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BIOPHILIC DESIGN GUIDELINES

BIRD-SAFE BUILDING GUIDELINES

Bird-Safe Building Guidelines
Published by:
National Parks Board

These guidelines will be updated periodically to reflect updated information on bird-safe buildings.

Front Cover: A Brown Shrike, a common migratory bird to Singapore, perches against an urban backdrop. Image credit: Bryan Lim

SUMMARY OF CONTENTS

CONTENTS

This document tracks the revisions to these guidelines, effective from 01 April 2022.

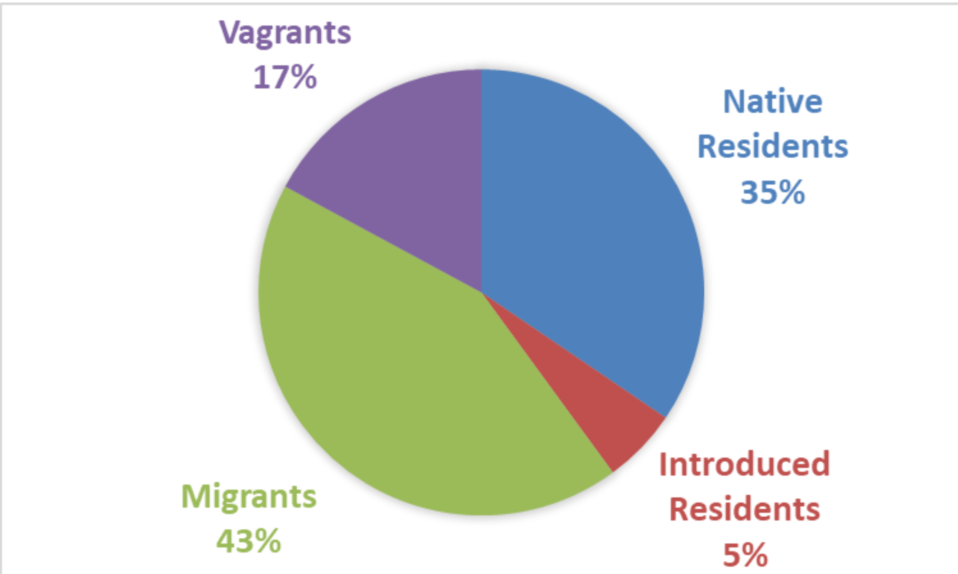
Chapter No	Chapter Title	Revision to Guidelines

1 OVERVIEW OF BIRD ECOLOGY AND BIRD-BUILDING COLLISIONS

Singapore's Birds

Singapore is one of the smallest countries in the world, encompassing an area of just over 720 km^2. Despite its small size and highly urbanised state, more than 400 species of birds have been recorded in the country. An increasing number of Singaporeans taking up birdwatching and nature photography, coupled with the increased intensity of greening efforts across the country, means the number of recorded bird species will only increase in the years to come.

Singapore's birds can be broadly categorised into three categories, namely (a) resident species, (b) migratory species, and (c) vagrants. Resident species are defined as both native and introduced birds that occur all year round in Singapore and breed here. Migratory species refer to birds that undertake annual migrations to avoid the northern winter and the associated drop in food resources. Migratory birds in Singapore can be further divided into two categories – (i) passage migrants, which are birds that use Singapore as a refuelling stop on their journeys to more southerly destinations and usually spend a few days to a week here, and (ii) winter visitors that use Singapore as a winter getaway and spend up to six months of the year here. Last but not least, vagrants are usually migratory birds that are blown off course while on migration as a result of factors such as bad weather. As these birds may only be observed once or twice over the course of decades, they are classified separately from the more regular migratory species.

