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## PROBLEM, PROSPECTS AND SMART MANAGEMENT OF PREDATORY BIRDS IN AGRICULTURE: A REVIEW

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### ABSTRACT

Birds are an integral part of biodiversity and ecosystems. However, they can still cause significant economic damage to crops, especially in standing crops such as maize, sunflower, wheat, sorghum, barley, rice, broad beans, and legumes, as well as fruits like guava and grapes. Farmers incur significant annual losses in terms of production and economic return due to bird depredation. Some of the birds causing significant damage to crops are the house sparrow (*Passer domesticus*), the baya weaver (*Ploceus philippinus*), the parakeet (*Psittacula krameri*), and the peafowl (*Pavo cristatus*). This article explores the impact of bird depredation on agriculture and synthesizes the literature on the extent of crop damage caused by various bird species along with different conventional control methods as well as recent technological advancements. This article presents various traditional and modern management strategies, along with the challenges associated with these methods. Conventional techniques such as auditory-visual deterrents, chemical repellents, Physical barriers, habitat modification, and lethal measures are studied, and their efficacy and limitations are reviewed. The article also explains the high potential of the Internet of Things, including smart scarecrows and ultrasonic repellers for bird management. A clear understanding of the behavior and patterns of crop damage by birds is necessary to develop cost-effective and practical means for bird management. This article aims to enhance knowledge sharing among farmers, researchers, and policymakers in the formulation and implementation of effective strategies for reducing bird damage in agriculture.

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### INTRODUCTION

Feathered friends or foes? This question of how birds impact agriculture is far from simple. While celebrated for their role in controlling insects, birds can also inflict significant damage on crops, creating complex challenges for farmers (Pejchar et al., 2018). On-farm agricultural activities are a complex combination of numerous factors that work together to achieve better production. Maintaining the balance between agricultural productivity and ecological sustainability is a significant challenge in

today's world. This tightrope walk becomes more sensitive while considering the impacts of predatory birds on standing crops. BirdLife International (2023) describes birds as a significant component of the world's biodiversity, belonging to the class of warm-blooded vertebrates that have feathers, wings, and beaks, playing an essential role in maintaining a healthy ecosystem. While some birds play a crucial role in the ecosystem by aiding pollination and controlling insect pests (Bianchi et al., 2006), others can cause significant economic damage

(Chellappan et al., 2023). According to the Department of National Parks and Wildlife Conservation & Bird Conservation Nepal (2022), 892 species of birds are found in Nepal (Poudyal et al., 2024).

It is very challenging to keep birds out of agricultural fields, and also, these birds may transmit foodborne pathogens (Rivadeneira et al., 2018). The problem of crop depredation becomes even more severe during the harvesting season (Kale et al., 2014). Although an exact estimate of the yield loss due to bird pest is not known, farmers integrate several traditional and conventional techniques to prevent grains and fruits from being damaged by pests and birds during production and storage (Kale et al., 2012). The extent of pest damage to crops is dependent on several factors and varies considerably. These factors include the total area under cultivation, local pest density, the type and variety of crops grown, growing season, and even the physiological condition of the pest and birds themselves (Chellappan et al., 2023).

Substantial economic losses to crops have been reported worldwide. Sharma et al. (2019) reported 10–40% yield losses in rice and millets due to the damage caused by the rose-ringed Parakeet (*Psittacula krameri*) and the Baya Weaver (*Ploceus philippinus*) in South Asia, particularly in India and Nepal. Similarly, in sub-Saharan Africa, damage of up to 80% in sorghum and millet during outbreaks of the Red-billed Quelea (*Quelea quelea*), the most destructive grain-eating bird globally, has been reported, notably in Ethiopia and Tanzania (Cheke, 2018). Galahs (*Eolophus roseicapillus*) and Sulphur-crested Cockatoos (*Cacatua galerita*) in Australia are responsible for 15–30% damage in sunflower and wheat, particularly in New South Wales and Queensland, as reported by Tracey et al. (2007).

