Citizen science to address the global issue of bird–window collisions

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Bird–window collisions (BWCs) are a major threat to avian populations, annually causing up to one billion bird deaths in the US alone and untold numbers of fatalities worldwide. Until recently, there has been limited institutional and governmental recognition of this issue and few coordinated, national-level efforts to address it. To fill this need, citizen-science campaigns have stepped in to generate scientific information about BWCs, raise public awareness, and advocate for policy and actions to reduce collisions. We review the BWC issue and showcase how citizen-science programs in multiple countries have achieved these outcomes. Additional citizen-driven successes in addressing BWCs are possible if key constraints are overcome, including funding limitations and challenges of proactively engaging stakeholders who can reduce BWCs at scale. Addressing this global conservation issue will also require building upon the recent increase in attention to BWCs by government agencies, nongovernmental organizations, commercial entities, and professional scientists.

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Birds are among many wildlife taxonomic groups experiencing massive losses in diversity and abundance as a result of human impacts (Dirzo *et al.* 2014). Since 1970, 57% of bird species in North America have experienced population declines, resulting in 3 billion fewer breeding individuals (Rosenberg *et al.* 2019). This pattern, along with similar reductions in bird populations worldwide, has led to a redoubling of scientific efforts to identify causal mechanisms and to a refocusing of attempts to manage key threats and conserve bird populations. While avian conservation has traditionally focused on prominent threats like habitat loss, increasing attention is turning toward direct sources of anthropogenic mortality (eg predation by domestic cats, collisions with energy infrastructure and buildings) that collectively cause billions of bird fatalities in the US alone every year (Loss *et al.* 2012, 2015b).

Collisions with buildings and their windows (hereafter "bird–window collisions" or BWCs) are a major cause of avian mortality, annually responsible for up to one billion bird deaths in the US (Loss *et al.* 2014), tens of millions of deaths in Canada (Machtans *et al.* 2013), and innumerable deaths worldwide (Rebolo-Ifrán *et al.* 2019; Yang *et al.* 2021). The species most vulnerable to collisions (eg hummingbirds, warblers, thrushes, and sparrows in the western hemisphere) (Loss *et al.* 2014) receive substantial public and conservation interest due to their declining populations, and to the aesthetic values and ecosystem services they provide to society (Whelan *et al.* 2015). Reflecting the critical importance of this issue, reducing BWC occurrence has been recognized as one of seven simple actions that can help stem the decline of North America's avifauna (www.3billionbirds.org). However, until recently and despite calls for action for decades (Klem 1990), institutional and governmental acknowledgement of this issue has been limited, and there have been few coordinated efforts

In a nutshell:

- Bird–window collisions (BWCs) threaten avian populations worldwide, but until recently, relatively few conservation organizations have addressed this issue
- Citizen-driven campaigns have become important generators of scientific advances, leaders in public mainstreaming of this threat, and advocates for bird-friendly building policies and actions
- Citizen-science programs illustrate the diverse approaches and partnerships required to successfully address BWCs, and are well positioned to raise further awareness of this issue among policy makers, conservation practitioners, and the public
- Increased funding and support to address BWCs is needed from government and nongovernmental organizations, professional scientists, and commercial sectors

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to address it. This represents a fundamental gap in the process of connecting a causal mechanism with direct conservation action to reduce a known threat to bird populations.

To address this gap and link science with action, citizen-science programs have formed to generate information about BWCs, educate and raise awareness among the public and policy makers, and advocate for laws and conservation actions to reduce collisions. Citizen science refers to science, engagement, education, and policy campaigns that include participation and/or leadership by members of the public and involve varying levels of collaboration with professional scientists. Although the term "citizen science" is imperfect, we use it here because of its widespread application (with the caveat that "citizen" can refer to any community member and not only legal citizens of a nation) and to avoid confusion and unintended harm caused by use of alternative terms (Cooper *et al.* 2021).

We review the BWC issue and showcase citizen-science programs in multiple countries that are addressing related science, education, and action goals, including Lights Out Texas, China Anti-Bird Window Collision Action Alliance, and the pioneering Fatal Light Awareness Program (FLAP) Canada. We also discuss how citizen science is positioned to make additional contributions if major constraints are overcome, and how the increasing attention being given to BWCs by government and nongovernmental organizations (NGOs), commercial entities, and professional scientists will be needed to support citizen science and address this key threat to birds.

