**A Global Perspective on Bird-Window Collisions: Factors and Contemporary Mitigation Measures**

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**ABSTRACT**

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| Bird window collisions are one of the leading causes of Bird deaths throughout the world. Millions and billions of birds die annually due to window collisions. Sadly, this number in reality would be even higher due to the lack of awareness among the common people and predation of the affected bird individuals. As the rise of modern development takes place at a rapid rate, the cases of bird window collisions may also rise. Factors playing a major role are use of reflective windows (also known as 1-way windows locally) and construction of tall skyscrapers in the path of affected birds which mostly are migratory. |

*Keywords: Bird-Window collision, Avian collision, Bird conservation, Bird death, Bird mortality*

**1. INTRODUCTION**

Bird window collisions or window strikes are a rising problem in urban or rural areas as development in these areas are happening at a rapid rate (McDonald 2008). Window strikes are among the top three causes of deaths of birds by humans (Loss, Marra and Will, 2015). The main cause of bird window collisions are the reflective windows which are being used on a large scale in modern architecture (Klem 2014). Millions and billions of birds die throughout the year although these numbers are just a mere assumption as lack of knowledge and various factors like predation (Klem 1990), disposing the carcass without reporting makes it difficult to know actual numbers. Though these reflective windows make any architecture look fascinating, wonderful and marvelous, it comes with a great drawback of bird window collision, birds think that these glass reflections are nothing but sky or the birds may even think that the glass is not just present and end up colliding with the window pane (Klem 2014) The main objective of this paper is to evaluate the causes of bird window collisions and mitigation efforts and to understand how much new research has been done on the topic of bird window collision in India.

**2. MATERIALS AND METHODS**

A study period of 2018 to 2024 was selected for this review as no data is available for these years further, detailed literature search from 2018 - 2024 was done on google scholar with keywords like “Bird window collisions”, “Bird Window Strikes”, “Window strikes”. Further each and every research paper was studied for the region of their study. All relevant papers were then reviewed and papers having less relevance were not considered. Further all these papers were then represented in a graph and in tabular form which compared the number of papers published to the region from which the papers were published. Further detailed literature study was done to evaluate the causes of bird window collisions and also current mitigation efforts towards it.