In North America, Common Grackles (*Quiscalus quiscula*) and Red-winged Blackbirds (*Agelaius phoeniceus*) inflict 5–15% losses in corn and sunflower crops, costing millions of dollars annually in the U.S. Midwest (Linz et al., 2011). The severe and widespread impact of bird pests on food security and rural livelihoods has been highlighted by various authors, emphasizing the need for integrated and region-specific management strategies. It has been documented that a relatively small percentage of bird species are responsible for the majority of crop damage (Whistler, 2007). Common culprits include the baya weaver (*Ploceus philippinus*), house sparrow (*Passer domesticus*), parakeet (*Psittacula krameri*), and peafowl

(*Pavo cristatus*) (Chellappan et al., 2023). Predatory birds, although ecologically significant as natural pest controllers, cause considerable economic loss in crop production. Despite their dual role, most studies to date have focused on specific bird species and their damage to particular crop types, along with localized control methods such as visual and acoustic deterrents, and the integration of innovative and sustainable technologies to some extent (e.g., drones, AI-based detection, and eco-engineering practices). There is a clear gap in the literature that synthesizes the multifunctional role of predatory birds, their economic implications, and the feasibility of ecologically sound management strategies across agroecosystems. This article provides a brief overview of predatory birds in crops, their behavior, and the extent of damage, as well as effective management strategies. It also encompasses different challenges associated with conventional management strategies and explores a new horizon of predatory bird management.

## METHODOLOGY

Rigorous literature search and analysis were employed to prepare this manuscript. Relevant scholarly databases and academic journals were systematically searched. Relevance of the topic to the article selection, publication date, and credibility of the authors and journals were the criteria for selecting articles for this collection. Key words such as predatory birds, crop damage by predatory birds, control of predatory birds in agriculture, traditional methods of predatory bird control, and IOT in predatory bird management were used to acquire relevant articles. The key concepts were extracted after identifying potential articles. Synthesizing information involves categorizing studies by problem and various management practices employed globally. Multiple studies were critically evaluated and compared to highlight gaps, controversies, and advances in exploring bird depredation.

## RESULTS

### Bird Pest Damage

A total of 892 bird species has been recorded in Nepal to date (DNPWC and BCN, 2022), accounting for approximately 8% of the world's bird species (BCN and DNPWC, 2011).

Birds have been an essential component of beauty, and many cultures have a fascinating place in their mythology for birds from ancient times. Birds have a complex status

(beneficial/depredatory/neutral/unknown) concerning their habitat. Most of them are essential pollinators and indicators of a healthy ecosystem, while some, i.e., 25 species (2%), are reported to cause damage to human interests (Chelleppan et al., 2023). Less attention has been given to studying bird pest damage and its management in crops compared to other agricultural problems (Gebhardt et al., 2011).

The impacts of bird damage can be severe and management costly for many producers. Most research on bird damage primarily consists of individual studies on

either a single bird species affecting multiple crops or multiple species impacting a single crop. It thus has a limited focus (Anderson et al., 2013). House sparrow (*Passer domesticus niloticus*) and hooded crow (*Corvus cornix*) have been known to damage crops like barley, rice, wheat, sorghum, sunflower, broad bean, grape, and pea (Khattab et al., 2001; Attia, 2006; Mostafa et al., 2008; Attia, 2013). Senar et al. (2016) reported maximum damage up to 70% with an average damage of 0.4% to 37%, depending on the crop type, caused by the monk parakeet.

**Table 1. Percentage of damage caused by bird pests in different crops.**

Name of bird Pest	Crop	Damage%
Crow ( <i>Corvus splendens</i> ) (Khattab et al., 2002)	Maize	>13%
Rose-ringed parakeets ( <i>Psittacula krameri</i> ) (Ahmad et al., 2012)	Citrus	53.3%
	Guava	48.3%
Blue peafowl ( <i>Pavo cristatus</i> ) (Senaratna et al., 2019)	Rice	83.5%
	Other cereal crops	62.5%
	Spice crops	33%
	Leafy Vegetables	19.5%
	Plantation crops	14%
	Tubers	6%
	Legumes	11%
Small Bee-eater ( <i>Merops pusillus</i> ) (Sidhu & Kler, 2018)	Guava	15%
Wire-tailed Swallow ( <i>Hirundo smithii</i> ) (Sidhu & Kler, 2018)		16%
Brown Rock Chat ( <i>Oenanthe fusca</i> ) (Sidhu & Kler, 2018)		18%
White-cheeked barbet ( <i>Megalaima viridis</i> ) (Chakravarthy, 2004)	Mango and Papaya	2 – 4%
grey-headed swamp hen ( <i>Porphyrio poliocephalous</i> ) (Chellappan et al., 2023)	Sugarcane and rice field	10-50%
Baya weaver ( <i>Ploceus philippinus</i> ) (Sridhara, 2016)	Rice	1.8-5.8%
	Wheat	0.2-41%

