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Tactile and Auditory Repellents to Reduce Wildlife Hazards to Aircraft

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Wildlife within the airport environment are hazards to human safety. Lethal removal of targeted individuals reduces the immediate threat, but other approaches should be integrated into control programs to make them more effective and to help meet legal and ethical considerations (Dolbeer et al. 1995). When negative media attention, special interest groups, or calls for restrictive legislation influence public opinion, the resulting public pressure can preclude effective wildlife management and lead to subsequent population control problems (Torres et al. 1996, Coolahan and Snider 1998, Conover 2001). Nonlethal management activities to reduce wildlife use of airports may include habitat modification, exclusion from roosting and nesting areas, and repelling animals from desired locations. When considering repellents alone, there are many that are untested, temporarily effective, or cost-prohibitive (Dolbeer et al. 1995). Effective nonlethal repellents must affect some aspect of physical receptors or psychological perception of the intended targeted animals. In birds and mammals the primary physical receptors are visual (see Chapter 2), auditory, and tactile (Dooling 1982, Fay 1988, Clark 1998*a*). As explained in Chapter 3, the sense of smell is also important for birds and mammals. In this chapter we focus on auditory and tactile repellents, particularly the physiological bases for tactile and auditory repellent efficacy. We also examine some behavioral aspects of species that influence the efficacy of repellents.

Animal Sensory Capabilities

One must account for the auditory capability of animals when evaluating acoustic frightening devices. Auditory capabilities are measured in part by sound frequency in Hertz (Hz) and sound pressure level (SPL), the logarithmic measure of the pressure of a sound in decibels (dB) relative to a standard reference pressure in air (dB SPL), typically 20 μPa. Despite physical differences, the ears of mammals and birds work remarkably similarly. One obvious difference between the two groups is that avian ears are not externalized, yet have feather patterns that can focus sound waves into the ear in much the same way as the external mammalian ear. The avian inner ear differs from the mammalian inner ear, with one interior bone instead of three (Gill 2007). Even though the avian ear is structurally simpler than the coiled cochlea of a mammal, with its straight or slightly coiled cochlea (inner ear), the acoustical efficiency of birds is similar to that of mammals (Gill 2007). In both mammals and birds, hair cells in the cochlea serve as auditory sensory receptors. However, some birds, unlike mammals, have the ability to regrow some damaged hair cells (Ryals et al. 1999, Stone and Rubel 2000).

In general, birds hear well within a limited frequency range, whereas human hearing spans a wider range. Humans can detect sounds at frequencies from about 0.03 to 18 kHz (Heffner and Heffner 1992), with an absolute sensitivity at 0 dB SPL (Durrant and

Lovrinic 1984). Birds react most to sounds from 1 to 3 kHz, with an absolute sensitivity from −10 to 10 dB SPL (Dooling 1978, 1982; Stebbins 1983; Dooling et al. 2000). However, the range of sounds detected among species varies markedly. Downy woodpeckers (*Picoides pubescens*) are most sensitive to sounds from 1.5 to 4.0 kHz (Delaney et al. 2011), whereas barn owls (*Tyto alba*) are most sensitive from 6.0 to 7.0 kHz and at sound pressure levels as low as −18 dB SPL (Fay 1988). Rock pigeons (*Columba livia*) can detect low frequencies (0.05 Hz; i.e., in the infrasound range <20 Hz), but it is unknown how pigeons use this capability (Fay and Wilber 1989, Fay and Popper 2000). Also, birds, unlike some mammals, do not hear ultrasonic (≥20 kHz) sounds (Schwartzkopff 1973, Dooling 1982).

White-tailed deer (*Odocoileus virginianus*), one of the most hazardous mammals to aircraft (Biondi et al. 2011, DeVault et al. 2011), hear from 0.25 to 54 kHz up to ~60 dB SPL. When measured using auditory brainstem response, deer were most sensitive to sounds from 4 to 8 kHz at 42 dB (D'Angelo et al. 2007). However, when measured using a behavioral audiogram, deer were most sensitive at 8 kHz and −3 dB SPL (Heffner and Heffner 2010). When measured at an intensity of 60 dB SPL, domestic dogs (Canidae) hear sounds between 0.067 and 44 kHz and domestic cats (Felidae) between 0.055 and 79 kHz (Heffner and Heffner 1992, Heffner 1998).