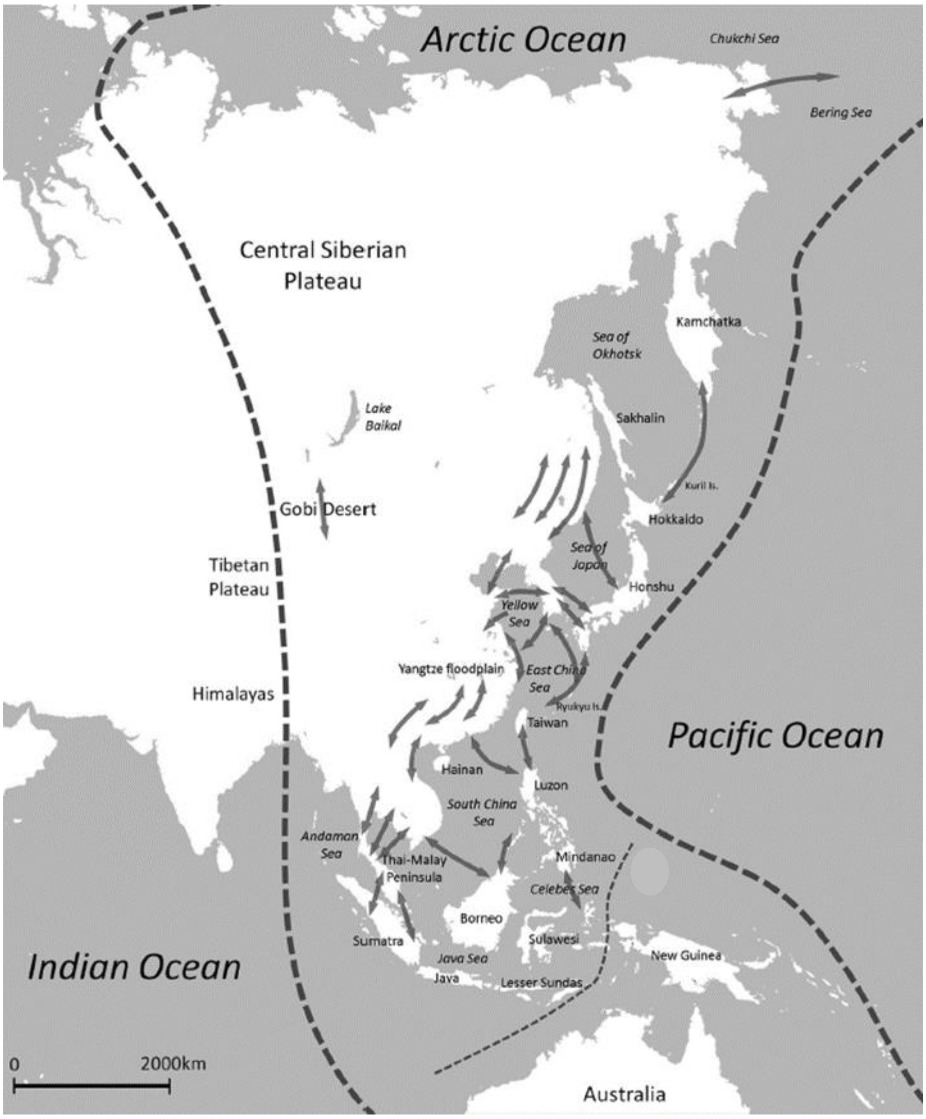


A simplified breakdown of Singapore's birds by status. Migratory birds (i.e. both regular migrants and vagrants) account for 60% of all recorded species.

Out of over 400 bird species recorded in Singapore to date, regular migratory species account for 43% of all recorded species, with a further 17% comprising vagrants. This publication focuses on the impact Singapore's highly urbanised landscape has on the migratory birds that pass through the country annually, specifically in the area of bird-building collisions.

Bird Migration and Threats to Migrating Birds

Every year, an estimated 4 billion migratory birds (Newton 2007) migrate from temperate regions in places such as Eurasia and North America to tropical latitudes in South America, Africa and Asia during the northern winter. The routes used by these migratory birds on their annual migrations are known as 'flyways'. All of Southeast Asia, including Singapore, lies within the East Asian-Australasian Flyway (EAAF), one of the nine major flyways worldwide. The EAAF encompasses 22 countries and extends from Alaska (United States) and eastern Russia through East and Southeast Asia down to Australia and New Zealand (EAFFP 2012). In total, more than 600 species of migratory birds are known to use this flyway (Kirby *et al.* 2008), with some making an annual round trip of more than 10,000 kilometres from their breeding grounds in Siberia to their wintering grounds in Southeast Asia.



Map of the EAAF showing the annual movement of migratory landbirds from the temperate regions of northern Asia to Southeast Asia. Image credit: Yong Ding Li

The Republic of Singapore, located at the southern tip of the Malay Peninsula, is geographically significant on the EAAF. For many migratory birds, the final sea crossing from Singapore to the island of Sumatra represents the final leg of their epic journey from their breeding grounds in northern Asia to their Southeast Asian wintering grounds. Additionally, many species of migratory birds also spend the winter in Singapore as well.

Different species of migratory birds have different strategies for surviving these arduous journeys. In general, all migratory birds alternate between periods of flight and stopovers to replenish their energy reserves (Sheppard & Phillips 2015). Larger birds such as raptors and waterbirds migrate during the day to take advantage of hot air currents known as thermals, which are generated by solar radiation on the Earth's surface. These thermals rise from the land surface and enable these birds to soar across the sky, thereby reducing the energy required for flight. However, many smaller birds migrate at night. This not only enables them to use the diurnal hours to forage for food, but also allows them to take advantage of lower temperatures and an absence of diurnal predators like raptors (Sheppard & Phillips 2015). These nocturnal migrants generally depart shortly after sunset and land at a suitable stopover site before dawn (Kerlinger 2009). All avian migrants, be it diurnal or nocturnal, are strongly affected by weather conditions. Inclement weather such as tropical storms and fog often cause birds to land prematurely or spend extended periods at a stopover site until local conditions improve (Sheppard & Phillips 2015).

Unsurprisingly, these journeys are fraught with peril, and natural threats such as predation have been compounded by anthropogenic ones like habitat loss and hunting, leading to a global decline in migratory bird populations (Yong *et al.* 2015). Specific to the EAAF, habitat loss and hunting have been identified as the most significant threats to the migratory birds along this flyway (Yong *et al.* 2015). However, bird-building collisions have also been identified as a potentially significant, yet poorly documented threat on the flyway (Yong *et al.* 2015). Unlike other threats, bird-building collisions kill migrants indiscriminately irrespective of their fitness levels, and have been shown to adversely affect migratory songbird populations in North America (Loss *et al.* 2014). A similar situation is expected on the EAAF as well, and the next section summarises the current body of knowledge on bird-building collisions in this region.

