March 1991

Bird Hazing and Frightening Methods and Techniques (with emphasis on containment ponds)

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March 29, 1991

BIRD HAZING AND FRIGHTENING METHODS AND TECHNIQUES

This volume of detailed information was prepared as part of a larger, more encompassing project under contract with California Department of Water Resources (Contract Number B-57211)

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The statements, conclusions, and recommendations in this report are those of the authors and do not necessarily reflect those of the California Department of Water Resources. The mention of commercial products, their sources, or their use in connection with activities reported herein is not to be construed as either actual or implied endorsement of such products, nor is criticism implied of similar products that are not mentioned.

INTRODUCTION

Our primary purpose in preparing this overview of bird-hazing or frightening methods and techniques is to provide the owners and operators of agricultural evaporation ponds with all possible information on hazing to minimize bird use of the ponds and reduce their exposure to possible contamination from accumulated substances, such as selenium.

While our main objective was to assist pond managers, our coverage of bird hazing is intentionally broad enough to be highly relevant to protect many agricultural crops and some aquaculture facilities from bird depredations, and to reduce bird numbers at airports where the potential for bird-aircraft strikes is high. The discussion of many hazing options may be also valuable for use in repelling birds from accidental oil spills and to repel birds, specifically waterfowl, from disease-contaminated water.

Much of the contents of this manual is derived from researching the available literature. However, this is intermixed with the personal knowledge of the authors based on their education, laboratory and field research in managing bird problems, and experience in applied bird control, especially in the area of pest bird management related to agricultural production.

In bringing together all of the best information, the pros and cons of 18 hazing methods and techniques are discussed along with their effectiveness when used for common bird problems. Unfortunately, little has been published specifically on the hazing of birds from toxic containment ponds, and even less on hazing of shorebirds. Much of the data, however, can be bridged from bird problems of agricultural production to pond situations.

The available equipment and material used in the hazing approach is described along with how it functions and methods of operation. Various hazing methods are more efficacious for some bird species than others, and these are detailed when known.

Some methods have far more potential for use at evaporating ponds than others; but knowing all approaches opens the door to different options or combinations of methods. Sufficient information is provided so that a pond manager can assimilate adequate knowledge of a technique, and the biological principles involved on how and why it works, to proceed in setting up a hazing program.

Variety and novelty are the key issues in successful hazing because some members of the bird population may habituate to the use of the same technique over long periods of time, especially if only one or two hazing methods are being used area-wide.

Innovations in bird-hazing strategies are generally derived from a willingness to move away from the more traditional methods and explore new approaches. If this volume, even in a small way, encourages exploration into novel strategies or combinations, our efforts will have succeeded.

In addition to the 18 hazing or frightening methods discussed, we have included a section on the use of overhead wires as a psychological barrier to some species. Complete exclusion of birds from ponds with the use of netting is also included. Neither of these methods is considered hazing but rather an exclusionary method. Although expensive, they are effective approaches to some waterbird problems. The techniques are important and useful enough to make their inclusion essential.

We have not included bird exclusion or repelling methods and techniques commonly used in urban, suburban, and industrial situations, which most often involve how to keep birds off or out of buildings or other man-made structures. Thus, sharp projections, tacky substances, and curtains that prevent birds from entering active doorways are deliberately not included. The use of chemical repellents such as Avitrol®, and chemosterilants such as Ornitrol® to inhibit reproduction, is also excluded as well as discussion of lethal avicides and trapping. None of these is applicable to minimizing bird use of evaporation ponds where the protection and welfare of the bird populations are of primary concern.

We have provided the sources of some materials and equipment because it is essential to know where to obtain the needed supplies and equipment if hazing approaches are to be explored or routinely used. Intelligent selection of the best or most appropriate supplies and equipment is possible only if the potential user is aware of what is available and can discuss product characteristics with suppliers.

The mention of commercial products or trade names and their sources is not to be construed as either actual or implied endorsement of such products, nor is criticism implied of similar products not mentioned. Materials and equipment should be used as directed by the manufacturers or distributors and in accordance with any laws or regulations that might govern their use or their use for hazing certain bird species. No comments made or implied herein should be construed as circumventing these issues.

Sources of various materials and products often change, with some suppliers going out of business while new ones appear. Manufacturers and distributors sometimes move or are bought out, and their addresses and phone numbers changed. For these reasons we cannot be certain that the sources provided are currently accurate as to addresses or what they supply. We apologize for any errors and omissions.

Pertinent references are cited for those who may wish to explore the subject further or obtain greater details. References are listed at the end of each section to make it easier for the user to quickly refer to those most significant. Where a section contains many articles, the most important have been designated as key references.

ACKNOWLEDGEMENTS

Postgraduate researcher William A. Erickson deserves much of the credit for his library research and for the preparation of the early drafts of the majority of the sections. We are also grateful to Rosemary A. Stefani, Kevin Hall, and Garrett Hulsizer for the early drafts of several sections. Our thanks to Ann E. Koehler for the library research conducted while employed on a related Sustainable Agriculture project; her efforts contributed significantly to this project also. Our sincere gratitude to Dorothy E. Beadle for her helpful editing and the typing of the manuscript. We are very much indebted to Walter E. Howard for the use of his extensive reference collection on vertebrate pest control, which was invaluable in assembling this overview. This compilation was principally funded by the California Department of Water Resources with minor funding from the University of

California Sustainable Agriculture and IPM Programs. Stephen A. Ford of the Department of Water Resources was highly instrumental in the initiation of this project, for which we are most appreciative. The excellent cooperation received from Water Resources, especially from Dale K. Hoffman-Floerke, made the project a pleasure.

GAS-OPERATED EXPLODERS

Gas-operated exploders, occasionally referred to as gas or propane cannons, have been commonly used to repel pest birds in agriculture and around airports since the late 1940s (National Pest Control Association 1982, Archiron 1988). These devices produce extremely loud, intermittent explosions, usually at fixed 1- to 10-minute intervals as desired, that exceed the blast of a 12-gauge shotgun. Present-day exploders consist of a bottled gas supply, separate pressure and combustion chambers, an igniting mechanism, and a barrel to direct and intensify the noise of the explosion. A regulator at the gas supply can be manually adjusted to vary the interval between explosions, depending on the situation and bird species present. Early gas exploders worked by igniting a mixture of air and acetylene produced by dripping water onto calcium carbide powder (Wright 1963, Frings and Frings 1967). They were sensitive to temperature changes, however, and required daily maintenance to remain operational (Stephen 1961, Zajanc 1962). Carbide exploders were eventually replaced by more reliable models similar in action but operating with bottled acetylene gas, butane, or propane. Today most exploders on the market operate with bottled propane gas. A standard refillable 20-lb propane gas tank produces about 12,000 explosions.

The effectiveness of gas exploders depends on a variety of factors, including the species and numbers of birds present, availability of alternative sites for repelled birds, the density of exploders, interval between explosions, and wind conditions (Blokpoel 1976, Vaudry 1979, National Pest Control Association 1982). Exploders often provide adequate to good protection, especially when supplemented with other bird-scaring devices, such as scarecrows, pyrotechnics, biosonics, and firing of live ammunition (Zajanc 1962, DeHaven 1971, Pierce 1972, Bivings 1986). Hunted birds (e.g., waterfowl species) that associate danger with loud noise and migratory species usually are more effectively repelled than are resident species firmly established at a site. As with most bird-hazing devices, habituation can be a problem when using gas exploders. Birds may become accustomed to the loud blasts after only a few days. To alleviate habituation, exploders should be moved periodically (e.g., every 1 to 3 days) within the area needing protection (Pierce 1972, Salmon and Conte 1981, Bivings 1986). Stationary units can be elevated on a platform or tripod and faced downwind to increase their range (Besser 1978, Kopp et al. 1980). Mounting units on rotary tripods enables them to rotate after each blast, thereby projecting blasts in all directions if desired. Portable units mounted on pick-up trucks also have been used effectively in some agricultural settings (Mitchell and Linehan 1967). The interval between explosions can be changed periodically to delay or minimize habituation. Double-shot models also are marketed.

EFFECTIVENESS IN AGRICULTURAL SETTINGS

Gas exploders are widely used to protect agricultural crops from bird depredations. They have been useful for reducing blackbird damage to crops such as corn (De Grazio 1964, Dolbeer 1980), rice (Pierce 1972), and sunflower (Besser 1978). They are generally considered to work best when reinforced with other bird-frightening devices (De Grazio 1964, DeHaven 1971, Kopp et al. 1980). In agricultural fields with moderate bird pressure, one exploder can generally protect about 10 acres of crop from blackbirds (Pierce 1972, Vaudry 1979, Dolbeer 1980), although DeHaven (1971) states that up to 25 acres of rice can be protected if other devices are used along with the exploders.

Besser (1985) found that exploders, when moved periodically within fields, provided adequate protection against blackbirds attacking sunflower during the 6-week period the crop was susceptible to damage. He believes exploders have saved more sunflower than any other protection measure (Besser 1978). De Grazio (1964) noted that exploders were used extensively and effectively for protecting field corn from blackbirds in North Dakota. In one test, yield reduction from bird damage was only 1%, versus 43% in an unprotected field. Exploders apparently have not significantly reduced bird damage to grapes, however.

Of 149 grape growers surveyed, 90% stated that exploders and other mechanical devices were not very effective bird-dispersal techniques (Besser 1985).

Stickley et al. (1972) conducted a field trial to determine the effectiveness of gas exploders and Avitrol, a chemical frightening agent, for protecting corn from blackbirds in Ohio. A Latin-square design was used, whereby treatments, including a control (i.e., untreated period), were alternated within each field for 6-day periods. The six test fields ranged in size from 5 to 17 acres. For the exploder treatment, two exploders, each firing every 2 to 3 minutes, were located at midfield so that each covered approximately one-half of the field. Damage to the ripening corn was assessed during each treatment to determine efficacy. Exploders provided the best protection. Damage was 81% less than during untreated periods, whereas Avitrol reduced damage by 56%. Trial design might have been flawed, however, because the effects of one treatment might have carried over into the following treatment period.

Hobbs and Leon (1987) attempted using stationary and rotating exploders to protect citrus groves from depredations of great-tailed grackles (Quiscalus mexicanus) in Texas. They used one exploder per 10 to 20 acres and relocated them weekly to alleviate habituation. Efficacy was dependent on where exploders were located, their rotation within an orchard, and reinforcement with pyrotechnics and live ammunition. Exploders were most effective when supplemented with the firing of bird bombs and when they were located nearby water, trees, and bushes, which were "hot spots" for bird activity.