Hearing a sound and reacting to a sound require two different processes, however. Heffner (1998) describes these processes as sensation and perception, where sensation is the ability to detect a sound and perception is the ability to respond to the sound. This ability to respond is dependent not only on the physics of stimulus transmission, but also the ecological saliency of the stimulus (see Guilford and Dawkins 1991, Phelps 2007). We would expect an animal's perception to change as it habituates to a sound that is not negatively reinforced (see, however, Biedenweg et al. 2011). Vesper sparrows (*Pooecetes gramineus*) sometimes maintain breeding territories at airports despite noises associated with jet engines or passing vehicles. Yet vesper sparrows occupying territories in open fields that are not subject to constant airport noise, but are near roads, often cease singing and hide when a car door is closed or a vehicle drives by (Seamans, personal observation; see also Summers et al. 2011).

In addition to auditory stimuli, animals perceive their environment through touch, primarily through contact with the skin. The skin of birds is relatively thinner than that of mammals, but as in mammals the skin serves multiple purposes. Skin provides a protective envelope for the body, some thermal insulation, and is a large sensory organ especially sensitive to temperature, pressure, and vibration (Stettenheim 1972, Schwartzkopff 1973). Although not apparent, the skin on a bird's foot is thick except at the hinges between the scales, where it is sensitive to tactile stimuli (Stettenheim 1972, Clark 1997). The trigeminal nerves in the avian bill are also sensitive to oral stimuli (Schwartzkopff 1973, Clark 1998*a*), which has been the basis for development of primary foraging repellents (e.g., methyl anthranilate–based products including Bird Shield and Bird Stop [Mason et al. 1989, Belant et al. 1996*b*, Clark 1998*b*]; Chapter 3). White-tailed deer have demonstrated sensitivity to electrical stimuli of 5.9 kV through their feet, a finding used in the development of electric mats as barriers against deer (Seamans and Helon 2008). Raccoons (*Procyon lotor*) have sensitive forepaws (Tremere et al. 2001) with good motor capability (Kaufmann 1982); therefore we assume they are reactive to tactile stimuli through their feet.

Premise for Efficacy

All vertebrates react to painful or noxious stimuli (Bateson 1991). Nonlethal techniques that cause direct pain or discomfort generally prompt animals to move away from the stimulus. However, both intra- and interspecific responses can vary depending on the situation, individuals involved, and type of stimulus (e.g., Hoffman and Fleshler 1965, Belant et al. 1997, Clark 1998*b*, Seamans and Blackwell 2011).

Most nonlethal management techniques are designed to evoke a response to a perceived predatory threat, which provides a strong motivation for animals to flee (Lima 1988, Keys and Dugatkin 1990, Lima and Dill 1990, Frid and Dill 2002). Flight from predators may be innate (Tinbergen 1948), learned, or enhanced

via learning (Curio 1975, Kruuk 1976, Ydenberg and Dill 1986, Guilford 1990; see also Clark 1998*b*, Griffin 2004). A vast literature exists showing that prey response to a predator (i.e., antipredator behavior) varies due to numerous factors, including time of year in relation to breeding, frequency of predation risk, distance to escape cover, approach of the predator, type of habitat, and behavior of conspecifics (e.g., see Lima 1994, Cresswell et al. 2000, Elchuk and Wiebe 2002, Caro 2005, Devereux et al. 2006). In addition, humans represent a threat that generally elicits antipredator behaviors from most animals (e.g., see Bélanger and Bédard 1990, Evans and Day 2001, Frid and Dill 2002, Fernández-Juricic et al. 2003, Marzluff et al. 2010). Against birds, the efficacy of scare devices likely depends also on how targeted animals perceive stimuli relative to energy constraints and risk factors that affect foraging site selection (Suhonen 1993, Krams 1996, Elchuk and Wiebe 2002, Fernández-Juricic and Tran 2007).

The fate of animals frightened from a targeted area is often unknown but highly variable. Therefore the return rate of animals harassed or repelled from target areas offers a metric for method efficacy. Resident Canada geese (*Branta canadensis*) harassed from a park or residential area generally travel <2 km (1.2 miles) and eventually return to the original site (Holevinski et al. 2007, Preusser et al. 2008). Aversive stimuli used against black bears (*Ursus americanus*), including nonlethal methods that caused pain, proved to be fairly ineffective in preventing bear returns to urban areas (Beckman et al. 2004). Even incidental disturbances of nontarget animals have demonstrated that other factors (i.e., nest defense) can override fear produced via novel stimuli. For instance, red-cockaded woodpeckers (*Picoides borealis*) returned to nests on average 4.4–6.3 min following the firing of 0.50-caliber blank rounds from a machine gun within 152 m (499 feet) of nests, but they did not leave nests when experiencing sound-exposure levels <65 dB SPL at distances >152 m (Delaney et al. 2011). Factors such as breeding season, availability of natural and anthropogenic food resources, and predation can clearly interact to diminish or enhance repellent effectiveness. An understanding of the context of application is critical in determining the types and necessary integration of repellent methods.