### Predatory Bird Management

An understanding of why and how birds consume crops is required to design and test cost-effective bird management practices. Bird damage results from processes operating at nested spatial and temporal scales, following the classical “hierarchical principle” in ecology (Fox et al., 2017). Where, acquaintance with three scales of bird’s preferences is essential: the region of roosting of the damaging birds through the avian annual cycle, landscapes of roosting and foraging grounds as well as crop fields, and ultimately the crop fields where they forage. Farmer’s field scale practices include an intermediate scale of landscape management

relevant to damage prevention during the cropping season. These methods, however, employed at the field scale, could cause unwanted damage to neighboring fields and may be less effective. Long-term effective management practices, hence, require planning of the population and habitat management throughout the region (Sausse et al., 2021).

### Auditory-Visual Frightening Devices

The extensive use of a wide range of audio-visual deterrents has been increasingly adopted for managing pest birds in farmers’ fields. Sound-based devices have proven effective in deterring birds. Common noise

deterrents include screamers, bangers, whistlers, squawkers, noise bombs, scare cartridges, and similar devices (OWA, 2010). In addition, human activities such as rattling cans, cracking whips, yelling, honking horns, or firing guns have also been reported as practical means of repelling nuisance birds from crop fields (OWA, 2010; Ainsley and Kosoy, 2015). When a predator catches a bird, the prey often emits distress calls that may shock the predator into releasing it. Recordings of these distress calls are played through speakers placed in bushes near the fields. The playback frequency should be adjusted according to bird activity levels and played

at regular intervals. This technique has been found effective, particularly in small-acreage crops and orchards.

Successful use of this method to deter native predatory bird species has been reported by Anderson et al. (2021), Khan et al. (2011), and Mahesh et al. (2017). However, these distress calls may sometimes attract other bird species, inadvertently increasing the bird population in the area. Berge et al. (2007) and Delwiche et al. (2007) mentioned that it may also disturb non-target species, affecting their behavior and interactions with the environment.

Table 2. Specific Methods employed for various categories of Pest repellent techniques.

Category	Specific Methods employed
Audio-Visual	Screamers, Bangers, Whistlers, Propane sound cannons, Ultrasonic sounds, Distress calls, Gunfire, Squawkers, Sonic nets, High-intensity sounds, Lasers, Dogs, Humans, Scarecrows, Corpses or effigies, Predator models, Kites, Kite hawks, Balloons with eyespots, Drones, Lights (flashing, rotating, strobe, searchlights), Falconry, Mirrors, Reflectors, Reflective tapes, Flags, Rags, Streamers, Dyes or colorants, Air dancers
Tactile	Spikes, Sticky substances
Chemical	Antraquinone, Methyl anthranilate, Keyplex-350, DRC-1339, MeasuroI
Habitat Modification	Lure crops, Bait stations, Sacrificial crops, Removal of roost structures, food, and shelter
Reproductive	Immune contraceptive vaccines, Chemo-sterilants, Contraceptives,
Exclusion	Electric fencing, Nets, Anti-perching devices, and Overhead wires
Lethal	Shooting, Avicide, Nest destruction, Egg destruction
Multi-Faceted	Optical gel, Pyrotechnics, Drones, Falconry

Source: Rivadeneira et al., 2018; Baral et al, 2019; Lindell,2020

The use of automatic cracker stations has also proven successful in deterring depredatory birds such as grey-headed swamphens and peafowls, both during the day and at night. The sound produced by the crackers at regular intervals acts as an auditory repellent (Chellappan et al., 2023). Other commonly used audio deterrents include propane sound cannons, pyrotechnic devices (e.g., those using calcium carbide and water), shotgun shell crackers, and acetylene exploders (Rivadeneira et al., 2018).