Exploders were found to be the most cost-effective method for reducing blackbird damage, mostly by red-winged blackbirds (Agelaius phoeniceus), to ripening corn in Connecticut (Conover 1984). Other methods tested in separate fields included Avitrol and hawk kites (plastic kites imprinted with an image of a flying raptor). Field sizes ranged from 7.5 to 20 acres. In exploder trials, only one exploder, firing every 10 to 15 minutes, was used per field. Damage assessments and bird counts were made weekly during the 4-week trial to determine efficacy. Exploders reduced damage by 77% when compared with untreated fields. Most damage occurred during the first 2 weeks, suggesting that habituation was not a factor. The cost:benefit ratio for exploders was 6.1:1. Each exploder, including a 24-hour timer and propane supply for 4 weeks, cost $62 to operate, assuming a life expectancy of 8 years for the exploder. Dolbeer (1980) estimated a cost of $3 per acre, excluding labor, for protecting corn from blackbirds in Ohio, assuming one exploder covers 10 acres and has a life expectancy of 5 years.

Exploders have also been utilized to protect swathed wheat, barley, and oat fields from waterfowl depredations in Canada

(Stephen 1961). Depredating species included mallards (Anas platyrhynchos) and pintails (A. acuta) and lesser numbers of green-winged teal (A. carolinensis), blue-winged teal (A. discors), and baldpate (A. americana). The number of exploders needed in each field was determined by adding units until waterfowl were discouraged from landing and feeding. Exploders firing once per minute were deployed for an average of 15 days per field. The number of exploders needed was not directly proportional to field size. Ninety-eight fields averaging 67 acres in size required only one exploder, 30 fields averaging 84 acres required two exploders, and 11 fields averaging 87 acres needed three exploders. Most damage occurred within 1.5 miles of major waterfowl loafing sites. Within this area, one exploder was found to protect an average of about 45 acres, whereas 60 acres could be effectively protected by one exploder in fields further away. Green-winged teal were more difficult to repel than were mallards and pintails. No evidence of habituation was found. In some fields more exploders were added because waterfowl numbers were increasing in the general area and some fields were being plowed, which reduced the number of available feeding sites. Besser (1985) also reported that about 40 acres of crop could be protected from waterfowl depredations with one exploder.

Another Canadian study reported successful hazing of ducks and sandhill cranes (Grus canadensis) feeding in field crops

(Sugden 1976). One exploder was found to be sufficient to protect 160 acres, a much larger area than reported in other studies. Many fields in the area were not protected, however, and these provided alternative feeding sites for repelled birds. Exploders might not have been as effective if all fields had been protected.

Tipton et al. (1989) used exploders as one of several methods to deter great-tailed grackles from citrus groves in Texas. Exploders were used in nine 1-acre groves. In three groves, an exploder was located in one corner and faced the middle of the grove. A double-shot exploder on a rotating platform was placed in the middle of three groves. In three additional groves both types of exploders were used, and they were reinforced four times daily by firing of shellcrackers over the grove. The exploders were tested from 1 June to 1 September. Bird pressure varied considerably among the groves, and trial results were inconclusive. The authors suggest, however, that exploders might be effective in fall and winter when grackles move daily from grove to grove and are less well established.

Rappole et al. (1989) repeated the study of Tipton et al. (1989) to examine possible detrimental impacts of exploders on white-winged doves (Zenaida asiatica) and mourning doves (Z. macroura) nesting in the citrus groves. Two exploders were located in each 1-acre grove for 6 to 8 weeks. In many instances, incubating and brooding doves departed from their nests when the exploders fired, especially those nesting within 60 yards of an exploder. The impacts on nesting success were not determined, however.

The most effective method of scaring blackbirds from rice fields in Arkansas has proven to be a combination of propane exploders, pyrotechnics (shellcrackers, bird bombs, rocket bombs, rope firecrackers), and biosonics (Bivings 1986). Advantages of using exploders in this program are that they are loud, economical, and require relatively little labor. Exploders have not been effective when used alone, however, because of habituation problems.

USE AND EFFECTIVENESS AT AIRPORTS

Gas exploders have also been used occasionally to repel birds from airport runways. They have not been very effective, probably in part because birds at airports are accustomed to the extremely loud noises produced by aircraft. Blokpoel (1976) stated that gulls, usually the most abundant bird pest at airports, normally do not react to the firing of exploders. Heighway (1969) mentioned that exploders were fired at the ends of an airbase runway to frighten birds prior to the landing or departing of aircraft. Their effect was not known, however, because trained raptors and shellcrackers also were used at such times to scare the birds.

Wright (1963) reviewed bird-scaring methods at British airports and concluded that exploders have little effect in deterring birds from runway areas. Ten exploders located at intervals on both sides of one runway deterred birds for only about one week. Birds quickly became habituated, and several were even observed perched on the exploders. At another airport, exploders had little effect in deterring gulls. In another trial, two exploders placed about 500 yards apart, moved twice daily, and supplemented with silhouettes of men holding guns apparently deterred some gulls and corvids but not smaller birds.

USE AND EFFECTIVENESS IN OTHER SETTINGS

Exploders have been used with some success at fish-rearing facilities. Most Mississippi catfish farmers believe that exploders can be beneficial in scaring fish-eating birds if they are used along with other harassment methods (Stickley and Andrews 1989). When used alone, however, only 9% of 97 farmers considered them to be "very effective." Fifty-one percent of the respondents considered them "somewhat effective," and 40% considered them "not effective." Of 235 fish-rearing facilities surveyed by Parkhurst et al. (1987), 19 reported using exploders to deter predators. Only one facility considered them successful, whereas 11 reported limited success and 7 had no success.

Salmon and Conte (1981) believe that exploders can effectively deter birds at aquaculture facilities if used properly and reinforced with other frightening techniques. They are reported to be especially effective in repelling herons, including great blue herons (Ardea herodias) and black-crowned night herons (Nycticorax nycticorax), diving ducks, and blackbirds (Mott 1978, Salmon and Conte 1981). One exploder can generally protect 3 to 5 acres if its location is changed every 2 to 3 days, although more exploders may be needed in some situations.

Martin and Martin (1984) used exploders, an ultrasonic device, and alarm and distress calls to attempt repelling cormorants, gulls, and pigeons roosting on a pier tower in California. Exploders were the only sound deterrent that effectively dispersed these species. Although not specified, the number and placement of exploders was considered crucial for successful hazing.

Exploders used alone generally had little effect in deterring cormorants (Phalacrocorax carbo) from fish ponds in the Netherlands (Moerbeek et al. 1987). A combination of exploders because trained raptors and shellcrackers also were used at such times to scare the birds.

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NEW DEVELOPMENTS (Modified Exploders)

In the past several years, exploders operating in synchrony with visual deterrents have been developed, although not well tested. One such marketed device, called the Razzo, sends a brightly colored, plastic "butterfly" up a 30-ft pole when an exploding device detonates. The butterfly slowly flutters down the pole after the blast. The effectiveness of this device is not known, however. Another device consists of the head and torso of a human effigy mounted on top of a traditional exploder (Archiron 1988). The scarecrow has outstretched arms possessing fringed plastic sleeves and wears a hat. When the exploder detonates, the scarecrow is propelled 3 feet into the air, then spirals down with its fringes fluttering. The unit sells for about $500, but no efficacy data were provided.

A pop-up scarecrow operating with a double-shot exploder was tested against blackbirds attacking sunflower in North Dakota in 1981 and 1982 (Cummings et al. 1986). The scarecrow consisted of the upper torso of a life-sized, inflatable plastic human effigy mounted on the arm of a CO_2-operated pop-up device. Each scarecrow worked in synchrony with an exploder, popping up above the sunflower heads 15 to 30 seconds before the double blasts (0.8 seconds apart) of the exploder. Units were tested in five fields ranging in size from 4 to 48 acres. Units were deployed at a density of one scarecrow-exploder for each 4 to 10 acres. Tests were conducted for 15 to 20 days, with alternating 5-day sequences between treatment and no treatment (i.e., device deactivated). Damage to ripening sunflower heads was assessed every 5 days during the duration of the tests.

Damage was reduced 78% within three fields during periods the scarecrow-exploders were operating but only 8% and 31% in two fields where the birds were well established near a large blackbird roost. No data were obtained on the efficacy of scarecrows or exploders used alone. Equipment and gas supplies for each unit cost $925. Cost of operating one unit per 6 acres was estimated at $14 per acre, assuming a life expectancy of 10 years for equipment. The authors conclude, however, that the scarecrow-exploders would be cost effective only in fields annually receiving more than 18% bird damage.

Terry (1987) also tested the pop-up scarecrow's effectiveness in repelling ducks and geese from a 25-acre pond at Dulles International Airport in Virginia. Two pop-up scarecrows operating in synchrony with a Double-John gas exploder were mounted on rafts and anchored so that each protected one-half of the pond. Each unit operated every 20 to 30 minutes for a 2-week period. Although not extensively evaluated, the units showed promise for repelling black ducks (Anas rubripes), Canada geese (Branta canadensis), canvasbacks (Aythya valisineria), ring-necked ducks (A. collaris), ruddy ducks (Oxyura jamaicensis), and possibly other species. Bufflehead (Bucephala albeola) were not deterred by the devices.

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C. Frensch Ltd., 168 Main Street E., Box 67, Brimsby, Ontario L3M 4G1, Canada (Purivox).

Margo Horticultural Supplies Ltd., RR 6, Site 8, Box 2, Calgary, Alberta T2M 4L5, Canada (Purivox).

Pisces Industries, P.O. Box 6407, Modesto, CA 95355 (Purivox).

Reed-Joseph International Co., P.O. Box 894, Greenville, MS 38702 (Scare-Away Cannon).

H. C. Shaw Co., 1648 Shaw Road, Stockon, CA 95205 (Zon cannons).

Smith-Roles, 1367 S. Anna St., Wichita, KS 67209 (Bird Scarer Cannon).

Wildlife Control Technology, 2501 North Sunnyside #103, Fresno, CA 93727 (Zon and Scare-Away cannons).

*Compiled from: Timm 1983 and others.

HUMAN PATROLS

Patrols by humans on foot or in vehicles have long been used for hazing or frightening birds in agricultural crops and other situations, although its use has not been extensively investigated from a scientific point of view as to its effectiveness. It is generally accepted that it reduces damage, but it is unclear whether it is cost-effective as a sole control method. Human patrols are generally used in combination with other techniques, such as shooting or firing cracker shells, to provide variety in an integrated hazing program. Subjective evidence strongly supports the contention that such combined methods enhance hazing results. Various vehicles have been used as transportation around the area being hazed. The type of vehicle used varies greatly and includes motor scooters, motorcycles, 3-wheelers, quadrunners, dune buggies, and other types of all-terrain vehicles. Cars and pickup trucks have commonly been used and, on occasions, even tractors. Shooting may be done from the vehicle, or the vehicle is stopped frequently to fire cracker shells, etc. The hazer may leave the vehicle for intermittent periods to patrol on foot and return to move on to another nearby location. Thus patrol methods can be varied considerably to enhance results. The use of aircraft for hazing has been omitted from this overview as it is a subject unto itself.

Humans on foot, cycles, horseback, or in vehicles may intentionally or inadvertently cause birds to flee (Owens 1977), Kenward 1978, Burger 1981). Reactions vary among species, however, and many may rapidly habituate or, if approached too closely, move only a short distance away and return soon after the people depart. The presence of humans is probably best utilized to reinforce the danger associated with other frightening techniques during their operation or servicing.