Auditory Repellents

Biosonic Stimuli

Auditory repellents are marketed as either ultrasonic, sonic, or biosonic calls. Human-made sounds are thought to frighten birds and therefore rely on the perception of danger (e.g., risk-disturbance hypothesis for nonlethal threats; Frid and Dill 2002). Loud (i.e., >90 dB SPL) sounds may also cause physical distress. The underlying assumptions of biosonic recordings of bird alarm or distress calls are that (1) birds perceive such calls as natural warnings that danger is present and will subsequently flee (Lima and Dill 1990, Hurd 1996, Goodale and Kotagama 2008) and (2) birds are not as likely or will take longer to habituate to alarm and distress calls than other sounds (e.g., human-made sounds) because the calls are related to evolutionary signals of danger (Thompson et al. 1968, Johnson et al. 1985, Bomford and O'Brien 1990). Cliff swallow (*Petrochelidon pyrrhonota*) nesting activity was reduced 50% when alarm and distress calls were played in the nesting area (Conklin et al. 2009). Carrion crows (*Corvus corone*) responded to distress calls more than to effigies (Naef-Daenzer 1983). Likewise, Spanier (1980) found that about 88% of black-crowned night herons (*Nycticorax nycticorax*) left aquaculture facilities at the broadcasting of distress calls, and that no habituation was noted after six months. Researchers conjectured that herons that did not respond to distress calls were nonresident herons that had not established associations with conspecifics and therefore were not inclined to respond to the calls.

However, response to alarm calls may be species specific. Goodale and Kotagama (2008) found variation to response based on species ecology. Cook et al. (2008) found that unless a lethal element was added to distress calls, gulls (Laridae) habituated to the calls, whereas Coates et al. (2010) saw no response from wild turkeys (*Meleagris gallopavo*) to alarm calls. European starlings (*Sturnus vulgaris*) stopped responding to distress calls after about seven days when there was no negative reinforcement (Summers 1985). Additionally, call complexity may influence inter- and intraspecific responses (Soard and Ritchison 2009, Courter and Ritchison 2010, Fallow and Magrath 2010). Alarm and distress calls, though useful in bird control, are likely

Fig. 4.1. Biologist firing a pyrotechnic device from a specially designed pistol. Pyrotechnics are widely recognized as effective wildlife control tools when used as part of an integrated control program. Photo credit: Thomas W. Seamans

limited by context as well as by species behavior and ecology.

As discussed above, birds cannot hear ultrasonic sounds. Despite this fact, many ultrasonic devices are marketed as pest control devices. Bomford and O'Brien (1990) reviewed multiple studies that indicate ultrasonic stimuli are not aversive to birds, rodents, or insects. Although deer can hear in the ultrasonic range (D'Angelo et al. 2007, Heffner and Heffner 2010), in field trials they failed to react to ultrasonic devices, possibly because they were not loud enough for the deer to hear (Curtis et al. 1997, Belant et al. 1998, Valitzski et al. 2009).

