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European Starlings

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INTRODUCTION

European starlings (*Sturnus vulgaris,* Sturnidae) are native to Europe, southwest Asia, and North Africa and have successfully established populations on every continent but Antarctica (Rollins et al. 2009). In 1890 and 1891, a member of the American Acclimatization Society, Eugene Scheiffelin, released 100 starlings into New York City's Central Park, with the objective of introducing all the birds mentioned in the plays of William Shakespeare to North America (Cabe 1993). He was successful, as 16 pairs survived and reproduced prolifically. Starlings reached the Mississippi River in 1928 and were observed on the West Coast in 1942. In a little over a century, the United States (U.S.) starling population grew to approximately 200 million (Feare 1984; Cabe 1993; Johnson and Glahn 1994), but has now declined to about 140 million (Jernelov 2017). They now inhabit all of North America. Their range extends southward to the Bahamas, Central America, the Yucatan Peninsula, Puerto Rico, Jamaica, and Cuba. There are no subspecies in North America. Genetic analysis indicates that all starlings in North America descended from the New York City colony (Cabe 1993). Outside their native range, starlings are considered to be one of the most destructive invasive bird species worldwide, nominated by the Invasive Species Specialist Group, a science and policy network under the Species Survival Commission of the International Union for Conservation of Nature, to the "100 World's Worst" invaders (Lowe et al. 2004; Rollins et al. 2009).

We propose seven factors contributing to the success of the European starling as an invasive species. Starlings (1) nest in cavities that are protected from weather and predators; (2) compete successfully with native cavity-nesting birds, often taking nest sites from other birds; (3) use a wide range of nest locations, including natural cavities in trees, nest boxes, and holes in buildings, large signs or billboards, and a variety of other structures; (4) show an inclination for juvenile birds to disperse widely after fledging; (5) have bills, eye placement, and flock-foraging behaviors that are well adapted for foraging on grubs and other larvae just under the soil surface; (6) have an omnivorous diet with ability to forage in a wide array of places, including pastures, lawns, urban food and grain-handling areas, waste and landfill sites, and livestock facilities; and (7) are adapted to thrive in cold climates, typically migrating southward in winter only from north of 40° latitude, thus reducing energetic costs and risks associated with predation and foraging in unfamiliar areas.

European starlings are not protected by the Migratory Bird Treaty Act and no state laws in the United States directly protect them. State or local laws, however, may stipulate humane treatment of animals and regulate or prohibit certain management techniques such as harassing, trapping, shooting, or use of toxicants to kill starlings. Regardless, local law enforcement and government agencies should be contacted before attempting to harass starlings.

PHYSICAL DESCRIPTION

During spring and summer, starlings are glossy, dark-colored birds, but during winter, the body feathers are tipped with white speckles (Figure 15.1). In late winter, iridescent hues of green and purple become prominent in males on feathers of the head and neck. Overall, females are duller and less glossy than males. Juveniles are tannish colored until their first prebasic molt in early fall, after which they resemble adults. Starlings measure about 20 cm in length with a rounded body and short tail with females (69–93 g) smaller than males (73–96 g). Their wings (31–40 cm long) have a green or purple sheen.

Both mandible length and coloration are consistent within sexes. From late December through June, both sexes have bright-yellow mandibles measuring about 1.9 cm in length. The lower mandible of females typically has a pale-pink base, whereas males have a pale-blue base. Mandibles in both sexes become dark after June. Adult females often have a light-colored ring that surrounds the iris. In comparison, adult males typically have uniformly brown-colored eyes.

FOODS

Starlings are omnivorous, with a substantial diet of invertebrates (e.g., coleopteran [beetle] and lepidopteron [moths and butterflies]) larvae obtained from fields and

FIGURE 15.1 Female European starling (*Sturnus vulgaris*) in winter plumage. (Photo by Dr. Hays Cummins, Miami University.)

lawns, especially during nesting season and in areas where the ground remains unfrozen and moist. From midsummer to early fall, starlings forage on wild and cultivated fruits and ripening corn, especially sweet corn (Tupper et al. 2014). In the winter, particularly when the ground is snow-covered or frozen, they frequent feedlots, dairies, and urban landfills, where food is abundant and energy laden (Morrison and Caccamise 1990; Caccamise 1991). Starlings require 14–42 g per day of fatty foods in winter, but up to 400 g of berries and grapes, showing that they can efficiently digest fats, but are less efficient at processing carbohydrates (Martinez del Rio et al. 1995).

MIGRATORY PATTERNS

In southern and mid-latitudinal regions of the United States, starling flocks begin to disperse by late January or mid-February, as resident starlings start establishing reproductive territories. At the same time, migrant populations are affected by migratory restlessness, marked by changes in activity areas and longer daily movements (Kessel 1953; Dolbeer 1982). A northeastward spring migration occurs from mid-February to late March, and southwestward fall migration occurs from September to early December. Starlings are short-distance migrators that often travel only 400–500 km to reach reproductive areas; however, some travel 1000–1500 km, especially to escape heavy winter snows that cover food sources. Starlings living in the Midwest and Great Lakes region of North America regularly migrate (Kessel 1957; Dolbeer 1982), whereas starlings nesting south of 40°N rarely migrate (Kessel 1957; Dolbeer 1982; Cabe 1993). In North America, starlings sometimes associate with flocks of blackbirds (Icteridae) in winter, but are not closely related to blackbirds, which are native to North America.

