

# Australian magpies exhibit increased tolerance of aircraft noise on an airport, and are more responsive to take-off than to landing noises

G. D. Linley<sup>A,C</sup>, K. Kostoglou<sup>B</sup>, R. Jit<sup>A</sup> and M. A. Weston<sup>B</sup>

<sup>A</sup>Avisure, McDonald House, 37 Connor St, McDonald House, Level 4, Burleigh Heads, Qld 4220, Australia.

<sup>B</sup>Deakin University, Centre for Integrative Ecology, School of Life and Environmental Sciences, Faculty of Science, Engineering and the Built Environment, Melbourne Campus, 221 Burwood Hwy, Burwood, Vic. 3125, Australia.

<sup>C</sup>Corresponding author. Email: [glinley@avisure.com](mailto:glinley@avisure.com)

## Abstract

**Context.** On airports, birds often exhibit escape behaviour in response to aircraft. Avian escape behaviours can enable birds to effectively avoid collisions with aircraft, although some are maladaptive and may increase the risk of collision (e.g. erratic flying). Habituation and habituation-like processes among birds potentially mediate the likelihood of aircraft–bird collisions. Moreover, because managers exploit avian escape behaviour to reduce bird–aircraft collision risks, habituation may decrease the efficiency of bird-hazard management.

**Aims.** Our aim was to better understand avian behavioural responses to approaching aircraft, which may inform bird-hazard management.

**Methods.** We examined the response of Australian magpie, *Cracticus tibicen*, a species commonly involved in collisions with aircraft, to the noise associated with take-off and landing in three areas: airside, on airport but not airside, and off airport.

**Key results.** Magpies responded to aircraft noise in a nuanced way. Take-off produced more responses, and more intense responses, than did landing; both resulted in more frequent, and more intense, responses than did a ‘silent’ control. Responses were least likely, and response latencies were longer, airside, followed by on airport but not airside, and off airport. Intensity of responses was similar across these areas.

**Conclusions.** Magpies on the airside were least responsive, and this might influence their strike risk.

**Implications.** Given that most wildlife collisions occur during take-off and landing and at low altitudes, and that take-off has greatest overall strike risk, the lack of responsiveness of airside-inhabiting magpies may contribute to collision risk.

Received 27 October 2017, accepted 5 April 2018, published online 25 May 2018

## Introduction

Continual expansion of the global aviation industry means the rate of collisions between aircraft and wildlife (bird strike) is increasing (Allan and Orosz 2001). Bird strikes are a source of human and wildlife fatalities, can damage equipment and create major delays. Globally, methods such as lethal control and habitat manipulation are used to manage strike risk (Dolbeer *et al.* 1993; Dolbeer 1998; Baxter and Robinson 2007; Thomson *et al.* 2007; Patrick and Shaw 2012; McKee *et al.* 2016).

Understanding bird behaviour in response to certain stimuli has major ramifications for how to best manage and reduce the chance of bird strikes. The classic paradigm that applies to bird–aircraft strikes is that encapsulated in a series of theories related to wildlife escape (Cooper and Blumstein 2015). Essentially, birds, like other animals, monitor their environment for risk (‘stimuli’, usually predators) and initiate a response that manages that risk (usually escape). Avian responses to humans and their machines are stereotypically similar to responses to

predators although the degree of risk associated with these stimuli (inferred through response distances) varies among stimuli (Weston *et al.* 2012; Cooper and Blumstein 2015; Lima *et al.* 2015). Avian behavioural characteristics can mediate the likelihood of a bird strike. Escape behaviour has the potential to avoid or to cause bird–aircraft collisions. Postmortem on birds struck by aircraft has shown that many strikes occur on the posterior and ventral side suggesting that many species exhibit escape responses to aircraft but are apparently unable to escape due to speed of the approach (Bernhardt *et al.* 2010). Additionally, escaping birds face into the wind, so, initially, they fly in the same direction as the approaching aircraft (Burger 1983). Timely responses of birds presumably enable birds to avoid collisions with aircraft.

