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Meta-analysis of avian behavioural responses to aircraft noise

T. K. Kler[1]*, P. Sharma[2], G.S. Sekhon[2] and R.K. Aulakh[3]

Department of Zoology, Punjab Agricultural University, Ludhiana 141 004, Punjab, India

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ABSTRACT

Natural environments are now seriously affected by human-made noise, creating complex acoustic circumstances that are unheard of in most locations. Expansion of aero industry and increase in air traffic whether civilian or military is accompanied by large scale noise pollution and habitat disturbances. The present communication is based on meta-analysis of 47 research papers highlighting impact of aircraft noise on avian behavior and communication related to both routine and breeding activities. Aircraft acoustics have been reported to modify behavior of 22 species of birds by changing their specific song structure, communication, population abundance, territorial defence behavior, modifications to reproductive success, impaired vocalization and predator-prey interactions. Recent studies have also uncovered additional negative effects of aeroplane noise on avian behavioral responses by modifying their stress reactions, foraging activity, flight or flushing reactions and avoidance of noisy environments. The ability of bird species to counteract the masking effect of noise through changes in vocal amplitude, song and call frequency, song component redundancy, as well as temporal shifts to avoid noise have been revealed by comparative avian studies conducted in noise free environment. There seems to be a big lacuna in our understanding of influence of aircraft noise on avian community structure, intra/inter species relationships and their prey populations having possibilities of destabilizing effect on intertwined food webs. Detailed studies are required on aircraft noise versus avian population interactions so as to come up with interventions to mitigate their impacts on avian habitats, breeding potential and population abundance; in addition to reduction in noise levels in aviation, maneuvers to reduce noise during landings and take-offs, and to safeguard wildlife in airport influenced areas.

Key words: *Aircraft noise, Avian behaviour, Avian communication, Avian fitness*

Introduction

Birds are an especially vocal taxon, using their vocalizations to establish and sustain their territories, attract mates, warn off predators, exchange food, and maintain social cohesion (Slabbekoorn, 2004). Songbirds have complex neural systems that allow them to learn songs and unique neuromuscular innovations for song production (Zeigler and Marler, 2008). Despite the widespread influence of aircraft noise on wildlife, its impacts are still largely unexplored and therefore a variety of taxa have been affected by noise (Slabbekoorn, 2010) especially songbirds possessing one of the most sophisticated animal languages we are aware of (Perez *et al.,* 2012). Vocal communication is beneficial as it encodes species information in signals and transfers them over comparatively long distances (Gil *et al.* 2015). The unique sound propagation characteristics of acoustic habitat impose selection pressure on bird species

([1] Principal Ornithologist, [2]Ph.D. Scholar, [3]Associate Professor)

due to which birdsong has evolved to serve as a sound signal (Wiley, 2015). European blackbirds depend heavily on vocal communication because they employ songs for mating and territorial displays (Sierro *et al.*, 2017). Air transport is considered most effective as it can cover long distances in relatively short duration of time and therefore its demand is increasing around the world. In order to serve this demand, airports, airfields, and runways are being developed along with expanded aircraft flights which lead to the emergence of harmful noise levels affecting various bird species (Zhandildinova and Moldabekov, 2022).

Anthropogenic noise from aircrafts affects birds in myriad ways, including stress responses, fright-flight responses, avoidance responses, foraging behaviour, changes in reproductive success, increased vocal communication interfering with the ability to hear predators and other important sounds, and potential changes in populations. Present review highlights the negative effects of aircraft noise on avian species as well as the adaptations in behavior repercussions of these responses on fitness, abundance and breeding success.