LOCAL MOVEMENTS

Understanding local starling movement patterns is important in developing management options, especially when starling populations conflict with human activities and result in complaints by citizens to local wildlife officials. A variety of options are available to manage such conflicts, with the more suitable approaches depending on the numbers of starlings, the conflict location and situation, and other factors. Knowledge of starling movements, behaviors, and preferred roost sites is critical for developing effective management strategies. To that end, Homan et al. (2008, 2010, 2012, 2013) and Gaukler et al. (2012) used radio-tagging technology in a series of studies to develop a better understanding of starling movements and related activities in rural and urban areas across several states known for large wintering starling populations.

Three starling behavior studies related to daily movement patterns were conducted in the last decade around concentrated animal feeding operations (CAFOs). In one study, Homan et al. (2013) captured and radio-tagged starlings in early fall at dairies in northeastern Ohio. They found that birds visited the dairies where they were initially captured (home sites) on 85% of the days and spent 58% of each day at the dairies. Interchange of radio-tagged birds (n = 40) among dairies located 4.1–11.0 km apart was seven times less than two dairies located 1.3 km apart. In addition to using home-site roosts, these birds also used a distant roost (22 km).

In a second study, Homan et al. (2010) radio-tagged and tracked starlings using three CAFOs in the northern Texas Panhandle. They discovered that fidelity to sites of capture (home feedlots) was different among the three radio-tagged cohorts. Cohorts from Sites A and C were recorded at home feedlots on 48% and 59% of tracking days, respectively, whereas the cohort from Site B was at its home feedlot 95% of days. Use of roost sites appeared to depend on habitat composition surrounding the study feedlots. Site B was agricultural in nature with open fields and pastures prevalent near the feedlot, whereas cohorts from Sites A and C used urban areas and a small CAFO. Homan et al. (2010) concluded that higher habitat heterogeneity reduced rates of daily use of home feedlots for starlings using Sites A and C. This tends to complicate management strategies because starlings may be erratic in their daily use of CAFOs, and thus urban areas, when present, may be used as refuges by birds affected by management toxicants, leading to adverse public exposure to dead and dying birds.

Finally, Gaukler et al. (2012) monitored site use and movements of radio-tagged starlings during the winter months at two CAFOs in central Kansas. Their data showed starling site fidelity was 68% and 55% for Sites A and B, respectively. Minimal exchange (9%) occurred between Feedlots A and B, showing that starlings rarely abandoned the feedlot where they were captured, but they did observe a bird 68 km from their capture site. Gaukler et al. (2012) suggested that reducing bird numbers within the feedlot might lower the risk of spreading pathogens among feedlots.

Three studies on starling movement were also conducted in three urban areas: Omaha, Nebraska; Indianapolis, Indiana; and central New Jersey. Closely monitoring movements and activities of starlings can provide baseline knowledge needed when developing wildlife management options in urban settings. In downtown

Omaha, Homan et al. (2008) captured and radio-tagged starlings that were considered to be a public nuisance. They were able to find roost sites that were previously unknown, including a major roost that was contributing birds to the downtown roost. Some radio-tagged birds were local and never left Omaha. In comparison, other radio-tagged birds made daily trips of 5–16 m to towns and rural areas mostly in western Iowa, returning to roost in Omaha. The birds used food processing plants, grain depositories, industrial parks, feedlots, water treatment facilities, and power plants. Lawns and alleyways of residential areas also received heavy use.

In a second study in central New Jersey, Homan et al. (2012) radio-tagged starlings at three sites to help determine their movements, behaviors, and roosting sites. Biologists needed this information to help find starling carcasses after implementing a successful toxic baiting program. Starlings using a rural study site showed strong site fidelity with birds roosting on site and moving an average of only 2 km during the day. In comparison, starlings in the urban–suburban mosaic showed less fidelity, wandering 4–6 km from the banding site and seldom roosting on site. They found no interaction among roost sites by radio-tagged birds. Homan et al. (2012) predicted that most baited starlings would be found within 6 km of the bait site.

In a third study, Homan (unpublished data) captured and radio-tagged starlings in downtown Indianapolis ($n = 11$) and 5 km southwest of the downtown area ($n = 38$). They combined the data from all tagged birds and found that between December 2006 and March 2007, the farthest relocation of a starling was 19 km from the site of capture. Most of the locations were confined to areas relatively close ($\leq$10 km) to the downtown area. Major areas of daytime use were commercial–industrial properties surrounding an airport and a sanitary landfill, and the landfill itself. These sites of activity were about 6–11 km south-southwest of downtown Indianapolis. Besides roosting at several sites in the downtown area (e.g., buildings, monuments, and industrial sites), the radio-tagged birds also roosted on airport grounds. Several smaller satellite roosts were also found in the vicinity of the major roosts.

Data from these six case studies showed that starlings are adaptable and may fly considerable distances from their roost to find a rich food supply. Further, movement patterns likely are dependent on the degree of habitat heterogeneity in the area surrounding the roost site, with more heterogeneity associated with increased movement. Given these results, it seems prudent to use radiotelemetry technology to accurately assess the movements and activity areas associated with a particular roost prior to implementing management actions to reduce human–wildlife conflict. This is particularly important if use of toxic bait is considered for reducing the population.