To avoid danger in their environment, birds must perceive approaching threats. Bird visual systems and responses are complex and response times are, at least in some species, linked to the speed of the oncoming stimulus or are specific to areas

where stimuli travel at different speeds. Thus, birds may struggle to escape from rapidly moving stimuli (Weston *et al.* 2012). However, aircraft noise is a key aspect of the stimulus available to birds, which might enable them to respond to aircraft in a timely fashion. Noise is known to elicit a variety of responses in birds, which can be dramatically different among species, and which depend on the sound volume (Dunnet 1977; Burger 1981, 1983; Ellis *et al.* 1991; Arévalo and Newhard 2011). Aircraft are associated with different noise profiles when taking off and landing, those phases of the flight when they are most prone to bird strikes (Burger 1983). A long-term dataset from the USA indicated that 61% of strikes occur on landing and 35% during take-off (Dolbeer *et al.* 2015). However, available studies that show the effect of take-off and landing noise on bird escape responses do not include Australian birds or conditions, and studies of avian responses to aircraft noise are limited. The available studies that have examined the effect of aircraft on birds have generally involved military aircraft, and low overflights, and have almost always been away from airports (Burger 1981; Brown 1990; Ward and Stehn 1990; Ellis *et al.* 1991; Conomy *et al.* 1998b; Delaney *et al.* 1999; Goudie and Jones 2004). No study known to us has examined whether responses to noise on and around an airport vary in relation to the degree of exposure to aircraft, or whether different phases of aircraft flight (landing versus take-off) elicit different responsiveness.

Birds make complex decisions regarding escape, and apparently modify their responses on the basis of the prevailing risk environment (Weston *et al.* 2012). Rock doves (*Columba livia*) exposed to vehicles reduce responsiveness over time compared with naive individuals (DeVault *et al.* 2017). One process that may affect escape is habituation and habituation-type processes (Blumstein 2016), where responsiveness to a stimulus decreases in areas where the stimulus is common and generally benign. This may be due to individual learning or habituation-like processes such as selection (van Dongen *et al.* 2015), and has implications for effective avoidance of aircraft, and for effectiveness of bird management (e.g. hazing). Birds living near aircraft may reduce responsiveness, which is adaptive insofar as risky escape flights are less likely, but may mean birds approach or tolerate aircraft at closer proximities.

In Australia, 16 096 reported bird strikes on aircraft occurred in 2006–2015 (Australian Transport Safety Bureau 2017). Of all identified bird taxa, Australian magpies (*Cracticus tibicen*) are ranked the 6th most struck bird, with 513 strikes 2006–2015 (5.9% of 8717 strikes); 22 magpie strikes involved multiple birds (4.4% of 502 strikes; Australian Transport Safety Bureau 2017). Thus, magpies are a species involved in substantial numbers of collisions with aircraft in Australia. Light aircraft in Australia are common, and smaller-bodied aircraft are particularly vulnerable to bird strike as resultant damage can be catastrophic (Burger 1983; Dolbeer *et al.* 2015).

We investigated whether Australian magpies exhibited different responses to light aircraft noise in three areas that differed in distance from, and exposure to, aircraft. We aimed to (1) discern whether Australian magpies living in close proximity to aircraft exhibit reduced responsiveness in comparison to individuals that are less frequently exposed to close passes by aircraft, and (2) determine whether responses

varied between noise associated with take-off and that with landing.

## Materials and methods

Point Cook RAAF Base (henceforth, ‘the base’) is a small aerodrome located 29 km south-east of Melbourne (37.930757°S, 144.754115°E). The predominant air traffic consists of Cessna 172, a single-engine, low-air-speed aircraft. The base consists of the following two areas: (1) ‘airside’, the part of the aerodrome that is made up of a mixture of short, grassed areas, runways; and (2) ‘airport but not airside’, a large area away from actively operating aircraft dominated by roads, short-grass areas and buildings. The third zone, ‘off airport’, the Point Cook Coastal Park, consists of a large area of native vegetation and saltmarsh that abuts the airport. All areas consisted of open grassed areas used for magpie foraging, with a similar availability of perches.

