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Effects on birds due to urbanization and potential solutions-a case study in Shenzhen, China

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Abstract. Urbanization has been bringing severe impacts on birds as industrial civilization develops. As urban areas rapidly expand, in addition to traditional problems such as industrial pollution and habitat loss, some seemly minor effects attract researchers' attention. Common problems among these are noise pollution, light pollution, and bird-building collision. Past studies focus on the effects exerted on birds, but there is a lack of assessments of the real-life application of these findings. Therefore, Shenzhen, a first-tier city in China, is taken as a case to discuss how some of these indirect problems arise, how they affect endemic birds, and solutions that are either potential or have already brought good effects. By making a rough assessment of the city's situation, it is concluded that Shenzhen's government and the public have taken many actions to make the city more environmental-friendly, i.e., installing acoustic barriers along highways and planting trees to limit the impact of noise pollution. However, for some newly emerged issues like mitigating bird-building collisions, academic studies have just begun and many improvements can be made. By analyzing these problems and solutions in a specific city, a rough reference for the level of environmental protection in one of the advanced cities in China is made. But more future studies about these problems should be made both regionally and domestically, and ecological effects should be further considered by the local government while making decisions.

Keywords: Shenzhen, noise pollution, light pollution, bird-building collision, migratory birds

1. Introduction

As a developing country with a staggering speed of infrastructure construction and urbanization, China faces numerous environmental problems. In recent years, environmental protection issues have been receiving more and more attention from society. Numerous research and policies were made, raising the general public's awareness about environmental protection. However, there is one severe problem that is usually overlooked: urbanization.

Urbanization is a worldwide unstoppable progress. Turning undeveloped or rural areas into cities signals the growth of the economy and brings many benefits to residents and local government. However, the progress of urbanization is also accompanied by the arise of many environmental problems. The public has given their attention to some direct impacts brought by urbanization like habitat loss and industrial pollution, and has broadly advocated or worked to alleviate these traditional problems. However, as research goes further, many indirect impacts are discovered, such as noise pollution, light pollution, and bird collisions. These problems still have not received enough attention from policymakers

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and the general society. But hopefully, by making some analysis in this paper, the general public who do not know much about these problems can be more concerned about them and devote their power to protecting the environment and birds or other animals closely linked to human lives.

2. Noise pollution

2.1. Status and causes of noise pollution

Cities are noisy. Especially in highly developed cities like Shenzhen, noise pollution has been a problem for a long time. Some local survey in Shenzhen indicates that this kind of airborne pollution is so severe that cannot reach the standard. In some crowded, busy areas, the noise level exceeds the GB standard by 50% [1]. Common sources of anthropogenic noise in Shenzhen can be traffic, entertainment facilities, real estate development, and construction, which are closely related to urbanization and the city's development. Therefore, as long as the city exists, and attracts increasing immigrants from both the domestic regions and abroad, as the economy grows and the population surges, urbanization will be in progress, and the noise pollution will only become more severe. Grievous noise pollution can not only lower residents' living standards but also can affect the lives of countless city birds.

2.2. Effects of noise on birds

There have been enormous studies revealing the impacts of noise pollution on birds. In areas where city and wilderness converge, noise pollution can alter bird communities by forcing some birds to abandon the area. Big birds with lower frequency signals are more susceptible to noise since their calls tend to be influenced by the energetic mask effect [2]. Researchers in Japan conducted an experiment. They simulated a noisy road in areas of vast forest and grassland. Results show that the birds in the forest area were severely affected. They concluded that there was about a 38% to 31% reduction in the total number of birds and abundance within species in the near area of the noise than the ambient area, and about 27% to 23% than the far area of noise [3].

Not only species that have poor adaptation ability will be affected, but for city-tolerant species, strong noise can also affect their behavior [4]. Research focusing on the cognitive behavior of songbirds in a city reveals that heavy traffic noise can worsen their inhibitory control, which helps maintain high concentration and is a critical ability for doing tasks. Also, traffic noise is likely to cause neophobia for lid-flipping tasks, for exposed birds tend to have more trials to learn the task. The same situation exists for color association and spatial memory. Moreover, birds will be less likely to follow the demonstrator when foraging, which means that their social learning ability is affected to some degree. And these are only the influences on the cognitive aspect. A study in Australia suggests that noises can have an impact on Australian magpies' sleeping quality. Another research in the USA suggests that highway noises will cause an ineffective transfer of information between birds [5]. In this case, northern cardinals fail to respond to the alarm calls that are used to avoid predators. Numerous same types of studies reveal more about the influences of noise pollution on birds. There may be limitations that reduce the accuracy of the results, but noise can certainly have negative influences on birds regardless of their tolerance and adaptation ability.