Noise profile of aircrafts

Noise is defined as unwanted sound that may result in disturbance and annoyance. Noise profiles produced by aircraft are complex and broadband, due to many components simultaneously producing sound at both high and low frequencies (e.g. engine noise and airframe noise) (Manci *et al.*, 1988). Sound is typically measured by the levels of volume and frequency. The sound pressure level (SPL) is a measurement of the loudness of a sound and is measured in decibels (dB). Aircraft noise is caused by airflow around the aircraft fuselage, wings and engines, with different aircraft producing different noise levels, frequencies and tones (Girvin, 2009). Aircraft noise profiles manifest in a frequency range that is audible to many wildlife species in range of 500-5000 Hz (Khardi, 2009), and are relatively of high intensity compared to other anthropogenic noise sources. Areas approximately 300 m from a jet take-off are exposed to approximately 100 dBA that is perceived by humans to be 32 times louder than traffic noise (Etzel and Balk, 2011). Intense noise during aircraft preparation for takeoff and engine testing is another source of noise. Noise comes from both natural and artificial sources and is a significant barrier to acoustic communication because it can obscure the signals, preventing the flow of information (Nathanson *et al*. 2020). The entire habitat ecology and breeding biology of bird species is affected by aircraft noise in and around airports and airfields (Table 1).

Reduction in avian abundance

Key factors influencing bird community and diversity are habitat structure and complexity (Sohi and Kler, 2017). Noise can have a chain effect on avian communities through changing species relationships. According to Francis *et al*. (2009), habitat quality lowered for many bird species because of their inability to communicate effectively. Breeding bird communities could also get affected by the reduced diversity of nesting species. Barber *et al*. (2010) noticed that the majority of responses to aircraft noise by avian species were negative. The difference in bird communities between noisy and quiet sites appears to be driven by site preference as three of the studied avian species nested only in loud sites where as fourteen nested only in quiet, control sites. Alquezar *et al*. (2020) revealed that the abundance of airport adapter species in avian communities of disturbed airport environments showed signs of an ongoing process of biotic homogenization that results in reduced beta diversity among different sites, either by the loss or the increment of species. To conserve biodiversity, understanding how different species react to aircraft noise this unique influence, particularly those with important ties to the environment, may be essential.

Behavioral changes in avian communication

Brumm (2004) in his study revealed that male Nightingales (*Luscinia megarhynchos*) at noisier locations sang with higher sound levels and tried to mitigate the impairments on their communication to maintain a given transmission distance of songs used in territory defense and mate attraction. Nesting passerine birds display a combination of postures and calls, to communicate that they are in need of food (Wright and Leonard, 2007). Individuals with longer and louder calls generally receive more frequent food visits. Masking has the potential to disrupt this acquisition of food if communication is disturbed. Through masking, anthropogenic noise could be inhibiting communication necessary for survival and therefore impacting reproductive success (Kilner and Hinde, 2008). An increase in artificial noise over the past few decades has significantly

Table 1. Literature showing impact of aircraft noise on different species of birds