Behavioural responses of Australian magpies to audible playback stimuli were recorded between June 2016 and February 2017. We performed ‘trials’, whereby we played randomly allocated recordings of take-off, landing or neither (‘control’, i.e. we broadcast a blank soundtrack) to a variety of bird species. We avoided repeat sampling of birds within any session, and did not perform a trial within 50 m of any other trial. Only magpies (which were common) were sampled sufficiently and are the focus of the present paper (see Table S1, available as Supplementary Material to this paper, for summaries of data for other species). Trials were all car-based, and consisted of three 30-s phases: pre-, during and post-playback. Focal birds were haphazardly selected if they were within 50 m of the vehicle, were foraging (i.e. non-vigilant), and no real aircraft or other stimuli were active. We used the pre- and post-phases to ensure that any responses that occurred were due to the aircraft playback. The playback stimulus consisted of an audio recording of a Cessna 172 landing and taking off, as well as a control (such aircraft can cause substantive responses in birds; Conomy *et al.* 1998a). Both recordings were made using a Roland, R-26 portable digital recorder (sensitivity set to high), and ME62/K-6 omni-directional Sennheiser microphone, set 30 m from the place of take-off or touchdown and featured little background noise (for each recording, wind and external noise were reduced using the noise-reduction effect in Audacity 2.1.2 without any loss of quality). The recordings captured the entire noise associated with incoming or departing planes from a stationary point, and were made at Point Cook airfield. Playbacks were of the cleaned but original recordings, at a set amplification (same settings), and were played through a hand-held megaphone (TOA er-1215). Thus, the intrinsic differences in volume between take-off and landing were preserved; however, these were slight (means, at megaphone; take-off, 109.9 dB; landing, 109.7 dB). Volume was set at a realistic level (at the mean distance between broadcast and magpies (30 m), the average peak volume of playbacks was 97 dB, being at the upper end of the range (61–96 dB) of volumes associated with Cessna 172 operations. All trials were in fine weather, with slight or no wind. All trials were recorded by a video, using a Nikon 5100 DSLR with a 70–300-mm lens on a window mount. The distance between the bird and the observer (Dist<sub>car</sub>) was measured with a laser rangefinder.

We derived the following response variables from the ‘during’ phase of each trial:

- (1) Presence of a response (binary, analysed with GzLM-specifying binomial distribution and logit link);
- (2) Response intensity using an ordinal response scale (1 = no response, 2 = vigilance, 3 = walk or run away, 4 = fly away), which described the response of birds to the stimulus and was analysed using a GzLM (specifying an ordinal distribution and logit link); and,
- (3) Latency of response (the interval, in seconds, between the start of the playback and the initiation of a response, analysed using a general linear model, GLM).

We also explored the volumes involved in the playback experiment, so as to ensure that these were equivalent among areas. The peak (in dB) of both audio recordings was measured with Roland R-26 portable digital recorder (sensitivity set to high), and ME62/K-6 omni-directional Sennheiser microphone at increments of 10 m, starting at zero and ending at 50 m within the three areas. A repeated-measures GLM (predictor was the volume of take-off and landing (repeated)) showed no effect of area ( $F_{2,14} = 2.590$ ,  $P = 0.110$ ), but an expected significant negative effect of distance ( $F_{1,14} = 139.099$ ,  $P < 0.001$ ).

Models included terms for the area in which the trial was conducted (‘region’ i.e. airside, on airport but not airside, and off airport) and the type of noise used (‘soundtrack’ i.e. take-off, landing or control). An interaction between these terms was initially included in all models; however, because none of the interactions was significant, all models were run with main effects only. All models included the covariate of the distance between the observer and the bird (Dist.<sub>Car</sub>) to adjust for variation in this measure, which is also associated with the sound volume experienced by the bird.

