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RESEARCH

A framework and guide to community-science bird-window collision monitoring: insights from a 29-year-old program with over 200 annual volunteers

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Abstract
Bird-window collisions are a major threat to wild birds. Collision monitoring programs that train volunteers to collect standardized data on bird-window collisions are an important tool for advancing the understanding of collisions, evaluating mitigation effectiveness, and promoting bird-safe actions and policies. These programs can drive change across scales, from guiding interventions at individual buildings or campuses to supporting the development and adoption of bird-friendly legislation at broader spatial scales. These programs are often local community-science initiatives, enlisting trained volunteers to conduct surveys – and starting, managing, and maintaining such programs can be challenging. For example, many groups and organizations are unsure how to begin a new collision monitoring program, struggle with staffing and time limitations, have low volunteer turn-out and retention, and collect inefficient data. NYC Bird Alliance (formerly NYC Audubon) has managed its Project Safe Flight collision monitoring program (PSF) since 1997; the program now engages over 200 volunteers annually, and the collision data collected has contributed to making NYC a more bird-safe city through supporting bird-safe design of new buildings, bird-safe retrofitting of existing buildings, and the successful passage of city-wide bird-safe design and lights-out legislation. In this paper, based on nearly 30 years of experience running a large and effective collision monitoring program, we provide an actionable framework documenting the key aspects of starting and managing such a program, with the goal of producing actionable data to drive bird-safe change. We provide guidance on developing a robust, standardized monitoring protocol; strategically selecting areas for monitoring; creating program materials; recruiting, training, and effectively managing volunteers; and maintaining a standardized and effective dataset.

Keywords Bird-building collisions · Bird-window collisions · Citizen science · Collision monitoring · Community science · Framework

Introduction

Bird populations in North America have declined significantly since 1970. Losses in overall numbers of breeding individuals are not restricted to rare and threatened species but also include once common and widespread species (Rosenberg et al. 2019). Birds are impacted by many human-introduced threats including bird-window collisions, which are a leading anthropogenic cause of avian mortality and are estimated to kill over one billion birds every year in the United States alone (Loss et al. 2015; Klem et al. Jr 2024; Kornreich et al. 2024).

In North America, collisions occur year-round but are most frequent during the spring and fall migration seasons, when large numbers of birds journey to their breeding/wintering grounds (Borden et al. 2010; Basilio et al. 2020; Riding et al. 2021; De Groot et al. 2021). Collisions occur at buildings of any height – high-rise, mid-rise, and low-rise – and in urban, suburban, and rural landscapes (Loss et al. 2014). Birds, like humans, cannot see glass directly and need visual cues to detect barriers created by windows and other glass structures (Klem Jr and Saenger 2013; Sheppard 2019). Without effective mitigation, birds presumably see a clear path for flight or the reflection of nearby vegetation

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or sky and try to fly through, resulting in a collision. Factors that have been shown to influence collision risk include architectural variables such as amount of uninterrupted glass (Hager et al. 2013; Cusa et al. 2015; Loss et al. 2019; Riding et al. 2020), building size (Hager et al. 2017), and facade shape (Riding et al. 2020), as well as landscape variables such as proximity to habitat that attracts birds (Klem et al. 2009; Gelb and Delacretaz 2009; Borden et al. 2010; Loss et al. 2019; Basilio et al. 2020).

Artificial light at night (ALAN) can exacerbate collision risk as well, particularly for nocturnal migrants, which make up the majority of North America's migrating birds (Dokter et al. 2018). At broad spatial scales, ALAN attracts nocturnally migrating birds and concentrates them in areas with high densities of glass buildings (La Sorte et al. 2015; Sorte et al. 2017; McLaren et al. 2018). ALAN at individual lit facades has also been associated with higher collision risk compared to unlit facades (Lao et al. 2020; Van Doren et al. 2021; Korner et al. 2022). Weather conditions that are unfavorable for migration can compound the effects of ALAN, and can also increase collisions by impacting the densities of birds that stop over at a given location or by altering the birds' behaviors. For example, unfavorable weather conditions can drive birds to fly at lower altitudes, putting them in greater proximity to buildings. Weather conditions may also impair birds' vision and their ability to detect or respond to obstacles (Lao et al. 2022; Scott et al. 2023; Chen et al. 2024).

Significant reductions in collisions have been achieved through two types of intervention: actions to turn off non-essential lights at night (Lao et al. 2020; Van Doren et al. 2021; Korner et al. 2022) and bird-safe glass, whether manufactured as such or made bird-safe via applied retrofit products (e.g., patterned adhesive films, tempera paint, external insect screens, paracord window curtains, and other materials; see Klem Jr and Saenger 2013; Brown et al. 2019, 2021; De Groot et al. 2022; Riggs et al. 2022). Lights-out initiatives and/or bird-safe glass can be adopted voluntarily at individual buildings, for example, through participation in an Audubon Lights Out program (National Audubon Society n.d.), or mandated through local legislation, such as Int. 274 and 271 (The New York City Council 2022a; 2022b) and Local Law 15 of 2020 (NYC Buildings 2020) in New York City (NYC), NY, USA; Ordinance 7864-NS (Berkeley Municipal Code n.d.) in Berkeley, California, USA; D.C. Law 24–337 (D.C. Law Library n.d.) in the District of Columbia, USA; and the Toronto Green Standard (City of Toronto 2017) in Toronto, Canada.

Historically, there has been limited governmental or institutional acknowledgment of bird-window collisions and few efforts to implement solutions on a national level (Loss et al. 2023). Community-science (also known as citizen-science) programs have become important sources of scientific research (Loss et al. 2014, 2023). These programs typically document dead or injured birds opportunistically and/or through standardized methods, often enlisting volunteers to conduct regular surveys. (Some programs employ paid, professionally trained technicians rather than, or alongside, volunteers.)

Collision monitoring programs are typically enacted to have a conservation impact by understanding or preventing bird-window collisions (Loss et al. 2023). Collision monitoring may be used to simply increase awareness of collisions, or more specifically, answer scientific questions, guide local collision mitigation efforts, or influence conservation policy. However, like many forms of research, the outcomes possible from collision monitoring can be influenced by the initial design of the program.

Collision monitoring produces important descriptive data about collisions (e.g., which species are most frequently found and are thus potentially most vulnerable), which is important knowledge that may aid in those species' conservation (Loss et al. 2023). Descriptive data or photographs of collected birds can also be used to raise awareness of collisions and serve as a moving call to action (see Fatal Light Awareness Program Canada's annual dead bird photo [FLAP Canada 2026]). Beyond descriptive analysis, data collected through collision monitoring may also be used to address scientific questions when collected under a standardized protocol that allows for spatially and temporally comparative data. For example, collision monitoring can be used to answer broad research questions about collisions, such as identifying factors that influence collisions (Klem et al. 2009; Hager et al. 2013, 2017; Loss et al. 2019; Lao et al. 2020, 2022; Riding et al. 2020; Van Doren et al. 2021; Korner et al. 2022; Scott et al. 2023; Chen et al. 2024), better understand the scale of collisions (Loss et al. 2015), or evaluate the effectiveness of collision reduction mitigation measures in real-world conditions (i.e., outside of a testing facility; see Klem Jr and Saenger 2013; Brown et al. 2019, 2021; De Groot et al. 2022; Riggs et al. 2022). Likewise, collision monitoring can be used to answer scientific questions of local importance, such as identifying priority areas for collision-reduction mitigation.