2.3. Case in Shenzhen: Shahe area

For all these reasons, it can be reasonably inferred that birds in Shenzhen are in trouble with noise pollution. And the situation in Shenzhen may be much worse since most land is exploited. Take some specific locations in Shenzhen for example. Shahe Park, which is a large-scale eco-park located in the center of the Nanshan district, is named after a nearby river, where many herons and egrets, sometimes kingfishers, gather to forage for food. As a rare expanse of continuous green area, it plays a key role in Shenzhen's ecological environment. However, roads are constructed next to the riverway throughout its course until it ends in the sea. The nearby areas of many reaches are highly developed, in which business buildings and high streets are constructed. These busy areas can bring heavy traffic and severe noise pollution, especially at night. Based on previous studies, birds nesting in nearby areas can be presumably

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affected. Considering that most birds active along the river are waterbirds, which usually have relatively large bodies and thus with low-frequency calls, the influence of noise pollution along the river might be even greater due to the masking effect.

2.4. Case in Shenzhen: Shahe area

Buildings and constructions are irremovable. Therefore, noise pollution can never be eradicated. Also, at river reaches near Shahe Park and more similar reaches, the roads are built too close to the river, in some places the distance is roughly 10 meters for greensward. With insufficient greenery space, the river is almost directly exposed to the noise source. This situation should be avoided when planning roads. However, there might be ways to at least reduce the influence of noise pollution created by human activity. Some highway constructer may choose to add acoustic barriers, but it requires a high cost, which is not economic and inconvenient to be built in these areas. One more appropriate way to limit the impact is to plant more trees and shrubs in the green belt. Fortunately, this strategy has already been used in the area. The only deficiency is that those trees are too small and cannot play the role of blocking the noise and enriching the ecosystem well.

The government has been introducing policies to improve the environment, suggesting several methods to reduce noise pollution caused by traffic. For instance, local offices can eliminate loud-noise construction programs in areas that are sensitive to noise like those along river bands. Also, in situations where the road must be built, construction units can use low-noise pavement technology or materials to reduce noise pollution in the future when the roads are put in use. For roads that have already been built, related offices should regularly repair the road surface and keep it plain.

However, the reality is much more complex and is more difficult for these policies to be conducted completely. Still, construction programs are in progress from time to time, the greenery is still deficient, and road surface repair sometimes can cause more noise. What is surely advantageous is to regularly hire experts or organize volunteers to monitor the environmental quality and report. Hopefully, noise pollution in these areas can gradually be weakened over time.

3. Noise pollution

3.1. Status and causes of light pollution

Noise pollution is usually accompanied by light pollution in the process of urbanization. In general definition, light pollution is the excessive use of artificial light, especially at night. In specific, light pollution can be classified as astronomical light pollution and ecological light pollution. The one that can cause difficulties in observing the sky is classified as astronomical light pollution, and the other one that can alter the natural light condition and cause negative effects on living organisms is classified as ecological light pollution [6]. Only ecological light pollution will be discussed in this paper.

Similar to noise pollution, the sources of light pollution are usually traffic, decorative illumination, and lighting facilities. As technology develops and is applied to more fields, light pollution becomes more diverse and extensive. For instance, street lights, the most commonly used illuminating devices, can cause different types of effects, as illustrated in the graph below, that can influence both humans and birds [7].

As cities rapidly expand and the use of illuminating devices increases, the impact of light pollution on birds is growing more and more severe, and becoming a problem that urgently needs to be addressed.