An Overview of Bird-Building Collisions

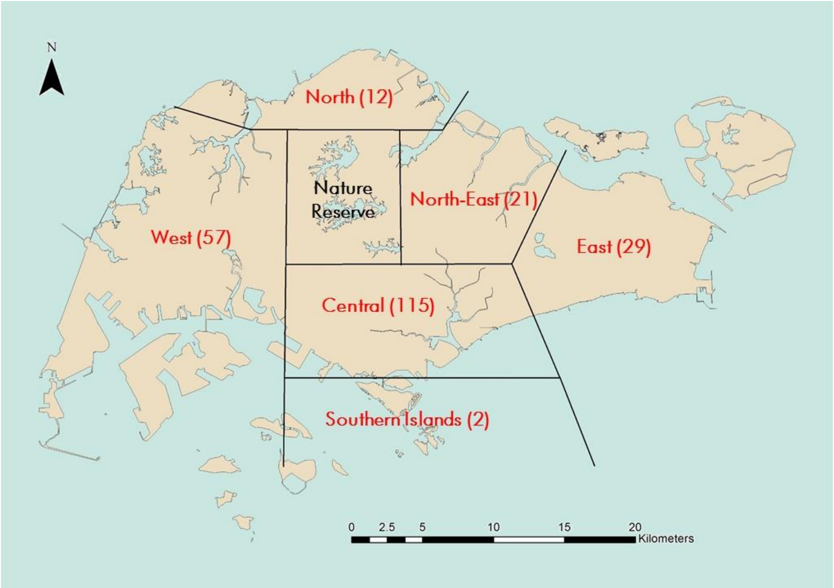
The ubiquitous presence of buildings and other man-made structures in the global landscape present a significant obstacle to avian flight. The collision of birds into buildings and other man-made structures, also known as bird-building collisions, constitutes a major anthropogenic source of bird mortality. In the United States, bird-building collisions account for the deaths of hundreds of millions of birds per annum (Loss *et al.* 2014). Migratory bird species whose routes pass through major urban centres are especially vulnerable to bird-building collisions. This problem is exacerbated by light pollution from urban buildings at night which both attracts and disorientates nocturnal migrants (La Sorte *et al.* 2017), leading to increased collision rates in urban areas.

The phenomenon of bird-building collision has been relatively well studied in North America and there is comparatively greater awareness of the issue among the general populace there. Some cities, such as Toronto and San Francisco, also have legislation associated with making new developments more bird-friendly. In contrast, there is little information on the magnitude of this problem elsewhere, especially in Asia. Given that this region includes some of the world's most densely populated urban centres like Shanghai (China), Hanoi (Vietnam) and Bangkok (Thailand) (Yong *et al.* 2015), it is highly likely that migratory bird collisions are a serious yet overlooked threat to the migratory species that use the EAAF.

Studies examining bird-building collisions along the EAAF have been limited, with most studies confined to East Asia. One such study on Hong-do Island off South Korea found collisions with buildings to be the primary cause of mortality for migrating buntings, pipits and white-eyes (Bing *et al.* 2012). A study involving the migratory and globally threatened Fairy Pitta (*Pitta nympha*) on Jeju Island, also in South Korea, concluded that other than natural predation, window strikes were the most serious threat to the pitta population on Jeju (Kim *et al.* 2013). Similarly, on the island of Hokkaido (Japan), 63 species were identified as victims of bird-building collisions between 1980 and 1997, with increased mortality rates during the migratory season (Yanagawa & Shibuya 1998). A recent study by South Korea's Ministry of Environment recorded that 378 birds had died as a result of collisions with 56 buildings and soundproof walls across South Korea and estimated that bird-building collisions in South Korea claimed the lives of 8 million birds a year (The Korea Bizwire 2019). The results of these studies suggest anecdotally that, collectively, avian mortality from building collisions is likely to be high along the EAAF owing to the many densely populated urban centres these migrants have to navigate through annually.

Migratory bitterns like this Black Bittern (Dupetor flavicollis) were frequently reported victims of bird-building collisions in Singapore between 1998 and 2016. Image credit: Lim Kim Chuah

Located at the tip of the Thai-Malay Peninsula, and north of the Riau Archipelago of Indonesia, Singapore is a known stopover point on the routes of many migratory species using the EAAF. Its highly built-up environment and well-lit nightscape present an imposing barrier to many migratory species. A recent study summarising reports of bird-building collisions involving migratory birds over a 19-year period from 1998 to 2016 documented 237 incidents involving 40 species (Low *et al.* 2017). Collisions were mainly reported during the autumn migration from September to November, and certain groups of birds, namely pittas, flycatchers and bitterns, appeared to be particularly vulnerable. Additionally, most of the reported collisions originated from the central and western regions of Singapore, which may correspond to the shortest sea crossing between Singapore and Sumatra.



Reported bird-building collisions in Singapore by region between 1998 and 2016. Image credit: Low et al. 2017

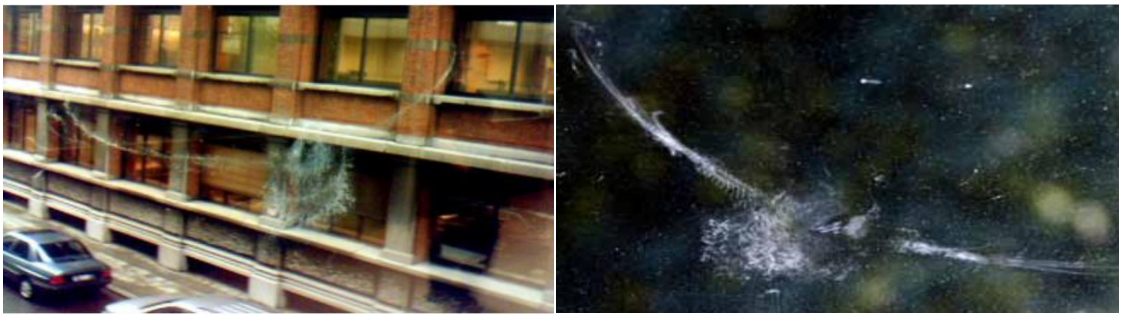
Further research also indicated that migratory birds were not the only birds affected. Between 2013 and 2017, a study focused on resident birds documented 104 mortalities from 32 species resulting from bird-building collisions (Tan *et al.* 2017), with the majority of cases involving Pink-necked Green Pigeons (*Treron vernans*) and juvenile Asian Glossy Starlings (*Aplonis panayensis*).