**3. RESULTS AND DISCUSSION**

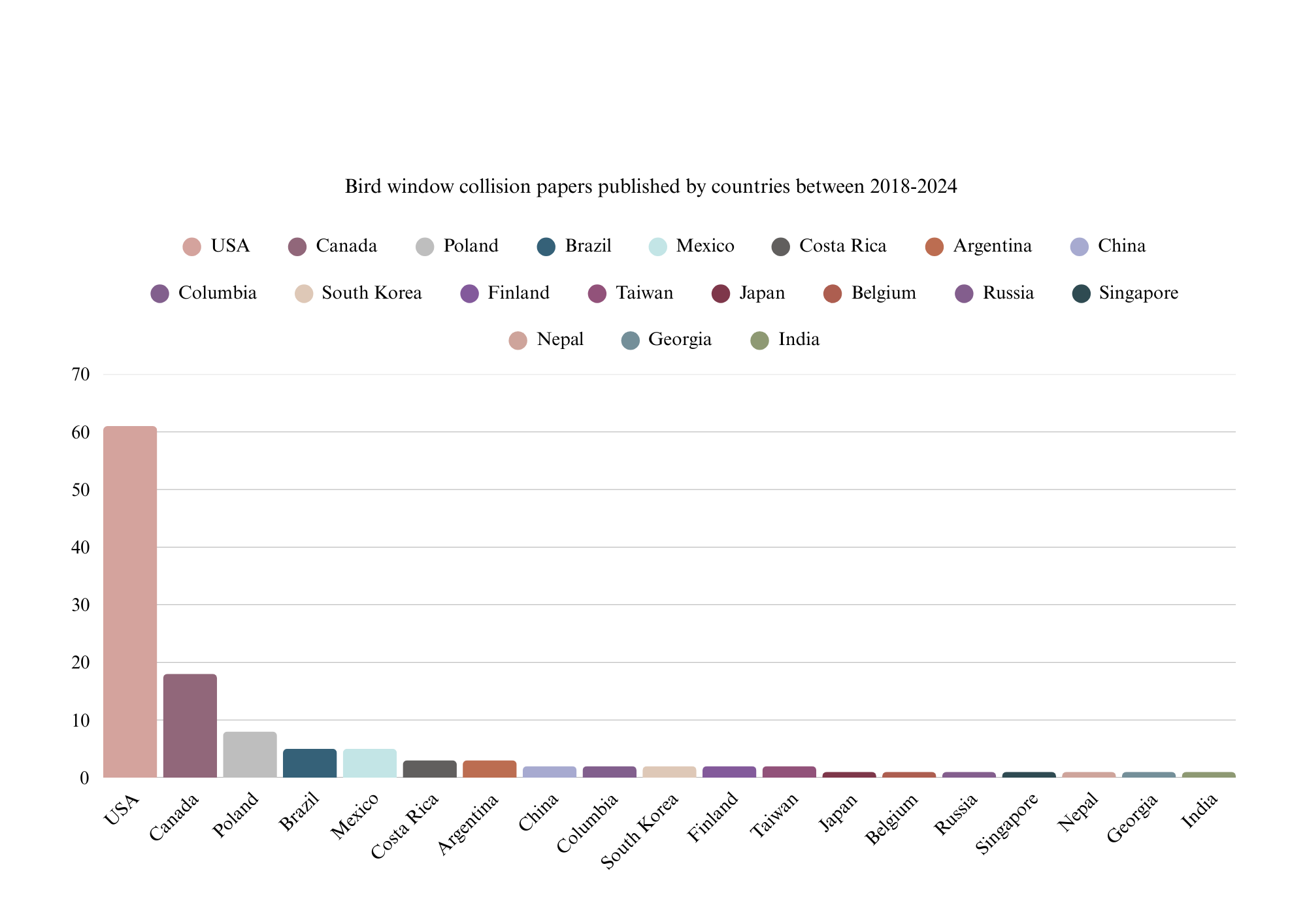
After detailed analysis, a total of 120 papers relevant to bird window collisions were found (cited in reference). Most papers were found from the US (61) and Canada (18). Further papers were from Poland (8), Brazil (5), Mexico (5), Costa Rica (3), Argentina (3), China (2), Columbia (2), South Korea (2), Finland (2), Taiwan (2), Japan (1), Belgium (1), Russia (1), Singapore (1), Nepal (1), Georgia (1), India (1). In case of paper from India, google scholar database did not show any paper published from India hence a separate web search was made with the keywords “Bird window collision research paper in India” and only 1 research paper was found. Further the data was then represented in