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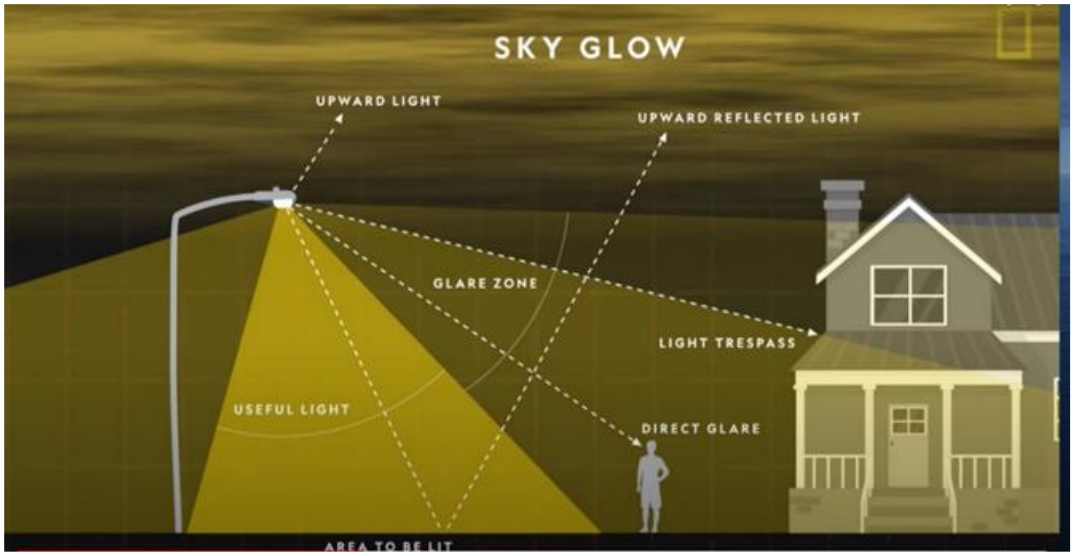

Figure 1. Different effects of light pollution, as adapted from [8].

3.2. Status and causes of light pollution

Merely looking at birds, numerous studies have proved that, at night, simply artificial light itself can have countless negative influences on different aspects of birds, such as sleep, digestive efficiency, and circadian rhythm. For example, several experiments on the impact of light at night on a particular species of commonly seen birds, great tits, were conducted by different groups of researchers. One conducted in Wilrijk, Belgium, shows that lighting throughout the whole night will cause free-living great tits to sleep less and wake up earlier in the morning [7]. Another study shows a similar response from captive great tits, that after the light treatment, these birds also wake up earlier [9]. For rearing great tits, the influence can be even greater. One study reveals that light at night can cause female great tits in the feeding period to sleep later and wake up earlier, therefore sleep less, and more frequently begging behavior of 10-day-old chicks, which also suggests that artificial light at night can have an impact on developing birds [10]. This is confirmed by other experiments and studies, like the one focusing on the responses from developing quails, which reveals that light during nighttime can decrease the digestive efficiency of developing quails [11]. Also, another study using chickens as research organisms, though its original purpose is to anticipate the potential influence of night lighting on humans, reveals that night lights can disable detection of the peaks of the allopregnanolone and lower the level of it in experimental chickens. Allopregnanolone is a kind of chemical substance released by a tiny gland named the pineal gland, which is also responsible for producing and releasing melatonin, a kind of hormone that relates to the day-night timing and circadian rhythms. Even more studies about this aspect suggest artificial light at night can negatively influence the amount produced of this kind of hormone. For example, one piece of research on zebra finches suggests that light can suppress the production of melatonin and alter neuronal structure [12]. Another study suggests a similar result, that artificial light at night can reduce melatonin, and cause the death of neurons in the brain [13].

Except for the physiological effects exerted on city birds, light pollution can even have determinative effects threatening countless lives of migratory birds. The reason why light pollution can influence migratory birds more seriously is that migration is a challenge to birds' adaption ability. The migration process itself is highly risky since birds have to leave their familiar habitats and travel through various new environments. Therefore, during this period, choices are critical: they must ensure it is the right time to migrate and there is an abundant food source during the journey. However, the fact is that migratory birds are being affected when making these choices. Previous studies reveal that nocturnal birds will be attracted by light pollution during their nighttime migration and abandon resource-rich forest areas, reducing the possibility of successful migration [14]; light pollution before migration will advance

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the migration time of the purple martin, a small migratory songbird, and mistime the food abundant time, which is especially harmful to birds that are already in decline [15]; it also has a close relationship with the risk of bird-building collisions, which will be discussed later. In contrast with the ideal situation to minimize the impact of light pollution on these birds, light pollution is at the highest level within the migration path [16].