Finally, we wished to examine whether any observed responses to aircraft noise mirrored responses to other stimuli. We performed standard pedestrian approaches to magpies across the three areas, according to the protocols described in Weston *et al.* (2012). This involved recording a starting distance (SD) and flight-initiation distance (FID), using a laser rangefinder, and analysing FID (response variable) against the covariate SD and the fixed factor region. Means are presented with standard errors throughout.

## Results

The model examining the presence of a response showed main effects of region and soundtrack (Table 1). The only significant difference in the probability of a response among regions was that responses on airside ( $0.20 \pm 0.07$ ) were less likely than those on airport but not airside ( $0.86 \pm 0.78$ ;  $P < 0.001$ ). The probability of a response outside the airport did not differ from that on airport but not airside ( $0.67 \pm 0.12$ ;  $P = 0.198$ ). All pairwise comparisons within soundtrack were significant (the highest  $P = 0.007$ ), with the probability of a response to take-off, landing and control being  $0.95 \pm 0.02$ ,  $0.82 \pm 0.06$  and  $0.03 \pm 0.02$  respectively.

The model exploring the variation in response scale showed no effect of region but a significant effect of soundtrack (all pairwise comparisons had  $P \leq 0.002$ ) and Dist.<sub>Car</sub>. ( $\beta$ ,  $-0.04 \pm 0.02$ ; Table 1). Median response scores were 1.0 for airside, 2.0 for on airport but not airside and 2.0 for off airport.

For trials where a response occurred, we analysed the time to a response (s) against region, soundtrack and Dist.<sub>Car</sub>. Dist.<sub>Car</sub> ( $\beta$ ,  $0.08 \pm 0.03$ ) and region had significant effects (Table 1). Responses on airside ( $8.17 \pm 0.71$  s) were delayed longer than those on airport but not airside ( $6.06 \pm 0.60$  s) or off airport ( $5.68 \pm 0.56$  s). The only pairwise comparison with a low  $P$  value (0.074) was between off airport and the non-airside areas of the airport.

Flight-initiation distances (FID) to a human stimulus did not differ across the three regions (GLM,  $R^2 = 0.183$ ; region,  $F_{2,46} = 0.817$ ,  $P = 0.448$ ; starting distance,  $F_{1,46} = 9.445$ ,  $P = 0.004$ ) and overall was  $27.98 \pm 1.88$  m.

## Discussion

The present study has shown patterns of responses consistent with the idea that Australian magpies exhibit decreased responsiveness to aircraft noise on airports (reduced occurrence, and increased latency, of responses). It also suggests that they respond more to the louder noise associated with take-offs than to landings. However, even on airside, responses remained common and birds discriminated between the soundtracks (perhaps a generalised response to sound volume). Overall, birds continued to respond to aircraft in a manner that was consistent with discriminatory anti-predator behaviour. We cannot attribute

**Table 1. The response of Australian magpies to playback of aircraft taking-off, landing and a silent control on airside, on airport outside the airside, and off airport**

Distance is the distance of the research vehicle from the focal birds when the trial began (‘Dist.<sub>Car</sub>’). Bold indicates a significant effect