1. Graphical representation of number of papers published by countries (Fig 1),

2. Graphical representation of number of papers published each year (Fig 2),

3. Overall causes and mitigation efforts of bird window collisions (Fig 3)

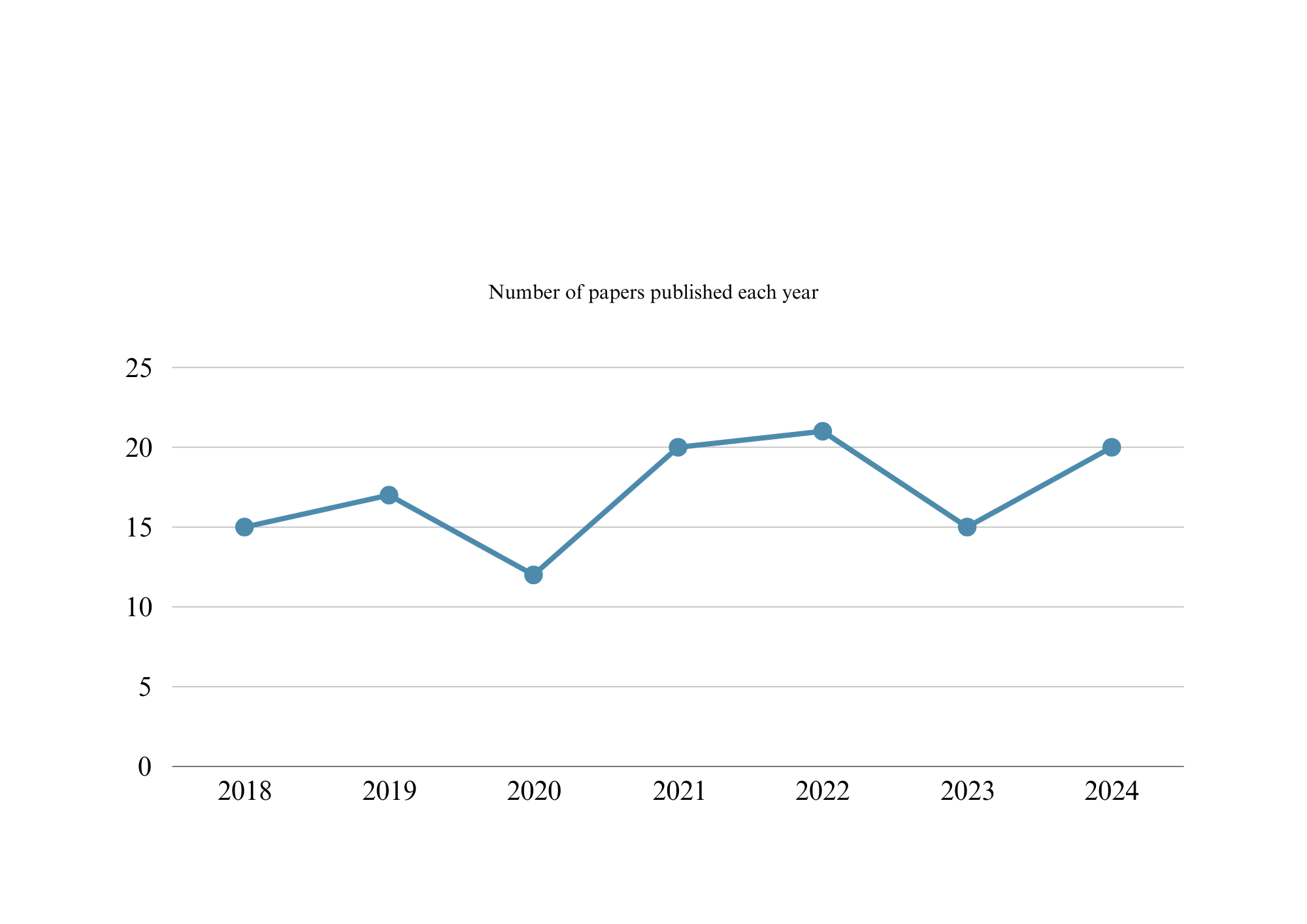
4. Overall number of papers published by countries each year in tabular format (Table 1)

