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The Role of Windows and Vegetation in Manhattan Bird Collisions

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Abstract

From 1997 to 2005, over 4500 bird collisions were recorded in Manhattan (New York City), two-thirds of which were fatal. 101 bird species were involved in these collisions, primarily from the warbler, sparrow, and thrush families, with most collisions involving neotropical migrants during spring and fall migration. Most collisions occurred during the day at the lower levels of buildings where vegetation was reflected in large glass exteriors. At several high-collision sites, strike rates of well over 100 birds per year and mortality rates of 80% or more were significantly higher than rates reported by other researchers. More research is needed to understand specifically how building design, landscaping, and avian physiology contribute to bird collisions so mitigation techniques and strategies can be identified. The increasing usage of exterior glass as a construction material, together with the continuing popularity of landscaping as a design element, likely presents a significant threat to migratory bird species, particularly those with declining populations.

Introduction

For more than a century, structures incorporating glass panels or windows have been known to pose a hazard to birds (Klem 1989). Some researchers maintain that, after habitat loss and fragmentation, collisions with such structures represent the greatest human-related threat to bird populations (Klem et al. 2004). Both reflective and transparent plate glass has been shown to be lethal to resident and migratory birds during daytime hours (Klem 1989, 1990). As more natural habitat is modified by development that incorporates such glass, this threat is likely to increase (Klem 1990). Annual avian mortality from collisions with glass for the continental US is estimated at 97.6 to 975.6 million birds (Klem 1990).

Night collisions with various structures such as communications towers and well-lit high-rise buildings pose an additional threat to nocturnal migrants, especially during inclement weather (Avery et al. 1976, Ogden 1996, Shire et al. 2000, Gauthreaux and Belser 2003). Several species involved in daytime and nighttime collisions are also listed on the US Fish and Wildlife Service's (USFWS) *Birds of Conservation Concern (2002),* previously known as *Species of Management Concern,*[3] and the *Audubon WatchList (2002).*[4]

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[3] This list identifies bird species that require prompt conservation attention to stabilize or increase their populations or to secure threatened habitats.

Previous bird-collision research has mostly focused on non-urban areas. However, daytime collisions also occur in urban areas, as evidenced by records dating back at least to 1978 (Ogden 1996). Data gathered by individuals, scientists, and bird-rescue organizations in Chicago, Toronto, and New York City demonstrate that urban collisions tend to occur during spring and fall migration, when the limited vegetation available in cities provides critical stopover habitat. Data gathered by FLAP (Fatal Light Awareness Program) in Toronto, a bird-rescue effort that initially focused on nighttime collisions, have shown that urban collisions occur during the night, especially during inclement weather (Ogden 1996). Other urban research suggests that while birds are drawn to tall, lit structures, this does not necessarily result in collisions (DeCandido 2005).

NYC Audubon's Project Safe Flight (PSF) was founded by Rebekah Creshkoff in 1997 to monitor bird collisions at New York City's World Trade Center and World Financial Center and was later expanded to monitor selected buildings throughout the borough of Manhattan and beyond. To date, over 4500 bird collisions involving dead and injured birds have been recorded,[5] with nine species appearing on the *Audubon WatchList*[6] and seven on the USFWS's *Birds of Conservation Concern*.

Dead Golden-crowned Kinglet, Morgan Mail building, 2005. Photo: Yigal Gelb

Although urban bird collisions have been covered in the popular press in recent years, we wanted to address the dearth of scientific research in this area. In 2005, we conducted studies to investigate the main factors involved in these collisions. Light is clearly a factor in bird collisions at communications towers (Avery et al. 1976, Ogden 1996), and may well play a role in concentrating night-migrating birds over urban corridors. However, devising an experiment to test this hypothesis was beyond our abilities. We therefore focused on what happens once birds are already in the urban environment. Our guiding hypothesis assumed that 1) higher strike rates occur at windows that reflect vegetated areas, and 2) very high strike rates occur at reflective windows opposite relatively large concentrations of vegetation.

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[4] This list, developed by BirdLife International and Partners in Flight, places species in three conservation categories: red, yellow, or green.

[5] Interactive database available online at www.nycaudubon.org.

[6] The nine species documented in New York City fall into the Yellow category. This category includes species that are declining at a slower rate than those in the red category.