For individual buildings, collision monitoring programs can provide building owners with specific data that can drive change, or can be used as a trackable metric for quantifying the impact of reduction efforts or the scale of the problem. Data collected can influence organizational policies, resulting in increased uptake of mitigation measures (e.g., Partridge et al. 2025). Collision monitoring data can also be used to drive legislative change, via advocacy and strategic collaboration with both governmental and non-governmental partners (Loss et al. 2023).

However, while standardized collision monitoring programs can be a valuable asset to drive local and national

bird-safe change, they can be difficult to get started and to maintain for prolonged periods of time. Common challenges range from ensuring data are collected in a consistent, standardized manner to maintaining volunteer engagement. For example, a lack of a standardized protocol may result in insufficient data to accomplish programmatic goals, or produce datasets that are not comparable to those produced by other collision monitoring programs. Because collision monitoring, which involves exposure to dead, dying, and injured birds, is emotionally taxing, volunteer retention is often difficult. Similarly, coordination of volunteers can be time consuming, and organizations often have limited management capacity.

NYC Bird Alliance's Project Safe Flight collision monitoring program (PSF), started in 1997 by members of NYC Bird Alliance (formerly NYC Audubon), has grown to engage over 200 volunteers annually in its monitoring of collisions across NYC. PSF is one of the oldest collision monitoring programs in North America (but see Fatal Light Awareness Program Canada [FLAP Canada 2026] and [Chicago Bird Collision Monitors 2012] for other long-running collision monitoring programs). Building-specific collision data from PSF's long-term data set has enabled NYC Bird Alliance to effect both new and retrofitted bird-friendly design changes at multiple sites across NYC, including The Jacob K. Javits Convention Center and the Metropolitan Museum of Art; the success of both retrofits has then been demonstrated via post-retrofit monitoring. The PSF data set has also provided evidence that an estimated 250,000 birds die each year from collisions in NYC – and the apparent scale of the problem helped NYC Bird Alliance and partners effectively advocate for the passage of landmark bird-safe building (NYC Buildings 2020) and lights out legislation (The New York City Council 2022a; 2022b). These actions have reduced bird deaths and provided examples for municipalities across the globe to follow.

Our administration of PSF through nearly 30 years of continuous monitoring during spring and fall migration has supplied valuable lessons learned and provides a case study for the development of new community-science collision monitoring programs. In this paper, we provide a framework for establishing, running, and maintaining a robust community-science collision monitoring program. This framework can serve as a guide to creating a standardized collision monitoring protocol, starting and maintaining a long-term program of monitoring conducted by volunteers, and keeping a robust database that can be used to reduce collisions and meaningfully contribute to effective conservation of wild birds. The framework is applicable to establishing collision monitoring programs in any human-inhabited environment, including urban, suburban, and rural areas. While there is no one method of collision monitoring that works for all programs, and program coordinators should consider their own capacity, resources, and goals when developing a program, the tools shared in this framework can be used to design or improve programs of all sizes, whether enacted in full or individual sections.

Incidental vs. standardized collision monitoring

Bird-window collision monitoring generally falls into two complementary approaches: incidental observations and standardized surveys. Records of incidental observations (i.e., opportunistic reports of collisions, often by the general public, also known as crowd-sourced data) can provide useful information on species affected and help identify particularly hazardous buildings, especially in areas where standardized monitoring is not yet established. Because such data can be submitted by anyone, anywhere, they can supplement the data collected through an existing collision monitoring program and broaden its geographic reach. Several available crowd-sourced data tool options enable the collection of collision data. Three in the western hemisphere are dBird (n.d.), Global Bird Collision Mapper (n.d.), and iNaturalist (n.d.).

Crowd-sourced data have some fundamental limitations because of their lack of standardization, however. Such data is produced by an uneven sampling effort and, often, there is no way to report non-detections (i.e., "zeros"; Isaac et al. 2014; Isaac and Pocock 2015; Mair and Ruete 2016; Johnston et al. 2021). In addition, crowd-sourced data can be skewed towards areas where there are more people available to find collision victims or where more people know about the crowd-sourced collision reporting tool. For scientific analysis, standardized surveys, conducted according to standardized monitoring protocols, offer clear advantages. By recording survey timing, frequency, effort, and search area, standardized approaches produce consistent, repeatable datasets that include both detections and non-detections. Inclusion of non-detections along with associated metadata such as survey effort, weather conditions, and factors influencing carcass persistence and detectability, is essential for robust analysis (Isaac et al. 2014).

Standardized datasets are more limited in their geographic and, often, temporal scope compared to crowd-sourced datasets, but they enable the use of statistical models that account for variation in effort and detection probability, support comparisons across sites and time, and allow for rigorous evaluation of mitigation strategies. See Loss et al. (2019), Riding et al. (2021), Van Doren et al. (2021), Brown et al. (2021) and Chen et al. (2024) for some examples of studies done with data collected through standardized collision monitoring.

Creating a standardized collision monitoring protocol and related concerns

In order to produce quality, standardized data, a collision monitoring program requires that all participants consistently follow a clear and comprehensive monitoring protocol designed to accomplish the goals of the program. At minimum, a monitoring protocol should include specific instructions for survey timing and scheduling; quality data collection including variables to be recorded and data submission; survey location; and survey methods including handling of dead and injured birds. The *Project Safe Flight Volunteer Manual*, appended here as Online Resource 1, includes the monitoring protocol provided to PSF volunteers, along with a list of initial monitoring supplies and additional useful information. The following considerations should be taken into account when creating a monitoring protocol suitable for a particular study area and set of research goals.

Survey timing and scheduling: season and time of day

Bird collisions occur year-round, with peaks in collisions varying by geographic location (Ocampo-Peñuela et al. 2016; Basilio et al. 2020; Zyśk-Gorczyńska et al. 2020; De Groot et al. 2021). Collision monitoring can vary with season to coincide with the greatest risk, or be scheduled to understand collisions during a specific time of year. For example, in regions where migration is prevalent, collisions are most frequent during the migration seasons, when high densities of migrating birds are moving between non-breeding and breeding grounds (Basilio et al. 2020; Riding et al. 2021). In NYC, we conduct PSF monitoring during the principal weeks of spring and fall migration: from late March to early June and from mid-August to mid-November (BirdCast n.d.).

To ensure consistent effort spatially and temporally, the same number of surveys should be conducted at each monitored site and on each day of monitoring. The time of day that surveys are conducted should be consistent or designed to answer specific research questions. For example, since most collisions occur in the early morning around sunrise (Riding et al. 2021), PSF volunteers in NYC are required to conduct surveys between 06:00 h and 08:00 h.