Response variable and model type	Predictor variable	Model results
Presence/absence of response. GzLM specifying binomial distribution and logit link.	Region	<b>Wald <math>\chi^2_2 = 16.862</math>, <math>P &lt; 0.001</math></b>
	Soundtrack	<b>Wald <math>\chi^2_2 = 44.792</math>, <math>P \leq 0.001</math></b>
	Distance	Wald $\chi^2_1 = 0.600$ , $P = 0.439$
Response scale. GzLM with ordinal distribution and logit link.	Region	Wald $\chi^2_2 = 3.101$ , $P = 0.212$
	Soundtrack	<b>Wald <math>\chi^2_2 = 53.317</math>, <math>P &lt; 0.001</math></b>
	Distance	<b>Wald <math>\chi^2_1 = 7.810</math>, <math>P &lt; 0.005</math></b>
Time to response (untransformed; for only those trials where a response occurred; excluding the factor level ‘control’ as $n = 3$ ) GLM; $R^2_{Adj} = 0.151$ .	Region	<b><math>F_{2,98} = 4.003</math>, <math>P = 0.021</math></b>
	Soundtrack	$F_{1,98} = 1.253$ , $P = 0.266$
	Distance	<b><math>F_{1,98} = 5.959</math>, <math>P = 0.016</math></b>

these adaptations to specific processes, such as within-animal learning, local selection or recruitment, or a situation where magpies alter their responsiveness in a spatially dynamic fashion, i.e. by adjusting responsiveness to the prevailing acoustic environment or according to specific localities (Legagneux and Ducatez 2013).

Habituation, adaptation or tolerance to or of certain stimuli, including noise, can alter bird behaviour both in the short and long term (Brumm 2004; Quinn *et al.* 2006). We have shown, for the first time, decreased responsiveness of a passerine to aircraft noise among birds closest to aircraft. Conomy *et al.* (1998b) showed that one of two duck species habituated to jet aircraft noise. Although acute and dramatic responses of birds to aircraft noise are short-lived (e.g. the present study), some bird species exposed to aircraft noise exhibit altered behavioural time budgets for hours (Goudie and Jones 2004). Longer-term adaptations to aircraft noise are also known. Analysis of birdsong in high-noise environments has shown that individuals exposed to high levels of background noise sing with higher sound levels (Brumm 2004; Bermúdez-Cuamatzin *et al.* 2010), and some even advance their dawn chorus apparently to avoid overlap with aircraft noise (Gil *et al.* 2015).

The ability to habituate to or tolerate common stimuli, thereby altering behavioural characteristics, has led to certain species adapting to human-dominated environments such as urban areas (Blumstein 2006; Lowry *et al.* 2011), and the same may apply to airports. For example, aircraft noise may discourage some birds from breeding (Awbrey and Hunsaker 1997) and could conceivably exclude more sensitive species or individuals (van Dongen *et al.* 2015). Quieter aircraft (Burger 1985) may mean previously excluded species may be increasingly able to inhabit airports. Similarly, selection for experienced birds may occur; young birds may be disproportionately struck by aircraft and vehicles (Burger 1985). Also, experience reduces responsiveness to oncoming vehicles for rock pigeons (DeVault *et al.* 2015). These processes may contribute to the results we describe here.

Although enhanced tolerance of aircraft noise occurred among magpies, no such pattern was evident for pedestrian approaches. Although we tested only two stimuli (aircraft noise and a pedestrian), results suggest not only that Australian magpies are able to discern effectively among different stimuli (McLeod *et al.* 2013), but also that tolerance itself varies among stimuli. Stimuli to which habituation or tolerance occurs may be frequent, predictable and benign (Mumme *et al.* 2000; Blumstein 2016). In our study system, aircraft are likely to be more common and predictable than are pedestrians.

As the aviation industry continues to expand, bird strike is an ever increasing issue and poses major risks to humans and wildlife (Allan and Orosz 2001; Australian Transport Safety Bureau 2017). Globally, a wide range of tools are implemented to effectively reduce the risk of a bird strike (Patrick and Shaw 2012; Dolbeer 2013). Although many countries and airports favour actively culling birds in the vicinity of an aerodrome, a method that may reduce bird strike in the immediate term in some circumstances (Dolbeer *et al.* 1993; Dolbeer 1998), little evidence is available to suggest that these measures are effective over the long term (i.e. these measures require ongoing management intervention to remain effective). Our work and that of others (Harms *et al.* 1997;

Conomy *et al.* 1998a, 1998b) has shown that some birds can increase their tolerance to aircraft noise, but it remains to be demonstrated whether this is a result of selection or within-individual learning, or other processes. A critical information gap centres on the strike risk of individuals in relation to their behavioural characteristics.