NESTING

Starlings typically nest in holes in trees, buildings, and nest boxes that are also preferred by native bird species, including eastern bluebirds (*Sialia sialis*), purple martins (*Progne subis*), wood ducks (*Aix sponsa*), and several species of woodpeckers (Cabe 1993). Proper nest box construction reduces starling occupation. For example, most starlings cannot enter a bluebird nest box with a properly sized 3.97-cm-diameter entry hole. Starlings will evict wood ducks, screech owls (*Megascops* spp.), and other cavity nesters from nesting boxes that by necessity must have large-diameter openings. In this case, regular monitoring and nest cleaning are required. Breeding starlings have a high degree of nest site fidelity (Kessel 1957); however, young-of-the-year disperse widely to find new breeding sites. Pairings are socially monogamous, with sexual maturity occurring at one year, but first-year birds may fail in their attempts to establish reproductive territories when there are limited nest sites available and abundant experienced birds. Depending on latitude, the reproductive period lasts from late March through early July. A pair of starlings annually hatches one or two clutches, consisting of four to six pale blue eggs. Incubation is 12 days and primarily by the female. Both parents feed the nestlings a variety of invertebrates for 21 days and continue up to 10 days after the fledglings leave the nest (Tinbergen 1981; Ricklefs and Smeraski 1983; Drent et al. 1985; Craig and Feare 1999).

POPULATION DYNAMICS

The North American starling breeding population is estimated at 57 million (Partners in Flight Science Committee 2013). Starlings are prolific and have a 48%–79% rate of nest success, with 60% of adults surviving annually, but 80% of nestlings failing to survive to reproduce (Kessel 1957; Royall 1966). Mortality rates are greater in fall and winter because of migration, scarcity of natural foods, and inclement weather. Causes of mortality include disease, predation, and starvation; none of these are believed to regulate the population. Each year, 80–100 million starlings die of natural causes and 1–3 million are killed at CAFOs during winter. Parasites and extreme weather events that limit availability of invertebrates can cause mortality of adults and nestlings (Boyd 1951; Gromadzki 1980; Tinbergen 1981). The major population limiting factor, however, could be availability of nesting sites that are shared with 27 native cavity nesters (Koenig 2003). Further, Koenig (2003) suggested that the interaction of native cavity nesters and starlings is complex and warrants additional research at multiple spatial scales.

ROOSTING BEHAVIOR

During summer, fall, and winter, starlings gather in roosts that may range in size from a few hundred to over 10 million birds. Roosts sometimes include an abundance of blackbirds and smaller numbers of other birds (e.g., robins, *Turdus migratorius*; northern cardinals, *Cardinalis cardinalis*) (Heisterberg et al. 1990). Starlings typically leave their roosts at sunrise, departing on a direct route for daytime foraging and resting areas (i.e., activity areas) that are often within 24 km of the roost, but can be up to 50 km away (Dolbeer 1982). Activity areas average 7–10 km^2 and usually are centered on food sources including landfills, granaries, food processing plants, and CAFOs. The majority of starlings arrive at their activity areas within a couple hours of sunrise.

By late afternoon, starlings begin to return to their roost. Returning flights can take up to two hours to complete, with several foraging stops along the way. Starlings may pass over smaller roosts, some lying closer to the main areas of daily activity, to reach larger roosts lying farther away. Flight lines leading toward the roost become obvious about an hour before sunset. Flocks will often stage near the roosting site using wooded areas, power lines, bridges, industrial superstructures, and other sites with plentiful perching substrates. Forays to nearby open grounds occur during the staging period, with birds briefly feeding. Entry into the roost begins about 30 minutes before sunset. Starlings may use a large roost consistently for weeks or months.

Night roosts can be in rural, urban, and suburban venues where shelter from the wind and cold temperatures can be found on tall buildings, bridges, conifer stands, tree groves, and vegetated wetlands (Homan et al. 2008, 2010, 2012). Urban roosts typically have from 10,000 to 30,000 starlings. Morning departures from urban roosts are difficult to track because starlings leave at first light and break into smaller flocks often going in several directions. Urban starlings use surrounding industrial parks, recreation areas, granaries, landfills, and suburban areas throughout the day. Very few starlings remain within the urban area proper. Outlying agricultural habitats within 40 km of an urban roost may be used. Upon returning to an urban roost, starlings stage in secluded industrial areas and commercial areas within a few kilometers of the roost site.

Urban roost sites in city centers may be spread across several urban features, including multistoried buildings, landscaping (especially evergreens), monuments, signage bracing, superstructures, and overpasses (Homan et al. 2008, 2012). Urban roosts are often satellite roosts, lying within a few kilometers of a bigger, main urban roost that serves as the primary roost source. Main roosts are usually located in secluded urban areas where public access is limited, but may be less than 8 km from a roost in the city center. Birds switch occasionally between satellite roosts and the main roost. Main roosts are found in industrial parks, landscaped commercial complexes, abandoned buildings, recreation areas, railroad yards, woodlots, wetlands, bridges, and wooded buffer zones. Main roosts in urban areas can harbor more than 100,000 birds and be difficult to find. For example, a 100-yard section of a four-lane railroad overpass in Omaha, Nebraska, held approximately 70,000 starlings roosting on the concrete support structure and cable pipes underneath the overpass during January (Jeff Homan, pers. comm., U.S. Department of Agriculture [USDA] Animal and Plant Health Inspection Service [APHIS]). Urban roost sites are devoid of birds throughout the day; however, excretal whitewash on perching sites will indicate that a site could be a major roost.