Visual deterrents include searchlights, flashing or rotating lights, reflective tape, mirrors, rags, flags, lasers, streamers, humans, dogs, raptor models, scarecrows, carcasses, kites, balloons with eyespots, hawk-shaped kites, mobile predator models, and water dyes or colorants (Bishop et al., 2003). Reflective ribbons (red or yellow on one side and silver or holographic on the

other) are widely used to deter purple moorhens, rose-ringed parakeets, and plum-headed parakeets. The sudden flashes of light produced by the sun's reflection and the buzzing noise created by the wind startle the birds and drive them away, making this method highly effective during bright, sunny days. However, birds tend to become habituated to these deterrents after 15 to 20 days, reducing their effectiveness. Furthermore, these ribbons are ineffective in isolated crop fields or under low-light conditions (Rao and Dubey, 2016).

Scarecrows resembling human figures, enhanced with unpredictable motion and loud sounds, are also widely used to deter birds (Grant et al., 2011). Other visual deterrents include helium-filled balloons with or without eyespots, hawk or owl kites, spotlights, strobe lights, Mylar tape, and lasers (Kross et al., 2012; Harris et al., 2018). These deterrents can also play a role in

stimulating natural predator behavior in agroecosystems by encouraging the use of raptor perches or nest boxes (Lindell et al., 2018; Peisley, 2017). Lasers have been suggested as an effective tool for deterring specific species, such as gulls and double-crested cormorants (Chellappan et al., 2023). However, contradictory findings exist. For example, Blackwell et al. (2003) found that rock doves, mallards, and geese initially avoided the laser beams, but reoccupied their roosts later the same night. Similarly, Gorenzel et al. (2002) reported that while lasers initially dispersed birds, they often returned shortly after the initial dispersal.

### **Chemical bird deterrents**

Chemical bird repellents, such as taste and behavioral repellents, are also effective in managing bird pests. Two different types of repellents are in use: primary repellents, which deter birds due to their taste or smell, and secondary repellents, which are not immediately repulsive but result in discomfort or disease when consumed (Bishop et al., 2003). These, however, are challenging to apply, expensive, have reduced efficacy compared to laboratory settings when replicated in the field, require licensing, and some overlap with lethal deterrents (Rivadeneira et al., 2018). Methyl anthranilate, a common food additive, can be used as a biodegradable, non-toxic bird repellent, leading to a considerable decrease in crop loss of 88% to 99% when crops are treated. Anthraquinone is another commonly used chemical to deter birds, with a reported decrease of up to 93% in rice consumption (York et al. 2000). Other chemicals include 3-chloro-4-methylaniline hydrochloride, 3-chloro-4-methylaniline, and 3-chloro-4-methylaniline hydrochloride (Carlson et al. 2011). The repelling ability of chlorpyrifos, resulting in a reduction of more than 80% in feeding rates relative to untreated sunflower, has been reported by Linz et al. (2011).

### **Physical Barriers**

The use of various physical barriers to deter predatory birds from encroaching on crop fields has been employed. Netting is a practical, non-lethal, long-term method used as a standard technique (Franklin and Ver Cauteren 2016). Netting is one of the effective methods, as it is potentially 100% effective, non-toxic, noiseless, and reusable. However, it has some drawbacks, including expensive methods, being easily damaged, and

posing a hazard to beneficial birds and their ecosystem service-providing activities. Other exclusions include overhead wires, electric fencing, and anti-perching devices, such as spikes, which are also considered tactile deterrents (OWA, 2010). Extruded nets are another commonly used physical barrier that captures and kills numerous birds (Sausse et al., 2021).

Planting tall-growing forage sorghum around the perimeter of a sunflower field, a practice known as “crop screening” is another commonly used method that acts as a physical barrier. Similarly, wrapping plant parts to deter predatory birds is also practiced, but the feasibility and efficacy of this technique are questionable (Rao and Dubey, 2016).