Given that the figures documented in these studies reflect only a small fraction of the actual number of birds killed, bird-building collisions are likely a serious, yet overlooked, threat. This document seeks to outline bird-safe building guidelines that could be practised in Singapore, based on successful examples from other cities, for new developments. In addition, solutions that can be applied to existing buildings to make them more bird-friendly are also highlighted. It is hoped that this document will raise awareness and spur collective efforts to make Singapore's built environment more bird-friendly.

Main Causes of Bird-Building Collisions

1. Increased Use of Glass in Modern Urban Architecture

In the urban built environment, there is an increasing use of glass in the construction of buildings. While humans are able to discern the presence of glass surfaces through cues like frames and dirt, birds are unable to perceive such cues, particularly when they pass through unfamiliar environments while on migration. Birds often collide directly into glass surfaces at full speed as they attempt to reach greenery reflected on them or fly through reflected passageways, resulting in severe injuries and deaths (Sheppard & Phillips 2015).



The imprinted outline of birds that have collided into these glass surfaces are clearly visible, demonstrating the sheer force of impact of these collisions. Image credits: David Fancher (left) and Hendrik Dacquin (right)

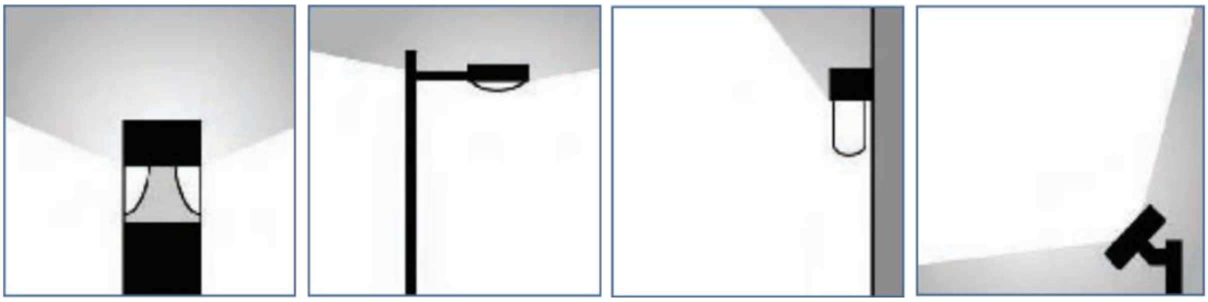
2. Building Location and Orientation

The location and orientation of buildings with respect to the surrounding habitat and landscape contribute to bird strikes (bird-building collisions) as well. Glass façades in modern architecture readily reflect any surrounding vegetation. Since birds have difficulty distinguishing reflections of vegetation from actual vegetation, the risk of collision is increased when glass façades are used (Sheppard & Phillips 2015).

Highly reflective glass surfaces positioned close to roadside greenery or urban green spaces are especially dangerous to migratory birds moving through these areas. Image credit: Low Bing Wen

3. Urban Lighting

Night-flying migratory birds are generally attracted to light and are inclined to fly towards point sources of light. As such, spill light (i.e. light that escapes from the main light source) from building interiors or from exterior fixtures tend to attract and disorientate these birds (Christine Sheppard *in litt.*). Birds may also become entrapped within these illuminated zones and succumb to exhaustion or predation, or may collide into buildings.



Examples of up-lighting that can increase the risk of bird-building collisions in urban areas. Image credit: San Francisco Planning Department 2011

4. Greenery in and Around Buildings

Birds are attracted to visible indoor vegetation and reflections of vegetation on buildings. The likelihood of collision is increased when birds unknowingly fly into buildings in an attempt to reach pockets of visible indoor vegetation or perimeter vegetation reflected on glass surfaces. Singapore is a City in Nature that is well endowed with greenery in and around buildings, and efforts to intensify urban planting are underway to increase the ecological and climatic resilience of the country. Building owners and developers will therefore need to adopt architectural practices, such as treating glass façades situated close to greenery, in order to reduce the danger of buildings to birds.

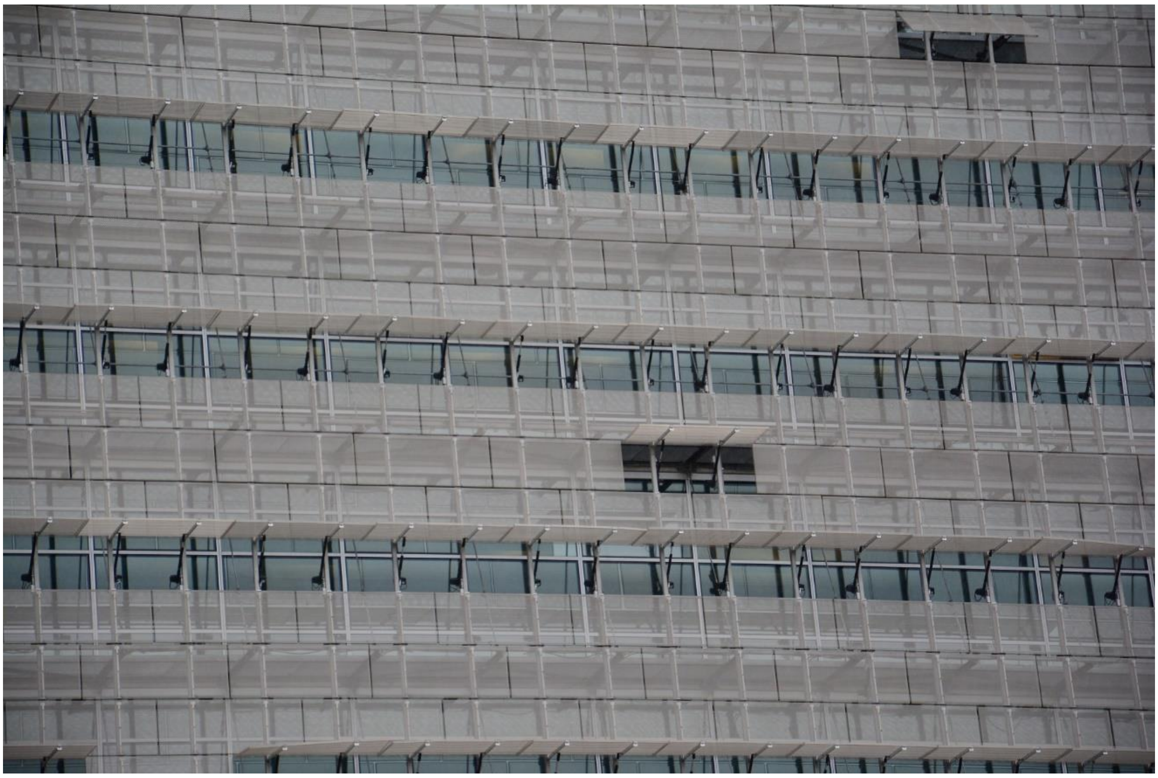
Indoor vegetation (left) and reflections of vegetation in a private courtyard (right) situated in close proximity to untreated glass façades are likely to attract birds and increase the chance of collisions. Image credits: Christine Sheppard