In suburban areas, starlings roost in conifer and deciduous tree stands in residential and business areas, tree groves in parks and abandoned lots, and in vegetated lowlands (Homan et al. 2012). Suburban roosts are much smaller than urban roosts, consisting of just a few hundred birds. Although suburban roosts are usually smaller than urban roosts, many of them can be scattered throughout the suburban landscape.

In agricultural landscapes, starlings may roost at wildlife refuges, game management areas, private wetlands, and abandoned or accessible buildings such as aircraft hangars and agricultural equipment storage buildings. Wetlands with dense stands of emergents can be a preferred habitat for mixed-species flocks of roosting birds, including blackbirds, robins, and starlings. Thick stands of evergreens also are used. Roost sizes in agricultural landscapes can exceed one million birds during winter and attract flocks from over 50 km. Starlings may also use CAFOs as roosting sites. A CAFO can host a few hundred to a few thousand roosting starlings, depending on its size. Although starlings that roost at CAFOs may also feed there, they may, alternatively, leave the CAFO shortly after sunrise and return in the afternoon.

AGRICULTURAL IMPACTS

Starlings damage apples, blueberries, cherries, figs, grapes, peaches, and strawberries by partially or wholly eating the fruit (Nelms et al. 1990; Tobin et al. 1991; Tracey et al. 2007; Lindell et al. 2012; Anderson et al. 2013) (Figure 15.2). Starlings can begin to damage fruit in May, with early damage done by aggregated family groups that can number 1000 birds. Tobin et al. (1991) assessed bird damage to cherries in New York, and found that early ripening cultivars in the study area suffered the most bird damage and, therefore, might warrant the grower's maximum attention. Two decades later, Lindell (2015) conducted quantitative damage surveys in Michigan and found that bird damage to cherries was highest during low-yield years and in early-ripening varieties (Figure 15.3). Further, damage was highest under power lines, at field edges, near night roosts, and in areas with little human activity. Large fruit is more likely to be partially damaged by pecking and slashing (Tracey et al. 2007). Pecked fruit reduces the quality of the fruit and increases vulnerability to diseases and crop pests (Pritts 2001). Pimentel et al. (2000) estimated that yearly starling damage to fruit and grain crops was US$800 million, based on estimated losses of US$5/ha.

In 2012, Anderson et al. (2013) conducted a survey of Honeycrisp apple, blueberry, cherry, and wine grape growers in California, Michigan, New York, Oregon,

FIGURE 15.2 Bird damage to sweet cherries in late May 2012 in Michigan. (Photo by S. Wieferich.)

FIGURE 15.3 Quantitative damage assessments are needed for economic analyses. (Photo by George M. Linz.)

and Washington to estimate costs of bird damage. Growers ranked starlings either first or second among bird species believed responsible for damaging the five crop types in the survey and estimated that birds annually damaged US$70 million of grapes. Grape producers ranked starlings first among three major grape depredating bird species, which included American robins (*Turdus migratorius*) and wild turkeys (*Meleagris gallopavo*). Other results from the 2012 survey of producers indicated damage from birds of US$51 million to sweet cherries and US$33 million to blueberries. Overall, Anderson et al. (2013) estimated that bird damage costs per hectare ranged from US$104 in Oregon tart cherries to US$7267 in Washington Honeycrisp apples. Aggregate bird damage in the five crops and states was estimated at US$189 million.

In the United States, starlings are not considered serious pests in cereal crops or oilseed crops. Even so, producers of sweet corn in several midwestern states annually complain about starling damage during the ripening period, but the amount of damage to sweet corn caused by starlings has not been documented. Starlings also will pull sprouts of some grain crops, but damage appears to be minor and intermittent.

FEEDLOT AND DAIRY IMPACTS

Large flocks of starlings that sometimes number over 100,000 exploit the resources found at CAFOs during late fall and winter (Figure 15.4). Starling use of CAFOs varies greatly, and ease of dispersing flocks appears dependent on weather, especially

FIGURE 15.4 Starlings at a cattle feedlot. (Photo by J. Thiele.)

temperature and snow cover (Linz et al. 2007). Damage to livestock yards and dairies is greatest during winter months because insects and other natural foods are typically unavailable (Linz et al. 2007). Open feeder systems are ideal for starlings because they provide access to livestock rations and easy escape from human and predator threats. Damage estimates at CAFOs showed that over a period of 60 days in the winter, a flock of 1000 starlings can eat about 1.5 tons of cattle feed, representing a loss up to US$0.92 per feedlot animal (Depenbusch et al. 2011). About 250,000 starlings that were using a feedlot in Kansas increased the cost of feeding a ration of steam-flaked corn by $43 per heifer over a 47-day period between mid-January and March. Costs in lost production (i.e., livestock weight gained per unit feed consumed) over this period was $1.00 per animal. In 1999, three feedlot operators in Kansas estimated a loss of $600,000 from bird damage alone (U.S. Department of Agriculture 2000). Data reported in 1968 from Colorado feedlots indicated the cost of cattle rations consumed during winter by starlings was $84 per 1000 starlings (Besser et al. 1968). With the current cost of feed, the associated losses would certainly be much higher.