Pyrotechnics

Pyrotechnics are auditory and visual devices that rely primarily on an explosion or other loud noise to scare birds (Mott 1980). The effect of a particular device might be sound alone or the combination of a particular sound with the light and smoke from the percussive component. Such devices include rifles and shotguns that fire live ammunition or blanks, or 12-gauge shotguns and flare pistols that fire exploding or noise-making projectiles (e.g., shell crackers, bird bombs, bird whistles, whistle bombs, or racket bombs; Fig. 4.1). The use of pyrotechnics to scare birds is widely recognized as an effective bird management tool (Booth 1994). The Humane Society of the United States (Hadidian et al. 1997) recognizes pyrotechnics as effective and humane scaring devices. Cleary and Dolbeer (2005) list the use of pyrotechnics as an effective means of reducing bird hazards at airports. However, some authors note that birds habituate to pyrotechnics and other scare devices (Blokpoel 1976, Inglis 1980, Slater 1980, Summers 1985). Limited lethal control has been suggested as a means to prolong the efficacy of pyrotechnic devices or to make the devices effective again after habituation occurs (Hochbaum et al. 1954, Slater 1980, Summers 1985, Smith et al. 1999), but limited empirical data have been provided to support this supposition. An exception is work by Baxter and Allan (2008), which showed that shooting some free-flying gulls at one feeding site enhanced the effectiveness of pyrotechnics, but that corvids did not respond similarly. Additionally, Cook et al. (2008) demonstrated that techniques including a lethal component were more effective at deterring birds than techniques with no lethal component. Killing one or more birds may provide the visual or auditory cue that stimulates a response by conspecifics (Guilford and Dawkins 1991). The presence of a dead bird alone can elicit a risk-avoidance response, but the perception of lethal attack might be a critical element for improving efficacy of effigies for some species (Avery et al. 2002, Seamans 2004, Seamans and Bernhardt 2004, Seamans et al. 2007*b*).

Exploders

Gas-operated exploders (e.g., gas cannons or propane cannons) have been commonly used since the late 1940s to repel pest birds from agricultural fields and airports (Gilsdorf et al. 2002). An exploder produces an extremely loud, intermittent explosion that exceeds the blast of a 12-gauge shotgun, which it is intended to simulate (Fig. 4.2). The assumption is that birds will associate the blast with gunfire and flee the area. Conover (1984) found exploders to be effective at reducing bird damage to corn, yet Washburn et al. (2006) found gulls at an airport did not respond to exploders even when lethal control with shotguns was conducted at the same site. Belant et al. (1996*a*) found that short-term responses of white-tailed deer to motion-activated exploders varied seasonally, but that regularly activated exploders were ineffective. As with other methods,

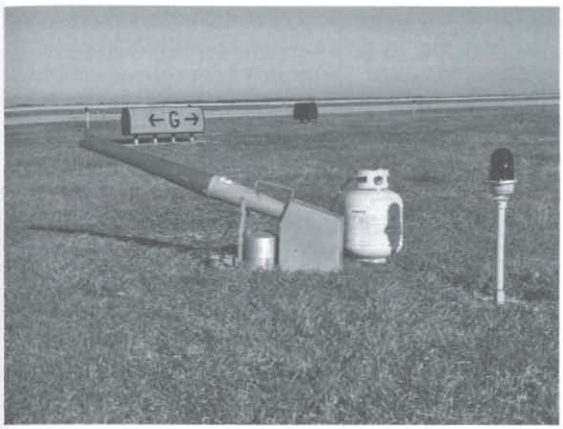

Fig. 4.2. Propane exploders have long been used to repel birds by simulating the sound of a shotgun blast, which is thought to represent a threat to birds. Photo credit: Thomas W. Seamans

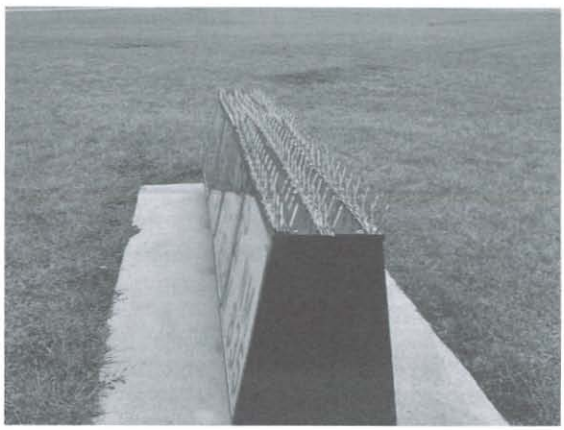

Fig. 4.3. Perching deterrents often include sharpened spikes affixed to areas attractive to birds; shown here is one such deterrent atop an airport sign. Photo credit: Todd Stewart

species-specific responses may vary depending on time of year, reproductive status, and environment in which the control tool is being used.

Tactile Repellents

Tactile repellents can be spikes of various designs, electric shock, tacky or sticky substances, moving or static wires, or chemical compounds designed to affect pain or discomfort (see also Chapter 3). In principle, all of these devices work by creating a painful or uncomfortable stimulus for the birds. Although many are listed for use against multiple bird species in numerous situations (Hygnstrom et al. 1994), few have been thoroughly tested.