### **Habitat Management**

Habitat modification strategies encompass a range of activities, from providing better-quality forage or shelter in alternative locations through lure crops or sacrificial crops to simply removing roost structures, food, and shelter, thereby forcing birds to relocate elsewhere (Ainsley & Kosoy, 2015). Pest birds exhibit higher activity around particular habitats, and changes in these habitats tend to decrease their damage. These may be due to suitability for breeding, nesting, and roosting, as well as a preference for foraging (Whittingham & Evans, 2004). Constant disturbance to nesting locations forces breeding birds to abandon their breeding grounds in crop fields and migrate to alternative locations (Chellappan et al., 2023). The reduced abundance of high-quality nesting habitat and a reduction in the volume of non-cropped vegetation deter breeding, leading to shorter breeding times and seasons. Similarly, it also leads to reduced food abundance and decreased probability of predator detection or avoidance (Van der Veen, 2000). Maintaining shorter within-field vegetation and hedgerows (generally used as protective cover) decreases foraging in main crops, which is also because taller and thicker hedgerows are found to be more preferred for nesting by birds (Whittingham & Evans, 2004; Hinsley & Bellamy, 2000).

### **Lethal measures**

Different lethal measures commonly used to control birds are the use of avicides, shooting, egg destruction, and nest destruction. These measures are expensive and time-consuming, as well as frowned upon by the public, since they contrast with the concepts of protection and

environmental stewardship (Linz et al., 2015). Lethal control of birds is not an effective or appropriate method for preventing crop damage, primarily when used in isolation, due to environmental risks, including harm to non-target birds, and a lack of long-term efficacy, resulting in an imbalance of a necessary component of agricultural ecosystems (Ainsley and Kosoy 2015). Reliance on lethal measures exists because birds become habituated and adapted to non-lethal management strategies (Cook et al. 2008).

### **Problems and prospects of different management strategies**

Despite the everyday use of visual and/or acoustic bird surveys, there have been difficulties in assessing their effectiveness due to the absence of robust bird counts, legitimate controls, and behavioral analysis (Avery and Werner, 2017). The efficacy of such deterrent devices decreases when birds become accustomed to these disturbances. The potential use of artificial intelligence and drones, however, may enable the real-time targeting of bird pests through autonomous flight, which will also alleviate prevalent labor constraints (Klug, 2017; Egan et al., 2020). Some progressive work has been done to improve audible signals and camouflage the emergence of seedlings by cover crops, such as barley or faba beans, to prevent damage to sunflowers. A significant problem with these field-scale methods is the risk of shifting bird species foraging and damaging neighboring unprotected fields (Rodrigues et al., 2011). The potential of different chemicals as bird deterrents has been evaluated for a long time, with limited success. However, there is a reduction in efficacy when moving from the aviary to the field, and specific difficulties arise for use on different crop growth stages (Esther et al., 2013; Kaiser et al., 2020). The cognitive abilities of birds enable them to interpret and adapt to their changing environment, which is shaped by the use of physical barriers and habitat management practices. Hence, birds tend to develop adaptive capacity, thereby reducing the effectiveness of preventive measures over time (Werner et al., 2010; Bishop et al., 2003). Eliminating unwelcome visitors has been an obvious solution for many producers. Lethal culling operations, when permitted by local regulations, are subject to disadvantages such as cost inefficiencies, public resistance, and risks to non-target species. Even in the most efficient scenario, lethal management (Linz et al., 2015) provides temporary relief.

### **The way forward: Innovative Crop Protection methods**

Designing a cost-effective damage prevention method requires a thorough understanding of how and why birds consume crops (Fox et al., 2017). Limited research and methodological challenges related to bird damage and its management worldwide underscore the importance of establishing effective and efficient networks to facilitate the sharing of knowledge and feedback within a structured framework. This needs an association between multiple stakeholders, including researchers (agronomists, ecologists, and socio-economists) and farmers (Sausse et al., 2023). Development of a practical approach that includes all actors of the production chain, both at the farm and regional levels, is essential. An efficient linkage between the numbers of actors, including public and private institutions, and farmers' associations, with a common aim of sustainable crop production in a particular region (local, national, and international), is required for this.