In summary, the majority of bird strikes can be attributed to modern urban architectural design that often involve heavy usage of large glass panels and is exacerbated by other factors such as urban lighting. In order to mitigate these incidents, modifications to a building's design and materials, as well as associated lighting strategies are needed. The subsequent sections will explore various methods to incorporate bird-friendly features into both existing and newly constructed buildings.

2 GUIDELINES FOR DESIGNING BIRD-FRIENDLY BUILDING EXTERIORS

Building Façades

When designing the exterior of a building, visible structural details or bird-friendly features such as columns, balconies, sunshades and lintels should be considered if the building façade contains glass. These features either hide glass from view or minimise reflections, thereby lowering the likelihood of collisions.



Visible structural details like perforated steel panels hide glass from view while providing benefits like filtering sunlight. Image credit: Benjamin Lee

Greenery and Glass Surfaces

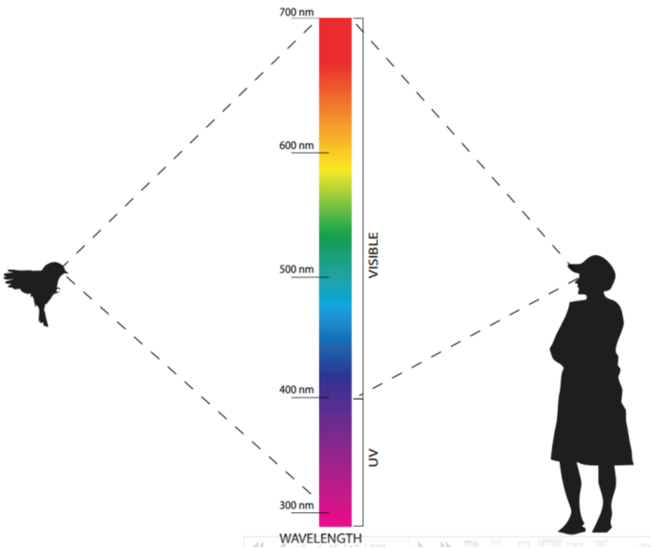
In small exterior courtyards or atriums that feature plants, it is best to avoid having glass surfaces around these areas, as birds are likely to be attracted to the reflections of vegetation. Alternatively, when vegetation is close to a glass surface, the glass surface should be treated to reduce the risk of collisions.

Internal Treatments for Glass Surfaces

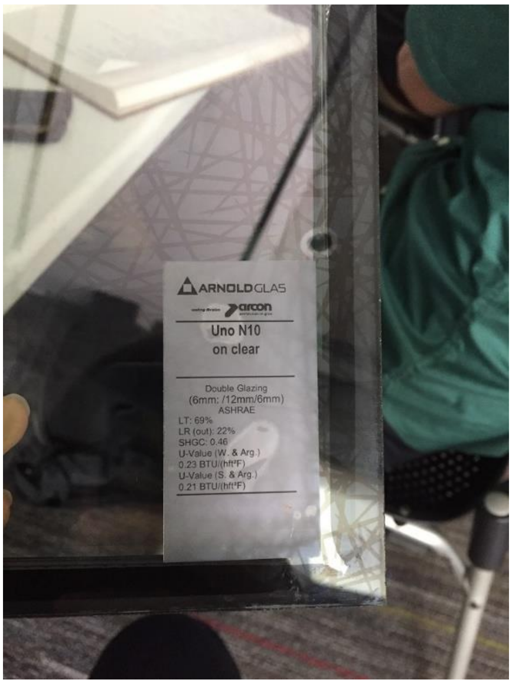
1. Ultraviolet and Low Reflectance Glass

Unlike humans, many birds are able to see in ultraviolet (UV) in addition to colours in the visible spectrum. Hence, UV-reflecting and/or absorbing patterns on glass surfaces can be seen by birds and prevent deadly collisions.

UV patterns require strong contrast to be effective, especially in the early morning and later afternoon when UV in sunlight is low. This may be achieved by retrofitting existing external glass surfaces with external films that have a UV coating or using newly manufactured sheet glass with UV glazing (Klem 2009; Klem & Saenger 2013). Field experiments showed that UV signals should reflect minimally 20—40% from the wavelengths of 300—400 nm in order to be effective in preventing bird-building collisions (Klem & Saenger, 2013). Additionally, the use of low reflectance materials such as frosted glass can also be explored.