Barriers

Spikes and wires in various arrangements are used in numerous situations, most often as barriers to deter birds from perching or loafing sites. Avery and Genchi (2004) evaluated the effectiveness of six different antiperching devices consisting of various arrangements of spikes, monofilament web, or a cone for deterring birds from perching. No single device was effective for all five species tested, as birds were able to find perching space that avoided contact with the spikes of some of the designs. Categorically, larger birds such as owls and vultures require different devices than do smaller species (e.g., brown-headed cowbirds [*Molothrus ater*] and fish crows [*C. ossifragus*]). Seamans et al. (2007*a*) tested an antiperching wire and a spike-style device in an aviary setting, both of which were effective against European starlings, red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), mourning doves (*Zenaida macroura*), and rock pigeons (Fig. 4.3).

Conklin et al. (2009) tested surface modifications in an effort to deter cliff swallows from nesting on highway structures. Polyethylene sheeting reduced nesting activity, although swallows were still able to build nests. However, silicon-based paint did not deter cliff swallows from nesting (Delwiche et al. 2010). Blocking ledges with sheeting or other materials placed at an angle of 45° or more also excluded birds from nesting and loafing areas (Williams and Corrigan 1994).

Chemical Applications

Reidinger and Libay (1979) reported that applying glue on perches near rice fields deterred birds for five to eight days. Belant (1993) found that roofs with tar surfaces reduced herring gull (*Larus argentatus*) nesting activity. Clark (1997) reported that starlings avoided perching on structures that had been treated with one of several dermal contact repellents that irritated the dermis on their feet, demonstrating agitation in response to 5% oil extracts of cumin, rosemary, and thyme. Furthermore, starlings avoided perches treated with

R-limonene, S-limonene, or β-pinene (Clark 1997). Products such as Hot Foot and Tanglefoot (polybutene-based repellents), although not based on the above extracts, are marketed as tactile repellents (Clark 1998*b*).

Electric Shock

The use of electric shock to keep wildlife from entering or using specific areas has seen limited field testing. However, the premise that an electrical stimulus is uncomfortable and that animals will avoid protected areas has been tested in numerous behavioral experiments with a wide variety of animals. Electric barriers of various designs have been used against white-tailed deer (Chapter 5). Smith et al. (1999) suggested using an electric fence to reduce Canada goose entrance into protected areas. Seamans and Blackwell (2011) found that an electrified perch repelled brown-headed cowbirds and rock pigeons, but that each individual had to experience the shock, as there was no apparent communication between flock members that deterred other individuals from the treated perch. Breck et al. (2006) developed an electrified repellent device that is activated by depressing a metal plate that completes a circuit. Although originally developed to deter black bears from concentrated food sources, it may deter other wildlife from spatially confined areas requiring protection. As long as an animal receives the uncomfortable sensation of an electric shock, it is likely that such a device will be effective (see Chapter 5 for further discussion). Unless a salient cue is provided with the stimulus, however, habituation to the shock could occur, as the electric impulse is not observable (Seamans and Blackwell 2011).

Compressed Air

Blasting air directly onto birds or through hoses that move rapidly and erratically also have been used to harass birds from roosting or loafing areas. When air is directed at high velocity and pressure, birds can be forced to move to alternative sites (White and Jinings 2006). In addition to the force of the air displacing some birds, the noise associated with airflow may displace birds that are not directly impacted, particularly as other flock members flee and alarm calls are sounded. Unlike instances when alarm calls alone are used and birds habituate to them (Summers 1985, Cook et al. 2008), the physical displacement of birds should reinforce the alarm calls and reduce potential for habituation.

Summary

The principles behind auditory and tactile repellents are well founded in the biology of target species and behavioral ecology. The basis for the development of these repellents is the assumption that animals will flee and avoid treated areas in response to fear-provoking stimuli (e.g., alarm calls or explosive devices), physical barriers, or methods producing discomfort or pain. However, key components of these and other repellents include context application, association of the treatment with a negative outcome, and integration with other methods.

An understanding of context relative to method efficacy is especially important to controlling wildlife in airport environments, where a variety of noises (e.g., high-decibel engines) and visual stimuli (e.g., large moving objects, flashing lights), generally thought to be repellent to wildlife, are present and tolerated by birds and mammals. Research into the ultimate fate of animals after being targeted by a repellent would allow us to discern whether we are solving a problem, perhaps through dilution, or shifting the problem to a new site. Additionally, population studies to determine ultimate effects on survival of local populations following repeated control activities may be insightful to managers dealing with groups with opposing opinions about control activities.

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