). Research on species in urban environments is lacking in comparison to research on species in their natural environments, or in laboratory settings. Similar to anthropogenic noise, species in urban environments are likely also exposed to other disturbances in addition to ALAN, which can have increased negative effects (Candolin, 2024).

CASE STUDY ONE: ALBERT PARK, MELBOURNE, AUSTRALIA

Albert Park Reserve

Albert Park Reserve is a 560-acre recreational park in Melbourne, Australia and is only 1.9 miles from the center of Melbourne's business district (Figure 7). The park includes biking trails, walking paths, an 18-hole golf course, and picnic areas, as well as fishing and watersports at a large lake in the center of the park, which is key habitat for local bird populations ("Albert Park Visitor Guide," n.d.).

Figure 7. Albert Park Reserve in Melbourne Australia ("Albert Park," n.d.).

Formula One Australian Grand Prix

The Formula One Australian Grand Prix has been held at Albert Park annually since 1996. Infrastructure for the event, including trackside fencing, guest facilities, and grandstands are set up 2 months before the Grand Prix, and removed within 6 weeks after the event, leaving the park without motorsport until the following spring (Racing Circuits, "Albert Park, Melbourne"). The park receives approximately 5 million visitors per year, and 300,000 of those visit the park during the four-day Grand Prix (Payne et al., 2011).

Wildlife and biodiversity. There are more than 5,000 native and introduced species within Albert Park Reserve, including local and migratory birds. Migratory birds, such as the great egret and sacred ibis, utilize the park during migration, and other species such as black swans and pacific black ducks use the park year-round. Kookaburras, ringtail possums, and cockatoos are other common species found at Albert Park Reserve ("Albert Park Visitor Guide," n.d.).

Responses of an Urban Population of Black Swan to an Annual Formula One Event

The population, behavioral, and physiological responses of the local population of black swans (*Cygnus atratus*) at Albert Park Reserve was studied before, during, and after the annual Formula One Australian Grand Prix in 2011 (Payne et al., 2011). Their main goal was to investigate the effects of intense short-term noise disturbances on an urban population of wildlife. The urban population of black swans in the study use the lake in the center of Albert Park (Figure 8). The study asserts that different species respond differently to disturbances of varying intensity, duration, and frequency, and that some species may be able to adapt to some types of disturbances.

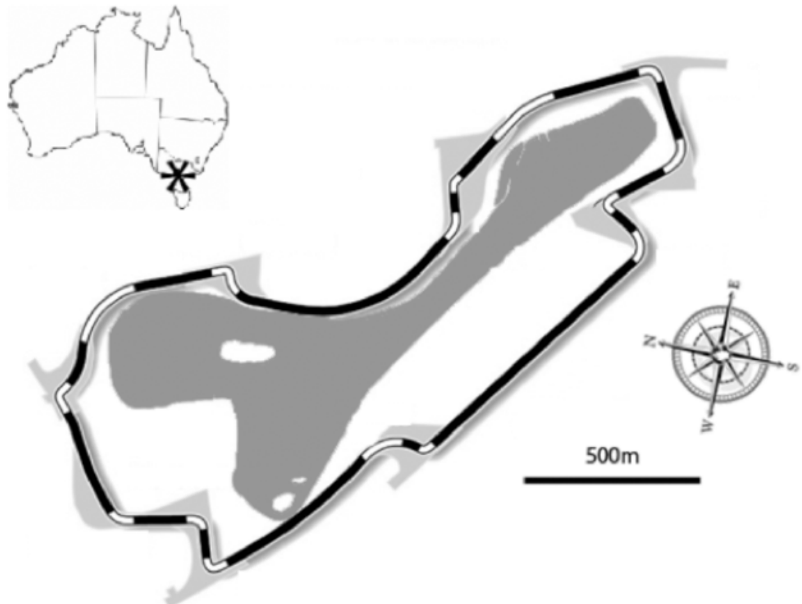

Figure 8. Map of the Grand Prix Circuit in Albert Park. The lake is illustrated by grey, while the circuit is alternating black and white. The location of Melbourne is illustrated by the asterisk on the map of Australia (Payne et al., 2011).