Studies on Bird Species Common Name	Scientific Name	Impact of aircraft noise	References
Sooty Tern	*Sterna fuscata*	Mass failure of hatching	Austin *et al.* (1970)
White Pelican	*Pelecanus erythrorhynchos*	Population decline	Bunnell *et al.* (1981)
Herring Gull	*Larus argentatus*	More fights due to aggressive behavior resulting in lower mean clutch sizes	Burger (1981)
Leghorn Chicken	*Gallus gallus domesticus*	Increased hatchability due to sonic booms	Bowles *et al*. (1994)
Common Nightingale	*Luscinia megarhynchos*	Reduced conspecific territorial defence behaviour	Brumm (2004)
Common Chaffinch	*Fringilla coelebs*	Increased vigilance resulting in reduced feeding and increased predation risk leading to fitness cost.	Quinn *et al.* (2006)
Red-winged Blackbird	*Agelaius phoeniceus*	Short-term and long-term effects on song tonality	Hanna *et al.* (2011)
European Serin	*Serinus serinus*	Increase in song activity up to noise levels of about 70 dBA	Díaz *et al.* (2011)
Black-capped Chickadee	*Poecile atricapillus*	Started using higher frequency songs with shorter duration and lower frequency songs with longer duration in response to high aircraft noise	Proppe *et al*. (2011)
House Sparrow	*Passer domesticus*	Reduced parent-offspring communication	Schroeder *et al.* (2012)
White-crowned Sparrow	*Zonotrichia leucophrys*	Reduced glucocorticoid levels	Crino *et al.* (2013)
American Cardinal	*Cardinalis cardinalis*	Shift in song frequency	Luther and Magnotti (2014)
Zebra Finch	*Taeniopygia guttata*	Immediate and long-term effects on song.	MacDougall Shackleton (2015)
Red-headed Bunting	*Emberiza bruniceps*	Short-term adaptations by singing at a higher frequency and a lower rate	Dooling and Popper (2016)
Great Tit	*Parus major*	Feeding and vigilance behavioural modifications	Klett-Mingo *et al*. (2016)
Blue Tit	*Cyanistes Caeruleus*	Impaired parent-offspring communication resulting in reduced reproductive success.	Lucass and Müller (2016)
Spotted Towhee	*Pipilo maculatus*	Reduced conspecific territorial defence behavior	Kleist *et al*. (2016)
Chipping Sparrow	*Spizella passerina*	in response to increased background noise.	
European Blackbird	*Turdus merula*	Increased time spent on singing	Sierro *et al.* (2017)
Zebra Finch	*Taeniopygia guttata*	Reduced corticosterone levels More time spent in vigilance resulting in less efficient foraging	Evans *et al.* (2018)
Common Chiffchaff	*Phylloscopus collybita*	Become aggressive, impaired hearing and shifted their songs to lower frequeny when exposed to loud aircraft noise	Wlofenden *et al.* (2019)

Table 1. *Continued ...*

Studies on Bird Species Common Name	Scientific Name	Impact of aircraft noise	References
Red-headed Bunting	*Emberiza bruniceps*	Shifted song at loud frequency and slow rate in response to high aircraft noise	Wlofenden *et al.* (2019)
Brent Geese	*Branta bernicla*	Longer feeding times in aircraft noise disturbed locations	Wolfenden *et al.* (2019)
Common Swift	*Apus apus*	Displacement behaviour of feeding the young	Hahn and Yosef (2021)

damaged the stability of ecological systems and species communication, having both direct and indirect effects on avian communities by impairing their capacity for communication (Ortega, 2012). At low levels of ambient noise, male American Cardinals (*Cardinalis cardinalis*) responded more strongly to songs of average frequency than to songs with shifted frequency, but the difference vanished at high noise levels, indicating that frequency shifted songs were not advantageous for communication at higher noise levels (Luther and Magnotti 2014). Lucass and Müller (2016) revealed that noise interfering with the ability of parent Blue Tit (*Cyanistes caeruleus*) to communicate with their offsprings while providing parental care, can adversely affect the rate of provisioning, increasing hunger in nestlings and reducing their chance of survival and, ultimately resulting in reduced reproductive success According to Wolfenden *et al.* (2019) Chaffinches avoided singing during aircraft takeoffs all day, supporting the hypothesis that the extremely loud noise from airports could impair avian communication.

Behavioural changes in foraging and vigilance activities

High ambient noise can impact the availability of auditory information to birds, changing their foraging and vigilant behavior which could lead to decreased growth and overall health. According to Quinn *et al.* (2006) Chaffinches (*Fringilla coelebs*) altered their interscan interval in response to background noise, and significantly reduced the number of pecks they made while feeding. Their enhanced vigilance resulted in a decreased feeding, compensating for the elevated predation risk. When perceptions of threat are inhibited by noise, species often increase vigilant behavior and more time spent vigilant means less time foraging indirectly resulting in reduced fitness. Klett-Mingo *et al.* (2016) in a study conducted at Barajas Airport in Madrid, Spain, revealed that when aircraft noise peaked, Great Tits (*Parus major*) spent majority of their time guarding not in feeding. Additionally, the length of feeding sessions decreased during the loudest part of the day and then increased afterward. It was proposed that these behavioural adjustments aid foragers in visual detection of potential predators in environments where loud noises impair auditory perception. Evans *et al.* (2018) also revealed that captive Zebra Finches (*Taeniopygia guttata*) foraging in the noisy area spent a lot more time vigilant than the birds foraging in the quiet area, which led to less effective foraging. According to Wolfenden *et al.* (2019), the study done on Brent Geese (*Branta bernicla*), who are disturbed by aircraft noise every half-hour, feeding takes 30% longer than it does for birds in less disturbed locations. Future research can look at how anthropogenic noise modifies the causal relationships between risk perception, foraging and vigilance.