In addition to causing economic losses due to eating cattle food, wild birds harbor microorganisms, including *Campylobacter*, *Listeria*, *Salmonella*, Shiga toxin-producing *Escherichia coli* (STEC), *Yersinia*, and *Cryptosporidium* (Feare 1984; Gautsch et al. 2000; Clark and McLean 2003; LeJeune et al. 2008). Starlings have been implicated as sources of pathogens causing disease and economic losses to livestock producers (LeJeune et al. 2008; Carlson et al. 2010, 2011, 2012; Gaukler et al. 2012). Avian salmonellosis (primarily, *Salmonella enterica*) has been documented in starlings and is transmissible to humans, poultry, and livestock (Feare 1984). Starlings also carry *Mycobacterium avium paratuberculosis*, which causes Johne's disease in cattle (also known as paratuberculosis) (Matthews and

McDiarmid 1979; Corn et al. 2005). The bacteria are excreted in feces and milk. Johne's disease costs the United States dairy industry $200–$250 million annually (Ott et al. 1999; Beard et al. 2001). STEC is another disease that might be transmitted by starlings to cattle. In the cattle industry, annual costs of illnesses related to *E. coli* STEC exceeded $267 million (NCBA 2004). Humans may get this disease from consuming tainted food products, especially ground beef. Further research is needed to better clarify the role of starlings and other factors in the transmission or prevalence of disease.

Carlson et al. (2011) refined our understanding of the impacts starlings have on disease transmission to cattle. They conducted a study where starling numbers were reduced using the toxicant compound DRC-1339 (3-chloro-4-methylaniline hydrochloride, also 3-chloro-p-toluidine hydrochloride, 3-chloro-4-methylaniline) to evaluate relationships between starlings and *Salmonella enterica* within CAFOs. Within the starling-reduced CAFO, compared to a control CAFO, epidemiological evidence of *S. enterica* disappeared from feed bunks and substantially declined within water troughs following reduction operations. Further, they found that *Salmonella enterica* contamination of both cattle feed troughs and water troughs was significantly related to numbers of starlings. Carlson et al. (2012) also showed that the interaction between European starlings and ambient air temperature explained the occurrence of *S. enterica* in cattle feed. Specifically, the risk of *S. enterica* contamination of cattle feed by starlings was greatest when winter temperatures were highest (≥10°C). Thus, they concluded that the risk of *S. enterica* contamination of cattle feed by starlings will be worst on the few winter days when daytime high temperatures are above freezing and large numbers of birds are present. Because these conditions will be most common in the late winter and early spring, Carlson et al. (2012) recommend that starling control operations (population control, habitat management, exclusionary devices, and bird repellents) on feedlots and dairies be conducted as early in the winter as weather conditions allow. We caution, however, that multiple biological, environmental, and facility management factors could influence frequency and duration of *S. enterica* in cattle feces, including herd size and age, manure management and disposal, feed storage, access to bacterially contaminated waters, season, and influx of new cattle.

STEC and *Salmonella* spp. are two important foodborne pathogens in the United States that cause more than one million clinical illnesses each year. Direct medical costs resulting from infections of *E. coli* and *Salmonella* spp. are about US$400 million per year. Other starling-borne diseases that can infect humans and domestic fowl include *Chlamydophila psittaci,* a lethal bacteria that may cause avian chlamydiosis and respiratory psittacosis in humans (including chlamydiosis, psittacosis, ornithosis, parrot fever), usually from inhaling spores that live in dried feces (Grimes 1978; Grimes et al. 1979; Andersen et al. 1997; Conover and Vail 2015).

Economic impacts of avian-borne disease on herd health are substantial and likely annually exceed US$1 billion (Pimentel et al. 2000, 2005). Annual costs in the United States from gastrointestinal diseases in livestock caused by *E. coli* spp. (e.g., scours) and *M. avium* (Johne's disease) are estimated at US$600 million. The average cost of an outbreak of *Salmonella* among dairy cattle is US$4000 per farm per incident. Salmonellosis is a far more common affliction in livestock than either

E. coli or *M. avium*, and annual costs of salmonellosis probably exceed US$600 million. A survey of dairy producers in Pennsylvania in 2009, suggested that veterinary costs at dairies with flocks of starlings numbering between 1000 and 10,000 birds were 38% higher than at dairies without starlings (US$91 vs. US$66) (Shwiff et al. 2012). Although not statistically different, this result is suggestive and warrants further attention.

Starling fecal matter can pass transmissible gastroenteritis (TGE) to swine. For example, during the winter of 1978–1979 in Nebraska, starlings served as apparent vectors for an outbreak of TGE that caused the loss of 10,000 swine in one month (Pilchard 1965; Bohl 1975; Gough et al. 1979; Johnson and Glahn 1994). At current market value, this loss might be over US$1.0 million.