When creating protocols and determining survey timing, keep in mind that surveys must be safe and feasible for the volunteers. Consider volunteer well-being (e.g., is it safe for volunteers to be travelling to or present at monitoring sites before sunrise), when volunteers are available and how much time each day they are able to commit, and other constraints on volunteer availability (e.g., work or school obligations). Other elements to consider include the frequency and timing of cleaning by maintenance staff outside of the buildings to be monitored, which impact the likelihood of finding collision victims before they are removed, and the operating hours of local rehabilitation centers accepting injured birds, which impact the feasibility of volunteers transporting injured birds to a rehabilitator.

Collecting quality data from volunteers

Volunteers should record their collision data and survey effort on datasheets provided by the lead organization. Physical forms, digital forms, or both may be used.

Variables to be recorded and data submission

Datasheets should have a clear and simple design with fields for all variables that volunteers will be collecting. Each datasheet should have an area for the collection of the observer's name(s), the number of observers, the date, the route (i.e., a group of buildings in proximity to one another that are patrolled together during each survey conducted), whether the survey was cancelled before completion, environmental data like the temperature and weather conditions (e.g., sunny, cloudy, foggy, or precipitating), the survey start and end times for each building along the route, and the number of birds found at each building. For each bird found, volunteers should record the building, the specific facade (i.e., walls or glass, or subsections of walls or glass) where the bird was found, the species if known, the condition of the bird (i.e., whether it was dead or injured), and any additional comments. If volunteers will be entering their data online as well, provide clear instructions on how they should do so. For example, a QR code to a data entry form where volunteers can submit their data into an online database can be included on the physical datasheet. See Online Resource 2 for an example of the datasheet provided to PSF's volunteers.

To facilitate data summary and analysis, all collision monitoring data should be digitized. While open-access presence-only platforms for recording collisions such as dBird (n.d.), iNaturalist (n.d.), and Global Bird Collision Mapper (n.d.) are useful tools, they do not currently allow for the recording of absence data ("zeroes"). Standardized data should be maintained separately in a unique and secure database where absence and all associated metadata can be stored. For volunteers to enter data digitally, a data entry form linking to a shared database can be provided. Multiple online survey makers like Google Forms (Hager and Cosentino 2014), Microsoft Forms, and Survey123 (an ArcGIS product) are available for these purposes. Like the physical datasheet, the form should include fields for all data the volunteers need to collect. Like all databases, data entered should be reviewed for potential errors before it is considered finalized.

The importance of recording effort

Collision data is most useful when the effort that has gone into documenting collisions is recorded. To properly record effort, track the number of surveyors on a monitoring route during each survey, the name(s) of the surveyor(s), the time the survey begins and ends, and how many times a route is traversed during each survey (if a standard number of times is not specified in advance; Isaac et al. 2014; Johnston et al. 2021). The recording of effort is necessary to clarify the degree of risk a particular facade, building, or route represents, and also to make collision data comparable across sites and programs. For example, if 30 dead birds are collected in front of a particular facade, the understanding of the risk that facade presents is different if those birds are collected over five surveys versus over 100 surveys. Similarly, while reporting collisions as the total number of dead birds may make results more impactful for non-scientists, it is important to report collisions as the number of birds per survey (birds/survey), so that the scale of the problem can be better understood and the data accurately compared to other sites.

Survey location: mapping survey routes/buildings for volunteer use and long-term data analysis

To document each season's monitoring efforts and to provide volunteers with a visual reference for monitoring, a map of each route should be created (Fig. 1). To minimize confusion, route maps should be clearly labeled (e.g., with street names, building names, and any additional elements that will enable detailed and systematic data collection).

Building identifiers

Because buildings can have multiple names or addresses, confusion can arise if different collision monitors record data for the same building under different names or addresses (Loss et al. 2014). Assign each monitored building a building identifier (e.g., a number) unique to that building, in perpetuity, across the entire monitoring program. Building identifiers should be assigned sequentially in the order that they were added and should never be reused between two different buildings. This allows for data between different monitoring seasons to be analyzed together without needing to re-structure the data beforehand. Each building and its corresponding identifier should be listed on the route map along with the building address.

Facade identifiers

Each building should be subdivided into different facades where each distinct area of facade structure or orientation is assigned a unique identifier that is different from the ones used to label the buildings (e.g., if numbers are used for the buildings, letters may be used for the facades; Fig. 1). This level of granularity in the data allows not only identification of buildings where collisions are frequent, but also specific areas of a building that are the most dangerous, and which therefore should be prioritized for potential retrofits.

Survey methods, handling of dead and injured birds, and interactions with building staff

It is important that volunteers follow consistent procedures concerning the methods of conducting each survey, the collection of dead and injured birds, and possible interactions with the staff of monitored buildings.

Methods of in-person surveys

A survey consists of a collision monitor checking all areas of a route to look for dead or injured birds. Volunteers should only record data for the areas marked on their route maps. They should also be directed to randomize (e.g., by using a random number generator) the order in which they visit the buildings on their route and the direction/building they start from each time they do a survey. Randomizing the order ensures that the overall frequency of collisions documented at each building is not influenced by the time of day that the surveys were conducted, but rather reflects the actual frequency of collisions at that building in comparison to other sites.

Inexperienced volunteers may have difficulty finding birds at first (Riding and Loss 2018); they may be surprised by the birds' size or color, and providing photos in training sessions can help prepare volunteers to be more effective during their first surveys (Hager and Cosentino 2014). While surveying, volunteers should check for birds in or around anywhere they may have fallen or moved to while injured – including vegetation, overhangs, or benches, or even under or inside trash cans (Hager and Cosentino 2014). To avoid double-counting, dead birds should either be collected or discarded, and injured birds should be taken to a licensed wildlife rehabilitation center.

Every dead or injured bird found should be recorded, or if no birds are found, a zero must be documented (Loss et al. 2014; Hager and Cosentino 2014). Often, volunteers without a science background do not understand the value of recording "0 birds found" and thus, extra effort should be given during volunteer training to emphasize the importance of recording zeros. Recording zeros is important in order to make clear that a survey was conducted and that no birds were found. Zeros are also very important for comparability in collision rates across space and time, understanding where and when no collisions occurred, and for