Adaptations in avian territorial defense behavior

Vocal display in birds is thought to serve two primary purposes: attracting a mate and defending a territory. Krebs *et al.* (1978) in his experiment replaced singing males with speakers which resulted in prevention of re-occupation of the territory. Therefore impaired vocalization due to aircraft noise can affect territorial defence. Catchpole and Slater (2003) stated that avian songs play an important part in territorial defence and it becomes very difficult to defend a territory when the songs of a rival cannot be detected or discriminated from those of a neighbour which might result in loss of a territory or loss of paternity when rivals intrude undetected and engage in extra-pair copulations. Brumm (2004) reported that male Nightingales (*Luscinia megarhynchos*) at noisier locations sang with higher sound levels and tried to mitigate the impairments on their communication to maintain a given transmission distance of songs used in territory defense and mate attraction. According to Kleist *et al*. (2016), conspecific territorial defence behaviours of Spotted Towhee and Chipping Sparrow had reduced as background noise levels increased.

Stress and fright-flight responses of bird species

One potential impact of aircraft noise on vertebrates is stress, which is frequently characterized by its affect on neuroendocrine physiology. An organism's level of stress is influenced by the time of exposure to noise (Wikelski and Cooke, 2006). Romero (2004) found that sensitive bird species could experience an acute stress response after a brief, single powerful noise event. During an acute stress response, norepinephrine and epinephrine are instantly released, and the hypothalamic-pituitary-adrenal (HPA) cycle is subsequently initiated resulting in increased blood levels of the glucocorticoids. Crino *et al*. (2013) found that fledgling of White-crowned Sparrows (*Zonotrichia leucophrys*) exposed to noise had lower glucocorticoid levels and were in better physical conditions in comparison to control nests. However, Potvin and MacDougall Shackleton (2015) in their study on Zebra Finches (*Taeniopygia guttata*) revealed that continuous exposure to noise had immediate as well as chronic impacts on their vocalization. Additionally, the corticosterone level decreased after noise exposure, indicating less stress.

Avian breeding failure and sonic booms

Thompson and Parnell (1967) stated that when aeroplanes travel at supersonic speeds, shockwaves cause a sound that may be heard on the ground. Austin *et al.* (1970) found a widespread failure of hatching in Sooty Terns (*Sterna fuscata*), and hypothesized that the sonic booms of low-flying military aircraft might have been the culprit. The loss of White Pelicans (*Pelecanus erythrorhynchos*) in British Columbia was linked by Bunnell *et al*. (1981) to low altitude hazing from aircraft. Common Swifts (*Apus apus*) were shocked out of their slumber by the boom. Burger (1981) discovered that when supersonic transports sailed overhead, more breeding Herring Gulls (*Larus argentatus*) were driven off their nests and got into fights in which many eggs were destroyed. Due to the increased likelihood of fighting in a colony compared to solitary nesting couples, this resulted in reduced mean clutch sizes at the end of the incubation period in locations with high bird population. According to Bowles *et al*. (1994), exposure to sonic booms actually increased hatchability in domestic white Leghorn Chickens (*Zonotrichia leucophrys)*. Also Hahn and Yosef (2021) in his study on Common Swifts *(Apus apus)* found that when parents are under stress, they may participate in displacement behaviour such as feeding the young or engaging in an activity they are most used to doing with the nestlings. In the second scenario, they may get frightened and show behavior like scaling the walls.