Citizen response to the global BWC problem

Birds collide with windows because windows reflect nearby habitat or appear transparent, depending on glass reflectance and ambient light (Figure 1). While accounts of BWCs date back at least 190 years (Nuttall 1832), detailed studies first began in the 1970s (Klem 1989). Research has increased greatly over the past few decades, and in this recent era of BWC science, studies have identified species groups most prone to collisions and factors that increase collision risk. Information about BWCs remains sparse outside North America, but studies in the US and Canada have shown that collisions tend to peak in spring and fall and primarily impact migratory species, especially nocturnal migrants (Loss *et al.* 2014). However, large numbers of BWCs also can occur outside of migration periods, especially when food resources that attract birds (eg bird feeders, fruiting plants) are located near buildings (Ocampo-Peñuela *et al.* 2016; Brown *et al.* 2019). BWCs can occur at any time of day or night (Klem 1989), but in urban areas during migrations, collisions with large buildings (eg skyscrapers and buildings on office and university campuses) often peak during early morning and overnight (Riding *et al.* 2021).

BWCs also vary spatially, occurring most frequently at buildings with extensive glass surfaces and abundant nearby vegetation (Klem *et al.* 2009; Hager *et al.* 2017). Nighttime lighting emitted from and near buildings increases BWC risk by attracting nocturnally migrating birds, causing them to collide immediately or be drawn into urbanized areas where they may later collide during daylight hours (Lao *et al.* 2020; Van Doren *et al.* 2021). Related to these risk factors, BWCs can be reduced by constructing buildings with less glass, making glass more visible (eg using films and markers) (Riggs *et al.* 2022a), and mitigating nighttime light pollution in concert with systems that predict migration and BWCs using weather conditions and next-generation weather radar (NEXRAD) technologies (Van Doren and Horton 2018; Elmore *et al.* 2021; Horton *et al.* 2021).

Data provided by citizen-science programs have been crucial to advances in BWC research, and to the recent groundswell of public, policy, and conservation attention directed toward BWCs. In parallel to this citizen contribution, scientific interest in urban ecology has risen markedly (Aronson *et al.* 2017), alongside greater emphasis among conservation programs on providing bird-friendly habitat in cities (NAS 2022). Even a highly cited study in which it was estimated that BWCs annually kill up to 1 billion birds in the US relied on data from citizen-science programs (Loss *et al.* 2014). Citizen-driven efforts have also advanced understanding of BWC risk factors (WebPanel 1) (Shi *et al.* 2022). Awareness and policy advocacy campaigns led by these programs have made BWCs a topic that now captures widespread public attention and coverage in the popular media (Paddison 2021). Such campaigns have also made BWCs a focal point of policy discussions around the world and have contributed to the development of many proposed and enacted laws and standards guiding building design. These include New York City's bird-friendly design and construction requirements (City of New York 2020); "Bird Collision Deterrence" and "Light Pollution" performance measures in the Toronto Green Standards Guidelines (City of Toronto 2022); the Bird Safe Buildings Act of 2021 that has been considered by the US Federal Government (US Congress 2021a); and the Shenzhen (China) Biodiversity Action Plan 2022–2025, which calls for evaluation of building impacts on migratory birds and development of guidance for bird-friendly building design and renovation.

Other NGOs – notably, the American Bird Conservancy (ABC) through its Glass Collisions Program (ABC 2022) – have also promoted BWC awareness, policy, and management. Nevertheless, leadership by citizen-science programs has been critical because, with a few exceptions (such as US Fish and Wildlife Service's [USFWS's] initiative to reduce BWCs at federal buildings; USFWS 2022), limited attention and funding have been directed toward the issue of BWCs by major conservation organizations and government agencies.

Showcase: BWC citizen-science programs

Below and in WebPanel 1, we showcase BWC campaigns in several countries that are driving science, conservation, and policy efforts focused on this issue. These programs

span the full range of citizen-science projects, including contributory, collaborative, and co-created projects that capture varying levels of partnership with professional scientists, and programs that include no formal interactions with professional scientists (Shirk *et al.* 2012; Loss *et al.* 2015a). In North America, where most current BWC citizen-science programs are based, some are stand-alone organizations (eg Chicago Bird Collision Monitors, FLAP Canada) while others are directed by local conservation organizations, including local and/or state chapters of the National Audubon Society (eg New York City Audubon's Project Safe Flight).