Unlike humans, birds are able to see UV light in addition to colours in the visible spectrum. Image credit: New York City Audubon.

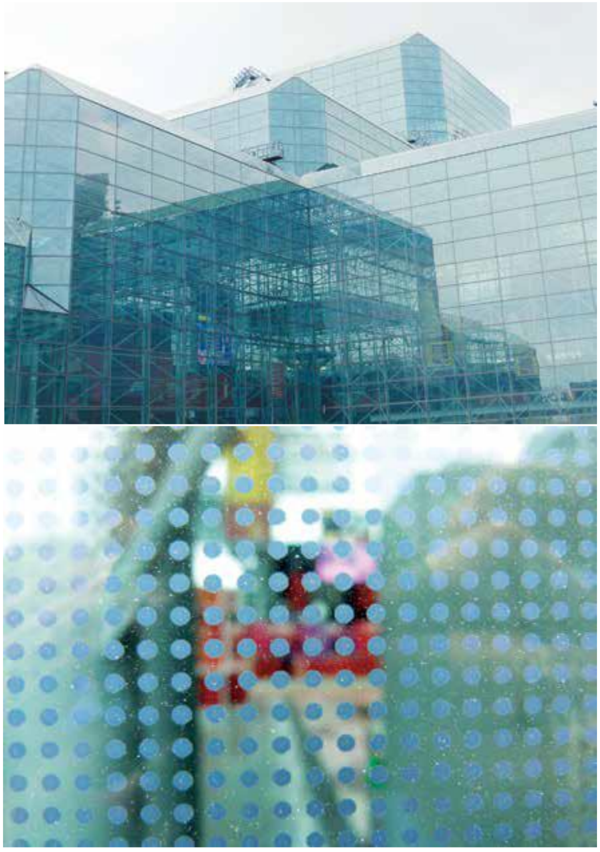


A sample of UV glass showing the UV patterns that birds can perceive. Image credit: Cheong Li Min

The use of frosted glass can help to mitigate bird strikes. Image credit: Chicago Bird Collision Monitors

2. Fritted Glass

Fritting is the application of ceramic patterns between layers of insulated glass to reduce light transmission. Frits are usually applied so that reflections will be obscured by the pattern, allowing birds on the outside to discern the glass surface readily. Frits need not be evenly spaced or densely applied to effectively deter collisions.



At close range, the fritted glass surfaces of New York City's Javits Convention Centre become apparent. This treatment has effectively deterred collisions while still providing views of the outdoors. Image credits: Glenn Phillips

External Treatments for Glass Surfaces

1. Decals and Stickers

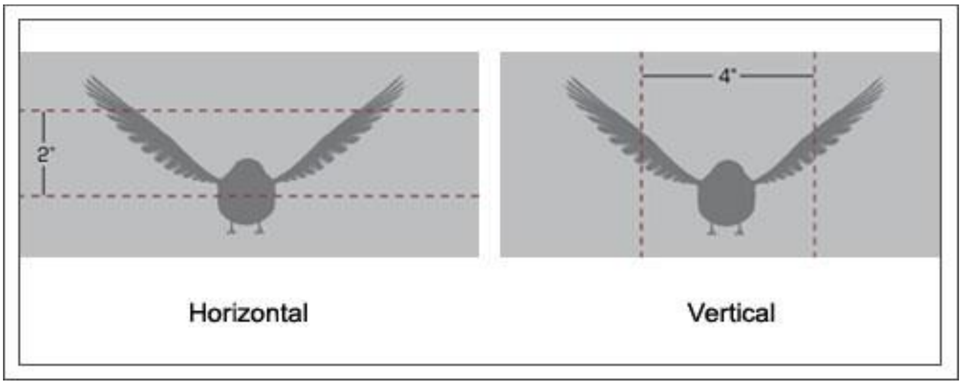
Decals and stickers are a popular, cost-effective and short-term method to reduce bird strike likelihood on existing glass surfaces. Patterns consisting of dots, stripes, and many other visually interesting and creative shapes could be applied on the glass to enhance the visibility of the surface to birds and deter collisions. Generally, the denser the pattern applied on the glass surface, the more effective it is in making the glass appear as a solid structure to birds. The patterns can be applied extensively to cover most of the glass surface or selectively to blend in with the surrounding landscape or other design features of the building (Sheppard & Philips 2015).

Narrow horizontal stripes applied externally to glass surfaces can be effective in deterring collisions. Image credit: Hans Schmid

Research has consistently shown that birds will not fly through horizontal spaces less than 2 inches (or 5 cm) high or through vertical spaces less than 4 inches (or 10 cm) wide, which is referred as the 2″ x 4″ rule (Sheppard & Philips 2015). Hence, the spacing, width and orientation of decals should ideally follow the 2″ x 4″ rule to effectively reduce the occurrence of bird strikes. For instance, the placement of vertical stripes less than 10 cm apart on an exterior glass surface has been demonstrated to be an effective method to prevent bird strikes (Klem & Saenger 2013).