Boats have also been used for dispersing waterbirds that are resting on open water out of effective range of frightening activities or devices operated from shore. Observations of the responses of waterbirds to recreational boaters indicate that boats of various types can be effectively used for hazing (Hume 1976, Batten 1977, Korschgen et al. 1985). Outboard motorboats are most commonly used; however, airboats have specific advantages.

Trained dogs can aid in the effectiveness of human patrols or can be used without the presence of human hazers. Trained dogs, for example, can be used to flush birds to expose them to trained raptors or other hazing methods that might not be highly effective if birds refuse to fly (Cooper 1970, Lefebvre and Mott 1987).

HUMAN PATROLS AND DISTURBANCES

Patrols by humans usually include the operation of bird-frightening devices such as shooting live ammunition or shellcrackers, or broadcasting bird distress or alarm calls. The presence of the operators usually is not considered when evaluating the efficacy of these methods. In some situations, birds may disperse at the approach of the operator even before the frightening stimuli is presented (Boulay 1977). Usually, however, it is difficult to separate the effect of the bird-scaring stimuli from the disturbance created by the operator (White and Thurow 1985). Human presence alone often may not be sufficiently frightening to disperse birds for prolonged periods (Owens 1977, Kenward 1978). Depending on the bird species and situation, birds may be already accustomed to people or rapidly habituate to human presence unless it is occasionally reinforced by shooting or other means. Birds frequently react by moving only a short distance but remain in the area needing protection or return soon after the people leave the site.

Several investigators have examined the effects of intentional or inadvertent human disturbance of various bird species. Kenward (1978) examined the influence of human activity on wood pigeons (Columba palumbus) feeding in brassica fields. Birds in roadside fields dispersed significantly less often when exposed to passing vehicles, except tractors, than to humans on foot. When field workers were present, pigeons were almost entirely excluded from fields. They always departed when exposed to passing tractors, cyclists, horsemen, or pedestrians, but left only 9% to 31% of the time when cars, buses, or trucks passed by. Closed vehicles had relatively little scaring effect unless they stopped near fields; then the birds always flew, even if people remained inside the vehicle. The tendency for pigeons to return after a disturbance depended on how long they had fed before it occurred. Birds returned much sooner if they had fed for only a short time prior to the disturbance and were still hungry.

Owens (1977) evaluated responses of brant geese to human disturbances at several sites in England. Geese flew when severely disturbed by boats or loud noises but often resettled at the same site within 20 minutes. When disturbed by people on the ground, however, they usually departed and went elsewhere. Geese were also more wary at sites associated with previous human harassment. In one area used by hunters, geese could not be approached within 550 yards, but the same geese were approached within 115 yards in areas where hunting was not allowed. Most hunted waterfowl species respond the same way and thus provide us with some of the strongest evidence that heavy hazing pressure does make the birds much more wary. Seasonal differences in responses were also noted. During winter geese could be approached more closely than at other times of the year. There was also a tendency for larger flocks to fly at farther distances from the disturbance than did small groups.

Human disturbance as a possible means of reducing nocturnal fish depredations by grey herons (Ardea cinera) was evaluated at a fish farm in Belgium (Draulans and van Vessem 1985). The farm consisted of 12 ponds encompassing about 2.5 acres. Disturbances were considered severe whenever farms visited the ponds during their normal activities, or as slight when vehicles passed on nearby roads. Severe disturbances resulted in an overall decrease in heron abundance on the ponds, but slight disturbances did not. Return time of herons after a disturbance varied according to several factors, including the intensity of disturbance, month, time of night, and weather conditions. Herons returned after an average of 91 minutes following a severe disturbance, but after only 48 minutes following a slight disturbance.

Moerbeek et al (1987) noted that human activity near fish ponds appeared to be a strong deterrent to cormorants (Phalacrocorax carbo) in The Netherlands. Cormorants fed much less frequently in ponds near buildings and entrance roads than in ponds in remoter areas. About 90% of the birds usually departed when a person arrived at a pond. Most, however, soon returned to the same pond or to one of several other ponds on the farm. The investigators suggested that establishing ponds near roads and buildings would likely minimize their use by cormorants.

Human disturbance also has been found to affect use of certain sites by ducks and geese. Human activity along a shoreline can deter scaup from their normal feeding sites (Cronan 1957). Goldeneyes often fly when people along the shoreline approach within 110 to 220 yards, although they frequently land elsewhere on the lake (Hume 1976). Madsen (1985) estimated the distance that pink-footed geese (Anser brachyrhynchus) feeding on land would tolerate vehicles passing on nearby roads in Denmark. Distances varied with flock size and season. Flocks larger than 400 to 600 individuals took flight when a vehicle approached within 330 to 440 yards in spring, but they flew at an average distance of 550 yards in fall. Increased wariness in fall was attributed to harassment by hunters. Depending on flock size, geese also rarely fed within 265 to 550 yards of roads that had a traffic volume of 20 to 50 passing cars per day. Even roads with 10 or fewer cars passing per day were avoided to some extent.

Burger (1981) examined the effects of intense recreational activities on a variety of bird species inhabiting a refuge in New York. Habitats were shoreline, saltmarsh, open bay, and ponds. Human activities included digging for worms or clams, horseback riding, jogging, walking, swimming, and workers cutting grass. Waterfowl species present included brant, Canada geese, mallards, black duck (Anas rubripes), American widgeon (A. americana), greater scaup, and coot. Snowy egrets (Egretta thula) and glossy ibis (Plegadis falcinellus) also occurred. Common shorebirds were dowitchers (Limnodromus sp.), dunlin (Erolia alpina), black-bellied plover (Squatarola squatarola), and sandpipers (Calidris sp.).

Bird reactions to people varied with the human activity occurring. People walking along the beach or jogging on paths around ponds always disturbed birds when they were present. Birds often ignored horseback riders and worm diggers even when they came within 18 to 20 feet. Men working around the ponds disturbed birds about 65% of the time, depending on how close they were. Birds were always present at ponds when workers were absent. When workers were present, however, birds were absent 50% of the time, indicating their presence likely was a severe disturbance. People walking on paths around ponds rarely disturbed birds, probably because they did not approach closely. The rapid movement of joggers and workers apparently was more threatening than the slow pace of people walking. Birds in open water usually did not flush regardless of the human activity occurring. Birds along the shoreline often did not flush, but those present on the beach usually did.

Responses of birds to these human disturbances also varied by species. Ducks usually flew to other areas, and herons, egrets, and shorebirds flew to distant marshes away from human activity. Gulls and terns were less frequently disturbed and often soon resettled at the same site. Some species, especially shorebirds, also tended to avoid areas heavily used by people.

Behavioral responses of wintering bald eagles (Haliaeetus leucocephalus) to human activity were assessed in Washington (Stalmaster and Newman 1978). Flushing distances caused by the approach of an investigator on foot were recorded, and distribution of eagles in relation to existing human activities were examined. Eagles flew when approached within 30 to 300 yards, and most did not return to the same feeding area until several hours after the disturbance. Eagles avoided most areas of high human activity, although they tolerated moderate activities. The authors also found that activities such as boating and fishing along a river were more disturbing if they occurred irregularly. Irregularity has generally been found to improve the results of all types of hazing because it is more difficult for the birds to habituate to irregular patterns of activity or sounds than to constant and regular patterns. Eagles appeared less disturbed by these activities in areas where they were a common occurrence.

Cooke (1980) gathered information on how closely 17 passerine species allowed him to approach before flying away. Only individuals or groups of fewer than 5 birds on the ground or perched less than 6 feet high were approached. As he noted, however, larger flocks may be more vigilant. Observations were made in both rural and suburban settings. Flushing distances ranged from an average of 194.1 feet for rooks (Corvus frugilegus) in rural areas to within about 16 feet for blue tits (Parus caeruleus) in both rural and suburban areas (Table 1). In general, small birds and those in suburban areas allowed the closest approaches before flying. Cooke (1980) speculated that suburban birds were more accustomed to human presence than those in rural areas.

HAZING BY BOATS

Hazing waterbirds by airboats or boats propelled by outboard motors is recommended in some situations and presents another means of transportation for human patrols. Remote-controlled model boats would also likely be effective in some situations, but little information exists on their use for such purposes. Hovercraft have also been considered, but nothing could be found in the literature where they were actually used.

Small, shallow-draft aluminum boats with noisy outboard motors are the least costly for hazing waterfowl or other water-loving birds from large containment ponds. Boats are particularly useful for large pond sites where hazing from shore is not effective in moving birds from the center of the pond.

Table 1. Flushing distances (feet) of 17 passerine species in rural and suburban areas in England (Cooke 1980). Observations included only individuals or groups $\leq$ 4 on the ground or perched $\leq$ 6 feet off the ground.

Species	Rural area		Suburban area	
	n	$\bar{x}$	n	$\bar{x}$
Skylark (*Alauda arvensis*)	28	48.3	0	
Rook (*Corvus frugilegus*)	43	194.1	0	
Jackdaw (*C. monedula*)	48	58.6	3	51.8
Great tit (*Parus major*)	13	19.1	14	18.1
Blue tit (*P. caeruleus*)	30	15.6	21	16.8
Song thrush (*Turdus philomelos*)	42	51.2	36	19.4
Blackbird (*T. merula*)	75	67.7	172	36.9
Robin (*Erithecus rubecula*)	20	22.7	29	16.5
Whitethroat (*Sylvia communis*)	21	37.9	2	29.2
Dunnock (*Prunella modularis*)	33	29.8	41	19.8
Pied wagtail (*Motacilla alba*)	11	27.9	3	26.9
Starling (*Sturnus vulgaris*)	39	56.1	73	38.2
Greenfinch (*Carduelis chloris*)	16	61.6	10	31.4
Goldfinch (*C. carduelis*)	2	37.3	13	23.3
Chaffinch (*Fringilla coelebs*)	19	28.2	43	23.0
Yellowhammer (*Emberiza citrinella*)	51	40.2	0	
House sparrow (*Passer domesticus*)	66	40.2	258	26.6

Reactions of waterfowl to recreational boats have been observed or systematically examined by several investigators concerned with impacts on human activities on waterfowl populations, and these provide us with some valuable data relevant to deliberate bird hazing. Cronan (1957), for example, noted that the greater scaup (Aythya marila) and lesser scaup (A. affinis) avoided their preferred feeding areas in Connecticut waters when boats were present. Thornburg (1973) studied movements of diving ducks on Keokuk Pool in the Mississippi River, and on numerous occasions he noted mass flights caused by continued harassment by boaters.

Owens (1977) noted responses of brant geese (Branta bernicla) to passing boats along the coastline of England. The geese usually ignored large boats and yachts even when they passed close by. Small boats with noisy outboard motors, however, almost always caused the geese to fly. In this situation, the fright reaction apparently resulted mainly from noise rather than the sighting of a large moving object.