### **Internet of Things (IoT): Smart farm protection solution**

In the age of smart farming, some innovative farm protection measures are the smart solution to the problem of pest birds in standing crop fields. The Internet of Things (IoT) is an integration of the virtual world with the physical world, utilizing the Internet as the medium of communicating and exchanging information. IoT refers to the use of interconnected devices and sensors to collect and exchange data about the agricultural environment and processes. IoT has been defined as a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Elijah et al., 2018). Smart farming solutions that utilize advanced technologies offer enhanced crop monitoring and protection against birds. These technologies address the limitations of traditional bird deterrent methods, which often lack effectiveness and efficiency. (Nandhini, 2024). Smart Agriculture Scarecrow is one of the recent inventions that works in three parts: object detection, message sending, and automatic height adjustment. A Passive Infrared (PIR) sensor detects the pest, and prevention is initiated by activating a servo, speaker, and blinking light, which

then sends an alert to the farm owner via the IoT cloud (Dange et al., 2023). This provides a more convenient and cost-effective solution than traditional scare strategies, such as trapping, hunting, and wood fencing.

Ultrasonic bird repellent is another commonly adopted strategy in predatory bird management, integrating IOT.

Sound frequencies above those heard by humans (20Hz - 20 kHz), known as ultrasonic sound, have been used for this purpose. Most birds hear within the same range as human beings (Encarta, 2003); however, some small birds can detect high-frequency sounds that human beings cannot, but they do not hear low-frequency sounds.

Table 3. Sensitive hearing Ranges (kHz) of Bird Species.

Bird Species	Hearing range (kHz)
Mallard ( <i>Anas platyrhynchos</i> )	0.3 - 23
Ring-necked Pheasant ( <i>Phasianus colchicus</i> )	0.3
Turkey ( <i>Meleagris gallopavo</i> )	0.1
Rock Dove ( <i>Columba livia</i> )	0.05 - 2.4
American Crow ( <i>Corvus brachyrhynchos</i> )	0.1 - 2
Brown-headed Cowbird ( <i>Molothrus ater</i> )	0.7
European Starling ( <i>Sturnus vulgaris</i> )	2
House Sparrow ( <i>Passer domesticus</i> )	0.675 - 6.75
Chaffinch ( <i>Fringilla coelebs</i> )	0.2 - 32

Source:(Beason ,2004)

Sensitive hearing of some bird species and ultrasonic range is presented in Table 3, which provides the basis for the construction of sonic bird repellents. Ultrasonic bird repellent comprises a frequency scanner, a frequency generator, a power drive, and an output transducer (Ogochukwu et al., 2012). A sound device emits sound in a specific frequency range to repel birds. The device uses multiple transducers for full coverage, creating an unpleasant environment that deters birds, though its effective range is limited. The deterrent system employs various object detection techniques that utilize cameras to monitor an area. The system analyzes the video feed to detect the presence of pests. When pests are detected, the system activates a deterrent, such as emitting irritating sounds. There are various object detection approaches, like Faster R-CNN (Region-based Convolutional Neural Network) (Du et al., 2022), SSD (single-shot Multibox Detector) (Kaliappan et al., 2023), RetinaNet (Safaldin,2024), YOLO (You Only Look Once) (Sunil et al., 2011), object detection approaches to detect objects in video streams. A smartphone app controls a system designed to deter pests. The system includes the smartphone itself, a control module, and various deterrent devices. These devices, such as scarecrows, audio systems, and lights, are activated remotely through the app with a short response time (Lee, 2016).

## CONCLUSION

Effective management of bird depredation requires a blend of traditional and innovative methods, including IoT-based solutions, to address the persistent issues of crop damage. The current strategies offer a differential rate of success, and the integration of IoT techniques enhances efficiency and adaptability. Upcoming future research should focus on comprehensive and sustainable management strategies. Collaboration among different stakeholders is essential for the advancement of these various efforts, ensuring that both agricultural productivity and ecological balance are maintained. A holistic approach will pave the way for more effective and environment-conscious bird pest management.

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