Albert Park is home to 130-210 black swans, and since black swans do not migrate seasonally, this group are permanent residents. Many of the individual birds are collared, allowing them to be individually identified. In this study by Payne et al. (2011), data were collected on four separate four-day periods during March and April 2022. On each day, data were collected in the morning and afternoon before, during, and after the Grand Prix weekend. The data included two census counts per day, noise levels taken at seven locations around the perimeter of the lake, 10-minute behavioral observations, and stress hormone sampling using hand-captured swans (Payne et al., 2011).

The average noise levels during the event were 12-16 decibels (dB) higher than before or after the event, which measured 61 dB and 59 dB respectively. The maximum noise level, however, was vastly more intense at 121.8 dB, nearly 60 dB higher. The population of swans increased throughout the study, with more swans at the lake after the Grand Prix than before. There were no significant behavioral changes throughout the experimental period. Basal plasma corticosterone levels, or stress induced hormone values indicative of chronic stress, were the highest before the Grand Prix and lowest three weeks after. T30 post-capture response plasma corticosterone values, or stress induced hormone values indicative of current stress, were the highest during the Grand Prix, and lowest one week after (Payne et al., 2011).

Payne et al. (2011) concluded that this urban population of swans had adapted a behavioral tolerance to this anthropogenic disturbance, but it does experience a physiological intolerance. They concluded that construction-related disturbances associated with the event may be the reason for lower population counts before the Grand Prix and suggest further integrated studies to investigate the longer-term impacts of intense, short-term disturbances on reproductive success, individual fitness, and population health (Payne et al., 2011).

CASE STUDY TWO: SINGAPORE GRAND PRIX

The Formula One Singapore Grand Prix is an annual night race at the Marina Bay Street Circuit in the heart of Singapore. The Marina Bay Street Circuit is a temporary circuit, set up in the weeks preceding the race weekend, and hosts more than 260,000 people during the event. ("2024 Impact Report", 2024). Singapore is highly urbanized and is one of the most light-polluted cities in the world (Coleman et al., 2023; Falchi et al., 2016). The lighting infrastructure necessary for the Singapore Grand Prix includes over 1,600 floodlights and more than 220 km of cables, producing 3,000 lux, 75 times more light than a standard road (Seregent, n.d.; "The First Formula One Night Race," n.d.). In 2023, the Singapore Grand Prix replaced their lighting system with light-emitting diode (LED) floodlights, decreasing energy consumption by 30%. In addition to cutting energy usage, they installed highly directional light beams at heights of 10 m to minimize light pollution by limiting skyglow, glare, and spill light (Sergent, n.d).

The same year the Singapore Grand Prix completed the switch to LED lights, a study by Coleman et al. (2011) examined the effects of LED lights in comparison to high-pressure sodium lights (HPS) on insects in Singapore. For insects, ALAN can cause fatal attraction, which occurs when phototactic insects are attracted to the light and either die when contacting the light bulb or fly around the bulb until exhaustion or predation occurs (Coleman et al., 2023).

Roadside and footpath luminaries were utilized between October 2017 through February 2018 to collect insects using sticky traps at LED and HPS sites to determine if LED lights were more attractive than HPS sites. Across 50 sampling events, they collected 525 arthropods from 12 orders and 72 families (Coleman et al., 2023). There was no statistical difference between LED and HPS sites. The study suggested that insects in Singapore may have adapted to decades of extreme light pollution and may respond differently to insects in dark locations. The study also highlights the importance of more research in light polluted areas and recognizes that the data collected in this study differs from an earlier study in rural New Zealand that did find LEDs more attractive to insects than HPS lights (Coleman et al., 2023).

The timeframe of the Singapore Grand Prix aligns with southward migration for seabirds utilizing the Singapore Strait, the sea channel between Singapore in the north and the Indonesian Riau Archipelago in the south (“F1 – The Official Home of Formula 1 Racing,” n.d.; Poole et al., 2014). The movement of seabirds in this corridor remained understudied until 2010 when monthly surveys began documenting the number of seabirds using the passage from a sport-fishing vessel and found that Singapore Strait is a key migration passage, specifically for the Swinhoe's storm-petrel (*Hydrobates monorhis*). These data suggested that birds using the passage favor the center or south side of the Singapore Strait, avoiding the north side of the passage closest to Singapore where there is heavy disturbance from shipping vessels (Poole et al., 2014).