Batten (1977) examined how closely several bird species allowed sailing boats to approach before taking flight. The study was conducted on a 128-acre reservoir in England that had up to 80 boats sailing at any one time, although most frequently on weekends. Great crested grebes (Podiceps cristatus) were highly sensitive to disturbance and most departed when boats sailed within 110 yards. Little grebes (Tachybaptus ruficollis) did not leave but avoided boats by staying close to marshy banks. Black-headed gulls (Larus ridibundus), common gulls (L. canus), and herring gulls (L. argentatus) either left the reservoir, moved to a marshy area not used by boaters, or flew to adjacent fields. Moorhens (Gallinula chloropus) generally remained close to marshy shores and were not affected by boats. Coots (Fulica atra) usually ignored boats unless they approached within 55 yards, and they were never seen leaving the reservoir because of disturbance by boats.

The principal waterfowl species present on the reservoir were mallard (Anas platyrhynchos), tufted duck (Aythya fuligula), porchard (A. ferina), and smew (Margus albellus). Most mallards and smew retreated to the marshy area not used by boaters, but most diving ducks left the reservoir when boats were active. Most ducks, however, tended to return by the following morning. The few teal (Anas crecca), wigeon (A. penelope), and goldeneye (Bucephala clangula) that were occasionally present usually departed at the onset of sailing activities and did not return. Tufted ducks and pochards generally began flushing when boats approached within 220 to 495 yards. Small groups of mallards and smew often allowed boats to come within 110 yards. Observations suggested that large flocks of any species were more likely to flush at greater distances than would small groups.

Korschgen et al. (1985) examined disturbance of diving ducks, especially canvasbacks (Aythya valisineria), by boaters on a migrational staging area in the midwestern United States. Other species in lesser numbers included lesser scaup, ring-necked duck (A. collaris), redhead (A. americana), bufflehead (Bucephala albeola), goldeneye, ruddy duck (Oxyura jamaicensis), and common merganser (Mergus merganser). Most disturbances were caused by fishermen and hunters in boats propelled by outboard motors. During the 50-day study, an average of 17.2 boats were present daily. Mean flock size of canvasbacks disturbed by boaters was 12,474, and minimum flight time per disturbance was 4.4 minutes. Typical behavior of canvasbacks when exposed to a disturbance was to spiral higher and higher in wide circles above the lake. Minimum flight time for all diving ducks was 3.4 minutes per disturbance. The distance between boats and flushed birds was not recorded, but on many occasions the ducks flushed as far as 0.6 miles from an approaching boat.

Reactions of goldeneyes to recreational boaters on a reservoir in England were observed on numerous occasions by Hume (1976). A single powerboat appearing on the water caused most birds to leave immediately, and all departed within a few minutes if a boat crossed the reservoir. On one occasion, 28 goldeneyes departed when a boat appeared on the water 770 yards away, and 27 others soon left. Even the sighting of boats towed behind 2 cars on a road near the shoreline caused one group of goldeneyes to flush at a distance of about 400 yards.

Tuite et al. (1983) evaluated waterfowl use of a 383-acre lake used by recreational boaters in South Wales. They censused waterfowl numbers and their distribution on the lake in relation to the number and locations of boaters. Fishing was the most common boating activity, followed by rowing and sailing. Disturbances increased through the morning as boating activities increased. Several species made little use of their preferred feeding and resting areas when an average of 8 to 10 boats were active. The authors concluded that boaters significantly restricted use of the lake by wintering waterfowl.

These investigations suggest that boats could effectively provide variety in an integrated hazing program where their use is feasible. They might be most appropriate on large bodies of water where waterfowl cannot be effectively hazed from shore with conventional techniques such as shellcrackers, bird bombs, or gas exploders that have limited range. They could allow a closer approach to waterfowl to more effectively employ such methods. Horns, sirens, or other noise-generating equipment could be placed on boats to diversify the frightening stimuli. Boats could also allow, where feasible, the placement and servicing of devices on floating or stationary platforms far from shore. Use of such off-shore devices might include human effigies, flashing lights at night, gas exploders, or a variety of other techniques used alone or in various combinations. Floating devices have not been thoroughly investigated, especially on large bodies of water, but some have shown promise for hazing birds on small ponds (Terry 1984, Boag and Lewin 1980). Operating costs, obstructions such as pond levees or windbreaks, strong winds, and fluctuating water levels may limit the use of boats in some areas, however.

Gilbert (1977) and Craven et al. (1986) mentioned that airboats were used as one of several techniques to haze Canada geese (Branta canadensis) from 30,000-acre Horicon Marsh in Wisconsin. Four airboats were operated both day and night in combination with hazing by aircraft and gas exploders. Some boat operators considered the boats to be of limited effectiveness, however, because geese in that area moved to mudflats where the boats could not bother them. Airboats also were used to haze an overabundance of wintering snow geese (Chen caerulescens) and Ross' geese (C. rossii) from the Bosque del Apache National Wildlife Refuge in New Mexico (Taylor and Kirby 1990). The boats were operated on the Rio Grande River to haze resting geese, and shellcrackers and hand-held mirrors which flashed sunlight toward birds were used simultaneously on land. Details of these boat hazing operations were not reported.

The loud noise created by airboats makes them particularly well suited for hazing birds from containment ponds as does their ability to be used in shallow waters and even to cross flat areas of no water. Small fast airboats would be preferred to larger or slower boats, and the more noise they produce, the better. Ramps could be designed to move the airboat from one pond to an adjacent one (Martin, pers. commun.). Shellcrackers or whistle bombs could occasionally be fired from the airboat for further frightening stimulus.

A two-person recreational hovercraft (such as the Baker Hoverstar, about $7,000, or the Scat Hovercraft), although relatively expensive, may have considerable merit for hazing birds from ponds. Moving from pond to pond would be facilitated by a hovercraft. Operators would require special hovercraft training. Although currently not considered very practical for hazing, hovercraft will be more sturdy and mechanically reliable in the future. As they become more popular as recreational vehicles, competition will bring about lower prices.

TRAINED DOGS

Well-trained dogs can add an extra frightening dimension to human patrols on foot or on bicycles. They can also be released from periodic patrol vehicles to frighten birds. The dogs must respond well to voice commands or to whistles. The larger and faster breeds of dogs seem preferred, and several dogs may be needed so as not to overwork them.

Trained dogs have been used with limited success to haze birds at fish-rearing facilities and on and around airport runways. Dogs were used to haze birds and/or mammals at 11 of 235 fish-rearing facilities surveyed by Parkhurst et al. (1987). Of the 8 facilities that rated their effectiveness, only 2 (25%) reported high success or elimination of the problem, whereas 5 (63%) reported only limited success and 1 (12%) reported dogs had no effect. No details were provided on the species hazed, however, or how or what breed of dogs were used. Dogs would likely be of limited value for hazing birds from agricultural fields because they could only be used in orchards or low-growing crops and where the dogs could easily access the field and where the dogs themselves did not damage the crop. In some circumstances where fields are small, they may be useful if restricted only to the periphery of the field. They also can be tethered on long running lines.

Trained dogs also have been used to disperse birds from airports to help reduce bird-strike hazards to aircraft, but usually with only limited success (Burger 1983). Numerous but unspecified difficulties with dogs at one airport in Canada led to abandonment of the test (Pearson 1967). Dogs, if not carefully controlled, may themselves be a hazard to landing and departing aircraft if they wander onto runways while pursuing birds (Lefebvre and Mott 1987). Birds may also rapidly habituate to their presence, often moving a short distance away when the dog approaches but not leaving the area needing protection (Mattingly 1976). Trained dogs were successfully used at one European airport, however, to flush birds from dense vegetation so trained falcons could attack and disperse them (Cooper 1970).

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SOURCES OF HOVERCRAFT

Fish Management Inc., P.O. Box 49, Highway 49, Inverness, MS 38753 ("Scat Hovercraft").

Hammacher Schlemmer, Mail Order Catalog Sales, 147 East 57th Street, New York, NY 10022 (Baker Hovercraft "Hoverstar").

GUNFIRE/CRACKER SHELLS

Gunfire with ammunition or fixed projectiles has long been used to frighten birds from agricultural crops, airports, roosts, and other problem situations. Similar to fireworks, these devices rely on an explosion or other type of loud noise to deter birds from an area (Mott 1980, National Pest Control Association 1982). Certain types may also produce visual stimuli such as a flash of light or burst of smoke. Devices include rifles and shotguns firing live ammunition or blanks and 12-gauge shotguns and flare pistols that shoot exploding or noisy projectiles, including shell crackers, bird bombs, bird whistles, whistle bombs, or racket bombs (Booth 1983). Signal flares also have been used at some airports but are more expensive than the other devices (Lefebvre and Mott 1987).

These devices can be especially useful in situations where sites need only be protected for relatively short periods of time (e.g., 1 to 4 weeks). Most bird species become habituated to these noises if used repeatedly over a longer period of time. Gunfire is considered more effective over longer periods when supplemented with other frightening methods such as gas exploders, air horns, etc. (Hochbaum et al. 1954, Dolbeer 1980). The methods used to patrol the area to be protected, the number of shooters, and the frequency of firing and time of day the programs are conducted are just as important to success as is the equipment or kinds of projectiles. Gunfire must be used with extreme caution because of the danger of stray bullets and exploding projectiles. Some projectiles may also prove to be a fire hazard as occasionally a malfunctioning round may start a dry grass fire.

TWENTY-TWO RIFLES

The most widely used rifle is the .22 caliber with long-rifle hollow-point ammunition. This rifle is considered an effective and economical scaring device where its use is legal and safe (Mitchell and Linehan 1967, Besser 1985). It is generally fired to scare and not to kill. The most useful technique is to have operators on patrol or shooting from a fixed elevated position. If roads are present, shooting from a truck bed provides both mobility and an elevated position (Meanly 1971). Shooting from a 10 to 20-ft stationary platform can also be beneficial in situations where the shooter must be above the surrounding vegetation (Mitchell and Linehan 1967, DeHaven 1971). An elevated position enables the rifleman to more easily observe birds and to direct the trajectory of the shot downward to lessen the hazard from stray bullets. Long-rifle shells can be hazardous up to one mile from the shooter and care is needed when firing. Twenty-two shorts travel less far than longs and, therefore, may be safer in some situations.

The .22 rifle has been widely used to scare birds from a variety of agricultural crops. Rifle fire alone can be effective in frightening waterfowl from rice fields, but its effectiveness is greatly improved when combined with a visual stimulus such as a scarecrow (Knittle and Porter 1986). The .22 also has been used to scare blackbirds from rice and corn fields (DeHaven 1971, Meanly 1971). From an elevated position, one rifleman can protect 40 to 100 acres of crop (Mitchell and Linehan 1967, Vaudry 1979, Dolbeer 1980). Besser (1985) recommends firing a round above the feeding or loafing birds, followed by a rapid series of shots behind them when they flush. Successful scaring was also achieved by firing several shots in rapid succession or at 5 to 10-second intervals (Vaudry 1979).