Our first example, Lights Out Texas (LOT), illustrates a successful approach to engage citizens in addressing BWC science, awareness, and action goals across a large, ecologically diverse US state. This approach relies on partnerships among diverse institutions, which has allowed LOT to expand its outreach and action campaigns across Texas and to conduct the first multi-city, citizen-led study of BWCs using a standardized monitoring protocol. Our second example, the China Anti-Bird Window Collision Action Alliance, demonstrates how a university initiative took a specific approach of engaging students, who can be considered citizen scientists (Harlin *et al.* 2018), to study BWCs in a region with little existing scientific information about this issue; this example also shows how partnerships can expand a local effort into a national campaign to increase scientific knowledge and foster conservation action, in this case across China. Finally, we highlight FLAP Canada's pioneering efforts over three decades, which have inspired development of many similar programs and provide a template for achieving diverse goals, including BWC education, policy development, and research, as well as bird rescue, rehabilitation, and conservation.

Figure 1. Birds do not perceive windows as a barrier because windows can (a) reflect surrounding habitat and (b) be transparent. Birds are also attracted to buildings by artificial nighttime lighting, which exacerbates collision risk, as shown in (c) for the 9/11 Tribute in Light memorial in New York City (the streaks in the light beams are migrating birds). Bird collisions are a growing concern due to the increasing number of glass-dominated buildings in many cities of the world, such as (d) Dallas, Texas. Images courtesy of: Wikimedia Commons/Tulumnes (a), Wikimedia Commons/GeographBot (b), KG Horton (c), and Wikimedia Commons/Gattacal (d).

Lights Out Texas (LOT)

"Everything is bigger in Texas", or so goes the popular slogan for the geographically largest and second most populous state in the contiguous US. In keeping with this catchphrase, Texas is also big for bird migration, and as such is an area of global importance for birds. Nearly two billion birds migrate through the state annually, including one-third of all spring migrants in the US and one-fourth of fall migrants (Dokter *et al.* 2018; Horton *et al.* 2019b). But cities throughout Texas also emit large amounts of light at night. In combination, these two factors – an abundance of migratory birds and nighttime artificial illumination – create a substantial risk of BWCs in the state. Indeed, among all US cities, Houston is ranked second and Dallas–Fort Worth third in having the highest light pollution exposure risks for nocturnally migrating birds, with four other Texas cities also making the top 100 (Horton *et al.* 2019a).

The above-cited studies indicating a substantial risk of BWCs in Texas, along with a highly publicized BWC event in Galveston in which almost 400 birds were killed (Bartels 2017), created a unique opportunity to leverage civic engagement around the issues of light pollution and bird collisions. In 2020, the citizen-driven LOT campaign was launched, with the goal of increasing awareness and action to reduce BWCs across the state (Figure 2). Reflecting the scope of effort needed to cover an area as large as Texas, protect its globally important bird migration, and address its outsized light pollution problem, the LOT campaign encompasses many metropolitan areas, including the cities of Houston, Dallas–Fort Worth, San Antonio, Austin, and El Paso, where collectively ~70% of the state's population resides.

A distinctive aspect of LOT is that many organizational partnerships had to be developed to scale this campaign statewide, with Texan by Nature, Audubon Texas, and the Texas Conservation Alliance assuming major leadership roles in coordinating efforts among cities. Local organizations (for instance, the Houston Audubon Society, Travis Audubon, Bexar Audubon Society, Perot Museum of Nature and Science) spearhead education and awareness activities

Figure 2. (a) Lights Out Texas (LOT) is a campaign to increase awareness of and promote actions to reduce bird–window collisions (BWCs) in the US state of Texas, which contains two of the top three US cities (and six of the top 100) in terms of having the highest exposure of migrating birds to light pollution (image shows light pollution per capita). LOT includes scientific monitoring of BWCs across six cities; (b) volunteer monitors in Dallas prepare for morning surveys of collisions. LOT distributes outreach toolkits to governments and businesses, which (c) has resulted in reductions in building lighting that protect migrating birds (two-part image shows before [left] and after [right] photographs of such a reduction at the same site). Images courtesy of: T Wallace (a), BJ Jones and TG Brys (b), and B LePard (c).

in their respective areas and encourage actions like pledges by municipalities and building managers to reduce nighttime lighting. These organizations also recruit, train, and coordinate citizen scientists, including participants who monitor buildings for BWCs during the spring and fall migrations. Further assistance is provided by the Texas Parks and Wildlife Department, which coordinates BWC data entry and management through a LOT iNaturalist page (iNaturalist 2022), and the Biodiversity Research and Teaching Collections at Texas A&M University, which receives and prepares casualty birds to museum standards, making specimens available to other researchers.