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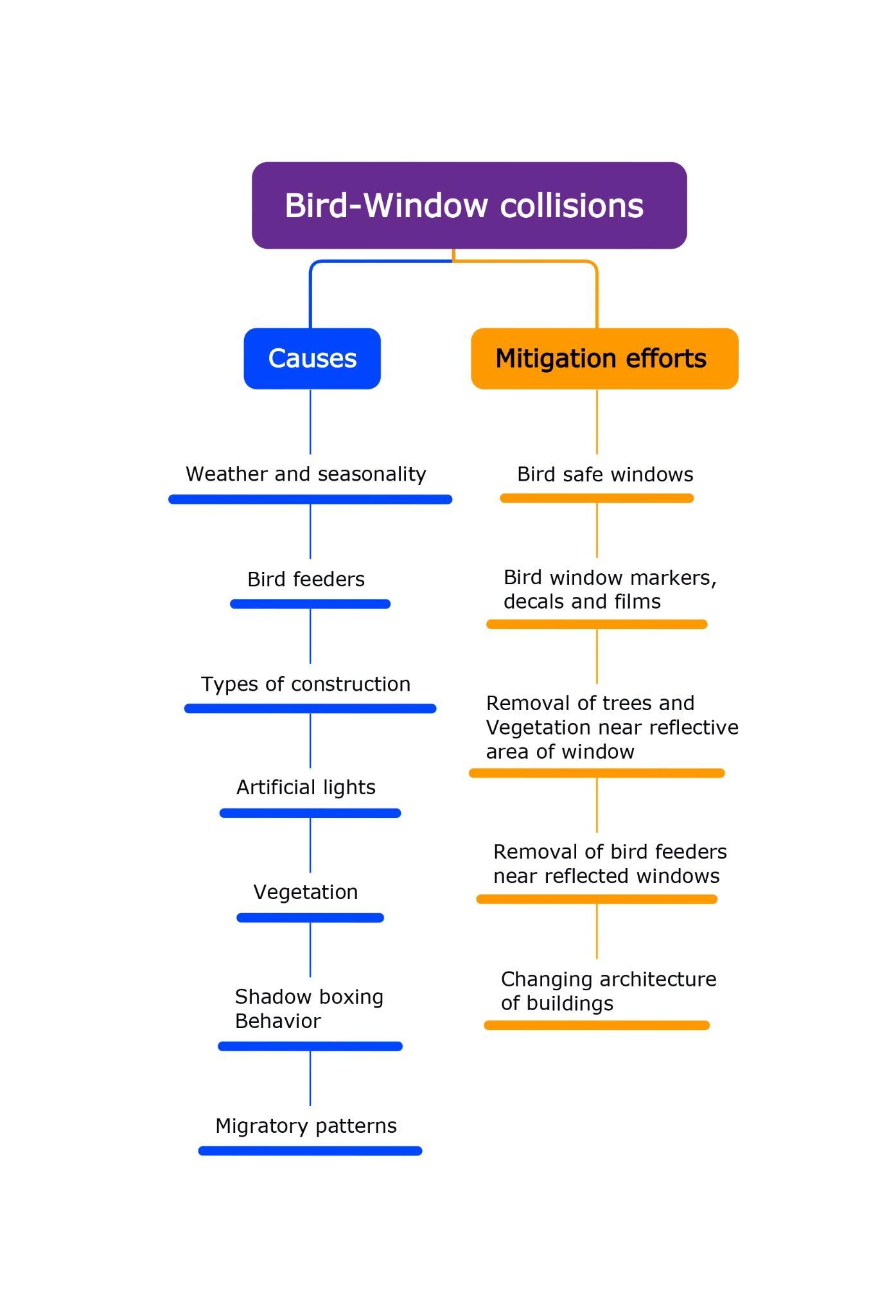
**Figure No. 1. Graph showing total number of papers published by each country between 2018-2024**

**Table No. 1. Table showing in detail the number of papers published by each country in each of the following year (2018-2024)**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Countries** | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **2024** | **Total** |
| **Usa** | 11 | 10 | 8 | 10 | 10 | 5 | 7 | 61 |
| **Canada** | 1 | 1 | 2 | 2 | 6 | 2 | 4 | 18 |
| **Poland** | 1 | 0 | 1 | 1 | 3 | 2 | 0 | 8 |
| **Brazil** | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 5 |
| **Mexico** | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 5 |
| **China** | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| **Argentina** | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 |
| **Columbia** | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| **South Korea** | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| **Finland** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| **Taiwan** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| **Japan** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **Belgium** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| **Russia** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| **Singapore** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **Nepal** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **Costa Rica** | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| **Georgia** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| **India** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| **Total** | 15 | 17 | 12 | 20 | 21 | 15 | 20 | 120 |



**Figure No. 2. Graph Showing total number of papers published each year (2018-2024) globally**

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**Figure No. 3. Overall causes and mitigation efforts regarding bird-window collision**