DISCUSSION

Parkland circuits, such as Albert Park, are in close proximity to wildlife habitat and host Formula One races annually. Street circuits, typically in dense urban environments, are generally not as close to wildlife habitat but can be capable of hosting nighttime races, as seen at the Singapore Grand Prix. Purpose-built circuits hold motorsport races at a higher frequency than either parkland or street circuits. These differences create varying levels of noise and light disturbance on wildlife. To understand the impact of motorsport on wildlife, research in real-world settings is necessary.

A key finding of my review is that motorsport noise far exceeds the minimum response level for terrestrial animals. Peak motorsport noise is notably higher than the minimum noise level for behavioral and physiological responses of wildlife (Figure 9). My review found that the illuminance at a nighttime motorsport event is nearly 600 times the minimum response level for terrestrial animals, and is more intense than other sectors like aviation, construction, and other sporting stadiums. On the basis of my review, wildlife is highly likely to exhibit behavioral and physiological responses due to anthropogenic noise levels and artificial light from motorsport events, though specific impact would vary by species.

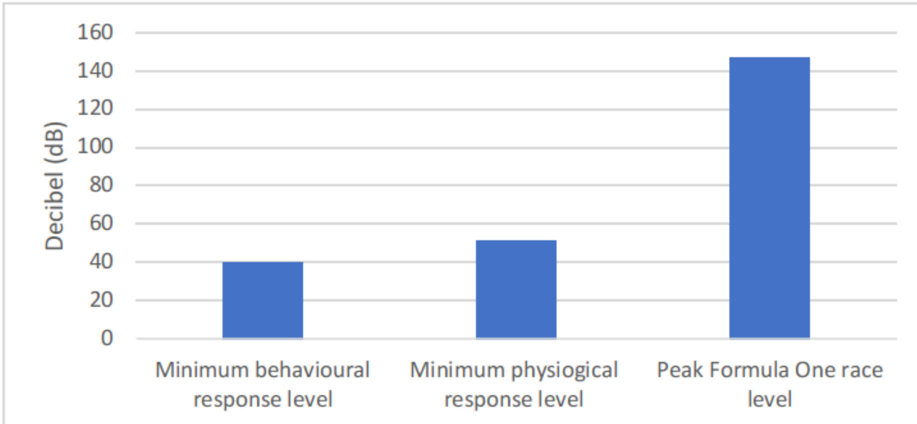

Figure 9. Decibel comparison of the minimum noise level for behavioral and physiological responses of terrestrial animals and the peak noise level of a Formula One race.

The intense noise produced by motorsport is highly likely to exceed the minimum noise level for behavioral and physiological responses at any surrounding habitat, even though the distance of wildlife from trackside will vary. From my review, I conclude that integrative research in real-world settings would fill this knowledge gap about the impact of motorsport on wildlife, as seen in the study regarding the black swans in residence at Albert Park (Payne et al., 2011). The black swans in residence had developed a behavioral tolerance to the anthropogenic disturbance of the Grand Prix, however it still elicited a physiological response. Based on general studies conducted in controlled laboratory environments or in rural wildlife populations, it would be expected that the black swans would elicit both a behavioral and physiological response, however, Payne et al. (2011) indicated that urban populations may be able to develop tolerances to intense disturbances. This result is similar to Coleman et al. (2023) who suggested urban insect populations had developed reduced sensitivity to such extreme levels of light pollution in Singapore. Tolerance does not negate the negative effects of anthropogenic noise or artificial light. This research would assist wildlife managers in finding improved management strategies that allow motorsport events to continue with limited wildlife disturbance. Continued research is necessary to understand the long-term impacts of intense noise disturbance and artificial light on a species behavior, physiology, and population dynamics.

Circuits like Albert Park are in close proximity to wildlife habitat and have direct effects on the surrounding wildlife, while circuits like the Marina Bay Street Circuit are in areas adjacent to important migration passageways and contribute to pre-existing disturbances. The magnitude of illuminance from the Singapore Grand Prix is far higher than general urban lighting and contributes to the already highly light polluted shoreline. The intense illumination from a Grand Prix event is a different disturbance than typically represented in studies and presents a unique opportunity to evaluate how the intense illumination effects species tolerant to ambient light and understand the contribution to pre-existing disturbances in the area.