Another distinctive aspect of LOT is its approach to monitoring and studying BWCs using standardized methodologies in multiple cities. This scientific approach is facilitated through collaboration with experts in bird migration and BWCs from universities in Texas and across the US, including the Cornell Lab of Ornithology, which co-founded the project. BWC monitoring generates data to inform LOT's education, awareness, and action goals, and represents an unprecedented opportunity for leveraging citizen-driven efforts to address previously unresolvable questions, such as how do BWC numbers vary among cities with different bird migration patterns, and how do optimum BWC management approaches (including the scale and timing of lighting reduction needed to reduce BWCs) vary geographically and in relation to factors like local sociopolitical constraints?

Although still in its infancy, LOT has already raised awareness of BWCs across Texas, leading to conservation successes in many urban areas throughout the state. Social media and outreach materials have targeted over 800 Texas-based companies, about 100 of which agreed to turn off their buildings' lights at night to protect migrating birds in spring and fall 2021. Seven municipalities, including Dallas, Fort Worth, and Houston, as well as Travis County, which includes the city of Austin, have issued public proclamations indicating their support and urging residents and businesses to turn off non-essential lights at night during critical migration periods (Cornell Lab of Ornithology 2022). The LOT campaign has received substantial media coverage, including 122 earned media placements that were viewed over 200 million times in 2021. One particularly notable aspect of LOT's outreach effort that has been crucial to building support has been the elevation of the BWC issue by Laura Bush, former First Lady and founder of the NGO Texan by Nature (Bush 2021).

China Anti-Bird Window Collision Action Alliance

As one of the world's mega-biodiverse nations, China harbors 1470 bird species, including nearly 600 migratory species that traverse three major migration flyways (Galbraith *et al.* 2014). One of these, the East Asia–Australasian Flyway, supports the greatest diversity and abundance of migratory birds globally but passes over regions (including eastern China) that contain the greatest concentration of humans worldwide, resulting in the greatest overlap between migratory birds and human-related threats to birds on Earth (Yong *et al.* 2015, 2021).

Although BWCs are recognized as a threat to Asia's migratory birds (Yong *et al.* 2015), the issue has received scant attention on the continent. In China, although the overall scale of BWCs (eg numbers of birds killed, which species are most affected) is largely unknown, it is increasingly apparent that rapid urbanization and population growth pose a major threat of BWCs to bird populations (Yang *et al.* 2021). To examine this emerging issue in greater detail, researchers at Duke Kunshan University, located 50 km west of Shanghai, began systematic monitoring of BWCs in fall 2018 to identify collision hotspots on campus. This study was notable in that it engaged university students in collision surveys (see WebPanel 1 for other examples of student-driven efforts). Preliminary information from this survey was used to motivate university investment in window film applications that make glass more visible to birds. Since the first monitoring season, BWC surveys

have been conducted every spring and fall to evaluate the effectiveness of these window retrofits (Shi *et al.* 2022).

Concurrent with this study, ornithological experts at the Chengdu Bird Watching Society led the development of a national, web-based portal through which the public could report BWCs nationwide on WeChat, China's most popular social media platform. In 2021, Duke Kunshan University and the Chengdu Bird Watching Society, with support from the China Youth Climate Action network, launched the China National Bird Collision Survey (Figure 3), the first systematic, national-scale BWC study in Asia. In spring and fall 2021, this project enlisted 314 citizen participants from 79 cities across China to conduct daily BWC surveys during peak migration periods. This effort resulted in publication of a report listing the bird species most frequently identified as collision casualties (eg Chinese blackbird [*Turdus mandarinus*], gray-backed thrush [*Turdus hortulorum*]) and factors positively associated with BWC occurrence (eg glass area, building height) (Shi *et al.* 2022). The report received widespread media attention across China. Building on this momentum, a partnership – the China Anti-Bird Window Collision Action Alliance – was formed in 2022, with continued leadership by Duke Kunshan University and Chengdu Bird Watching Society, and support from several nonprofit organizations (Friends of Nature, Guarding Wilderness, Shenzhen Mangrove Wetlands Conservation Foundation, and Shanshui Conservation Center). This alliance is spearheading a long-term citizen-science survey that generates data to inform conservation actions, raises awareness about BWCs among the public and in commercial arenas (eg architectural and glass-making industries), and advocates for policies and solutions to make China's cities more bird-friendly, such as recent projects to retrofit windows in Shanghai, Shenzhen, and Suzhou. Notably, students from Duke Kunshan University remain actively engaged in coordinating this national alliance through the training of citizen participants and by leading outreach activities.