**3.1 Causes of Bird Window Collision**

*3.1.1. Weather and seasonality:*

Bird window collisions occur all time of the year (Klem 1989, Bayne et al. 2012, Ocampo-Peñuela et al. 2016), although vast majority of them occur in the migratory seasons ( Kara M et al. 2023) Studies have shown that bird window collisions tend to be higher during migratory periods ( Bracey et al. 2016 ) Further due to weather there could be errors in migration decisions, flight and navigation which could increase chances of bird window collisions ( Kara M et al. 2023 ) and unpleasant weather could lead to error in the birds ability to detect and respond to obstacles (Marques et al. 2014) Weather conditions like precipitation, cloud cover or extreme weather conditions tend to influence time and magnitude of migration of birds ( Van doren et al. 2017) Further it has been seen that unpleasant weather may also lead to birds flying down to lower altitudes having more artificial light increasing their chances of collisions (Cochran & Graber, 1958, Van Doren et al. 2021) In relation to time , more collisions occur during day time (Klem 1989, Borden et al. 2010) . While in terms of migration most collisions occurred during sunrise and noon (Mckinney 2002, Sumrada et al. 2015, Aymí et al. 2017) while in terms of breeding season most collisions occur between late morning and early afternoon (Hager & Craig 2014). and studies conducted showed collisions highest in the morning although their frequency varied throughout testing sites (Hager & Craig 2014, Parkins et al. 2015, Kahle et al. 2016)

*3.1.2. Bird Feeders:*

The increase in popularity of wild-bird feeding has led to worry about bird window collisions , as in the past few decades homeowners have become progressively motivated to connect to the natural world as part of their daily lives (Fuller et al. 2008, Jones and Reynolds 2008, Robb et al.2008, Goddard et al. 2013).Use of bird feeders and their placement on the windows has been an interest of study among the researchers.( Kummer and Bayne 2015). The use of bird feeders has been known to consistently increase in the number of birds–window collisions. (Klem et al. 2004, Bayne et al. 2012, Kummer and Bayne 2015, Kummer et al. 2016). Birds of prey may also lead to collisions while chasing their prey. (Glue 1971, Newton et al. 1999). It is also observed that presence of bird feeders increases the number of collisions in all seasons except spring. (Kummer et al. 2016). A study conducted showed that Collisions were not random, collision and mortality rates was higher in rural residences with bird feeders, which decreases to rural residences without feeders, urban residences with feeders, urban residences without feeders, and apartments. (Bayne et al. 2012).

*3.1.3. Types of construction:*

Construction features of buildings such as, building height, adjacent vegetation, facade shape, and proportion covered by windows are most likely to influence the collision risk for birds already present near buildings. (Riding et al 2020). Birds residing in urban settings face numerous anthropogenic threats to survival, including mortality from bird-window collisions (Drewitt and Langston 2008). The rapid increase in the production of glass panes in urban designs, particularly after World War II, has increased the risk of bird collision. (Klem 1989). The glass having larger surface area makes it more difficult for birds to perceive the glass. (Parkins et al. 2015). Hence larger facade with high proportion of glass provides greater area for collisions relative to smaller facades with the same proportion of glass. (Riding et al 2020). Glass panes that reflect surrounding vegetation have increase the collision risk by three times. (Kummer et al. 2016). Many species of birds while landing for rest or to forage, may collide with reflective buildings (Klem 1989). Some studies suggest that, resident species may become habituated to the glass panes and may suffer fewer collisions (Parkins et al. 2015), although there is no evidence that birds actually learn to avoid these obstacles (Sabo et al. 2016).

*3.1.4. Artificial lights:*

The artificial light emitting from windows can disorient birds and can lead to collisions. (Evans Ogden, 2002, Keyes and Sexton 2014, Parkins et al. 2015). Hence artificial light is often a major cause of bird building collision (Sirena et al. 2020) of which most collision victims are nocturnal migraines. (Arnold and Zink, 2011, Loss et al. 2014, Nichols et al. 2018). At smaller scale, on nights with low clouds or visibility birds can get attracted towards artificial light emitted from building (Avery et al. 1976, Kerlinger et al. 2010, Rebke et al. 2019). The large number of birds affected by buildings are songbirds because they migrate at night, fly at low altitude, have tendency to be trapped and this disoriented by artificial light increasing their susceptibility to collision (Ogden & Lesley 1996). Bird collision on window during day time can occur due to daylight on the external surface and artificial light on the internal surface (Swaddle et al. 2020). Due to urban expansion, growth and increasing artificial light, Bird-window collisions are increasing and becoming a threat to migratory birds. (Cabrera-Cruz et al. 2018, Horton et al. 2019, Kyba et al. 2017, Seto et al. 2012).