3.3. Status and causes of light pollution

Though light in real life is usually dim and darker than the light used in laboratory experiments, more research has confirmed that it can still have deleterious impacts on birds [17]. Moreover, light pollution usually happens together with noise pollution in real life. Their simultaneous effects usually can make the situation even more severe, as described in another study, when light is combined with noise, more birds are negatively affected [18]. The location of the case for the combined effect of noise and light is a small lake in Shenzhen called Swan Lake. Swan Lake is surrounded by residential buildings, but nearly half of the bank is unexploited and cannot be reached. The unexplored side, where big trees flourish beyond the water, is an ideal habitat for countless water birds. There are abundant wading birds active during the whole year, such as great egrets, little egrets, Chinese pond herons, and black-crowned night herons, with common kingfishers occasionally being observed. It is a key habitat with such a high density of water birds foraging, nesting, and breeding. However, there is an entertainment park near the lake, with roller coasters and decorative illumination producing noise and light until late at night. The sky is dim on cloudy days because the clouds can reflect the lights to the observer's eyes, and the place where birds rest and nest. With all those studies mentioned above, the light and noise produced by the entertainment park have a high possibility to influence the adult birds, and underage birds during the breeding season. Some species that are supposed to have no responses to light pollution can also be influenced due to the combined effect of sound and light. Swan lake, being a rare and highly thriving environment, should not be casually destroyed. It deserves careful protection from the government and citizens.

3.4. Potential solutions

Researchers and governments have tried many methods to limit the impact of light pollution on birds. For instance, several cities have been considering or have been using amber light illumination, for amber LED illumination can have less impact on the environment. However, a study comparing the effects of white and amber light on Australian magpies and domestic pigeons reveals that the prevalently spread environmental-friendly effect of amber light actually can have varied effects depending on the nature of different species [19]. In the study, amber light has less impact on the sleep of the Australian magpies than white light, while white light and amber light have a similar disturbing effect on the sleep of domestic pigeons. It is concluded that amber light can only reduce the impact on the sleep of limited species, which means that the environmental-friendly effect of amber light may not be so significant. Though Shenzhen has not considered the negative effects of using amber illumination, not to mention installing amber illumination to reduce the impact on the environment, if the costs of amber light are taken into consideration, it is reasonable that Shenzhen may oppose the proposal of installing amber street lights as illumination.

Though controversy over the use of amber light is presented, there are still many other ways to reduce the impact of light pollution. In the case of the swan lake, workable solutions like advancing the lights-out time during the breeding season, reducing the use of decorative illumination of the nearby entertainment park, and advocating adjacent residents to close their blackout curtains at night can be taken to reduce the impact of light pollution exerted on birds living in the swan lake. Other than this case, the Shenzhen government should also take action to mitigate the impact of light pollution on other areas. For example, the government can impose restrictions on the usage of landscape lighting, such as laser light installed on the top of skyscrapers, and certain types of illuminating facilities such as non-shielded lighting that is usually installed in high positions used in building construction. And, when planning to

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develop new areas, the Shenzhen government can consider the different effects of the selection of different types of street lights, use fully-shielded street lights instead of non-shielded lights, and make sure that the light is lightening the right place to reduce trespass and reflection. In addition, the Shenzhen government should pay special attention to the use of light that is close to eco-parks or areas where many species thrive like Swan Lake. All in all, in either political, scientific, or educational aspects, still much work needs to be done in limiting light pollution.

The total area of mangroves in China has decreased slowly in recent years. The mangrove area was 21612.9 hm2 in 2019 [12] and was about 22800 hm2 in 2001[13], which had reduced by over 5%. The decline of mangroves is mainly due to three aspects: excessive salinity, devastation of storms and unsuitable temperature.