LARGE CALIBER RIFLES

Large caliber rifles can be more effective than the .22 rifle because of their louder report when fired and impacting and their greater range. Because they are potentially more hazardous and costly to operate, however, their use for frightening birds is limited.

SHOTGUNS

Shotguns with live ammunition or blanks also have been used to frighten birds from agricultural fields. They are considered less hazardous than rifles because of their limited range (150-200 yards). However, their shorter range generally makes them less effective than rifles for scaring birds, especially birds at a distance (Neff n.d., Meanly 1971). Their use requires foot or vehicle patrols or more operators, and ammunition is more expensive. Some birds soon learn to remain just out of range of shotguns (Zajanc 1962), and they become accustomed to the noise. When and where legal, shooting an occasional bird can help reinforce the danger associated with the shotgun blast (National Pest Control Association 1982), but care must be taken because crippled birds of some species may act as decoys and lure other birds to the area (Booth 1983). The shotgun blast is most effective when directed toward the birds because the sound is loudest within the 30-degree arc from the gun muzzle (Vaudry 1979).

One man on foot patrol with a shotgun can protect only about 5 acres of corn under attack by blackbirds (Mitchell and Linehan 1967). Used as the only bird-scaring technique, shotguns usually are ineffective and uneconomical for protecting corn. Shooting to frighten jays from orchards is a common method used by pistachio growers but is not highly effective. Birds quickly learned to avoid the roving shooters and returned to the fields soon after the shooters moved elsewhere (Crabb et al. 1986). Different shooting strategies improved on its effectiveness. Shotguns are best utilized to reinforce other types of scaring devices (Hochbaum et al. 1954, Dolbeer 1980, Booth 1983). Neff (n.d.) found them useful as a variation in a shooting program to protect rice from blackbirds. The effectiveness of rifle shooting from stationary platforms was enhanced by occasional vehicle or foot patrols with shotguns.

Stickley and Andrews (1989) surveyed Mississippi catfish farmers on means, effort, and costs of repelling fish-eating birds from ponds. Species present included double-crested cormorants (Phalacrocorax auritus), great blue herons (Ardea herodias), and great egrets (Casmerodins albus). Many (60%) of the 244 farmers responding to the survey harassed these birds by driving around their ponds and shooting (unspecified types of guns) to repel. Only 13% of these farmers considered shooting to be "very effective," whereas 47% found it "somewhat effective" and 40% "not effective."

Shooting to scare gulls (Larus spp.) from runways was tried as a method of reducing bird hazards to aircraft at an airbase in Scotland (Heighway 1969). Although initially effective, within a few weeks the gulls simply began moving outside effective firing range when the patrol team arrived. The technique was subsequently abandoned.

FIXED PROJECTILES (FIRED FROM GUNS)

Fixed projectiles include shell crackers, bird bombs, bird whistles, whistle bombs, and racket bombs. These are fired from a gun or pistol and are more expensive than live ammunition. However, they enable the operator to place an explosion or other noise in the air near the birds, which is generally more effective than a similar noise at ground level (Booth 1983). Shell crackers (scare cartridges) are fired from a 12-gauge shotgun and explode with a flash 100 to 150 yards from the operator. This gives a double sound effect with each round fired. They are relatively expensive, costing about 50 cents each when purchased in large quantities (Bivings 1986). For safety, the shotgun should be fired from the hip and inspected frequently for possible lodging of wadding in the barrel (Mott 1980). Single-shot break-open shotguns are recommended to facilitate cleaning of the barrel. The type of gunpowder used in the shells will determine how frequently they must be cleaned. Ear and eye protectors are recommended for all projectiles fired from guns.

Bird bombs or noise bombs are fired from a modified starter pistol and travel approximately 25 to 30 yards before exploding (Mott 1980, Fitzwater 1988). They are effective when range is not a factor and cost less than half as much as shell crackers (Bivings 1986). Whistle bombs, bird whistles, and racket bombs make hissing or whistling noises as they travel through the air but do not explode and thus are generally less effective than shell crackers or bird bombs, at least for some species (Booth 1983). If used intermittently along with cracker shells, they provide a variation of sound that increases the effectiveness of both as opposed to using one or the other alone. They can also provide useful variation when other bird-frightening methods are being used. The cost is approximately the same as for bird bombs (Bivings 1986).

Fixed projectiles are commonly used to frighten birds from airports, grain fields, vineyards, and roosts (Table 1). At airports they have been exploded between problem birds (e.g., gulls) and runways to frighten the birds in a desired direction and away from the path of the aircraft (Long 1982, Solman 1983). Mott (1980) used shell crackers and noise bombs to disperse blackbirds and starlings (Sturnus vulgaris) from roosts in Kentucky and Tennessee. Bird numbers at five roosts ranging in area from 10 1/4 to 70 3/4 acres were reduced by 96 to 100% after 3 to 7 evenings of hazing. Costs were estimated at $80 to $535 per roost. Roosts that had been established for some time were more difficult to disperse than those that had formed recently. Exploding shells also have been used successfully to scare ducks and geese from golf courses and open municipal water reservoirs, especially when control began as soon as birds began invading a site (Fitzwater 1988). deCalesta and Hayes (1979) used shell

Table 1. Use of fired projectiles (shell crackers, noise bombs, shotgun shells) for repelling specific bird species in various situations.

Bird species	Projectile used	Situation	Reference	Comments
Gulls	shell crackers	airports	Solman 1983	Most effective when gulls airborne
Gulls	gunfire	airports	Heighway 1969	Rapid habituation
Blackbirds Starlings	shell crackers, noise bombs	roosts	Mott 1980	One person can patrol about 2 acres of roost; highly effective
Blackbirds	shell crackers	rice fields	Meanly 1971	Most effective when used with other scaring techniques
Blackbirds	shell crackers	rice fields	DeHaven 1971	Best used as a supplement to other scaring techniques
Blackbirds	shell crackers noise bombs	rice fields sorghum fields	Bivings 1986	Effective when used with other bird-scaring methods
Starlings Robins Cedar Waxwings	shell crackers noise bombs	blueberry fields	deCalesta and Hayes 1979	Both projectiles equally effective; control must continue from dawn to dusk during period of crop suscept-ibility to be effective
Ducks Geese	shell crackers	golf courses	Fitzwater 1988	Most effective when birds first invade a site
Ducks	shotgun shells	grain crops	Hochbaum et al. 1954	Used with other scaring devices; shotgun was effective in scaring ducks from fields
Cormorants Herons Egrets	shell crackers bird bombs	fish ponds	Stickley and Andrews 1989	Most catfish farmers consider them "somewhat effective"

crackers and bird bombs to scare starlings, robins (*Turdus migratorius*), and waxwings (*Bombycilla cedrorum*) from grape fields. Birds left the fields 83 to 99% of the time when either device was fired, but their effect was temporary, and the birds soon returned to the fields.

Shell crackers were tested alone and in combination with taped distress calls at five British airfields in the 1960s (Brough 1968). Success was rated as "good," "moderate," or "poor," depending on the number of birds that dispersed. Trials were conducted against gulls, corvids (*Corvus* spp.), lapwings (*Vanellus vanellus*), and starlings. Success varied among species. Shell crackers alone produced good results with corvids and starlings 93% (15 tests) and 86% (21 tests) of the time, respectively. Gulls and lapwings were repelled only 62% (50 tests) and 73% (34 tests) of the time, respectively, that shell crackers were used alone. When shell crackers were combined with distress calls, however, good results were obtained 92% (153 tests) and 90% (20 tests) of the time.

Shell crackers, bird bombs, and bird whistles were used regularly by 21 (9%) of the 244 catfish farmers responding to a survey by Stickley and Andrews (1989). Most farmers (57%) considered them "somewhat effective" in repelling birds. Only 24% found them to be "very effective," whereas 19% deemed them "not effective."

There are several manufacturers of cracker shells and whistle bombs marketed under a variety of trade names. Users should be aware that products of some manufacturers attempt to or haveimproved their products over time. It may be well worthwhile to try a number of different kinds until you arrive at those that give the best or desired results.

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SUPPLIERS OF FIXED PROJECTILES*

Clow Seed Co., 1081 Harking Rd., Salinas, CA 93901 (bird bombs, whistlers)

Margo Horticultural Supplies Ltd., RR6, Site 8, Box 2, Calgary, Alberta T2M 4L5, Canada (bird bombs)

O. C. Ag. Supply, Inc., 1328 S. Allen St., Anaheim, CA 92805 (shell crackers)

Penguin Industries, Inc., Box 97, Parkesburg, PA 19365 (shell crackers)

Reed-Joseph International Co., Box 894, Greenville, MS (shell crackers, noise bombs, pistol launchers)

Stoneco, Inc., Box 187, Dacono, CO 80514 (shell crackers)

United Commercial Co., 5833 Perry Drive, Culver City, CA (or 100 W. Chicago Ave., Chicago, IL) (shell crackers)

Western Fireworks Co., 2542 SE 13th Ave., Canby, OR 97013 (shell crackers)

*Compiled from: National Pest Control Association 1982, Timm 1983 and Besser 1985

PYROTECHNICS (FIREWORKS)

Pyrotechnic fireworks that have been used for bird scaring include rope firecrackers, aerial bombs, and various types of rockets. They have mainly been used in agricultural fields to repel depredating blackbirds and starlings (Neff n.d., DeHaven 1971). The loud unnatural noises produced by these devices, especially when exploded overhead, frighten most birds away from the source of the noise, at least temporarily. If repeated day after day, the birds habituate to such noises; however, if used with occasional gunfire, they may perceive them to be a real danger for a longer period. Thus, some type of reinforcement is usually needed for these devices to be most efficacious or to remain effective for a prolonged period. Occasionally shooting a few birds with a shotgun, or shooting at the bird with a nonlethal size of bird shot is reportedly an effective means of reinforcement (National Pest Control Association 1982). The effectiveness of fireworks also can be enhanced by varying the timing and location of explosions and by using them as supplements to other types of frightening devices (Bivings 1986).

Fireworks must be used with extreme caution. Safety glasses and hearing protectors are recommended for operators because of the possibility of premature detonations (Kopp et al. 1980). Fireworks should not be used where fire hazards exist because burning fuses or misdirected rockets may ignite dry vegetation.

Federal, state, and local ordinances may prohibit their use in some states or regions or require permits for their use. Warning signs may also be required by regulations where these devices are operated (Booth 1983).

ROPE FIRECRACKERS

Rope firecrackers can either be made or purchased from commercial suppliers. The assembly consists of a 3/8- or 5/16-inch cotton rope comprised of 3-4 strands along which firecrackers are placed at desired intervals. Flash-salute type firecrackers, such as salutes or cherry bombs, are spaced along the rope by entwining their fuses among the cotton strands (Neff and Mitchell 1955, Hockenyos 1962). The cotton rope serves as the central fuse. As it slowly burns, fuses of the firecrackers ignite and they drop from the rope and explode. The timing of explosions depends on the burning rate of the rope and the spacing between firecrackers. One type of cotton rope used as a central fuse burns at a rate of about 6-7 inches per hour (National Pest Control Association 1982). Firecrackers spaced 1 inch apart would explode approximately every 8-10 minutes, but spacing can be varied as desired. Individual firecrackers produce an explosion that may equal or exceed the blast from a 12-gauge shotgun. Fire hazards can be minimized by placing a basket or metal trash can cover below the falling firecrackers.