The aircraft we recorded and used in the present study came from a noisy aircraft, and quieter aircraft may result in different avian responses (Burger 1985). We also note that our study species is known for its intelligence and ability to discriminate among stimuli, such as, for example, among different people (Warne and Jones 2003). Thus, other species may not necessarily habituate, tolerate -or discriminate with respect to aircraft noise (Conomy *et al.* 1998b).

## Conflicts of interest

The authors declare no conflicts of interest.

## Supplementary material

The supplementary material available from the Journal's website provides summary information on species other than the Australian magpie which were surveyed but were not used in the main analysis.

## Acknowledgements

This work was conducted under the auspices of Avisure permissions, Deakin University ethics approval B11-2015 and DEWLP permits. MAW was supported during write up by the Beach Ecology and Conservation Hub (Venus Bay). Two anonymous reviewers improved this manuscript and have our thanks.

## References

- Allan, J. R., and Orosz, A. P. (2001). The costs of birdstrikes to commercial aviation. In 'Proceedings of the 2001 Bird Strike Committee – USA/ Canada. Third Joint Annual Meeting', Calgary, AB. p. 2. (Transport Canada: Ottawa, Ontario)
- Arévalo, J. E., and Newhard, K. (2011). Traffic noise affects forest bird species in a protected tropical forest. *Revista de Biología Tropical* **59**, 969–980.
- Australian Transport Safety Bureau (2017). Australian Aviation Wildlife Strike Statistics: 2006–2015. (Australian Transport Safety Bureau: Canberra.)
- Awbrey, F. T., and Hunsaker, D. (1997). Effects of fixed-wing military aircraft noise on California gnatcatcher reproduction. *The Journal of the Acoustical Society of America* **102**, 3177. doi:10.1121/1.420822
- Baxter, A. T., and Robinson, A. P. (2007). Monitoring and influencing feral Canada goose (*Branta canadensis*) behaviour to reduce birdstrike risks to aircraft. *International Journal of Pest Management* **53**, 341–346. doi:10.1080/09670870701245231
- Bermúdez-Cuamatzin, E., Ríos-Chelén, A. A., Gil, D., and Garcia, C. M. (2010). Experimental evidence for real-time song frequency shift in response to urban noise in a passerine bird. *Biology Letters* **7**, 36–38. doi:10.1098/rsbl.2010.0437
- Bernhardt, G. E., Blackwell, B. F., DeVault, T. L., and Kutschbach-Brohl, L. (2010). Fatal injuries to birds from collisions with aircraft reveal anti-predator behaviours. *The Ibis* **152**, 830–834. doi:10.1111/j.1474-919X.2010.01043.x
- Blumstein, D. T. (2006). Developing an evolutionary ecology of fear: how life history and natural history traits affect disturbance tolerance in birds. *Animal Behaviour* **71**, 389–399. doi:10.1016/j.anbehav.2005.05.010