There may be different causes of the high salinity in different regions. Higher temperatures and stronger sea breezes than ever before have exacerbated the evaporation of seawater where the mangroves live, leading to higher salinity in the mangrove forests located along the lagoon called Ensenada de La Paz in Baja California Sur, Mexico [14]. Under soil salinity stress, plants will not absorb sufficient water and mineral nutrients, leading to malnutrition, low chlorophyll content and then affecting the effectiveness and efficiency of photosynthesis. At the same time, the general trend of excessive salinity is that the respiration consumes excessive energy, and the net photosynthetic productivity is low, which is not conducive to plant growth. In Brazil, decrease in annual precipitation and damming of rivers aggravated the coastal salinization, causing mangroves, for example, Amazon Macrotidal Mangrove Coast (AMMC), to be eroded and migrate to land [15].

In North America, Africa and Asia, storms uprooted trees and killed large numbers of mangroves [16]. Temperature affects the ability of mangroves to absorb CO2. Currently, the distribution of many mangroves is latitude limited by a minimum temperature of 16°C in the coldest months. Mangroves have expanded into salt marsh areas in high latitudes in both hemispheres due to rising temperatures and fewer frost events. However, plant mortality had been observed during severe winters at extreme latitudes [15].

In addition to the above factors, rising sea levels will also lead to the death of mangroves. Although mangroves are composed of mostly coastal plants near water, due to high erosion rates and sea-level rise, increased submerged periods can lead to leaf stomatal closure with longer time and chloroplast degradation, resulting in reduced photosynthesis rates. Hypoxic conditions and mortality can quickly appear if sea level rise persists [17].

4. Bird-building collisions

4.1. Status and causes of bird-building collisions

The third severe impact brought by urbanization is bird collision. The terminology of bird collision usually used in aviation refers to the collision between birds and planes. Airport workers have to pay attention to this dangerous phenomenon since once it happens, neither humans nor birds can survive. So far, there is plenty of research focusing on bird-plane collision, but with its high mortality of birds [20], another type of bird collision brought by urbanization draws researchers' attention: bird-building collision.

As the name suggests, bird-building collision, or bird-window collision, is the collision between birds and buildings (mainly windows.) As a newly emerged issue, the general public may not be familiar with its causes and impacts. Much research still needs to be done to fully understand bird-building collision and find out effective ways to eliminate it. But the known information is enough for researchers to conclude that the bird collision has a close relationship with urbanization and, as mentioned before, light pollution.

Many studies that paid effort to figure out the factors that contribute to the rate of bird-building collision suggest that the main external reasons for bird-building collision are the presence of extensive areas of windows, nighttime lighting from inner windows, and abundant vegetation or greenspace beside buildings [21-23]. But in one word, the root of the problem is the lack of consideration for animal welfare

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when designers initially decide on the appearance of these buildings and the arrangement of environments around them. Though the factors influencing bird collision are complex and comprehensive, leading to other unmentioned and unclear factors. It is definite that the bird-building collision is having a huge impact on birds that contributes to either fatal or non-fatal consequences, and there are things we can do to mitigate this effect.

4.2. Effects of the bird-building collision on birds

Due to the high speed of birds' flight, collisions can lead to immediate death or different degrees of injuries. The number of fatal collisions is extremely high that one estimation limited in north America suggests 100 million to 1 billion annual deaths [20]. Birds that are still alive after the collision may be severely hurt and can no longer recover again, which finally results in death.

Windows, especially the large ones, is the precondition for bird-building collision. Birds may be attracted, or confused, by the reflection or transparency of glass windows during the daytime and lighting at night. Another factor is the presence of vegetation, either ornamental or fruiting, near the buildings. Though abundant greenery is usually considered a good thing since vegetations provide a food source and increase the local abundance of birds, it will also increase reflection and risk of collisions if there are windows nearby. This is also associated with the direction of windows, windows near bird habitats facing the areas are likely to have a higher rate of bird collision [22]. Temporal factors can alter the rate of collisions too, and it is usually recorded a higher collision rate in the early morning [24,25]. Besides these, bird collisions are highly influenced by migration. Generally, the rate of collision is high in spring, suggesting the effect of migration [24], and nocturnal migrants are severely affected, partly due to the confusion caused by nighttime light pollution [22]. Additionally, the rate of collisions also varies between different species. Factors like local abundance, morphology, and traits of birds also contribute to the differences [21,22,25].

Figuring out the causes and effects of bird-building collisions can help people better understand the events. But to prevent them from happening, additional steps need to be taken, which are testing the efficacy of solutions and applying them in reality.