Fatal Light Awareness Program (FLAP) Canada

Emerging campaigns like Lights Out Texas and the China Anti-Bird Window Collision Action Alliance have succeeded due in no small part to efforts of pioneering citizen-science programs. Many of these trailblazers, including Chicago Bird Collision Monitors, New York City Audubon's Project Safe Flight, and others (see Loss *et al.* 2015a), have led public awareness, policy advocacy, and collision monitoring campaigns over the past 10–20 years. However, no program has been as globally influential as Fatal Light Awareness Program (FLAP) Canada.

Founded in 1993, FLAP Canada was the world's first organization to focus exclusively on the twin dangers of light pollution and BWCs. FLAP Canada's mission is to safeguard migratory birds in the built environment through education, policy development, research, and bird rescue and rehabilitation. FLAP Canada works with industry professionals, researchers, conservation groups, government agencies, and the public, to promote bird-safe practices and on-the-ground conservation.

FLAP Canada began as a grassroots effort to rescue birds that collide with buildings in downtown Toronto during the spring and fall migrations. Citizen-science volunteers with the organization scour the streets in early morning, searching for dead, injured, and disoriented birds, and record dates,

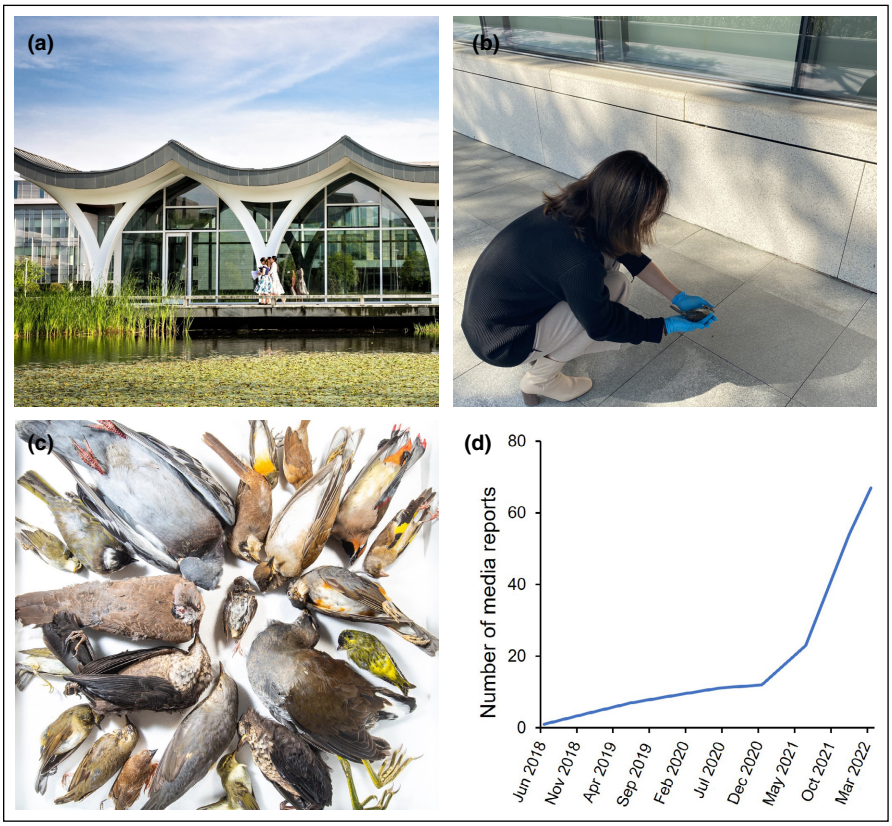

Figure 3. In 2018, researchers and student citizen scientists at Duke Kunshan University in China conducted bird–window collision (BWC) surveys that (a) found that the campus's glass-dominated buildings caused many collisions. In 2022, this effort evolved into the China Anti-Bird Window Collision Action Alliance, a national survey that (b) enlists citizen participants from across China to conduct collision surveys (a sample of casualties is shown in panel [c]), and raises awareness of and advocates for policies and solutions to make China's cities more bird-friendly. After the alliance released a report (Shi *et al.* 2022) that described which species are most often killed and identified building-related factors responsible for many collisions, (d) BWCs received increased media coverage across China, as determined through queries of Chinese search engines (eg Baidu), social media platforms (eg Weibo), and other online sources, and via tracking of media coverage, including interviews with project leaders. Images courtesy of: Duke Kunshan University (a), J Liu (b), and BV Li (c and d).

locations, and species of casualties (Figure 4). Injured birds are taken to wildlife rehabilitation clinics and unharmed birds are captured and released in nearby natural areas. In 1995, to mitigate what they realized was a major cause of BWCs, FLAP Canada worked with World Wildlife Fund Canada to launch the first "lights out" initiative: the Bird-Friendly Building Program. More than 70 buildings participated in this 5-year lighting reduction program, and a concurrent monitoring study illustrated a marked reduction in BWCs at participating buildings (Evans Ogden 2002). This campaign set in motion the reform of building management practices in Toronto and across Canada, and sparked dozens of similar initiatives across North America. Data on BWCs collected by FLAP Canada were also used in a lawsuit that set key legal precedents protecting migratory birds under both the provincial (Ontario) Environmental Protection Act and the federal Species at Risk Act.