*3.1.5. Vegetation:*

Buildings having nearby green areas may cause high collision rate and are threat to migratory birds, even in urban areas (Borden et al. 2010). Surrounding vegetation reflected on glass planes causes more collision than those that do not (Kummer et al. 2016). As vegetated areas attract nearby birds (Klem 1989, Klem et al. 2004) and this vegetated area is reflected in window of nearby building affecting collision rate (Klem, 2009, Hager et al. 2008). More the number of trees in an area, higher is the collision rate on the window (Lopez et al 2024). When vegetation is near the glass window, the collision rate increases (Gleb and Delacretaz 2006) and it makes it difficult for birds to differentiate between environment and reflected image (Gleb and Delacretaz 2009, Sameuls et al 2022). Number of collisions can also be affected due to greenery and bird feeders near buildings (Cusa et al. 2015, Kummer et al. 2016, Brown et al. 2019). Some birds are known to fly quickly through dense vegetation and hence are known to become collision victims because even if they detect the glass, they can't prevent them from stopping due to high speed (Chin 2016).

*3.1.6. Shadow boxing behaviour:*

Birds are known to be intolerant of seeing their own reflection on a reflected surface within its territory (Verea 2018). The bird may tend to mistake its own reflection as its competitor (Epstein and Koerner 1986) There is a close relationship between shadow boxing behaviour and breeding season hence shadow boxing occurs mostly during breeding season (Verea 2018). As birds are territorial during breeding season, they tend to drive away and attack the reflection of their own which they assume as a competitor (Temby 2003, Mayntz 2018). The degree of aggression of attacks and duration of attacks are unique for different species and also for individual birds (Mayntz 2018) And shadow boxing behaviour is found more to occur mostly in males but females are also occasionally involved (Robertson1935, Sutton 1947). Shadow boxing behaviour disappears after breeding season (Mayntz 2018) A study conducted has showed that shadow boxing may increase chance of Bird window collisions (Rebekh et al., 2025).

*3.1.7. Migratory Patterns:*

Bird window collisions tend to occur more frequently in the migration season of migratory birds (Elmore et al., 2021). Man made structures responsible for migratory bird window strikes are diverse ranging from high rise glass buildings to urban and rural homes (Gauthreaux and Belser 2003, Machtans 2013). Lots of birds migrate at night and factors like outdoor lighting, interior lights from inside the building may disorient migrating birds (Mclaren et al., 2018) and these birds may be attracted to the lights particularly during unpleasant weather (Verheijen 1958, 1985). Various studies have shown that migratory birds are at higher risk of bird window collision (Borden et al., 2010, Arnold and Zink 2011, Kahle et al. 2016, Sabo et al., 2016)

**3.2. Current Mitigation efforts**

*3.2.1. Bird safe windows:*

These are windows which are specifically designed and constructed in such a way which would help the birds to perceive the window, they are of various types and have different efficiencies. like fritted windows which have patterns fused inside glass which and have success in birds avoiding the window 89% of the time (Klem 2009). Other include UV treated glass which is based on the fact that birds perceive UV light, one of the examples would be ORNILUX®ultraviolet which as per studies reduce bird window collision by 66-71% (De Groot et al 2022)

*3.2.2. Bird window markers and decals and films:*

These include various decals or stickers or films which are applied to the external surface or the internal surface of the window with the idea that the bids would perceive the windows due to the stickers. Examples are decals of birds of prey, bird friendly artwork, circular stickers, patterns created using tapes, bird friendly films and also UV stickers and UV tapes. All of these have different ways and rules of application and tend to have different efficiencies. A study conducted found that bird friendly artwork was found to reduce bird window collisions by 96-100% (Crews and Christie 2022). Another study conducted also found that birds avoided windows by 40-47% if Haverkamp or Bird Shades film if they are applied on the external surface of the window (Swaddle et al 2022). Various studies also show good effectiveness of Feather Friendly® markers with decline in bird window collision by 53-75% (Winton, Ocampo-Peñuela & Cagle, 2018, Riggs et al 2023). Bird of prey decals also decrease bird window collisions although their effectiveness is not much (Brisque et al 2017) experiments have shown effective mitigation with stripes and dots applied on external window surfaces (Klem, 2009).