To help reduce bird strikes through the use of visual markers, here are some recommendations for the visual marker(s):

(1) maximum spacing of 5 cm by 10 cm (2″ by 4″), ideally 5 cm x 5 cm to account for even the smallest bird species
(2) minimum diameter of 0.5 cm for circular openings
(3) high contrast
(4) applied on a minimum of 85% of all exterior glass surfaces within the first 12 m of the building above the planted tree height



The 2″ x 4″ rule is a useful guideline when applying stickers and decals to glass surfaces. Image credit: U.S. Green Building Council (USGBC)

Decals applied onto the exterior glass surface of a building at a Spanish park eliminated collisions at this site (left). Creative designs drawn using paint can also be applied on windows to mitigate bird strikes (right). Image credits: Lena Chan (left) and Christine Sheppard (right)

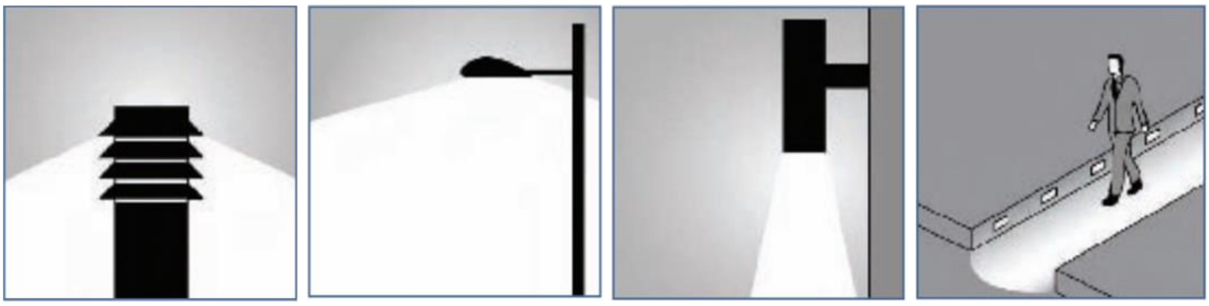
2. External Screens and Netting

External screens and netting are effective both in reducing reflections and cushioning the impact of a bird-window strike. Screens can be applied externally and still permit views from the inside while appearing opaque on the outside. External films applied on window surfaces, including one-way films that still permit views of the outside, have been shown to be effective in mitigating bird strikes (Klem 2009). Netting, on the other hand, should be installed at least 7 cm away from the front of the glass surface, so that impact does not carry birds into the glass (Sheppard & Philips 2015).

Application of window film on a glass surface facing a tract of vegetation successfully eliminated bird-window collisions (left). Application of netting as a bird strike mitigation strategy (right). Image credits: Philadelphia Zoo (left) and City of Toronto Bird-Friendly Development Guidelines 2007 (right)

Lighting Strategies

Bird-friendly building exteriors should incorporate appropriate lighting as well. Night-migrating birds, in particular, rely heavily on starlight to orientate their flight paths, so brightly lit urban areas can disorientate them. Hence, minimising spill light (i.e. light that escapes from the main light source) and reducing uplighting in urban areas, without compromising public safety, are critical in mitigating bird strikes. This could be achieved by appropriately directing and shielding external lighting to minimise attraction to night-migrating birds (Sheppard & Philips 2015). Some examples are shown below.



Examples of various external lighting fixture designs that minimise spill light. Image credit: San Francisco Planning Department 2011

In order to successfully mitigate bird-building collisions, bird-friendly building exteriors should be complemented with appropriate measures for building interiors, which will be discussed in the next section.

3 GUIDELINES FOR DESIGNING BIRD-FRIENDLY BUILDING INTERIORS

Indoor Greenery and Glass Surfaces

If there are glass surfaces in areas with indoor vegetation, the glass should be treated using the techniques described in Chapter 2. This minimises the risk of birds colliding into the glass surface while attempting to perch on indoor vegetation.

Glass surfaces in areas with indoor vegetation should be treated to mitigate the risk of bird strikes. Image credit: North-South Environmental Inc

Bird-Friendly Interior Elements

Bird-friendly interior design elements such as blinds, artwork installed close to glass, and/or coverings hung close to glass or sunshades could be integrated with glass windows or panels to minimise or break up reflections. They reduce the transparency of glass and enhance its appearance as a solid structure, thereby deterring collisions.

However, it is worth noting that the effectiveness of interior elements is greatly influenced by local lighting conditions. For birds to recognise bird-friendly design elements or patterns applied on the glass surface as an obstacle, those patterns must be made visible with sufficient interior lighting. For instance, patterns will be visible to birds when the interior lighting is equal to or of greater intensity to that of the exterior environment. However, when the interior light is of lesser intensity than the external environment, patterns on the glass surface will be masked from the view of the birds, and the glass surface will instead reflect the view of the facing habitat or sky, thereby increasing the probability of bird strikes (Klem & Saenger 2013).

As coatings on modern glass make these surfaces highly reflective, interior blinds are most effective in deterring bird strikes when left partially open, which will reliably break up reflections.

Partially open blinds (left) and curtains (right) are examples of interior elements that can reduce reflections, thereby mitigating bird strikes. Image credits: Christine Sheppard (left) and Chicago Bird Collision Monitors (right)

Interior Lighting Strategies

Interior lighting should be turned off at night or designed to minimise spill light (i.e. light that escapes from the main light source). The reduction of interior night lighting in cities can be achieved through the use of automatic controls, including timers, infrared and motion detectors rather than solely relying on the manual switching off of lights. At workplaces, unnecessary lighting of large areas should be minimised. Alternatively, retrofitting operational systems that automatically turn lights off after working hours could also be explored. At certain times where indoor lights must be switched on at night, it is best to minimise spill light by drawing shades or blinds.

Nocturnal light pollution can be reduced through the use of blinds or curtains (top) and individual workplace lighting (bottom). Image credit: Fatal Light Awareness Program (FLAP), City of Toronto Bird-Friendly Development Guidelines 2007

4 OPTIONS FOR MAKING EXISTING BUILDINGS BIRD-FRIENDLY

Collision Monitoring Programmes

Existing buildings can also be modified to mitigate bird strikes. Before any action is undertaken, building managers should first establish if their building is a hazard to birds. One way to do this is to set up a regular collision monitoring programme to identify potential hotspots where bird strikes frequently occur. Such programmes are able to document mortality patterns as well as provide important baseline data such as weather conditions and time(s) of the day when collisions occur. The data can also be used to evaluate the effectiveness of any measures implemented to mitigate bird strikes and whether additional actions are required. A reference for best practices in developing a collision monitoring programme can be found at this weblink: https://abcbirds.org/loss-et-al-best-practices-for-window-data-2014/.