Although BWC awareness continues to grow throughout North America, FLAP Canada recognized a major knowledge and education gap about this issue globally. To increase international action and awareness, FLAP Canada launched Global Bird Rescue (GBR) in 2019. GBR is a week-long event held annually where teams and individuals around the world search for and rescue BWC victims and submit data to the Global Bird Collision Mapper, furthering knowledge about species susceptibility and the overall scale of this issue in understudied regions.

FLAP Canada's reach and focus has grown far beyond a bird rescue program in one city, but since its inception, FLAP Canada has relied heavily on participation from community members to create change. Dedicated bird rescuers, who witness firsthand the damage caused by building windows as they collect data and rescue birds, often become the fiercest advocates for bird-safe building practices. Expanding these citizen-science programs, both locally and globally, not only has potential to save injured birds but also facilitates data-driven advocacy and fosters development of a network of bird-safety champions.

Constraints and opportunities

As evident from the examples presented above, citizen-science programs have made major contributions to addressing the BWC issue. Further citizen-driven successes are possible, but major constraints must be overcome. Crucially, a continued increase in attention toward BWCs by government agencies, NGOs, commercial entities, and professional scientists will be needed to support and expand citizen-science activities and successfully manage this threat to birds.

One major constraint is that BWC research and funding remain inadequate, despite the large amount of bird mortality associated with collisions. This limits resources available to citizen-science programs and other organizations addressing BWCs. As with citizen-science programs that concentrate on other ecological issues (Dickinson *et al.* 2012), most BWC-focused programs operate on a shoestring budget; rely on passionate, dedicated volunteers; and expend considerable time and effort in fundraising to support operating activities and compensate staff. Moreover, financial support stems largely from foundations and private donors because limited federal and state/provincial funding is available for BWC conservation and research. For example, other than the USFWS's Urban Bird Treaty Program, which provides modest funding for projects that reduce BWCs, we are aware of no federal grants in the US or other nations that focus on BWCs and are available to external organizations. Projects that use citizen science to study and manage BWCs may qualify for a handful of grants, such as those offered by the US National Science Foundation's Dynamics of Integrated Socio-Environmental Systems program. However, leaders of citizen-science programs may be unaware of these opportunities or lack the time and expertise to apply for such competitive grants, which are often aimed at promoting major scientific discoveries.