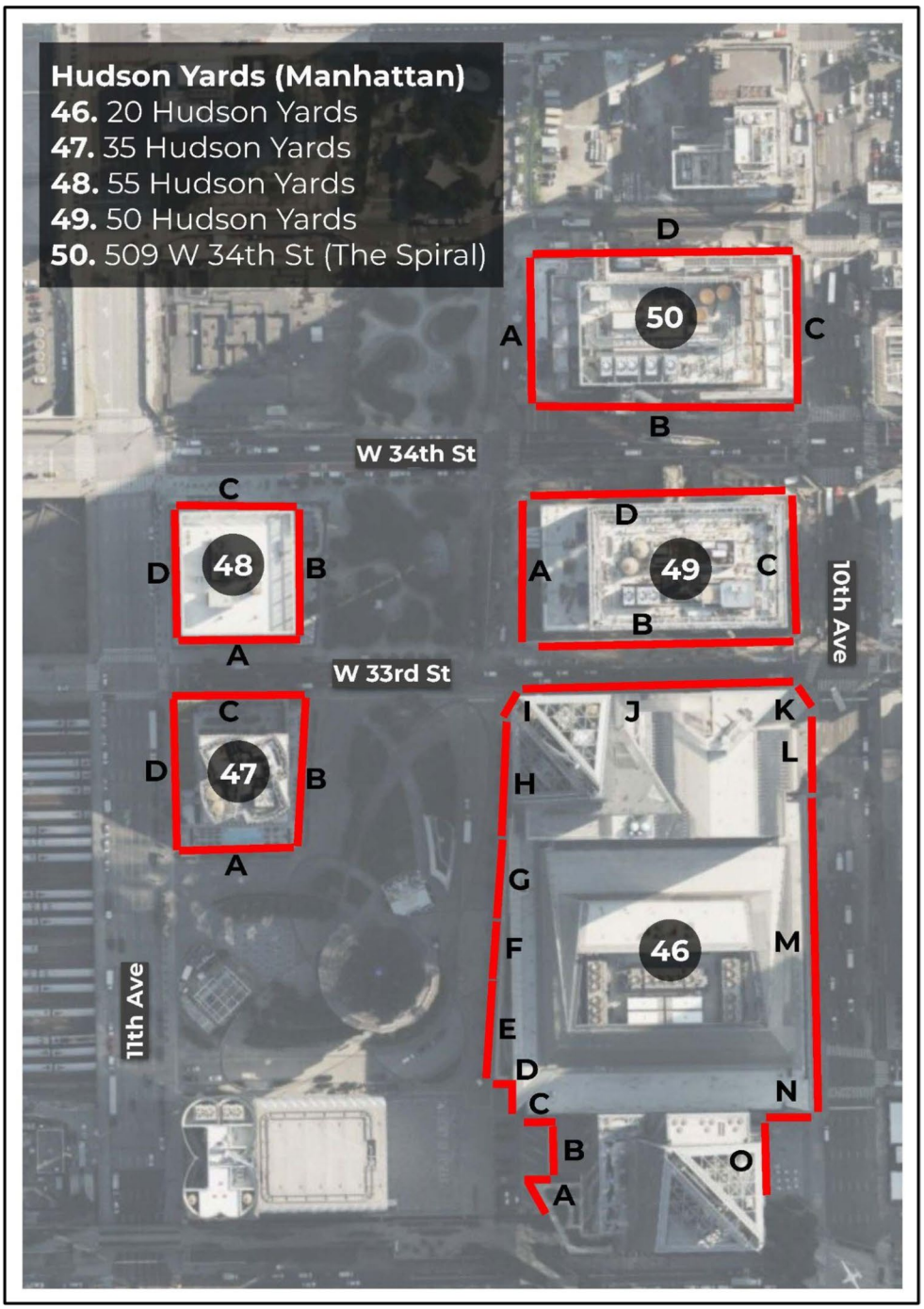

Fig. 1 Example of a route map provided to PSF volunteers. The name of the route is listed in a box in the top left corner along with the addresses of all buildings included on the route and their assigned building number identifier, corresponding to the building number identifiers displayed in circles on the map. The facades of each building are labelled with unique letter identifiers and outlined in red

detecting reductions in collisions as a result of successful bird-safe interventions.

"Incidental observations," or observations of birds found outside monitored sites or outside of a monitoring survey, should be kept separate from standardized collision monitoring data (Loss et al. 2014). Instead, such incidental observations should be reported to a crowd-sourced database for incidental collision observations, such as dBird (n.d.) or Global Bird Collision Mapper (n.d.).

Collecting dead birds

Typically, the majority of the birds that collision monitors find are dead birds, since many birds that strike glass surfaces and are not instantly killed move away and die elsewhere (Kummer and Bayne 2015; Korner et al. 2022; Samuels et al. 2022). Offering the volunteers an option to salvage (i.e., collect and save) bird carcasses is recommended for volunteer morale and research value (but a

permit is typically required, see Permits section below). If salvaging is feasible, carcass collection may be set as a required or an optional activity depending on the program goals and the resources available.

In order to collect carcasses, volunteers should bring gloves, disposable plastic bags, and labels to archive the carcasses properly. Volunteers may purchase these supplies themselves or, if program funds allow, be provided with these supplies. Birds of all kinds, from small birds like hummingbirds and kinglets to larger birds like hawks, may be collected. Volunteers should be prepared with plastic bags of various sizes (e.g., snack, sandwich, quart, gallon). Printed labels should include fields for (1) the date found, (2) the species, (3) the time found, (4) the volunteer's name, (5) if the bird was found during a monitoring survey (yes or no), (6) the location found, and (7) a unique identifier (this should be pre-filled by the program coordinator or left blank by the volunteers and later filled out by the program coordinator; see Fig. 2). The label should be completed and placed in the bag with the bird to which it corresponds. All carcasses collected should be brought to a designated drop-off site and stored in a freezer (or other cold storage) until they can be transferred to their final destination.

Handling and obtaining care for injured birds

Injured birds are often found sitting or lying on the ground during collision monitoring surveys. Severely injured birds may be unresponsive or slow to react to human approach, appearing puffed up, squinting, or with eyes closed. Some may appear dead at first but show signs of life (e.g., breathing) upon closer inspection. The majority of these birds, even when brought to a wildlife rehabilitator, do not survive. Kornreich et al. (2024) found that only approximately 40% of stunned/injured collision victims brought to rehabilitation facilities recovered and were released. However, prompt transport to a licensed wildlife rehabilitator likely provides the best chance of survival and recovery and is important for volunteer morale. A wildlife rehabilitation center that accepts injured birds, if there is one locally available, should be identified before monitoring begins. Provide volunteers with the rehabilitation center's address, hours, and drop-off policies.

Any stunned and injured birds that volunteers are able to catch (but see below, regarding raptors or large waterfowl) should be placed into separate containers during transport so that they do not bump into each other while enroute to a rehabilitation center. Paper bags, matched to the size of the bird, are ideal containers for injured collision victims because they are not only lightweight and collapsible (which makes it easy to carry multiple bags) but also soft and flexible, posing less risk of the bird further injuring itself while contained. Furthermore, paper bags are breathable and do not need to have air holes added to them, if the bird will only be inside the bag for several hours. See Online Resource 1 for the instructions provided to PSF volunteers on holding and catching injured birds.