Although rope firecrackers can withstand drizzle, a rain shield is needed in wetter weather.

Because explosions at ground level can be muffled by the surrounding vegetation, elevating the rope firecracker assembly 15-20 feet increases its effective range (Neff and Mitchell 1955). Hanging the rope firecrackers inside a piece of 6-inch diameter galvanized stovepipe elevated vertically on a pole is an efficient method of making them resistant to wet or windy weather and at the same time elevating the explosions. The pole with the stovepipe assembly can be wired to a metal fence post driven into the ground (Neff and Mitchell 1955). The wire can be detached to lower the assembly to the ground to replace the firecracker ropes. A basket made of 1/2-inch hardware cloth can be attached to the lower end of the stovepipe or a foot or two below to prevent burning firecrackers from falling to the ground, thus keeping the explosion at the appropriate height for maximum effectiveness.

Rope firecrackers have been used effectively against blackbirds in rice and corn fields, ducks in corn fields, and fish-eating birds at fish hatcheries (Neff and Mitchell 1955, Bivings 1986). They also have been used to successfully disperse starlings from roosting sites and vineyards (Hockenyos 1962, McCracken 1972, Fitzwater 1988). For scaring blackbirds from agricultural fields, Neff and Mitchell (1955) suggested placing setups 400 feet apart and exploding about 50-60 firecrackers per day at each setup. In large fields, they recommended using .22-caliber rifles to supplement bird frightening with rope firecrackers. Pierce (1972) found that rope firecrackers were effective against blackbirds when they were used along with .22 rifles or gas exploders. DeHaven (1971) indicated that about 5 acres of rice could be protected with an individual assembly that was elevated above the top of the rice panicles. Zajanc (1962) stated that about 4 acres of corn could be protected by one rope firecracker assembly placed at ground level, but approximately twice as much area could be covered by an elevated assembly.

Rope firecrackers are one of several bird-scaring techniques used against blackbirds damaging rice and grain sorghum in Arkansas (Bivings 1986). They work most effectively when periodically moved to new locations within a field. Although explosions are not as loud as those of bird bombs, rope firecrackers are cheaper (approximately $20 per gross), effective, and require relatively little labor (Bivings 1986).

AERIAL BOMBS

A two-shot repeating bomb is marketed specifically for crop protection. The device consists of two upright units mounted on a wooden block and connected by a fuse (Neff and Mitchell 1955). Forty bombs can be placed in a single unit, and several units can be spaced at desired intervals along a central cotton fuse. When a unit ignites, a bomb is propelled 20 feet upwards where it explodes, followed 5-6 seconds later by a second bomb. The next two-shot sequence follows after about 15-20 minutes.

Repeating bombs are more expensive than rope firecrackers but may be more economical for protecting large areas (Neff and Mitchell 1955). No bird damage occurred within 1,300 feet of an assembly placed in a Florida corn field under attack from blackbirds. In a Delaware corn field, damage was 50% less where units were spaced at 450-feet intervals than where they were spaced at 600-foot intervals.

ROCKETS

Various types of rockets are available for scaring birds. They are most useful for frightening birds that are some distance from the operator (Vaudry 1979). Roman candles also have been used to disperse birds from night roosts. Although more expensive than standard rockets, explosive rockets are more effective for scaring birds (Neff n.d.). The explosive rocket emits a hissing stream of sparks and explodes with a cloud of smoke or group of bright fire-stars. A launching device is needed and can be made from a piece of light pipe. A spike can be attached to the lower end of the pipe so it can be firmly stuck into the ground at any desired angle (Neff n.d.). Rockets should not be used where there is danger of fire at the launching point or where the rocket may land.

Signal rockets tested in the USSR reportedly had an effective range of about 1,300 feet, but most birds soon returned and settled at the sites from which they had been frightened (Blokpoel 1976). Rockets are best used in combination with other scaring techniques (DeHaven 1971). Neff (n.d.) found them to be effective against blackbirds in rice fields when used with rifle fire. After birds were frightened into the air by gunfire, they were dispersed by exploding rockets just above the milling birds.

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SUPPLIERS OF ROPE FIRECRACKERS AND FUSES*

J.E. Fricke Co., 40 N. Front St., Philadelphia, PA 19106 (fuse rope).

New Jersey Fireworks Co., Box 118, Vineland, NJ 08360 (rope firecrackers).

Wald & Co., 208 Broadway, Kansas City, MO 64105 (rope firecrackers).

Western Fireworks Co., 2542 SE 13th Ave., Canby, OR 97013 (rope firecrackers).

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ELECTRIC OR AIR-PRODUCED LOUD SOUND FOR REPELLING BIRDS

Electric or air-produced nonspecific, audible loud sounds have limited potential for bird hazing. Because of expense, they are best utilized for protecting small areas or adding variety to a hazing program incorporating other frightening stimuli (DeHaven 1971). Devices occasionally used include air horns and sirens (Theissen et al. 1957, Wright 1963, Parkhurst et al. 1987). In theory, any loud, startling noise will temporarily frighten birds (Frings and Frings 1967). Habituation to such noises usually occurs within 1 hour to 5 days, however (Boudreau 1968). Thus, their effectiveness is only temporary at best, although they may be useful for providing variety and delaying habituation when supplementing other bird-frightening devices (e.g., gas exploders, taped distress calls, shell crackers, etc.).

AIR HORNS

Air horns operate with compressed air to produce a loud, braying blast. Such units often are made up with a 12-volt air compressor and two trumpets to intensify the noise produced (Zajanc 1963, unpubl. report, California Dept. Agriculture). The longer trumpet (8.5 inches) produces sound at a frequency of 1000 cycles per second (cps). A second, shorter trumpet (6.5 inches) emits a blast at 800 cps. The interval between blasts is determined by the operator and can be varied as desired with an automatic timer. A commercial portable air-horn unit tested by Marsh and Wetherbee (1964, unpubl. report, California Dept. Agriculture) produced a noise output of 110 decibels (measured 20 feet from the source). These units were developed by the Agricultural Engineering Department at the University of California and later marketed commercially by a firm specializing in bird-scaring devices. Commercial units for bird control have not been marketed extensively and are difficult to find if available at all. However, they can be easily made by anyone handy with such equipment.

Zajanc (1963, unpubl.) tested air horns against birds feeding on grapes in a 57-acre vineyard. Birds, including about 500 starlings (Sturnus vulgaris) and lesser numbers of the house finch (Carpodacus mexicanus), mockingbird (Mimus polyglottos), mourning dove (Zenaida macroura), and sparrows, had been feeding in the field for about 10 days prior to the test. Two air horns were elevated 10 feet above ground, and blasts were staggered to increase their effectiveness. Birds had been feeding in the field for about 10 days prior to the test. During the first morning of the test, most birds soon left the field. Only 20 birds returned in the afternoon, but they soon departed when the horns blasted, and none subsequently returned prior to harvest. The only species not apparently deterred was the mourning dove.

Three air-horn units were used in another trial to attempt protecting a 6-acre lettuce field from depredations by crowned sparrows (_Zonotrichia_ spp.) (Marsh and Wetherbee 1964, unpubl.) Horns were elevated 6 feet above ground and directed toward areas of intensive bird damage. Each horn emitted a 1.5-second blast at 3-minute intervals. Units were moved periodically during the 8-week trial to delay habituation by the sparrows. Sparrows reacted to the blasts by rising, circling, and landing nearby. The disturbance helped reduce damage, but the experimenters suggested that adding more units and varying the timing and duration of blasts would likely be more effective.

Portable self-contained air-horn units have also been experimentally explored for use in keeping waterfowl from utilizing alfalfa fields in the Tule Lake Basin, California, following the application of toxic baits for meadow vole control. They were operated 24 hours a day and effectively kept waterfowl off these fields since many alternative feeding areas existed in the immediate area.

Little other information exists on the effectiveness of air horns and sirens for repelling birds. Wright (1963) mentioned that Klaxon horns were tried at an airport in England in 1955. Twenty horns were placed at 100-yard intervals along a runway. Gulls appeared to be more disturbed by the noise than were other species, but they were not sufficiently deterred that the horns could be recommended for use.

SIRENS

Theissen et al. (1957) conducted field tests to evaluate the effectiveness of an air-raid siren against mallards (Anas platyrhynchos) and pintails (A. acuta) on several Canadian sloughs. The siren was mounted on a truck to provide mobility. It produced sound in the range of 200 to 500 cps and had an estimated range of at least 2,000 feet. Treatments consisted of a series of 2- to 4-minute blasts, with a total treatment time of about 20 minutes per day per slough. Three sloughs, each having several thousand mallards present, were treated for 1 to 3 days during 1952. Results were encouraging, with mallard numbers declining greatly within 2 to 3 days. In 1953, however, few mallards were repelled from these sloughs, and most returned within 24 hours. Pintails at another site were not effectively repelled; about 75% flushed when the siren blasted, but numbers returned to pretreatment levels by the following day. The investigators concluded that the siren had little practical value for hazing these species.

Theissen and Shaw (1957) also tested a 30kw 200 to 400 cps siren against ring-billed gulls (Larus delawarensis) at a Canadian airport. Gulls behaved erratically when exposed to the noise. A group resting 1200 feet from the siren flushed rapidly during one test but soon landed only 600 feet away and remained there. In other tests, some gulls flushed and departed, whereas others circled and resettled, often landing closer to the siren.

Four of 235 fish-rearing facilities surveyed by Parkhurst et al (1987) reported using sirens to repel bird and/or mammal predators. Sirens were considered highly effective at two facilities, but two sites reported little or no success in eliminating their problem. No information was provided on the species repelled or the extent of the area protected.

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HAZING BY AIRCRAFT

Aircraft represent a costly but often highly effective means of hazing birds from large areas. Types of aircraft used or tested include fixed-winged airplanes, ultralight recreational aircraft, helicopters, and radio-controlled model aircraft. Airplanes occasionally have been and continue to be used to drive blackbirds and waterfowl from agricultural fields in the United States and Canada (Meanley 1971, Sugden 1976, Handegard 1988), and helicopters were employed to herd flightless geese (Timm and Bromley 1976). Ultralight and radio-controlled model aircraft have been field tested to evaluate their effectiveness for dispersing depredating or nuisance birds (Blokpoel 1976, Suaretz 1983, Briot 1984). The frightening stimuli produced by an approaching aircraft include both loud noise and the rapid approaching movement of a large object from above (or below if in flight). Other frightening devices (e.g., shooting, flares, sirens) sometimes are used to reinforce the danger associated with airplanes (De Grazio 1964, Handegard 1988), and model aircraft have been used with some designed to specifically resemble birds of prey (Saul 1967, Briot 1984).