Additional constraints affecting the success of BWC citizen-science programs relate to the challenges of engaging with and fostering actions by decision makers who can enact changes that reduce collisions at scale. Several publications summarize bird-friendly building design and management approaches (ABC 2022; NAS 2022), and the Leadership in Energy and Environmental Design (LEED) green building rating program includes an Innovation Credit for bird collision deterrence (US GBC 2022). Nevertheless, stakeholders like architects, property developers, and building management organizations normally do not seek out information and expertise on bird-friendly practices. Instead, concerned citizen-science programs often recognize a potential problem only after building plans are released or a building is constructed, limiting options to reduce collisions. A related constraint is the challenge of transitioning from communication and action campaigns that promote lighting reduction to those also encouraging actions to make windows more bird-friendly (eg using glass, markers, and films that increase the visibility of windows to birds). Major BWC events caused by light pollution have been used by citizen-science programs as entry points to collision mitigation through lighting reduction, which building owners and operators often find palatable due to its relative cost-effectiveness and ease of implementation. However, many daytime BWCs occur independent of light pollution, and reducing these collisions using one or several of the aforementioned products is more costly and often perceived to negatively affect building aesthetics.

Addressing these constraints requires additional funding for education, advocacy, research, and management efforts that lead to reductions in BWCs, including those directed by citizen-science programs. More funds could be made available if BWCs were to be recognized as falling under the purview of existing grant programs. Professional scientists can play a lead role in developing collaborations between their institutions and citizen-science programs (Loss *et al.* 2015a), which may

facilitate access to funding sources focused on scientific discoveries. As a threat to declining birds, BWCs could also potentially be addressed through programs that support conservation of declining wildlife, like the recently proposed Recovering America's Wildlife Act in the US (US Congress 2021b).

Identifying and securing new funding streams may also be required to support citizen-science programs and provide subsidies that help these and other organizations convince stakeholders to implement bird-friendly practices. Novel funding mechanisms and subsidies for BWC management could be integrated into laws aimed at bird-friendly design of new buildings and mitigation through retrofitting of existing structures. Such laws may encourage building designers and managers to collaborate proactively with BWC experts prior to construction. Legislation requires political buy-in, which relies on broad public support and mainstreaming of the BWC issue. Citizen-science programs have already substantially raised the profile of this issue, and their actions have informed legislation. For example, based on the efforts of its citizen-driven Project Safe Flight program, New York City Audubon successfully advocated for an amendment to New York City's building code requiring that bird-friendly materials be used in new buildings (Liao 2019).

The conservation social sciences (Bennett *et al.* 2017) may aid in addressing these constraints and identify education, advocacy, and communication approaches that motivate actions to reduce BWCs. Public engagement in conservation behaviors depends on many factors, including legal and economic contexts, personal and social norms, and perceived ability to effect change (Klöckner 2013; Dayer *et al.* 2020). Thus, information alone rarely motivates behavior change. Very little social-science research has focused on BWCs, and additional studies are needed to identify factors contributing to BWC-reducing behaviors. A human-dimensions study in Costa Rica found that although residents were aware of BWCs, they did not grasp the overall magnitude of this threat (Menacho-Odio 2018), and a survey of stakeholders from 18 US states and Canada revealed that respondents had positive views toward BWC management (Riggs *et al.* 2022b). Along with research showing that perceived severity of threats to avian populations affects willingness to support bird conservation (Eylering *et al.* 2022), such studies suggest that efforts to increase awareness of the magnitude of the BWC issue (eg the FLAP Canada event highlighted in Figure 4) may motivate action to reduce collisions. The broader social-sciences literature (Klöckner 2013; Mengak *et al.* 2019) suggests a need to provide incentives (eg grants/subsidies for bird-friendly actions), information about BWC-reducing measures and how stakeholders can enact them, and examples of success stories, like research or case studies confirming the effectiveness of glass treatments (Riggs *et al.* 2022a).

Although BWCs occur worldwide, little research and few citizen-driven science and action programs have focused on this issue outside of the US and Canada. In many nations, especially those in the Global South, funding limitations are especially severe and there is limited availability of dedicated citizen participants for citizen-science efforts. Citizen involvement in these countries, including for BWC-focused programs, may be enhanced by building large-scale consortiums and using online questionnaires and face-to-face interviews that increase participant engagement and retention (Requier *et al.* 2020). The role of student contributions – as demonstrated by the examples in WebPanel 1 as well as the China Anti-Bird Window Collision Action Alliance, which relied on university students for project leadership and outreach activities – suggests that engaging students may help expand the reach of BWC citizen science, especially in understudied and underfunded regions. FLAP Canada, which expanded activities internationally to include an annual event that encourages BWC data collection and education worldwide, provides another model for building global capacity of citizen science.