If there is no rehabilitation center that can accept wild birds nearby or if volunteers may not be able to bring the birds there themselves, consider providing alternative locations where injured birds can be brought for care (e.g., local individual licensed rehabilitators or exotic or avian veterinarians) and resources for alternative transportation options (e.g., local animal rescue and transport groups). If

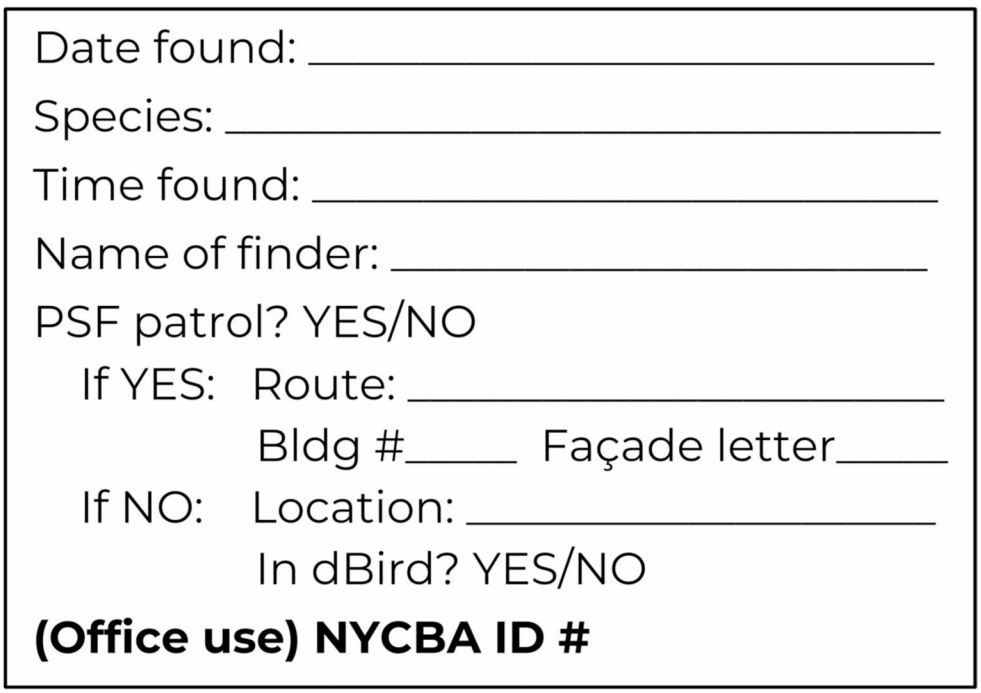

Fig. 2 Printable label that is used to tag dead birds collected during PSF with the date found, species, time found, name of the person who found the bird, and if the bird was found during a collision monitoring survey (yes or no). If the bird was found during a collision monitoring survey, volunteers write down the route, building number, and facade letter at which the bird was found. If the bird was not found during a collision monitoring survey, volunteers write down the location found and if they reported the bird to dBird (yes or no). At the bottom of the label is a field for a unique identifier which is left blank by the volunteers and completed by the program coordinator

volunteers may be holding onto injured birds for long periods while waiting to find alternative transportation, provide them with instructions on what they should and should not do while the bird is in their care.

Volunteers should not handle raptors or large waterbirds unless they have received prior training on how to do so safely, as handling these species can be dangerous for both volunteer and bird. Provide volunteers with information on whom to contact (e.g., park rangers, wildlife rehabilitators, etc.) and direct them to avoid attempting to rescue such birds themselves.

Volunteer interactions with building staff

As volunteers conduct surveys, they will likely interact with the staff of monitored buildings. It is important that volunteers are trained to be professional and friendly during such encounters. They should explain that they are volunteers who are conducting surveys for the coordinating organization(s) in order to document bird collisions. Often, building employees who work near their building's exterior will already be aware of or have experienced bird-window collisions, and are willing to share their insights or even save injured birds and carcasses to give to a volunteer collision monitor.

Most building staff encountered by volunteers will not have managing control of their facility, but may be able to connect the volunteers or the program coordinator with building management and decision-makers. PSF volunteers are provided with materials that include a brief overview of bird collisions and organizational contact information (Online Resource 3) to share with building staff. However, volunteers should remain professional and never pressure front desk, security, or janitorial staff to do anything they are not comfortable doing. These front-facing employees, though they may be helpful and/or concerned, are likely unable to make organization-scale change and may feel uneasy about collaborating with monitors or taking steps themselves to contact management. For example, in NYC, exterior cleaning staff have expressed concern about getting in trouble or losing their job if they do not sweep up dead birds found around their buildings.

Preparing for a collision monitoring season

Prior to the beginning of each monitoring season, the program coordinator must ensure any needed permits are acquired, scout out potential buildings and routes to monitor (whether previously surveyed or new), prepare materials for volunteers, and enlist and train volunteers. Project planning should begin at least six to eight weeks before volunteers actually set foot on the streets to begin monitoring (Fig. 3).

Permits

Permits may or may not be required for collision monitoring, depending on where monitoring will occur and the specific activities that will be conducted. Buildings on public property typically do not have permit requirements, but if surveying will be conducted on privately owned property or within a park space, written permission or a permit authorizing access for volunteers to conduct surveys may be necessary.

Activities such as salvaging dead bird carcasses may also require a permit, and these requirements should be considered for wherever the monitoring program is taking place. In the United States, a federal permit such as a 3-200-7: Migratory Bird and Eagle Scientific Collecting permit, issued by the United States Fish and Wildlife Service (n.d.), is required to collect migratory bird specimens when actively searching for birds (National Archives 2024). Each specimen collected must be tagged with the date of collection, the location where the specimen was collected, and the name of the person who collected the specimen. Records of all collected birds must be kept (U.S. Fish and Wildlife Service n.d.). A state license may also be required for carcass collection in the United States.

Selecting buildings and routes for monitoring

A collision monitoring program often starts off small, with just a handful of volunteers, and thus may focus on only a few buildings during initial survey season(s). As the volunteer team grows, so too can the number of buildings monitored and the area of coverage, though coordinator capacity in managing volunteers and parsing through data may still be a limitation. Therefore, choosing which buildings will be monitored each season should be done with clear intent. The design of a monitoring route should also be undertaken with several concerns in mind.

Selection criteria

Buildings and/or routes to be monitored should be selected strategically in alignment with predetermined goals that a program aims to accomplish. Such selection factors may include:

1. *Known or expected high collision risk*. Many collision monitoring programs focus a large part of their efforts on buildings that are of known high collision risk. These buildings may be identified through incidental reports made to crowd-sourced data collection tools or directly by community members who have noticed bird collisions. Alternatively, buildings without a known collision history but with features making them likely collision hazards (e.g., buildings that have large uninterrupted