The responses of birds to approaching aircraft are not well understood and likely vary greatly among species and situations. Some birds immediately panic and flee, whereas others may show varying degrees of indifference. Bird reactions can be influenced by many factors, including noise levels, height, color, speed, and flight pattern of the aircraft; their previous experience with aircraft; whether birds are migrants or well-established residents; and probably others (Neff and Meanley 1957, Blokpoel 1976, Handegard 1988). Nevertheless, where appropriate and feasible, hazing by aircraft can be a highly effective method of dispersing birds.

FIXED-WINGED AIRPLANES

Small two- to four-passenger or crop duster-type airplanes have been used to haze blackbirds from sunflower and grain crops and waterfowl from croplands and refuges. Success has varied with situation and species present. When airplanes were used to frighten blackbirds from rice fields, birds quickly habituated to the presence of the plane (Neff n.d.). Blackbirds often react by seeking refuge within the crop rather than flying away (Mitchell and Linehan 1967, Meanley 1971, Besser 1978). They may also take cover in trees or other suitable vegetation adjacent to fields. In such instances, a ground patrol may be needed to flush the birds so they can be herded by the airplane (Meanley 1971, Pierce 1972). Equipping airplanes with sirens, horns, or other devices are thought to increase their effectiveness (De Grazio 1964, Mitchell and Linehan 1967).

Success in scaring blackbirds from fields depends to a large extent on the ability and dedication of the pilot. Flying a regular pattern over the fields is considered less effective than pursuing and herding the birds as they rise from the crop (Neff n.d.). Airplanes are most effective when the pilot visits fields intermittently throughout the day, follows a low, irregular flight path, and occasionally changes motor speed or produces backfiring that adds to the birds' confusion (Neff n.d., Neff and Meanley 1957).

A relatively recent hazing program to alleviate blackbird damage to sunflower began in North Dakota in 1986 (Handegard 1988). The approach utilized is to harass flocks by flying low over fields with a Piper Super Cub, supplemented by shooting from the plane to frighten birds. After 2 years of hazing, Handegard (1988) concluded that fields suffering heavy bird damage must be hazed at least 3 times per week and preferably daily. Assistance from a ground team was also frequently needed to prevent birds from landing in adjacent marshes and shelterbelts. Hazing was most effective when the pilot flew slightly behind fleeing birds, keeping the plane between the birds and the ground. Flying too close to the birds fragmented large flocks. Although the effectiveness of this program is difficult to evaluate because of the large areas covered (6 districts of 7,000-10,000 mi^2, each with 1 plane), 64% of growers responding to a survey believed it helped reduce crop damage.

Handegard (1988) noted several factors that affected the success of aerial hazing. Hazing was only marginally successful against resident birds that had well established feeding patterns, but recently arrived migrants were more easily repelled. Birds also were more likely to leave fields if they had been previously hazed. Additionally, wind speed and direction and other weather conditions affected success. Optimum conditions were overcast skies and northwest winds of 10 to 12 mph.

Hazing waterfowl by airplane has helped reduce damage to grain crops by waterfowl in central California in the 1940's and 1950's. Horn (1949) reported that one plane could successfully herd ducks from 5,000 to 15,000 acres of rice, providing the birds had somewhere else to go. Flights were made twice daily over the fields. Biehn (1951) noted that waterfowl were extremely frightened by low-flying planes and could easily be driven from crops; one plane adequately protected about 10,000 acres. If waterfowl refused to fly as the plane passed overhead, hand bombs and flares were dropped to make them rise so the plane could get positioned below them and herd them away. Hazing was most effective at dawn and shortly before sunset when the waterfowl were flying to or from fields and could be more easily herded (Lostetter 1960). Using this technique, 2 planes effectively protected 30,000 acres of rice for 60 days during the period grain was susceptible to damage.

Aircraft also have been used for herding waterfowl in Canada but with less success than in California. Gollop (1951 cited in Sugden 1976) described 22 flights to attempt driving ducks from Manitoba grain fields. Airplanes were not effective for moving ducks away from the vicinity of cropland because grain fields were interspersed with numerous wetlands where the birds took refuge until the plane departed. Gollop (1960 cited in Sugden 1976) also unsuccessfully tried aerial hazing of sandhill cranes (Grus canadensis). Sugden (1976) believes that herding waterfowl by aircraft is not practical in Canadian grain fields, because fields are many and dispersed and operating costs are extremely high.

Hazing with airplanes was incorporated into a massive effort to disperse an overabundance of Canada geese (Branta canadensis) from a 30,000-acre wildlife refuge in Wisconsin (Gilbert 1977). Other methods included hazing at night with air boats and use of gas exploders, rockets, and other frightening devices. The effectiveness of the aircraft was not mentioned, however.

Belanger and Bedard (1989) examined responses of staging greater snow geese (Chen caerulescens) to a variety of disturbances along the Saint Lawrence River in Canada. Man-related disturbances, especially aircraft overflights accounted for $\geq$ 45% of 652 disturbances recorded in 471 observation hours during fall and spring. Other disturbances were caused by hunters, passing people, predators, boats, other vehicles, or were not identified. The impact of a disturbance depended on its frequency and cause. Disturbances by airplanes and helicopters passing overhead generally disturbed entire flocks, whereas other disturbances often affected only a few individuals. Geese frequently took flight even before the observers heard or sighted aircraft. Time spent in flight and time to resume feeding after a disturbance were greater when caused by aircraft than by any other recorded disturbance. Only 4% of all disturbances caused geese to leave the sanctuary in fall, but 37% of disturbances in spring provoked their departure. The investigators also found that when geese were disturbed at a rate of $\geq$ 2 disturbances per hour on any day, their numbers decreased on the site the following day. They believe that geese may learn to associate danger with particular sites having high rates of disturbance, and they may subsequently try to avoid such areas.

Observations of the reactions of brand geese (Branta bernicla) to passing aircraft were made by Owens (1977) along the coastline of England. Any aircraft below 550 yards' elevation within a distance of 1 mile would cause them to take flight. Slow, noisy aircraft, including helicopters, were the most disturbing. Although the geese partially habituated to other disturbances, including the proximity of people and some loud noises, they did not habituate to small, low-flying aircraft during the several months observations were made. The author suggests the intense response of brant to such aircraft possibly occurs in part because the aircraft may resemble large birds. Large birds with slow wingbeats, especially great black-backed gulls (Larus marinus), herons (Ardea cinera), and hen harriers (Circus cyaneus), often caused the geese to fly when they passed overhead.

Wildlife biologists conducting aerial censuses of waterfowl also have noted reactions of geese and ducks to approaching aircraft (Blokpoel 1976). Brant flushed when planes were more than 1,000 yards away. Snow geese and Canada geese did not fly until planes approached within a few hundred yards. Diving and dabbling ducks usually allowed an even closer approach of aircraft before flushing.

Some information on responses of other bird species to airplanes has been obtained from observing their reactions at airports where bird-strike incidents are an aviation problem, especially to military and commercial jets (Blokpoel 1976). The behavior of birds toward approaching aircraft varies considerably among species and is still not well understood. Gulls (Larus spp.) often panic when startled by aircraft and usually will not settle near a runway when there is much air traffic. Lapwings (Vanellus vanellus) react variably; some near runways often ignore planes, whereas others at distances up to 200 yards away become alarmed. Oystercatchers (Haematopus sp.) rarely fly away or only short distances. Rooks (Corvus frugilegus) are apt to fly if close to approaching planes, whereas starlings (Sturnus vulgaris) often depart when the plane is still some distance away. Wood pigeons (Columba palumbus) residing around airports usually are not disturbed by air traffic, but those migrating through an area may become much more alarmed.

Several limitations of airplanes likely preclude their widespread use for bird hazing. Operating costs are extremely high relative to other bird-hazing methods (DeHaven 1971, Besser 1978). Persuing low-flying birds also poses a risk to the pilot. Several crashes, including a few fatalities, have occurred during bird hazing activities (Hammond 1961, Knittle and Porter 1988). Aerial hazing also is not feasible during bad weather. This could be a serious limitation during prolonged periods of bad weather at critical times, such as when crops are ripening (Mitchell and Linehan 1967). Legal limitations to bird hazing also must be considered. Several changes in State and Federal laws governing the use of aircraft for herding or hazing certain wildlife species have occurred in recent years (Knittle and Porter 1988). Federal, State, and local regulations should be consulted and any necessary permits obtained before undertaking hazing activities.

ULTRALIGHT AIRCRAFT

Ultralight aircraft, which have become popular recreational aircraft in recent years, also have potential for use in hazing birds. Their main advantages are that they are relatively inexpensive to purchase and have a very low operating cost relative to that of standard fixed-winged airplanes and helicopters. When an ultralight and a helicopter were tested for aerial hunting of coyotes, costs of operating the ultralight were only about 20% that of operating the helicopter (Knight et al. 1986). Ultralight aircraft were tested to determine their effectiveness in hazing blackbirds from California rice fields, but tests were abandoned after a crash. Despite using licensed pilots to operate the aircraft, crashes were also a problem when ultralights were tested for hunting coyotes (Knight et al. 1986). Thus, their use for hazing birds may be limited to favorable conditions, especially calm days and relatively flat terrain. A small ultralight aircraft (Eagle) was tested for possible use in dispersing depredating cormorants (Phalacrocorax carbo) from ponds at a fish farm in the Netherlands (Moerbeek et al. 1987). Its effectiveness was not evaluated, but its maneuverability was considered better than that of a helicopter. Because of wind conditions, however, its use was not deemed feasible at the site.

HELICOPTERS

Little literature exists on the use of helicopters for hazing birds, but they have been used to herd flightless waterfowl to distant holding pens in remote areas of Alaska and Canada. Timm and Bromley (1976) used a 2-person Brantley helicopter to herd geese about 1600 yards across exposed Alaskan tide flats. About 30 minutes flying time was needed to move 52 adults and 123 goslings into a steady 22 mph wind. The charter rates was $250 per hour. In another drive, a 5-person jet Alouette helicopter was used to locate and herd 5 goose flocks through dense sedge and narrow strips of riparian willow habitat in Alaska (Timm and Bromley 1976). The geese were herded distances varying from 55 to 440 yards. Some birds escaped this drive, however, because a few adults crouched in vegetation and allowed the helicopter to pass overhead. The 50-minute operation cost $208. In both drives, helicopters were flown 1 to 16 yards above ground and 10 to 22 yards behind the geese. Lateral movements were sometimes necessary to guide geese in the desired direction. Helicopters also have occasionally been employed in Canada to herd snow geese and brant, but their use has not been well documented (Timm and Bromley 1976).

A small, two-seater helicopter (Hughes 300C) was tested to evaluate its effectiveness in repelling cormorants from fish ponds (Moerbeek et al. 1987). Most cormorants that departed soon returned, and the number of birds using the ponds did not decrease. Because of the poor results, the trial was discontinued after 2 days.