Histoplasmosis, a noncommunicable fungal disease of the lungs caused by *Histoplasma capsulatum*, can be contracted by humans, especially if they breathe spores in disturbed dust at starling roosts (DiSalvo and Johnson 1979; Storch et al. 1980; Chu et al. 2006). Most histoplasmosis cases occur in the mid-Atlantic, central, and southeastern states with 37 cases requiring hospitalization per 1 million persons (Chu et al. 2006). Most infections are asymptomatic and subclinical; between 50% and 80% of people who live in areas where *H. capsulatum* is common show antibody evidence of exposure, yet only 5% develop symptoms severe enough to be categorized as clinically sick. Symptoms include fever, cough, weakness, headaches, and muscle aches. Excreta need to accumulate for more than three years before fungal spore densities reach levels high enough to affect human health. Bird droppings must dry out and then be rewetted before spores can form. Although *H. capsulatum* is associated primarily with soils, it can be found growing inside of and around buildings. In 1990s, histoplasmosis was reported at a manufacturing facility in Nebraska used by starlings (J. Hobbs, Nebraska USDA APHIS Wildlife Services, pers. comm.). People at highest risk of exposure, however, are those working in agriculture, particularly poultry, or those who come in contact with bird or bat roosts that might have been abandoned a decade or more prior to disturbance (DiSalvo and Johnson 1979).

Finally, West Nile virus (WNV) was confirmed in North America in 1999 and since then has spread across the Unietd States. This is a serious and life-threatening disease to humans and wildlife. Sullivan et al. (2006) found that red-winged blackbirds are WNV hosts and can disperse diseases along their migratory routes. The role of starlings in dispersing WNV is unknown, but starlings can act as hosts for the virus (Bernard et al. 2001), and thus may be involved in spreading the disease among vertebrates including, humans, horses, and birds.

URBAN IMPACTS

Starlings sometimes roost in urban environments causing residents to voice concerns about the noise, smell, and unsightliness of starling roosts. Their excreta dirty plate glass, sidewalks, city monuments, landscaping, facades, and entryways, and create unsanitary conditions. Pedestrian shoes easily transfer feces, which potentially could harbor diseases, into buildings. Large deposits of excreta corrode metals, including support structures of buildings and bridges.

Maintenance costs can be substantial when large numbers of starlings roost in towns and cities. In one situation in Omaha, Nebraska, contracts for a single cleaning of windows of a large skyscraper were about US$50,000 (J. Thiel, Nebraska USDA APHIS Wildlife Services, pers. comm.). Finally, urban and suburban starlings commonly use exhaust vents of buildings as nesting sites. Nests can clog vents and create unsafe venting conditions for buildings.

Starling roosts near airports pose an aircraft safety hazard because of the potential for birds to be ingested into jet engines (Barras et al. 2003). Starlings have caused some of the most disastrous bird–aircraft strikes because of their body density and flocking behavior. For example, in Boston in 1960, starlings caused a crash that killed 62 people when they were ingested into engines of a Lockheed Electra aircraft on takeoff. Between 1990 and 2014 in the United States, starlings were identified in 3663 strikes on military and civilian aircraft (Dolbeer et al. 2015). Total costs were estimated at US$7 million, but no human fatalities were recorded.

INTEGRATED STARLING MANAGEMENT

Frightening Devices and Repellents

Humans have used harassment tactics to protect resources from birds for thousands of years. Simple devices such as human effigies (scarecrows) and loud noises from sticks clanging together have now been supplemented with animated scarecrows, recorded distress calls, propane exploders, battery-operated alarms, pyrotechnics (e.g., bangers, shell-crackers, and screamers), lights (for roosting sites at night), hawk kites, flashing metal coated tape, and ultrasonic devices (Conover 2001; Berge et al. 2007). Effectiveness of these devices varies; for example, ultrasonic devices are not effective because, with few exceptions (e.g., South American oilbirds, *Steatornis caripensis*), birds do not hear ultrasonic sounds. Propane exploders and pyrotechnics are the most popular frightening devices because of relatively low purchasing and operating costs. Outfitted with automatic timers that turn on and off each day, exploders are useful for reducing habituation, coordinating timing of the explosions with periods of heavy foraging, and may help in preventing noise complaints from neighbors. Pyrotechnics have an advantage over propane exploders when larger, more inaccessible areas need protection. In all cases, local law enforcement should be contacted for any necessary permits before using these devices.

Distress calls and alarm calls are used often in combination with visual stimuli (e.g., raptor decoy). Achieving adequate broadcasting coverage often requires expensive electronic systems; consider their cost when defending a large area against starlings. For example, Berge et al. (2007) conducted an evaluation of alarm/distress broadcast calls and found that when incorporated into a bird management plan, these devices helped reduce bird damage. These authors calculated that, assuming average yield and price for the Pinot noir vineyards (6.7 tons/ha, $2200/ton), and considering the cost of the broadcast units ($230 per unit), the estimated savings for adding broadcast calls to conventional methods was $700 per ha. These nonlethal tactics generally produce short-term relief unless their intensity and location are varied.

Using an integrated approach that combines auditory, gustatory, and visual senses is an accepted strategy to thwart habituation. Shooting live ammunition is sometimes used as a stand-alone dispersal technique and to reinforce other scare devices rather than as a method for population management (Bomford and O'Brien 1990). Shooting is labor intensive, requiring diligence and consistency. Starlings, especially during winter, focus their daily activities in relatively confined areas where pursuit and harassment with firearms is practicable. If time is limited, employ frightening devices in early morning and late afternoon, when birds are most actively feeding.