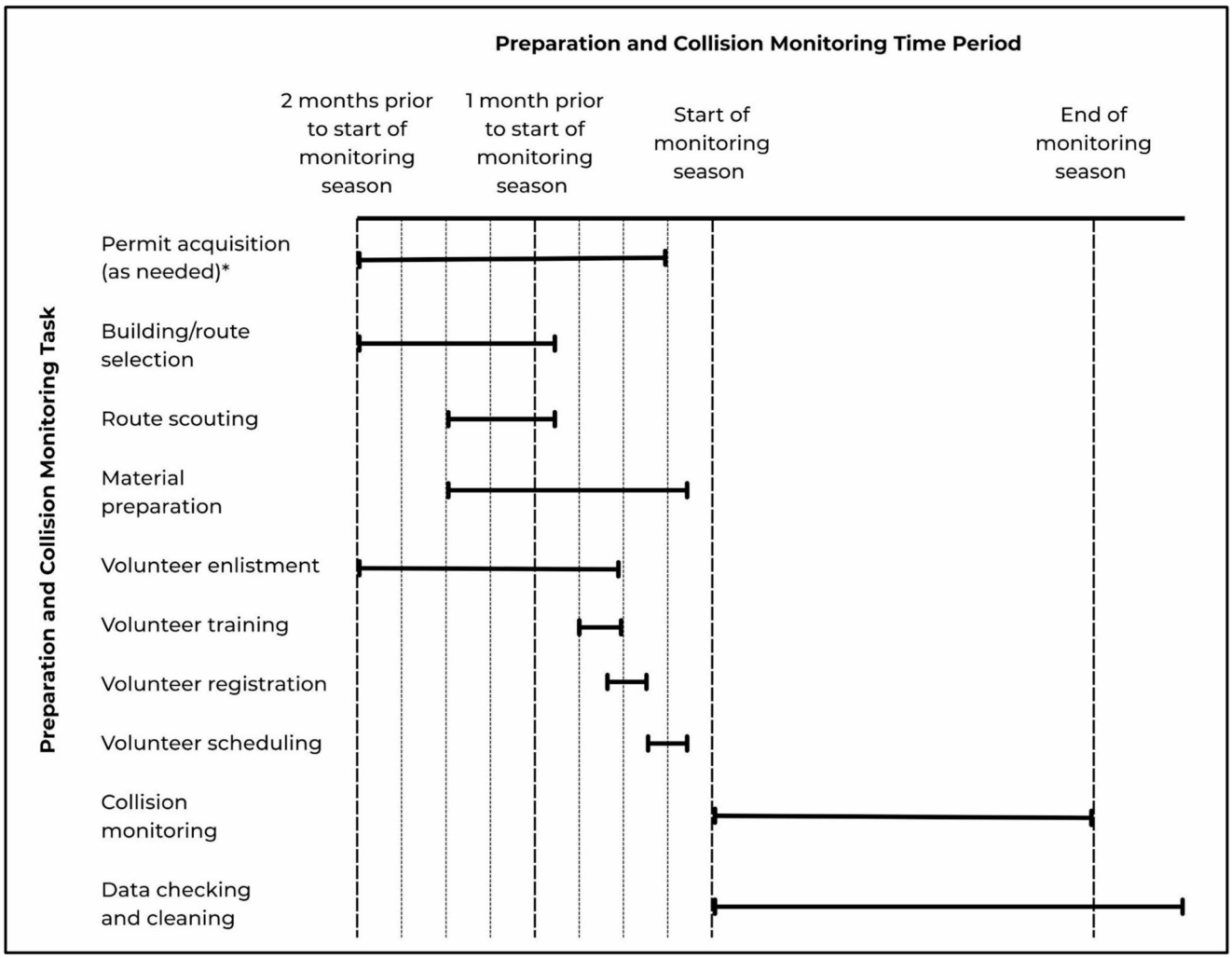

Fig. 3 Recommended timeline for acquiring permits; selecting buildings/routes; scouting routes; preparing materials; enlisting, training, registering, and scheduling volunteers; collision monitoring by volunteers; and checking/cleaning the data. Vertical dashed lines represent the start of a month; thin, vertical dotted lines represent weeks; and horizontal lines represent the time period during which a collision monitoring program task should be completed. *The time it takes to acquire permits depends on which permits are needed and, in some cases, may require starting the permit application process earlier than two months prior to the start of the monitoring season. Check with the permitting agencies on expected processing times to ensure that all permits will be issued by the first day of monitoring

glass facades that reflect nearby vegetation), are also appropriate choices for monitoring.

2. *Usefulness as a control site*. To contextualize the scale of collisions at any given building and to establish a baseline for comparison, it is important to monitor buildings that are not expected to have a high frequency of collision occurrences. For example, buildings with limited glazing may serve as useful control sites for establishing baseline collision rates for low-risk buildings. Control site buildings should either be adjacent to predicted high collision buildings that are being monitored or in a location with surroundings that are representative of a typical area in the study zone.
3. *Evaluation of bird-safe construction in real-world conditions*. Buildings constructed with bird-safe materials may be chosen for monitoring to evaluate how well those materials perform under real-world conditions. If possible, nearby buildings in similar surroundings and with similar construction or amounts of glass, but which are constructed with traditional glass not treated to be bird-safe, should also be monitored to provide a control.
4. *Potential to answer specific scientific questions*. Monitoring data may be used to answer a scientific question. For example, pre- and post-retrofit data is helpful for quantifying the beneficial impact of a bird-safe intervention (Brown et al. 2019, 2021; De Groot et al. 2022; Riggs et al. 2022). In order to collect this type of data, buildings may be chosen for monitoring based on previous monitoring and bird-safe retrofits. Alternatively, if the goal of the program is to understand the distribution

of collisions in a particular area, buildings can be chosen based on their location.

5. *Increased community participation and accessibility of science*. In selecting areas to be monitored, consider which local communities may be engaged as volunteers. For community members to participate, monitored buildings should be reasonably accessible from the community's residences, schools, or workplaces. In addition, monitoring locations must be accessible to the public or, if they are in private or otherwise restricted areas, permission for volunteer access must be obtained from building management or other relevant authorities

When choosing which buildings to monitor, consider limits in volunteer and agreed-upon time commitments. Buildings or routes chosen for monitoring should not take a prohibitively long time for a volunteer to survey. Generally for PSF, volunteers are expected to survey for up to an hour each morning. When grouping buildings together to build a monitoring route, the time it takes to complete each route (i.e., survey all buildings and travel between them) during each survey should be considered.

Routes should be scouted prior to the beginning of each monitoring period, even if monitoring is continuing from a previous season, to check for any changes at the buildings that might alter collision risk, data collection, or monitor access. Consider removing any inaccessible buildings, e.g., due to construction, from monitoring until access is reestablished.

Materials to provide to volunteers before they begin collision monitoring

It is important to provide volunteers with clear materials for effective data collection. Materials may include a blank, printable datasheet with a QR code to an online data entry form, if applicable (Online Resource 2); map(s) for the route(s) monitored (Fig. 1); a list of all buildings monitored with any special, building-specific instructions clearly stated; a collision monitoring volunteer manual (Online Resource 1); a shortened one- or two-page version of the protocol; a copy of any necessary permits; and blank, printable labels for carcasses salvaged, if volunteers will be collecting dead birds (Table 1).

Volunteer coordination

Community science enables collision monitoring programs to collect data on a much broader scale than can typically be accomplished solely by research scientists and paid staff (Loss et al. 2014).

Recruiting volunteers

Volunteer recruitment should begin several weeks prior to the first day of each monitoring season, but after routes are chosen (which allows for targeted outreach to potential volunteers near proposed routes). Potential volunteers can be reached via various platforms including social media, an organization's website, digital or printed newsletters or flyers, or through promotion by partner organizations. When recruiting volunteers, include a brief overview of the program, what monitors do, the estimated timeframe for the volunteer opportunity, the estimated time commitment, information on how to learn more or get involved, and any age requirements.