Track-specific research in real-world settings would also provide insight to the way noise travels and light reflects in different environments, which would provide insight into disturbance mitigation and provide valuable information for other sectors, such as aviation or other major sports. For example, the distance noise travels at a parkland circuit like Albert Park may be different than the way noise travels at a street circuit, such the Marina Bay Street Circuit in Singapore or Circuit de Monaco. Although aviation sectors and other sporting stadiums are larger in number and area than motorsport circuits, the noise level and artificial light intensity involved in motorsport events far exceeds the other sectors. Therefore, other sectors would be able to utilize the data collected at specific motorsport circuits to improve their own mitigation strategies, specifically in locations adjacent to wildlife habitat.

Recommendations

It is crucial to increase research efforts that address knowledge gaps associated with motorsport's impact on wildlife. For reviews and analyses such as this project, the PRISMA method would be an appropriate approach, as it provides a standardized framework for literature reviews and meta-analyses (Page et al., 2021). Field studies would provide the greatest insight on the effects of anthropogenic light and noise and should target a variety of different areas, such as suburban neighborhoods, community parks, edges of town, and dense urban environments. Research should also extend beyond insects and migratory birds, which have previously been studied when assessing the effects of artificial light at night. Studies that investigate longer-term consequences would be beneficial as well to determine longer-term impacts of anthropogenic disturbances. These studies should consider noise disturbance and artificial light disturbance, if necessary, and evaluate behavioral changes and physiological changes through hormone analysis, if possible. This research would provide a better foundational understanding of behavioral changes, physiological changes, and predator-prey dynamics at different levels of artificial light, anthropogenic noise, and urbanization pressure. These findings would be applicable to many other sectors and activities beyond motorsport, such as urban nature reserves, wildlife areas near heavily trafficked airports, and wildlife around other sporting events.

Track-specific research is essential to understanding the impact of motorsport on surrounding wildlife. Circuits that host race weekends should conduct their own assessments of the impact of their venue on local wildlife and ecosystems, or partner with researchers to conduct integrative studies. This is more attainable for larger, well-established circuits that host the highest motorsport categories, as funding, personnel, and resources are more accessible. Given the diversity of circuit types and racing categories, research at each circuit would close the knowledge gap about the impact on wildlife at various levels of urbanization and wildlife proximity. In addition, transparently publishing data on noise levels, light emissions, track development, and other relevant data, would provide important information for projects such as this one and would provide records to examine when conducting annual reviews on sustainability, carbon footprint, and other environmental impacts. With Formula One setting a Net Zero goal in the future, its circuits should also begin their own research for stakeholders, scientists, and researchers to evaluate each year to reduce unnecessary impacts on wildlife in addition to climate. If efforts remain focused solely on carbon footprint while forgoing efforts to limit other environmental disturbances, the goal remains an empty promise as carbon footprint, health of the environment, and wildlife are interconnected.

Aside from conducting circuit-specific research, I recommend increased duration between events to limit the frequency of intense noise disturbance that wildlife must regularly experience, especially at circuits near wildlife areas. The Singapore Grand Prix directly aligns with peak migratory periods, and the impact of the event on wildlife must be a consideration with the same level of importance as other logistical factors. Similarly, I recommend that motorsport regulators limit the number of nighttime events and reduce light use at circuits and facilities when events are not taking place to minimize unnecessary artificial light. As previously discussed, motorsport events exceed the known minimum behavior and physiological response levels for both anthropogenic noise and artificial light at night. Until species-specific impacts are better understood, limiting potential impact is a temporary solution that allows motorsport venues to continue operating and achieve their own objectives while reducing harm to wildlife.

CONCLUSION

There is a large knowledge gap on the impact of anthropogenic noise and artificial light from motorsport events on surrounding wildlife. Decibel output from motorsport exceeds the known threshold for behavioral and physiological responses in wildlife populations, and nighttime events emit large quantities of light that exceed the known lux levels that affect wildlife's behavior and activity levels. It is likely that wildlife surrounding motorsport events exhibit behavioral and physiological effects from the noise and light disturbance, however the variability among circuit types, locations, and racing categories makes definitive conclusions on the overall impact difficult. This variability can be addressed by integrative track-specific research focused on the surrounding wildlife and adjacent habitat at individual venues. The methods necessary to close this knowledge gap are accessible, if funding, intent, and action are aligned.

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