The compound 4-aminopyridine (Avitrol®), a restricted-use chemical frightening agent, is sometimes used (Avitrol Corporation 2013). Avitrol® baits are usually placed on grains or pellets and are diluted with untreated grains or pellets. Birds that eat the treated baits behave erratically and give warning cries that frighten other birds from the area. Birds that eat a 4-aminopyridine–treated particle usually die, as might hawks and owls that swallow grain bait while eating an affected or dead bird.

Bird repellents such as methyl anthranilate (MA) are trigeminal irritants that can be used to repel starlings from feedlots and fruit production facilities (Avian Enterprises, LLC. 2015). In birds, MA acts as a chemosensory repellent that causes irritation to pain receptors associated with the trigeminal nerve in the mouth and nostrils of birds. MA is registered for use on numerous fruit and grain crops. At relatively high concentrations (5000 ppm [0.5%] to 10,000 ppm [1%]), MA is a reliable sensory repellent. MA requires multiple applications because it rapidly degrades in the environment, solubilizes in rain, and requires strong concentrations to reach irritation thresholds. Although multiple applications might be needed, a positive cost-benefit ratio might be achieved when protecting high-value crops, such as cherries, blueberries, grapes, and sweet corn. The majority of field studies with MA applications to fruits, however, have shown either no repellency effect or very short-term effects. On the other hand, variability among test sites often encountered during field experiments makes quantitative assessments challenging.

Polybutenes, formulated under various trade names, are sticky materials that might discourage starlings from roosting on ledges and beams. However, labor costs and longevity might preclude using these compounds on large structures.

Exclusion

Nylon or plastic netting can be used to exclude starlings from barns, ledges of multistoried buildings, undersides of roof beams, rafters, and other perch sites. Although highly effective, the initial investment for nets is high and the nets must be monitored for tears and general degradation. Starlings can be excluded from buildings by installing 10-in.-wide door strips made of either heavy plastic or rubber. Install the strips with gaps less than 5 cm to prevent starling entry into the building. Other tactics include placing 45°-angle coverings of wood, metal, or Plexiglas® over ledges to prevent starlings from perching, nesting, or roosting. Metal protectors or porcupine wires are available for preventing roosting on ledges or roof beams.

Protection of ripening fruit is a high-priority agroeconomic issue for growers. Netting might be cost-effective where bird damage is expected to be high, and particularly cost-effective for preventing damage to high-value grapes (Tobin et al. 1991;

FIGURE 15.5 Netting is effective for protecting high-value crops, such as grapes. (Photo by S. Wieferich.)

Berge et al. 2007; Tracey et al. 2007) (Figure 15.5). Assuming a 10-year life span, the cost of labor, netting, and construction of an application-removal system for large-area netting is about US$1000/ha per year. Wine grapes, which can be valued at nearly US$19,760/ha for some varieties, may justify the use of large-area netting.

Lethal

Reducing the numbers of starlings to a tolerable level is among the variety of options available to manage human–starling conflicts, with the more suitable approaches depending on the numbers of starlings, the conflict location and situation, and other factors. Starlicide Complete™ (EPA Reg. No. 67517-8) is a commercially available pesticide registered for controlling starlings in CAFOs. Starlicide's active ingredient is compound DRC-1339, a slow-acting toxicant originally developed for controlling starlings around livestock and poultry operations (DeCino et al. 1966; Royall et al. 1967; West 1968; Carlson et al. 2012). Compound DRC-1339 Concentrate (also known as Starlicide Technical®) is a powder that can be custom-mixed with several bait substrates, including cracked corn, rolled corn, distiller's grain, milo, rolled milo, poultry pellets, raisins, and French fries. Compound DRC-1339 Concentrate is for use only by USDA-WS employees or those under their direct supervision.

Bird species exhibit a range of sensitivity to DRC-1339 (Eisemann et al. 2003). Starlings are highly sensitive to DRC-1339, with a single treated bait causing death in one to three days. Gulls, icterids, and corvids also are very sensitive to this toxicant (Eisemann et al. 2003). DRC-1339 is a slow-acting toxicant, so dead starlings are generally not found at the bait site. Baited birds can behave normally for several hours after ingesting treated bait, thus most birds succumb to the toxic effects in a night roost or at staging areas, often near water. Poisoned starlings are not dangerous to scavengers or predators as the chemical is quickly metabolized and excreted (Eisemann et al. 2003).

When the best solution is to reduce starling numbers with DRC-1339–treated baits, it is prudent to quickly find and properly dispose the carcasses to ease public angst over discovering carcasses. To that end, USDA WS policy requires that employees notify local government agencies (e.g., city, township, state government officials) of potential lethal management actions (U.S. Department of Agriculture 2009).

Sodium lauryl sulfate (SLS) is a surfactant that can be used only by USDA WS personnel or official cooperators for managing roosts of pest bird species, including starlings. SLS destroys the insulating properties of feathers, causing hypothermia. Generally, this technique has limited effectiveness because of the specific weather conditions needed and equipment logistics. SLS is for use only in winter conditions (<41°F) on upland roosts and cannot be sprayed over bodies of water or in areas of direct runoff. Wetted birds die as soon as 30 minutes after spraying with SLS. Before using SLS, the roosts must be observed for nontarget species. Field trials with SLS were conducted in southeastern Missouri between 2005 and 2007, using ground-based spray systems (Byrd et al. 2009). A pump delivered water at 6 gallons per minute per sprinkler head. Up to 12,000 starlings and 3000 blackbirds were killed at a 50,000-bird roost during a single SLS spray using four sprinkler heads. Other sprays were not successful. Poor results were obtained in three of eight roost sprays conducted in southeastern Missouri, attributed to low water quality that decreased the effectiveness of the SLS and pump malfunction.