While it can be helpful, volunteers do not necessarily need to be skilled in bird identification. No matter their skill level, volunteers should be provided with a way to submit photos of the birds they find (e.g., through an online data entry form or a shared drive). Volunteers can also be directed to resources such as Merlin (Cornell Lab n.d.) or iNaturalist (n.d.) to help with their species identification. Volunteers may collect carcasses provided that the necessary permits (see Permits section) have been obtained. Volunteers or staff skilled in bird identification can use submitted photos and collected carcasses to confirm species identification (Hager and Cosentino 2014).

Training volunteers

Volunteer training sessions are an important part of enlisting new volunteers. Depending on the number of prospective volunteers and the resources available, volunteer training may be conducted in-person, online, or both. Offering multiple training sessions on different days of the week and at different times of the day helps increase attendance. If trainings are held virtually, at least one session should be recorded for prospective volunteers who are unable to attend any of the sessions.

Trainings should include an introduction to the organization managing the monitoring program, an overview of bird-window collisions (e.g., the scale of collisions, why they occur, and the need to prevent them), and a review of the effectiveness of bird-safe intervention via local or published examples. Details of the monitoring program should be shared, including the routes that will be monitored for the season and the expectations for the volunteering role. Finally, specific details about monitoring methods and data recording protocols should be shared. For consistency of data, it is important to emphasize the need for standardized methods to volunteers, as well as the importance of submitting their data. Because finding dead and injured birds can be an emotional endeavor, volunteers often respond by focusing

Table 1 Content and notes for recommended materials to provide to collision monitoring volunteers for effective data collection

Material	Content	Notes
Printable datasheet	- Fields for: ● Observer name(s) ● Number of observers ● Date of survey ● Route surveyed ● Route start time ● Route end time ● Whether or not the survey was cancelled before completion (yes or no) ● Environmental data including weather type (e.g., clear/sunny, cloudy, precipitation, fog), weather severity (e.g., light, average, heavy), and temperature ● Building data including the building ID, start time, end time, any facades skipped, and number of birds found at each building ● Data for birds found include the building, facade, species, condition (dead or injured), and additional comments ● Additional notes - QR code for entering data into an online database (if applicable)	Use of this datasheet may be required or optional. If the physical datasheet is optional, volunteers may instead choose to record their data in a notes app on their phone or directly fill out an online data entry form as they do their survey. If a volunteer uses physical datasheets, they should be collected at the end of each monitoring season and kept as a backup copy of the data in case the digital data is damaged or lost. They may also be used to check the digitally-entered data for errors as needed.
Route map(s)	- Name of the route - Unique building identifier followed by the building address, for each building included on the route - Visual diagram of the route with each building clearly labelled with its unique building identifier and unique facade identifiers	
Buildings list	List of all buildings monitored with the following information for each building: - Route the building is on - Building address - Name of the building (if applicable) - Unique building identifier - Building-specific instructions/notes (if applicable)	
Collision monitoring volunteer manual	- Background about collisions and the monitoring program - Materials list - Complete, detailed version of the monitoring protocol - Instructions on how to handle dead and injured birds - Information on local wildlife rehabilitation options	
Quick protocol manual	- Key steps in the monitoring protocol - Key instructions on how to handle dead/injured birds	This is a shortened version of the monitoring protocol and bird handling instructions that should be two pages maximum. Volunteers, especially newcomers, should be encouraged to print this document and bring it with them for reference during their first few surveys.
Permit(s), if applicable	Digital copies of any required permits volunteers will need to complete monitoring activities	
Dead bird labels, if applicable	Fields for: - Date found - Time found - Species - Name of finder - Location found - Unique identifier specific to each bird - Any other information required by carcasses collection permits (if applicable)	

on saving injured birds or salvaging carcasses. While both of these efforts can be helpful, it should be made clear to volunteers that the standardized data they are collecting will have the biggest possible impact in protecting birds.

Registering and scheduling volunteers

Prospective new volunteers who have attended the required training should be sent a sign-up form where they can provide confirmation of their commitment and important personal details. This sign-up form should include fields for the volunteer's name, contact information, any information that needs to be submitted for permits that you have or will acquire, and your organization's volunteer agreement (if applicable).

Assigning volunteers to regular weekly shifts is helpful for ensuring consistent coverage throughout the entire season, though such regular shifts also require stricter commitments from volunteers and dedicated time from the program coordinator to create the schedule. If volunteers will be assigned to regular shifts, the sign-up form should also include fields for any information needed to create an effective schedule of volunteers' assigned days and routes. For example, if each volunteer will be assigned to regularly monitor a specific route on the same day every week for the entire season, the sign-up form should include fields where volunteers can select which day(s) of the week they are available to monitor and which route(s) they are interested in monitoring. Also inquire if volunteers are interested in being assigned to multiple weekly shifts (which is helpful if there are not enough individual volunteers for complete coverage with just one assigned shift per volunteer).

Some volunteers, however, may not be able to make a regular weekly commitment but still want to contribute. Providing an opportunity to sign up as a "floater volunteer" instead makes collision monitoring more accessible. Floater volunteers are not assigned to monitor any specific route or on any specific day of the week, but rather fill in for those who are assigned to regular shifts but cannot complete their survey at a given time.

Scheduling volunteers on a first-come, first-served basis can help ensure fairness. If doing so, inform them in advance of when they will receive access to the sign-up form, so that they can plan accordingly. Returning volunteers who participated the previous season may be given some priority in the scheduling by granting them access to the sign-up form before new prospective volunteers receive it – a benefit that helps with volunteer retention. New volunteers should be clearly informed if scheduling priority will be given to returning volunteers, and all new volunteers should receive the sign-up form link at the same time after the final training session has been completed.

Volunteers may be assigned to routes by themselves or with a partner/partners. The practice of partnering volunteers requires more individuals to cover a given number of monitoring routes overall, but can be an important safety precaution, especially if volunteers will be commuting or conducting surveys before sunrise and/or in unsafe areas. Partnered monitoring should be recorded as such in order to provide clear documentation of effort in the data (detailed above). Partnered monitoring also allows the partnered volunteers to split up tasks among themselves, which is especially helpful on days when high numbers of birds are found. Additionally, new volunteers can benefit from being partnered with an experienced volunteer who can familiarize them with the protocols or specifics of certain routes.

Communication with and among volunteers

Many platforms may be used for communication to and among volunteers, including social media groups (e.g., Facebook), instant messaging platforms (e.g., WhatsApp), or email listservs (e.g., Google Groups). The platform used should be easily accessible by all collision monitors and should be considerate of volunteer demographics and technical skill levels. For example, if many volunteers are not familiar with newer communication channels (e.g., Discord), they may be more comfortable communicating via an email listserv. Multiple communication channels can be used, but at least one must be used by all volunteers so that key information can be easily shared with the entire group.