- Blumstein, D. T. (2016). Habituation and sensitization: new thoughts about old ideas. *Animal Behaviour* **120**, 255–262. doi:10.1016/j.anbehav.2016.05.012
- Brown, A. (1990). Measuring the effect of aircraft noise on sea birds. *Environment International* **16**, 587–592. doi:10.1016/0160-4120(90)90029-6
- Brumm, H. (2004). The impact of environmental noise on song amplitude in a territorial bird. *Journal of Animal Ecology* **73**, 434–440. doi:10.1111/j.0021-8790.2004.00814.x
- Burger, J. (1981). Behavioural responses of herring gulls (*Larus argentatus*) to aircraft noise. *Environmental Pollution. Series A. Ecological and Biological* **24**, 177–184. doi:10.1016/0143-1471(81)90030-1
- Burger, J. (1983). Jet aircraft noise and bird strikes: why more birds are being hit. *Environmental Pollution. Series A. Ecological and Biological* **30**, 143–152. doi:10.1016/0143-1471(83)90011-9
- Burger, J. (1985). Factors affecting bird strikes on aircraft at a coastal airport. *Biological Conservation* **33**, 1–28. doi:10.1016/0006-3207(85)90002-3
- Conomy, J. T., Collazo, J. A., Dubovsky, J. A., and Fleming, W. J. (1998a). Dabbling duck behavior and aircraft activity in coastal North Carolina. *The Journal of Wildlife Management* **62**, 1127–1134. doi:10.2307/3802567
- Conomy, J. T., Dubovsky, J. A., Collazo, J. A., and Fleming, W. J. (1998b). Do black ducks and wood ducks habituate to aircraft disturbance? *The Journal of Wildlife Management* **62**, 1135–1142. doi:10.2307/3802568
- Cooper, W. E., and Blumstein, D. T. (2015). 'Escaping from Predators: an Integrative View of Escape Decisions.' (Cambridge University Press: UK.)
- Delaney, D. K., Grubb, T. G., Beier, P., Pater, L. L., and Reiser, M. H. (1999). Effects of helicopter noise on Mexican spotted owls. *The Journal of Wildlife Management* **63**, 60–76. doi:10.2307/3802487
- DeVault, T. L., Blackwell, B. F., Seamans, T. W., Lima, S. L., and Fernández-Juricic, E. (2015). Speed kills: ineffective avian escape responses to oncoming vehicles. *Proceedings of the Royal Society B* **282**, 20142188. doi:10.1098/rspb.2014.2188
- DeVault, T., Seamans, T., Blackwell, B. F., Lima, S., Martinez, M., and Fernández-Juricic, E. (2017). Can experience reduce collisions between birds and vehicles? *Journal of Zoology* **301**, 17–22. doi:10.1111/jzo.12385
- Dolbeer, R. A. (1998). Evaluation of shooting and falconry to reduce bird strikes with aircraft at John F. Kennedy International Airport. *Wildlife Society Bulletin* **21**, 442–450.
- Dolbeer, R. A. (2013). The history of wildlife strikes and management at airports. In 'Wildlife in Airport Environments: Preventing Animal–Aircraft Collisions through Science-based Management'. (Ed. T. L. DeVault, B.F. Belant, J.L.) pp. 1–6. (The John Hopkins University Press in association with The Wildlife Society: Baltimore, MD.)
- Dolbeer, R. A., Belant, J. L., and Sillings, J. L. (1993). Shooting gulls reduces strikes with aircraft at John F. Kennedy International Airport. *Wildlife Society Bulletin* **21**, 442–450.
- Dolbeer, R., Wright, S., Weller, J., Anderson, A., and Begier, M. (2015). Wildlife Strikes to Civil Aircraft in the United States: 1990–2014. Serial Report No. 21. (US Department of Transportation: Washington, DC.)
- Dunnet, G. M. (1977). Observations on the effects of low-flying aircraft at seabird colonies on the coast of Aberdeenshire, Scotland. *Biological Conservation* **12**, 55–63. doi:10.1016/0006-3207(77)90057-X
- Ellis, D. H., Ellis, C. H., and Mindell, D. P. (1991). Raptor responses to low-level jet aircraft and sonic booms. *Environmental Pollution* **74**, 53–83. doi:10.1016/0269-7491(91)90026-S