Methods

Two field studies were carried out in 2005 to test this hypothesis. The first study was conducted in downtown Manhattan in spring of 2005 (the “downtown study”) and the second study during fall 2005 (the “Morgan Mail study”).

Downtown Study (spring 2005):

We selected seven buildings whose exteriors included either large, reflective windows, or regular windows, or no windows. (For the purpose of this paper, the term “large windows” refers to windows that are 2.286 m x 1.34 m or larger). Opposite or near these windowed buildings were varying concentrations of vegetation. This week-long study was carried out from noon, May 7th, to noon, May 14th, 2005 – a period that generally coincides with peak spring migration in New York City. Several of these buildings also incorporated two other factors involved in bird collisions: tall structures (skyscrapers) and bright external and internal artificial light during nighttime hours. Additionally, bird collisions had previously been documented at five of these buildings. For comparison purposes, two known high-collision sites not among the selected sites– the Morgan Mail building and the World Financial Center – were monitored once every morning during this period.

The downtown study included the following seven buildings: 1 Battery Park Plaza; 17 State Street; Church of Our Lady of the Rosary (the Church); 1 State Street Plaza; 3 New York Plaza; the New York Telephone Company Building; and 55 Water Street (general coordinate: 40° 42’11.2” N, 74° 00’43.4” W). Building heights ranged from less than 40 m (the church) to 230 m, with four high-rises over 140 m. All tall buildings included glass panels; 17 State Street and 3 New York Plaza incorporated continuous glass exteriors, while 1 Battery Park Plaza, 1 State Street Plaza, and 55 Water Street incorporated additional design elements, such as columns. The low rise church had only a few relatively small windows. Outdoor vegetation included planters, deciduous street trees, a plaza with about ten deciduous trees situated more than 25 m from the building exterior, and the nearby Battery Park, a 8.1-hectare park with extensive lawn and mature shade trees, most of them deciduous, located 50m from the two nearest buildings. The New York Telephone Company building was used as a control, since it had no windows, street trees or other vegetation, and emitted no artificial light. Almost all exterior walls ran straight from the base of the building to the rooftop, with no setbacks or ledges that could prevent colliding birds from falling to the street level. Proximity to mass transit (i.e., subway stations) was also a factor in selecting study sites to ensure easy access for study participants. The total length of the route walked by study participants was 590 m.

To quantify the number of collisions at the downtown site, we relied on methodology developed by other researchers, in which a strike is registered when a dead or injured bird is found at the base of the building (Klem 1989, 1990, Dunn 1993, O’Connell 2001, Klem et al. 2004). Study participants walked the route slowly, looking for dead or injured birds from the base of the building to the gutter on the near side of the street. The number of strikes registered at the site was likely a minimum value due to “removal bias,” i.e., the removal of dead and injured birds by predators and scavengers (Dunn 1993, O'Connell 2001, Klem et al. 2004) and street sweepers or building maintenance staff (Klem 1990, O'Connell 2001). In order to minimize removal bias, building exteriors were monitored seven times a day, at 0:00, 4:00, 6:00, 8:00, 12:00, 16:00, and 20:00 hours. During the last 24 hours of this study, the monitoring was made to be continuous, with one or two participants walking the route back and forth. The same route was walked during each monitoring session, beginning at 1 Battery Park Plaza and ending at 55

Water Street. Participants recorded their findings on a data sheet that included the study route and a map on which to mark where birds were found.

The study period included May 12th, since both the intensity of spring migration and the number of known collisions generally peaked in New York City on that date. Overall light intensity at the site was gauged by taking photos from a distance that allowed us to capture the entire study site; photos were taken at 22:30 and at 2:00.