Maintaining a long-term collision monitoring program

In an effectively managed collision monitoring program, adequate support must be provided to program volunteers in order to retain those volunteers over time. Careful quality control procedures must also be created and followed to ensure the validity of collected data for future analysis.

Retaining volunteers across multiple seasons

Many collision monitoring programs struggle with high volunteer turnover and volunteer burnout. Retaining experienced volunteers is critical to the success and continuation of a community-science collision monitoring program as well as to the collection of consistent data that adhere to standardized protocols.

Providing emotional support

Collision monitoring can be an upsetting and overwhelming experience. It is critical that project managers understand that finding dead, dying, and injured birds is emotionally difficult, and that they actively provide support to volunteers. Managers should foster and proactively create a community in which volunteers can easily communicate and support each other, and in which they feel comfortable asking for help from the program coordinator and from fellow volunteers. If possible, offer dedicated events or other opportunities to share feelings that arise during collision monitoring.

Providing branded wearables such as t-shirts, lanyards, hats, and safety vests can help volunteers feel valued as members of the managing organization and more confident in their roles, and also allow them to be easily identified as representatives of the organization while conducting surveys.

Ensuring that bird carcasses are used for a "greater purpose" may help volunteers find some good in the dead birds they're finding. Carcasses can be donated to long-term museum collections, educational collections, or academics at research institutions, all of which can contribute to public education, research, and bird conservation.

Sharing successes so that volunteers know their work is making a difference

Volunteers are the critical component of any community-science collision monitoring program, and they should be told that their efforts are having an impact. Share program successes, even small ones, with volunteers and let them know that their efforts have led to positive change. Whether a success is passing new bird-safe legislation, getting the management of a bird-killing building to consider or complete a retrofit, or simply raising awareness about the problem of bird collisions, the resulting sense of accomplishment volunteers feel from their collision monitoring efforts may motivate them to continue volunteering (Sextus et al. 2024).

Regular and clear communication, celebration of successes, and acknowledgement of volunteers so that they know they are valued is key (Sextus et al. 2024). Email updates regularly and post accomplishments thanking volunteers on social media. Volunteer appreciation parties can be held to celebrate the work that volunteers have done over the past year; such events also provide an opportunity for volunteers to gather as a community and meet fellow collision monitors and organization members in person (Asah and Blahna 2013; Sextus et al. 2024).

Finalizing data

The program coordinator should review all volunteer-entered data and make corrections as needed. Volunteers may be enlisted and trained to help with data review if the program coordinator has limited capacity. Data reviews can be done regularly throughout the season or after monitoring has concluded, but to avoid potential errors and a loss of a season's data, submitted data should be reviewed regularly for at least the first two weeks as it is being entered. It is especially important to review data from new volunteers, to check for any misunderstandings of the protocols and to guide change early on. Common errors include surveys being conducted outside the correct timeframe, areas not on the route being included in surveys, no data being submitted when zero birds are found, incorrect frequency of surveys, and incorrect species identifications.

Caveats and limitations of standardized collision monitoring data

Even when well-trained volunteers conduct thorough, daily searches, only a small percentage of the collisions are actually found and documented in any given area. This is due to two main factors: (1) Few birds that hit glass fall directly beneath their collision points and (2) If carcasses or injured birds fall directly beneath their collision points, these birds are not often found by the monitors due to scavengers, predators, or their cryptic appearance.

Proximity of injured bird or carcass to collision point

Birds that hit and fall directly beneath their collision points represent only approximately 7 to 10% of the total number of collisions that occur. For example, Samuels et al. (2022) used a video camera to record collisions with a single window at a home. Of the 29 collisions recorded, only 2 (6.9%) resulted in immediate death and birds falling directly beneath the glass, while another 3 (10.3%) were temporarily stunned beneath the glass before flying away. Kummer and Bayne (2015) found similar rates of observed immediate fatality, with 7.5% of collisions resulting in carcasses beneath the glass but 92% of birds flying away. In a collision study with a large office building, Korner et al. (2022) conducted hourly collision monitoring overnight and recorded all stunned or dead birds. Of the 1,478 birds recorded, only 107 (7.2%) remained as carcasses that could have been discovered by collision monitors the next morning. In addition, many volunteer-based collision monitoring programs only have access to street-level areas that are publicly accessible. However, buildings often

also have ledges, overhangs, and other structures where a bird that collides higher up may land and be out of view and inaccessible. Thus, the majority of collisions with windows leave little evidence that can be found by a volunteer directly beneath the windows where the collisions occur.

Carcass persistence and detection

Even if a carcass or injured bird is left beneath a window, a collision monitor may not find that bird because of imperfect detection by monitors and because the bird may be removed by scavengers, predators, building cleaning staff, etc. before a monitor arrives. Carcass persistence and detection studies may be conducted alongside collision monitoring to get better estimates of the true number of birds that collide. However, keep in mind that carcass persistence is impacted by building cleaning schedules and that the presence of predators/scavengers can vary dramatically between different areas, even within the same city. In Stillwater, Oklahoma, USA, Riggs et al. (2022) estimated that 85% of birds that died immediately after colliding with glass bus shelters were recovered on a daily basis. Detection of building collision victims in the same city ranged from 69% to 76%, depending on the collision monitor's experience (Riding and Loss 2018). In a study conducted at Bryant Park in Manhattan, NYC, carcass persistence rates were found to be much lower. Parkins et al. (2015) demonstrated that collision monitors recovered only 37% of dead birds that were set along glass facades by researchers just hours before.

Navigating changes in protocols

Monitoring protocols can evolve as new information is discovered, programs grow, and program coordinators change. Keep detailed records of changes made to the study protocol, things that worked well and things that didn't, and why changes were made. Regarding monitored buildings specifically, keep notes on why specific buildings were selected and, if they are no longer monitored, why they were retired.

Conclusion

Standardized collision monitoring programs are valuable tools that deepen our understanding of why bird-window collisions occur, clarify the factors that influence such collisions, and help us find ways to reduce bird deaths. NYC Bird Alliance's Project Safe Flight collision monitoring program is one of the world's largest and longest-running collision monitoring programs. The data collected through nearly 30 years of continuous PSF monitoring has guided several bird-friendly retrofits in NYC and was instrumental to the passage of landmark bird-friendly buildings and lights out legislation. Its success is thanks to key factors including a standardized monitoring protocol; strategic selection of monitored buildings to achieve program goals; strong recruitment, training, management, and retention of volunteers; and maintenance of a robust long-term dataset. Implementation of a single standardized protocol across all currently operating collision monitoring programs would allow for standardized data to be more easily shared between groups, and for researchers looking to conduct analyses using data from multiple programs to compile that data without needing to restructure it. In this framework, we present the foundational components of such a standardized protocol, and highlight important considerations for creating, managing, and maintaining a collision monitoring program. While the applicability of some program components may vary due to differences in organizational capacity, goals, and resources, individual groups/organizations should keep these components in mind in adapting the guidance provided here to fit the needs of their own programs. Reaching out to coordinators of other existing collision monitoring programs and considering experiences from multiple coordinators and collision monitoring volunteers may yield other valuable perspectives that are not discussed in this framework.

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