Low-Cost Mitigation Measures

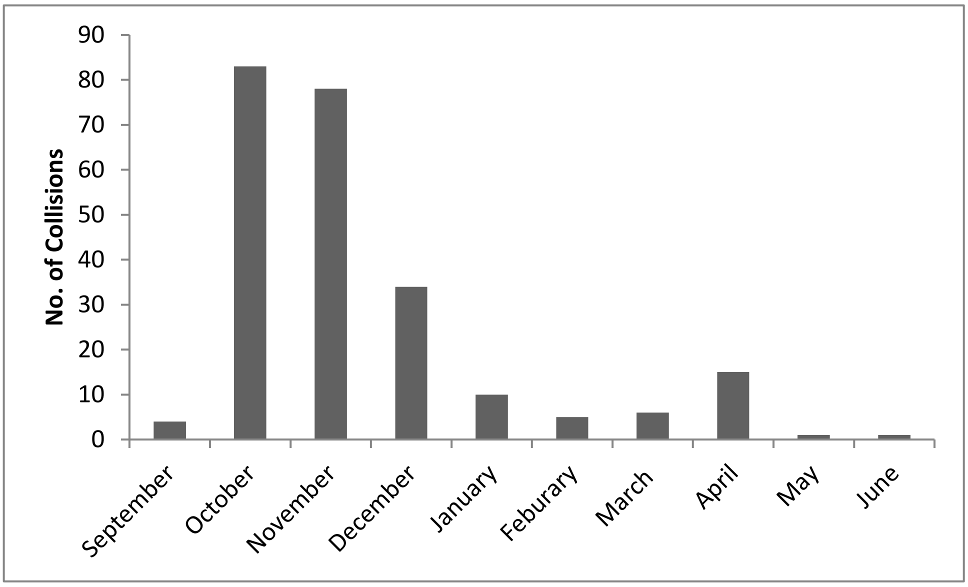
If a building is identified as a collision hotspot, a variety of low-cost measures can be undertaken to mitigate bird strikes. For example, if the existing perimeter vegetation is being reflected on the glass façade of a building lobby, an additional layer of screening vegetation could be planted very close (less than 1 metre) to the same glass façade to obscure reflections of the perimeter vegetation. Alternatively, non-reflective tinted screens and window films can also be applied on external glass surfaces to reduce reflections of the perimeter vegetation to mitigate bird strikes.

If the high incidence of bird strikes is associated with interior vegetation near glass surfaces, one could also consider dimming the lights in these areas at night to reduce the visibility of the vegetation to migrating birds.

The dimming of lobby lights in buildings with interior vegetation during the early morning hours can help reduce the visibility of interior vegetation to birds, thereby reducing incidence of collisions. Image credits: Chicago Bird Collision Monitors

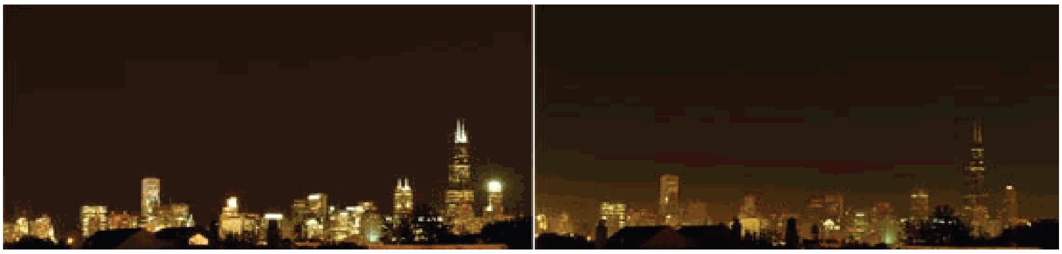
Seasonal Lighting Reduction

While bird collisions with buildings occur all year-round, incidents peak during the annual spring (from mid-March to early May) and fall (from mid-September to November) migration periods. The abundance of city lights and the unfamiliarity of the urban environment pose significant threats to migratory birds as they navigate through urban areas during these periods.



Reported bird-building collisions by month between 1998 and 2016 in Singapore, illustrating the peak collision period between October and November and a smaller peak between March and May. Image Credit: Low et al. 2017

As such, efforts to reduce or eliminate night lighting in offices, especially within groups of buildings, during these migratory periods can lead to significant reductions in bird-building collisions without any associated monetary costs. Such initiatives have been undertaken in various North American cities including Chicago, San Francisco and New York City.



Lights Out programmes to reduce nocturnal lighting in cities during peak migration periods provide cost savings and help mitigate bird-building collisions. These two photos are of the Chicago skyline taken before (left) and after (right) 11 pm of the same day during the fall migratory period. Image credits: New York City Audubon

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6 ACKNOWLEDGEMENTS

Contributors

The Editorial Team would like to express our heartfelt thanks to the following contributors who made this publication possible.

We would like to extend our thanks to **Dr Yong Ding Li**, **Dr Chris Hails, Dr Geoffrey Davison**, **Mr Alfred Chia** and **Mr Lim Kim Chuah** whose valuable comments have helped us improve the publication greatly.

We would also like to give our special thanks to **Dr Christine Sheppard** for allowing the use of her photographs and encouraging comments.

We are very grateful to contributors from San Francisco, in particular **Mr Peter Brastow**, **Dr Jack Dumbacher**, **Mr Andrew Perry** and **Ms Noreen Weeden** for sharing their knowledge with us and providing comments on the publication.

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