Morgan Mail Building and Morgan Mail Study (fall 2005):

To test whether strike rates along an exterior made up of large, reflective windows increase with increasing amounts of vegetation, we conducted a field study at the Morgan Mail Processing and Distribution Center (the “Morgan Mail building”), a six-story office building in midtown where relatively high numbers of bird collisions have been recorded since 2002. The building is located in Manhattan between 28th and 29th Streets and between 9th and 10th Avenues (40° 45’01.7” N, 73° 00’01.2” W). The building’s exterior was made up of windowless concrete walls for the first two stories and 440 large, reflective glass panels (each 2.3 m by 1.3 m) covering approximately 75% of the remaining four stories (the "windows" actually mask an interior-concrete wall). All exterior walls ran straight from the base of the building to the rooftop, with only shallow ledges approximately 10 cm deep. The southern perimeter of this building (247 m) faced a row of short street trees that did not reach the building’s window line. These trees were fairly equally distributed along the building’s perimeter, and were used to accurately map collision locations. Opposite the building, on the south side of the street that runs parallel to the building, was a row of street trees, most of which are London Plane trees (*Platanus x acerifolia*) that reached to the top of the building and were over 20 m tall. Beyond this row of trees extended a rectangular 1.42-hectare park (Chelsea Park), which included more tall trees (mostly London Planes), some of which were also reflected in the glass panels. Vegetation in the park was not uniformly distributed – the eastern portion included over 15 20-m trees, while the western portion (slightly less than half the entire park) was far less vegetated, with most of the space taken up by an artificial turf ballfield.

To quantify the amount of vegetation reflected in the building’s windows, we counted the number of trees on the opposite side of the street mirrored in the glass panels. There were 12 such trees along the vegetated section and four trees along the less-vegetated section. We categorized collisions as occurring in either one of these two sections.

Bird collisions were recorded using the same methodology described in the downtown study. The southern perimeter of the building was monitored throughout spring and fall migration in 2005. Daily monitoring was discontinued at this site once collision numbers tapered off toward the end of each migration season. Periodic monitoring during the winter indicated that strike rates remained low during this period.

In order to accurately tally and map collisions over the course of a three-day period, a field study was conducted from October 18th to October 20th, 2005, in which participants monitored the building exterior five times a day, at 6:45, 9:00, 12:00, 15:00, and 19:00 hours. For the purposes of this three-day study, the building’s western perimeter, extending from 28th to 29th Street (58 m), was also monitored. This perimeter served as a control for vegetation, since no vegetation was reflected in the widowed exterior.[7]

[7] Although five street trees faced the lower two-story concrete exterior.

Bird collisions at other sites in Manhattan:

Our ongoing monitoring of structures across Manhattan has revealed three additional sites that stand out in their high-collision numbers each season. As in the case of Morgan Mail, these sites feature large, reflective glass panels opposite relatively large concentrations of vegetation. Bird collision totals for these sites from fall 2005 are presented in Table 1:

- The **Metropolitan Museum of Art** (The Met) – a building only several stories high with many large transparent and reflective windows opposite large vegetated areas in Central Park, including two large and reflective glass window fronts angled at 20° towards the sky on both the north and south side of the structure (length: 60 m each) and two large, mirror-like windows on the west side of the building (length: 35 m each). These windows faced unrestricted vegetation ranging from shrubs to trees over 20 m tall. The building was monitored almost daily from September to December 2005. Total length of route: 659 m. (40° 46’45.8” N, 73° 57’47.2” W).
- The **Jacob K. Javits Convention Center** (Javits Center) – a building only several stories high with reflective black-glass exteriors. Most collisions occurred along the southern exterior where a parallel row of 20 6-m Honey Locust trees (*Gleditsia triacanthos*) ran 10 m from the building. Vegetation was also present along sections of the eastern and northern exteriors. Total length of route: 359 m. (40° 45’27.3” N, 74° 00’06.7” W).
- The **World Financial Center** (WFC) – a complex of several high-rise buildings. Exteriors include large reflective windows opposite vegetation, including individual trees, two sections of 20 trees about 6 m high, and a wooded urban park about half a hectare large. The site also included a six-story atrium with indoor vegetation. Total length of route: 1,100 m. (40° 42’47.7” N, 74° 00’57.0” W).

These sites were monitored no more than once a day during migration season, generally in the early morning hours. As a result, numbers of dead and injured birds reported likely underestimate the number of collisions that actually occurred at these sites. Training orientations were conducted to ensure that all study participants were informed about study goals and trained in monitoring procedures. Monitoring was discontinued at the end of each migration season as numbers dropped to zero; periodic monitoring during winter and summer months, especially at the high-collision sites of Javits, the Met, and Morgan Mail, found very few collisions. Injured birds that were found stunned were allowed to recover and then released in a park well away from buildings; birds with more serious injuries were taken to a rehabilitator.