Trapping starlings is time consuming, and success varies with time of year, population size, and amount of area needing protection. Starlings seem particularly easy to capture in the winter when food resources are often limited. For example, Thiele et al. (2012) captured nearly 5000 starlings in the greater Omaha, Nebraska area during winter with modified Australian crow traps and drop-in decoy traps stocked with decoy birds. Part of their success was attributed to providing good care for the decoy birds, including providing fresh food, water, and sheltered perching sites. They also replaced their decoy stock with newly caught birds periodically. Use of cage traps, however, at feedlots and dairies may not be cost-effective because of the comparatively low economic value of livestock feed and the large numbers of starlings that may be present. On the other hand, trapping starlings might be cost-effective at vineyards, fruit orchards, and berry farms for preventing starling damage early in the crop season because starlings, especially juveniles, are not trap-wary (Conover and Dolbeer 2007). Decoy traps allow wildlife managers and growers to reduce the numbers of depredating target species while greatly reducing the risks of taking nontarget species.

Habitat Modification

On-site management practices are important for mitigating starling damage at CAFOs and in urban settings. The primary goal is to limit the availability of food, water, and roosting sites. Where starlings are roosting, one option is to remove or thin perch sites used by starlings. Day roosts and night roosts may include tree stands, dense vegetation (e.g., evergreens) on lee sides of buildings, and emergent vegetation growing in wetlands and low-lying areas. Thinning young stands by 30%–50% may disperse roosts or prevent roosting. Pruning side branches of roost trees discourages roosting. Limit heat leakage from buildings, especially tall buildings with perch sites. Aquatic herbicides are commercially available to thin dense stands of emergents (Linz and Homan 2011) where applicable. In some regions, wetlands and dense thickets of bottomlands are highly preferred winter roosting sites. These sites may be located several kilometers from sites used for daily activities.

Cultural Practices

Both CAFO operators and urbanites can benefit from removing food sources and cleaning up spilled grains and garbage. Timed automatic-release feeders can be a good option to avoid parts of the day when starlings are likely to be foraging. For example, switch to afternoon or nighttime feeding schedules, if possible. Eliminate unnecessary pools of water; also, lower water levels in water containers to prevent starlings from drinking and bathing. Use feed with large forms of more than 0.5-in. diameter that starlings have difficulty swallowing. Feed losses to starlings can be nearly eliminated by using 0.75-in. × 3-in. extruded pellets.

Starlings naturally fear birds of prey. Thus, falconers can sometimes effectively move birds out of crops. It is labor intensive, requiring the falconer to be on site. It is expensive, costing more than US$500 per day. Most falconers prefer to use their birds in fairly open habitats, where chances of injuries to the falcons are low. Blueberries and other types of high-value fruits with shrubby habits are more fitted to falconry than treed fruits. Installation of nesting boxes and artificial perches for birds of prey at orchards, vineyards, and CAFOs has the potential to provide a low-cost alternative to falconry.

Determining Cost-Benefits

A rule of thumb for evaluating the economic feasibility of a management method involves comparing pretreatment costs of bird damage to the amortized costs of deploying a treatment method, and then assessing potential savings gained from applying the treatment. The resulting savings must be greater than the depreciated costs. A cost-benefit ratio of 1:2 or greater should be expected. Assuming all crop inputs were made before damage occurred, a general formula for agricultural and fruit crops would be as follows (using acres as the areal unit):

$$(A \times B + C/D) - ([A \times B] - [A \times E]) > F$$

where

A = economic production per acre (i.e., price received at sale)
B = proportion of anticipated bird damage under no treatment
C = amortized cost of using method (including labor, equipment, and maintenance)

D = acres of crop protected by method
E = proportion of damage after implementing treatment
F = depreciated value of method or other accounting for lost value and function

RESEARCH NEEDS

The reproductive biology of starlings is well documented, but data on regional migratory patterns and local movements in relation to feedlots, diaries, and urban areas are needed. These data are especially important as the climate changes and starlings (and blackbirds) potentially begin using more northerly winter roost locations (Strassburg et al. 2015). We speculate that these changes could compound conflicts with human endeavors, including issues related to airport safety and disease transfer among CAFOs. Scientists for USDA WS, in collaboration with North Dakota State University, The Ohio State University, and others, are beginning to gather these data. This information will be useful for developing risk assessments and economic impact models that will help determine the overall consequences of starlings. Additional efforts are underway to develop and evaluate better bait carriers for the compound DRC-1339. Better information is needed to determine the role of starlings along with other factors in the prevalence and transmission of diseases. Research that would compare population dynamics and limiting factors of starlings in Europe to those in North America would be instructive, as would research on the potential for enhancing bird predators as a starling management approach (Gaston 2010; Kross et al. 2012). Finally, research to better understand and manage the complex interactions between starlings and native cavity nesters at multiple spatial scales is warranted (Koenig 2003).

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