*3.3.3. Removal of trees and vegetation near reflective area of window:*

Presence of vegetation or trees have been found to increase bird window collisions. The proximity of vegetation near glass panes may lead to high collision rates and are a threat migratory birds and even in urban areas (Borden et al. 2010). hence trees or vegetation can be removed from near the window surface, although this may be species specific as some species of birds would tend to be more attracted to vegetation. A study conducted on collisions of cedar waxwings showed Fruiting pear tree proximity and mirrored windows increased risks of bird window collisions (Barbara et al 2020).

*3.4.4. Removal of bird feeders near reflected windows:*

Bird feeders have been found to consistently lead to increase in the number of bird–window collisions (Klem et al. 2004, Bayne et al. 2012, Kummer and Bayne 2015, Kummer et al. 2016 ) Bird feeders, when close to glass windows have a possibility to increase bird window collision (Klem 1990).houses with bird feeders consistently report more bird-window collisions that those without, regardless of how collision data have been collected (Klem et al. 2004, Bayne et al. 2012; ). A Study conducted showed that the presence of bird feeders may attract more birds towards windows and may increase the chance of collision, however this is dependent on various factors like seasonality and the species of birds hence removal of bird feeders alone may not decrease bird window collisions and other related factors too should be considered (Kummer and Bayne 2015)

*3.4.5. Changing architecture of Buildings:*

Considering the rising cases of bird window collisions several organizations have made guidelines in construction of bird friendly buildings (U.S. Fish and Wildlife Service 2016, American Bird Conservancy 2019, Fatal Light Awareness Program [FLAP] Canada 2019). Facades on a building cause a lot of bird window collisions as they have a large surface area of glass Therefore, hence efforts should be made to avoid the use of such facades ( Riding et al 2020 ) Artificial lights are also found to be significant in causing bird window collisions , hence buildings can considering placement of lights in such a manner that they reduce light pollution Leadership in Energy and Environmental Design (LEED) is a standard of building designs that are followed In US and Canada have been found to reduce bird window collision to some extent (Wood, J. S. 2014).

**4. CONCLUSION**

Hence our detailed analysis reveals the various causes and mitigation efforts. Our study reveals how the developed nations like US and Canada lead in their published studies regarding bird window collisions, this can be due to the fact the such nations have had been under rapid development which would have led to increased number of bird window collisions. For countries like India and Nepal or other countries, the reason for less studies are more likely to be related to less awareness among common people and researchers or it may be genuine that there are really no cases. Rapid development taking place in developing countries would also mean an increase in use of reflective glass and hence cases of bird window collision may rise in such countries. Further current mitigation efforts are known to reduce bird window collisions although most of these mitigation efforts are not cost effective and underdeveloped countries might not be able to apply these in their cases hence there is a detailed study required to find a cost-effective solution for bird window collisions. A similar and wonderful kind of study was also done by Basilio et al 2020 where they also listed out number of studies done and factors causing bird window collision although our study tries to go in more detail and also tries to mention more of the factors that lead to bird window collision, mentioning mitigation efforts and also raising awareness for developing countries which would see a rise in rapid development. Hence our study would be important in a way to achieve precautions related to bird window collisions in further developing countries. Our study also raises the need to have more studies related to this topic of bird window collisions as there is a high chance that most people are not aware of this issue and even if they find such cases they may ignore it. Our study also calls rescue teams and all wildlife educators to make their best as to raising awareness regarding bird window collisions and also provide valuable data to researchers using simple databases.

**5. LIMITATIONS**

Although we have gone through research paper databases manually looking for each and every paper, there can be a chance that some papers may not have been visible in the databases as they may not have been published in top journals or because of other not known causes.

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