Binomial goodness-of-fit was used to evaluate experimental results. We considered test results to be statistically significant when $P < 0.05$. We used SPSS 12.0.0 for Windows, release Sep. 2003.

Results

Downtown Study (spring 2005):

Four bird collisions were recorded by study participants during the week-long downtown study: Two injured birds – a Wood Thrush (*Hylocichla mustelina*), rescued May 10th at 04:17 at 1 State Street Plaza; and a Black-throated Blue Warbler (*Dendroica caerulescens*), rescued Mat 12th at 06:10 at 3 N.Y. Plaza. Two dead birds – a Northern Parula (*Parula americana*), found

May 14th at 8:30 at 55 Water Street; and a very degraded and unidentified dead bird found May 8th at 08:05 at 17 State Street. During this same period, 14 and 24 collisions were recorded at the Morgan Mail building and the WFC, respectively.

Readings for temperature, humidity, and wind velocity were typical for this time of year, and skies were mostly clear during the week-long study. The first days saw periods of overcast skies, beginning after midnight on the first night and lasting into the afternoon of the second day, and then beginning before midnight on the second night and dissipating by early morning; no precipitation was recorded throughout the study period. As was our experience in 2003 and 2004, bird collisions clearly peaked in Manhattan on May 12th. Several of the buildings in the study site were 25-50% lit at 22:30; almost all the tall buildings were dark by 2:00.

<u>Morgan Mail building:</u>

During 2005, 252 bird collisions, involving 54 different species, were recorded at the Morgan Mail building, 90% of which were fatal. Almost all birds were found during spring and fall migration (69% during fall), with 92% of all birds determined to belong to a purely migratory species. Monitoring along Morgan Mail's southern perimeter over the course of 2005 showed strike frequency to differ significantly between the vegetated (105) and unvegetated (39) sections (Binomial test, $Z = -5.42$, 2-tailed, $P < 0.0001$).

<u>Morgan Mail Fall 2005 study:</u>

Weather conditions during the three-day study included few to no clouds throughout the period. Over the course of this study, 28 bird collisions involving 13 different species were recorded at the structure, 82% of which were fatal (23 birds). Of the total number recorded, 27 were found along the southern perimeter and only one along the vegetationless perimeter serving as a control. Collisions recorded during the three-day study were aggregated by monitoring slot to produce a temporal chart of strike frequencies (figure 1). Sunrise during this study was approximately at 7:10 with Civil Twilight at approximately 6:45 and sunset at approximately 18:10 EDT.

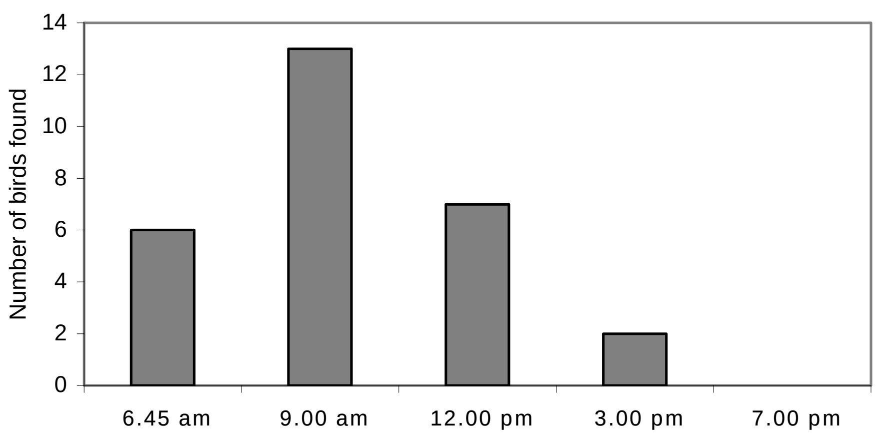

***Figure 1*: Time of collisions during three-day study, October 18th - October 20th, 2005**

Other Manhattan Sites in 2005:

Collision data for three high-collision sites in Manhattan are presented in Table 1. The top 20 species found to collide in Manhattan from 1997 to 2005 are presented in Table 2.