Reduction in avian fitness

High noise events may cause birds to engage in escape or avoidance behaviors. Ellis *et al*. (1991) stated that high noise levels may flush birds from perches or nests at the cost of extra energy utilization. These energy expending activities affect bird's survival or growth. In addition, the birds may spend less time engaged in necessary activities like feeding, preening and caring for their young. Kler and Kumar (2015) stated that differences in bird demography and nest site preference between landscapes are largely caused by variations in food availability. According to Frid (2003) avian species may flee in fear in response to aircraft noise, resulting in reduced fitness in terms of energy lost through decreased foraging time, increased parental care and vigilance, and desertion of preferred feeding grounds, territories, and habitat ranges. Territorial song masking could also lead to reduced fitness by lowering the signal's active space, reducing the size of the territories with fewer resources (Catchpole and Slater, 2003). Schroeder *et al*. (2012) showed that birds breeding in a noisy environment experience significant fitness cost. House sparrows reared in a noisy environment experienced reduced parental provisioning, lower fledging mass, and lower fledging and recruiting success. Meille're *et al*. (2015) in their experiment on House Sparrows showed that noise alone can affect a wild vertebrate's early-life telomere length. Reduced telomere length of affected House Sparrow nestlings may therefore suggest a detrimental effect of noisy environments on developing sparrows that may carry over later in life (i.e. reduced fitness). Future investigations should assess these potential fitness consequences of reduced telomere length in nestlings of passerine bird species. Wolfenden *et al.* (2019) stated that Common Chiffchaffs become more aggressive when exposed to loud noises produced during planes takeoff and landing which had the potential to damage their hearing. It was further mentioned that studied Common Chiffchaffs attacked speaker playing bird song more aggressively as compared to their counterparts living away from the airports related noise disturbances. The increased levels of aggressiveness may be a direct outcome of increased stress brought on by intermittent exposure to aeroplane noise. The birds at the airports not only became more aggressive but also started singing at a lower frequency, possibly due to hearing loss.

Uplifted frequencies in avian song structure

The small European songbird Serins (*Serinus serinus*), which is related to the canary, increased its song activity in response to rising levels of man-made noise up to a level of roughly 70 dBA. Thereafter, singing activity reduced as the noise level rose (Díaz *et al.*, 2011). When briefly exposed to low frequency white noise, Red-winged Blackbirds (*Agelaius phoeniceus*) enhanced the tonality of their songs, and birds residing in noisy habitats also showed greater tonality when singing in quiet situations indicating both immediate and long-term consequences (Hanna *et al.* 2011). When there is a lot of road noise, Black-capped Chickadees (*Poecile atricapillus*) use higher frequency vocalisations that are shorter in duration and lower frequency songs that are longer in duration (Proppe *et al.*, 2011). Male Red-headed Buntings (*Emberiza bruniceps*) changed their song rapidly in reaction to noise, singing at a louder frequency and slower rate when the level of noise was high, indicating that short-term adaptations, rather than long-term adaptations, were at work (Dooling and Popper 2016). Wolfenden *et al.* (2019) stated that Common Chiffchaffs become aggressive when exposed to loud aircraft noises and also impaired their hearing and as a result they shifted their songs to lower frequency.

Conclusion

To place noise management at the forefront of protection of bird species, it is essential to monitor various impact of noise pollution at ecological, genetic and physiological levels. The majority of management plans for airports around the world prioritize on actual aircraft collisions with birds, with little attention paid to noise pollution affecting them. For the creation of sustainable land use plans close to aircraft facilities, greater research into the multiple effects of aeroplane noise on avian fauna deserves urgent attention of ornithologists, ecologists and aerodrome planners. The information from these studies can be further utilized to develop sensible public policies that improve the ability of military and commercial aircraft to operate with less sound pollution thereby lowering the possibility of exposing wildlife especially avian fauna to noise disturbances.

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