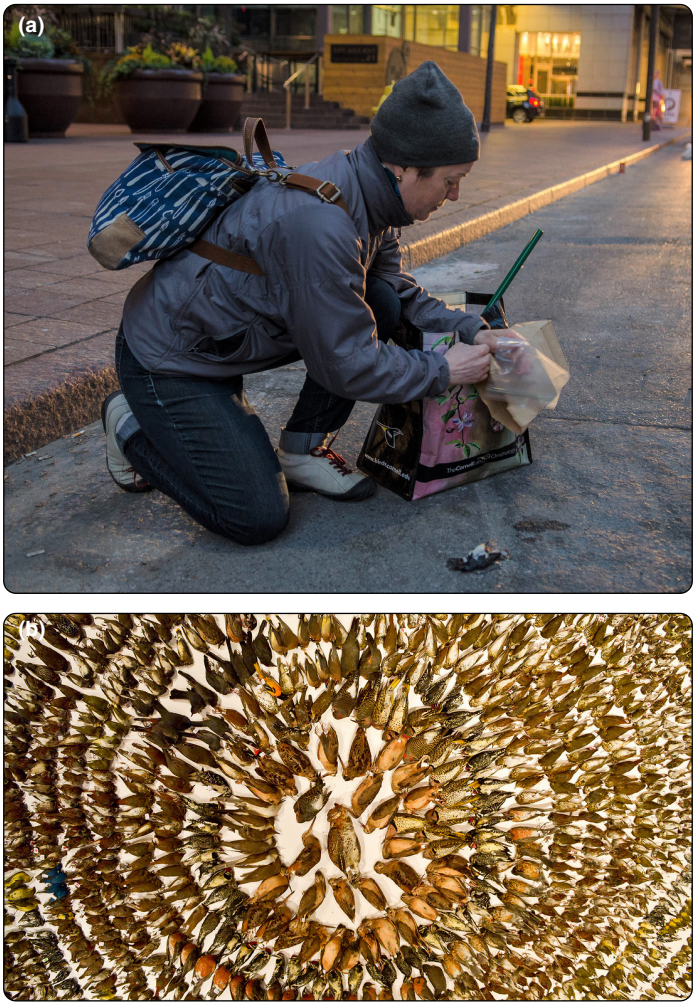

Figure 4. (a) While participating in a bird–window collision survey in downtown Toronto, Canada, a volunteer citizen scientist with Fatal Light Awareness Program (FLAP) Canada finds a dead bird. (b) To increase public and political awareness and advocacy, FLAP Canada holds an annual media event at which all collision casualties from the past year are put on display. Images courtesy of: A Sun (a) and A Li (b).

Conclusion

Citizen-science campaigns have made immense contributions to advance BWC research, educate and raise awareness about BWCs, and motivate the development and implementation of policies and actions that reduce this major threat to birds. These campaigns provide important lessons for addressing BWCs, like the need to develop diverse partnerships spanning broad geographic areas and the use of creative approaches for engaging non-traditional participants like students. Such lessons and the example campaigns we present here may be broadly instructive for leveraging citizen science to tackle other large-scale conservation challenges affecting birds, including anthropogenic threats like climate change and other direct mortality sources. Even greater citizen-driven successes in reducing BWCs are possible. Perhaps more than any other data source, collision records amassed by citizen-science programs appear capable of answering large-scale, conservation-relevant questions about the impacts of BWCs on bird populations and the effectiveness of actions to reduce these impacts. Moreover, citizen science is well positioned to further mainstream this issue among policy makers, conservation practitioners, and the public. Facilitating citizen-driven contributions requires overcoming funding limitations, engaging proactively with key stakeholders and decision makers, and expanding activities to additional countries to begin solving the BWC problem worldwide. A continued increase in support for BWC citizen science from government agencies, NGOs, professional scientists, and commercial sectors (eg architects, building managers, the glass industry) will also be crucial for addressing the global issue of BWCs and recovering bird populations that face this substantial threat.

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Data Availability Statement

No data were collected for this study.

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