***Table 1*: Total birds found during fall 2005 at three high-collision sites in Manhattan.**

Location	#birds found	# species found	Mortality rate	Monitoring period
Met	94	29	93%	Sep. to Dec.
Javits Center	102	20	81%	Sep. to Dec.
WFC	87	20	64%	Sep. to mid-Nov.

Over 4500 bird collisions were recorded in Manhattan from 1997-2005 (New York City), two thirds of which were fatal. 101 bird species were involved in these collisions, most of which were passerines, primarily from the warbler, sparrow, and thrush families. Almost all collisions occurred during spring and fall migration periods; involving primarily neotropical migrants.

***Table 2*: Bird totals for top 20 species involved in collisions in Manhattan, 1997 – 2005.** Taxonomy follows the American Ornithologists' Union 7^{th} Edition Check-list (2005).

Common Name	Scientific Name	Number of Birds found
White-throated Sparrow	*Zonotrichia albicollis*	737
Common yellowthroat	*Geothlypis trichas*	422
Ovenbird	*Seiurus aurocapillus*	275
Dark-eyed Junco	*Junco hyemalis*	248
Ruby-crowned Kinglet	*Regulus calendula*	127
Hermit Thrush	*Catharus guttatus*	125
Song Sparrow	*Melospiza melodia*	106
American Woodcock	*Scolopax minor*	104
Black-and-white Warbler	*Mniotilta varia*	100
Gray Catbird	*Dumetella carolinensis*	95
Swamp Sparrow	*Melospiza georgiana*	85
Golden-crowned Kinglet	*Regulus satrapa*	83
Black-throated Blue Warbler	*Dendroica caerulescens*	70
Blackpoll Warbler	*Dendroica striata*	69
Northern Flicker	*Colaptes auratus*	60
Yellow-bellied Sapsucker	*Sphyrapicus varius*	56
Magnolia Warbler	*Dendroica magnolia*	52
American Redstart	*Setophaga ruticilla*	45
Brown Creeper	*Certhia americana*	45
Wood Thrush	*Hylocichla mustelina*	43

Discussion

Our findings suggest that strike rates increase with increasing amounts of vegetation and glass—especially reflective glass—opposite the vegetation. Where these two factors – glass and vegetation – are limited in their extent, collisions can amount to only a few per year; but where such factors are dominant and "mirrored glass exteriors" face "forested patches" (O'Connell 2001), they create a high-collision site that can lead to several hundred collisions per year. The downtown study supports this conclusion, recording only three collisions along a route in which characteristics of high-collision sites were absent, while a total of 38 collisions were recorded at the Morgan Mail building and the WFC, even though these shorter routes were monitored only once a day.

The findings from Morgan Mail provide further evidence for the central role of reflective glass and vegetation in high-collision sites – the three-day Morgan Mail study recorded 27 collisions along the southern exterior facing the vegetated area but only one collision along the unvegetated western exterior. Furthermore, when dividing the southern exterior into vegetated and less-vegetated sections, our data for the entire year revealed nearly three times as many collisions along the more vegetated section compared with the less-vegetated section. While more research is needed to quantify the extent of bird collisions across Manhattan, it is likely that the majority of bird collisions occur at a relatively low number of high-collision sites.

In cases where reflective window panels face vegetated areas, we propose a two-step process that results in collisions: First, birds are attracted to vegetated areas (Klem 1989, 1990, Klem et al. 2004). Second, once there, the birds perceive reflected images of vegetation in the windows as continuous habitat, leading them to collide with the solid glass barrier.[8] While more research is needed to better understand how building design, landscaping, and avian physiology contribute to bird collisions, we found the following points noteworthy: it is likely that up to a certain limit, the farther the vegetation is from the window, the more lethal the site becomes, since a greater distances allows birds to gain momentum and hit the window with greater force (Klem et al. 2004). It is also possible that taller trees, by providing more habitat, may also be associated with higher mortality rates. Window angling may also play a role – at the Met, the two angled glass window fronts on both the north and south side of the structure were found to cause no collisions at all. Windows at the Met that reflected more vegetation were also found to be associated with more collisions than similar windows that were placed relatively higher and reflected less habitat and more sky.