- Gil, D., Honarmand, M., Pascual, J., Pérez-Mena, E., and Garcia, C. M. (2015). Birds living near airports advance their dawn chorus and reduce overlap with aircraft noise. *Behavioral Ecology* **26**, 435–443. doi:10.1093/beheco/aru207
- Goudie, R. I., and Jones, I. L. (2004). Dose-response relationships of harlequin duck behaviour to noise from low-level military jet overflights in central Labrador. *Environmental Conservation* **31**, 289–298. doi:10.1017/S0376892904001651
- Harms, C. A., Fleming, W. J., and Stoskopf, M. K. (1997). A technique for dorsal subcutaneous implantation of heart rate biotelemetry transmitters in black ducks: application in an aircraft noise response study. *The Condor* **99**, 231–237. doi:10.2307/1370247
- Legagneux, P., and Ducatez, S. (2013). European birds adjust their flight initiation distance to road speed limits. *Biology Letters* **9**, 20130417. doi:10.1098/rsbl.2013.0417
- Lima, S. L., Blackwell, B. F., DeVault, T. L., and Fernández-Juricic, E. (2015). Animal reactions to oncoming vehicles: a conceptual review. *Biological Reviews of the Cambridge Philosophical Society* **90**, 60–76. doi:10.1111/brv.12093
- Lowry, H., Lill, A., and Wong, B. B. M. (2011). Tolerance of auditory disturbance by an avian urban adapter, the noisy miner. *Ethology* **117**, 490–497. doi:10.1111/j.1439-0310.2011.01902.x
- McKee, J., Shaw, P., Dekker, A., and Patrick, K. (2016). Approaches to wildlife management in aviation. In 'Problematic Wildlife. A Cross-disciplinary Approach'. (Ed. F. M. Angelici) pp. 465–488. (Springer International Publishing: Cham, Switzerland)
- McLeod, E. M., Guay, P.-J., Taysom, A. J., Robinson, R. W., and Weston, M. A. (2013). Buses, cars, bicycles and walkers: the influence of the type of human transport on the flight responses of waterbirds. *PLoS One* **8**, e82008. doi:10.1371/journal.pone.0082008
- Mumme, R. L., Schoech, S. J., Woolfenden, G. E., and Fitzpatrick, J. W. (2000). Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. *Conservation Biology* **14**, 501–512. doi:10.1046/j.1523-1739.2000.98370.x
- Patrick, K., and Shaw, P. (2012). Bird strike hazard management programs at airports: what works? In 'Proceedings of the 5th Symposium of Flight Safety', 28–30 August, São José dos Campos/SP, Brazil. pp. 28–30. (Department of Science and Aerospace Technology)
- Quinn, J. L., Whittingham, M. J., Butler, S. J., and Cresswell, W. (2006). Noise, predation risk compensation and vigilance in the chaffinch (*Fringilla coelebs*). *Journal of Avian Biology* **37**, 601–608. doi:10.1111/j.2006.0908-8857.03781.x
- Thomson, B. (2007). A cost effective grassland management strategy to reduce the number of bird strikes at the Brisbane airport. PhD thesis, Queensland University of Technology.
- van Dongen, W. F. D., Robinson, R. W., Weston, M. A., Mulder, R. A., and Guay, P.-J. (2015). Variation at the DRD4 locus is associated with wariness and local site selection in urban black swans. *BMC Evolutionary Biology* **15**, 253. doi:10.1186/s12862-015-0533-8
- Ward, D. H., and Stehn, R. A. (1990). Response of Brant and Other Geese to Aircraft Disturbances at Izembek Lagoon, Alaska. Final report to Minerals Management Service, Intra-agency agreement 14-12-0001-30332. 193pp. (Alaska Fish and Wildlife Research Center: Anchorage, AK, United States.)
- Warne, R. M., and Jones, D. N. (2003). Evidence of target specificity in attacks by Australian magpies on humans. *Wildlife Research* **30**, 265–267. doi:10.1071/WR01108
- Weston, M. A., McLeod, E. M., Blumstein, D. T., and Guay, P. J. (2012). A review of flight-initiation distances and their application to managing disturbance to Australian birds. *Emu - Austral Ornithology* **112**, 269–286.