4.3. Case in Shenzhen: Futian Mangrove Ecological Park

As an advanced coastal city in southern China, Shenzhen has a beautiful environment, especially for the mangroves along its coast, where people crowd to watch birds in every year's migratory season. From a geographical and ecological perspective, lying in the mid-point of the East Asian - Australasian Flyway (EAAF), Shenzhen Bay plays a crucial part as a transfer station for numerous migratory birds. According to the 2021 annual report from the Mangrove Foundation (MCF) [26], a non-governmental public welfare environmental protection foundation, there are about 100,000 in total number and more than 190 species of winter migratory birds transit birds resting and foraging in the mangrove wetland of Shenzhen Bay each year. Being a place where millions of migratory birds gather in crowds, and with the high risk of bird-building collision due to massive migration, Shenzhen ought to take the responsibility for protecting these birds from the possibility of fatal collisions.

Contrasting with the ideal situation, little work is done in this field. In Shenzhen, many newly-built skyscrapers use extensive areas of reflective glass to show their superiority and advanced developments. This condition was true even for the main body of the Popular Science Exhibition Hall in the Futian Mangrove Ecological Park itself only few years ago. And it is indeed recorded bird-building collisions more than 10 times in total. Though it has now stickers preventing bird collisions on it, protection actions have not been taken on a large scale. Besides the lack of protection action against bird collisions, data recording bird collisions is scarcely collected. Nearly no research is conducted, and the awareness of this problem among both public and policymakers is poor. In the aspect of preventing birds from dangerous collisions with buildings, Shenzhen still has a long way to go.

4.4. Potential solutions

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Various collision-deterring techniques based on birds' features are invented. Direct methods such as covering and shading windows are proven to deter daytime collisions [23], but are not very acceptable to humans for their obstruction. Similarly, another effective strategy of installing patterned windows will have the same defect [27]. Also directly, for nocturnal migratory birds captivated by nighttime light pollution, research proves the efficacy of solving the problem from the roots—reducing internal lights at night throughout the migration season [22]. Though it is proven effective, it may not be suitable for residential areas, for, presumably, people will not be willing to change their daily habits merely for the sake of some birds, and may not be easily used on large scale.

Besides these human-depended solutions, more bird-based inventories are tested. For example, according to one feature of birds that most species are capable of seeing ultraviolet (UV) radiation, which is invisible to humans, windows treated to reflect UV are produced and proven to have a significant reduction in bird-window collisions [28]. These windows, since can reflect UV light, can be identified as obstacles by birds. An additional advantage of this kind of product is its transparent characteristic, that it is likely to be esthetically accepted by most people, and therefore has the potential to be widely used. However, it also has a crucial defect: there is little UV light in the early morning and birds are not likely to be able to see the reflection of UV from the window, while the early morning is identified as the peak of collisions [29]. The reflections may also be less detectable for birds in cloudy weather [30].

Similar to light pollution and noise pollution mentioned before, each case has no perfect solution. However, by learning more about these problems, developing technology, or even making concessions, humans can gradually limit their impact on natural environments and wild lives, and finally, coexist with nature in harmony

5. Conclusion

In the highly urbanized city of Shenzhen, the local ecological environment has long been influenced by various effects brought by urbanization, such as noise pollution, light pollution, and bird-building collisions. Local studies of noise pollution reveal that the noise level exceeds the GB standard. Light pollution is also severe, though there is no field investigation. Besides these types of pollution, the risk of bird collision is also high due to the planning of the city, which is composed of numerous skyscrapers with reflective glass surfaces. In prosperous areas, these harmful factors are especially influential. Shenzhen has been taking action to limit these effects. However, city management still lacks consideration and can harm these animals in various aspects. Data, information, and local survey are insufficient: there is little work done to evaluate light pollution and its effects locally. The study of bird-building collisions has just begun (there is little data collected and nearly no work done to mitigate collisions) and the phenomenon remains almost unknown to general citizens. Due to the limitation of this paper, the evaluation of these problems is rough and probably inaccurate. But it is certain that these problems exist in Shenzhen, and have not been addressed. More local studies can be conducted to find out causes and methods to effectively mitigate these problems in the future, and more policies can be made to solve these problems according to scientific research. Hopefully, Shenzhen can be made a better city to live in--both for people and birds.

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