Strike rates at high-collision sites were found to be significantly higher than previously reported. Other studies carried out in non-urban areas estimated about 30 bird collisions per year per building at various high-collision sites (Klem 1990, Dunn 1993, O'Connell 2001). At Manhattan's high-collision sites, about 100 collisions were recorded per site during the fall season alone, with 175 registered at the frequently monitored Morgan Mail building. Since other researchers do not report the sizes of the various structures, it is difficult to determine if size differences could account for the higher strike rates in Manhattan. However, anecdotal evidence from similar sites in Toronto, Ontario and Great Neck, NY suggests that even exteriors of 40 meters or less can be associated with hundreds of collisions per year (personal communication: Michael Mesure, Executive Director of FLAP; and Valerie DiNatale, Project Leader, respectively). Mortality rates at high-collision sites were also found to be significantly higher than previously reported. While other studies reported mortality rates ranging from 50-67%

[8] Structures with transparent windows that reveal views of potted plants indoors can also lead to this outcome.

(Klem et al. 2004), the Met, Morgan Mail, and Javits Center witnessed rates of 93%, 90%, and 81%, respectively, during fall 2005. While it is possible that the removal of live birds by predators bolstered these high rates, this seems unlikely as we would expect such predation to also remove dead birds.

Since reflections of vegetation are likely involved in most collisions in Manhattan, it is not surprising that most collisions seem to occur during daytime hours. Throughout the day, but particularly during morning hours, many birds are busy feeding at tree level, which is also when vegetation is most likely to be reflected in glass. Substantiating this conclusion is the fact that all high-collision sites we have identified to date include relatively large concentrations of vegetation opposite large, reflective windows. At the low-rising Morgan Mail building, the three-day study found that collisions occurred almost entirely during daytime hours. While monitoring was not as intense during nighttime hours during this study, no collisions were found to occur during the 19:00 slot, approximately one hour past sunset, and daytime collisions peaked at 9:00 and not at 6:45.

The week-long field study carried out in downtown Manhattan suggests that when factors that are known to cause nighttime collisions – such as tall, lit structures – are included, strike rates do not necessarily increase. During the entire downtown study, which monitored several very tall skyscrapers during peak migration, only one collision was recorded during the night. It is important to note that this does not mean that tall, lit structures do not pose a threat to migratory birds, especially given that the low number of bird strikes found during the downtown study may simply reflect the fact that during relatively clear skies, the rate of nighttime collisions at tall structures is low, a phenomenon also documented at communications towers (Cochran and Graber 1958, Avery et al. 1976).[9]

In contrast with other research, our findings show most collisions in New York City occurred during spring and fall migration. Both Klem (1989) and Dunn (1993) focused on sites with bird feeders and consequently found that many to most collisions occurred during winter; Dunn's data set (Cornell FeederWatch observations submitted by "citizen scientists") included only winter and early spring monitoring, further biasing her results. Both our results and those reported by Ogden (1996) and O'Connell (2001) indicate that sites without feeders experience significantly more collisions in the spring and fall compared with summer and winter. More research is needed to accurately estimate seasonal strike rates in North America.

A review of Manhattan bird-collision records reveals most species to be migratory. Our list of the top 20 bird species involved in collisions (Table 2) includes only migrants. Common resident species, although abundant at many of the sites we surveyed, were not frequent collision victims. For instance, for data collected from 1997 to 2005, no collisions were recorded for European Starlings (*Sturnus vulgaris*), and only eight and 17 collisions involved Rock Pigeons (*Columba livia*) and House Sparrows (*Passer domesticus*), respectively. While it is possible that bird behavior may be responsible for lower collision fatalities among certain bird species (Klem 1989), certain resident species, especially those that are thought of as “urban birds,” may have developed a way to avoid colliding with windowed structures.

[9] Attraction by city lights may play a more important role in causing avian mortality in other geographic areas, such as Toronto.

The bird-collision problem documented in New York City suggests that reflective glass panels opposite vegetation form a lethal combination for birds passing through the human-dominated landscape. The threat to migratory bird populations may be much broader, given that numerous structures across North America incorporate these characteristics. To make matters worse, the populations of several of the species involved in collisions are in a precarious state, leading to their inclusion in various conservation lists. Without proper measures, this threat is only likely to increase as we continue to rely on exterior glass as a construction material, together with the continuing popularity of indoor and outdoor vegetation as a design element, both in cities and beyond.


Reflected vegetation at Morgan Mail building, 2005. Photo: Nicole Delacretaz.

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