Mott (1983) examined the influence of low-flying helicopters on the roosting behavior of blackbirds and starlings at 12 winter roosts. All flights were made at night with either a Bell 206 Jet Ranger or Hughes 500D helicopter. Two to 30 passes were made 10 to 45 yards above the roosting vegetation at speeds of 25 to 35 mph. Extensive flushing of birds occurred on clear nights but not on overcast nights. Use of landing lights on some passes did not seem to influence the birds' behavior. Most birds, however, returned to the roosts soon after the helicopter passed over or departed.

RADIO-CONTROLLED MODEL AIRCRAFT

Several workers have tested the effectiveness of radio-controlled model aircraft for hazing birds. Blokpoel (1976) described 2 experiments conducted in Canada. Preliminary trials with a model airplane successfully dispersed dunlin (Calidris alpina) from salt flats near Vancouver Airport. The Canadian Wildlife Service also used model aircraft to haze birds in blueberry fields. Robins (Turdus migratorius) were effectively repelled when models were airborne, but they returned almost immediately when the aircraft landed. Sparrows, waxwings, and swallows did not appear to be bothered by the model. Radio-controlled model aircraft also were used a few years ago to frighten starlings from the city of Vacaville, California, reportedly with some effectiveness.

Saul (1967) tested a radio-controlled model designed to resemble a falcon. The model was built with conventional modelling materials and equipped with a standard motor and radio control. It was 3.5 ft. long, had a wing span of 5.75 ft., and weighed 8.5 lbs. Preliminary tests at an airport in New Zealand were said to be encouraging. The effective area of hazing was about a 0.25-mile radius around the operator, but the species repelled were not reported. Saul (1967) considers that such aircraft would be useful only for short-term hazing, however, because birds would likely habituate if the aircraft is used for prolonged periods.

Briot (1984) conducted 50 tests with radio-controlled model airplanes at airports in France from 1982 to 1984. Eight models were tested and each was equipped with electric motors or small gas engines. Models were designed to resemble birds of prey, small airplanes, or various geometrical shapes (e.g., triangles, saucers). Models were tested against gulls, pigeons, starlings, and lapwings. The approach of any model caused birds to rise and flee, although most landed only a few hundred yards away. One model aircraft could sufficiently cover an area of about 62 acres.

A radio-controlled model shaped like a falcon was used to attempt dispersing birds, mainly black-headed gulls (Larus ridibundus), from a dump site near Ben-Gurion International Airport in Israel (Suaretz 1983). The model was flown early each morning as birds approached the dump. Gulls were attacked from all directions and driven from the garbage. The model was usually operated 4 to 5 times per morning, remaining airborne for an average of 12 minutes per flight. Gas exploders, shell crackers, and taped distress calls supplemented use of the model. Gull numbers decreased 90%, from an estimated 30,000 to 3,000, after 2 to 3 weeks of hazing. Because combinations of the other frightening devices worked so well, however, use of the model aircraft was not deemed necessary.

The principal problem encountered with radio-controlled model aircraft is the need for a highly skilled operator (Saul 1967, Blokpoel 1976). Briot (1984) considers the method difficult to employ and believes it requires the services of at least 2 operators per airport. Because birds often return soon after model aircraft land, nearly constant hazing may be necessary, and this limits their use in many situations. They might best be used to provide variety in an integrated bird-hazing program.

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BIOSONICS

Biosonics as a repelling technique are based on acoustical signals emitted by birds and other animals to convey information to conspecifics. Two audible bird warning stimuli, distress and alarm calls, have been explored and/or used for acoustically repelling birds from urban and rural roosts (Brough 1969, Pearson et al. 1967), fish-rearing ponds (Spanier 1980), airport runways (Bridgman 1976, Blokpoel 1976), agricultural settings (Boudreau 1975, Naef-Daenzer 1983, Summers 1985), and other locations (Mott and Timbrook 1988). Distress calls are those emitted by birds when being restrained, attacked by a predator, or subjected to other types of severe conditions, whereas alarm or warning calls are usually given in response to the presence of an intruder or predator. Depending on the species and situation, these warning calls often cause conspecifics, and sometimes closely related species, to leave the immediate area. The use of natural communication signals to frighten birds has received considerable attention in the past several decades for managing certain pest birds (Frings and Frings 1967, Wright 1969). They have the advantage of being more effective than the use of unnatural sound and noises to repel nuisance birds as the birds do not habituate as rapidly to the distance or alarm calls.

Frings and Jumber (1954) first reported on the potential of distress calls for repelling birds. They found that captive

European starlings (Sturnus vulgaris) held by their legs emitted piercing distress calls that frightened other starlings. Recordings of these calls broadcast through a loudspeaker were used to disperse starlings from several urban roosts (Frings et al. 1955a). Subsequent trials with gull warning calls also showed promise in repelling herring gulls (Larus argentatus) feeding at dumps (Frings et al. 1955b). Not all bird species emit alarm or warning calls, however, and the distinction between alarm and distress calls is not clear for some species (Greig-Smith 1982, Schmidt and Johnson 1984). Warning calls are most commonly emitted by gregarious species, and large flocks usually are more responsive than small flocks or individuals (Brough 1968, Boudreau 1972).

Warning calls have been used to deter starlings, gulls (Larus spp.), corvids (Corvus spp.), Canada geese (Branta canadensis), night herons (Nycticorax nycticorax), and other species. Calls are usually broadcast in short bursts (e.g., 10 to 90 seconds) at intervals of 10 minutes or more, depending on the bird species and situation. Factors that likely influence their effectiveness include weather conditions, season, availability of alternative sites for repelled birds, group size, quality of recordings, number of broadcasting systems, and possibly others (Blokpoel 1976, Currie et al. 1977, Johnson et al. 1985). Although warning calls alone can occasionally repel birds, supplementing calls with other bird-frightening techniques (e.g., shell crackers, etc.) often increases their effectiveness as it fortifies the apparent threatening situation.

BROADCASTING AND RECORDING EQUIPMENT

Standard broadcasting equipment consists of a tape player, amplifier, and one or more loud speakers. High fidelity systems are not essential but may provide better results under adverse conditions such as strong winds (Bremond et al. 1968). Whatever system is used, care must be taken to ensure that components are compatible. Equipment can be operated manually or automatically as desired. Mobile units with speakers mounted on top of a vehicle or directed out windows are commonly used (Brough 1963, Boudreau 1975, Mott and Timbrook 1988). Portable units, consisting of a common trumpet-type speaker connected to a small cassette recorder that can be easily carried by one person, also have been used at remote starling roosts (Brough 1969, Boudreau 1975, Currie et al. 1977). Stationary units with elevated loud speakers are sometimes used in agriculture and occasionally at airports.

Warning calls can be recorded, but prerecorded calls of many bird species are available from commercial and noncommercial sources (Schmidt and Johnson 1982). Distress calls, which are easier to record than alarm calls, are most often used. Some workers recommend recording or obtaining locally recorded calls, because some bird species have regional dialects and their warning calls may not be recognized by conspecifics in other regions (Hardenberg 1963, Frings 1964). Federal, state, and local regulations should be checked before capturing any species or broadcasting their warning calls. A sensitive microphone and a good quality recorder are needed for recording. Reel-to-reel recorders are deemed more versatile and effective than cassette recorders, although the later can be used if necessary. Quality tapes should always be used.

RESPONSES OF CAPTIVE STARLINGS TO DISTRESS CALLS

Several workers evaluated the response of captive starlings to distress calls of conspecifics. Thompson et al. (1968) measured heart rates of starlings fitted with miniature FM transmitters and exposed to distress calls in an acoustical chamber. Heart rates rose sharply immediately upon exposure and peaked within 3 seconds, suggesting that calls need not be played continuously to induce a fright response. Group behavior also apparently reinforced the response, because it was greater when birds were in groups than when alone. Langowski et al. (1969) obtained similar results, with starlings responding equally well to playbacks of 4 seconds as to those up to 95 seconds in duration. They suggested broadcasting calls of short duration to minimize possible habituation or waning of the alarm response to calls played for long durations or continuously.

Johnson et al. (1985) evaluated the relative efficacy of distress calls, white noise, and a pure tone (917 cycles per second) on starlings housed in an outdoor cage. The birds responded only to the distress calls and white noise. Initial responses were similar. After 10 presentations, however, they began habituating to white noise but not to distress calls. Responses to distress calls also were more pronounced in summer than in winter, possibly due to seasonal differences in metabolic requirements or physiological state of the starlings.

EFFECTIVENESS OF DISTRESS CALLS IN THE FIELD

Numerous field trials and applied uses have been conducted against pest bird species since Frings and Jumber (1954) demonstrated the potential of warning calls for repelling birds. The majority of these were directed at displacing nuisance starlings and gulls. Many of these efforts in California and elsewhere were never published. A few studies and uses involved other species (Table 1). In the West, Boudreau was one of the earlier users of this technique (Boudreau 1968).

Table 1. Summary of effectiveness of distress calls for repelling birds in the field.

Species and situation	Effectiveness	Source
European starling (*Sturnus vulgaris*)		
urban roosts	complete or partial dispersal	Frings et al. 1954
urban roosts	highly effective	Pearson et al. 1967 Block 1976
rural roosts	highly effective	Brough 1963, 1968 Currie et al. 1977
orchards, vineyards	effective	Schwab 1964 Seibe 1965
cherry orchard	effective 1 week only	Summers 1985
blueberry fields	highly effective	deCalesta and Hayes 1979
airports	effective if used with shell crackers	Brough 1968
holly orchard	effective	Marsh 1962 (unpub.)
Gulls (*Larus* spp.)		
dumps	effective during 2-day trial	Frings et al. 1955b
dumps	effective only for a few days if used alone	Seubert 1963
airport	"very encouraging"	Hardenberg 1963
airports	not highly effective if used alone	Brough 1963
airports	good	Brough 1968
airport	habituation after 5 months	Heighway 1969
airports	effective to highly effective	Stout et al. 1974

Table 1 (cont.)

Species and situation	Effectiveness	Source
Corvids (Corvus spp.)		
airport	not highly effective if used alone	Brough 1963
airports	highly effective	Brough 1968
corn fields	highly effective	Naef-Daenzer 1983
Red-winged Blackbirds (Agelaius phoeniceus)		
corn fields	effective	Seubert 1963
corn fields	ground unit effective; aircraft unit not highly effective	De Grazio 1964
feedlot	highly effective	Seubert 1963
Canada goose (Branta canadensis)		
reservoir	effective but rapid reinvasion	Mott and Timbrook 1988
Night heron (Nycticorax nycticorax)		
fish ponds	effective	Spanier 1980
Indian baya (Ploceus philippinus)		
roost	highly effective	Swamy et al. 1980
Lapwing (Vanellus vanellus)		
airports	most effective in combination with shell crackers	Brough 1963, 1968

Starlings

Tests by Frings and Jumber (1954) first indicated that starlings could be frightened by broadcasting their distress calls. They had complete or partial success in dispersing several urban starling roosts in Pennsylvania and New York in 1953 and 1954 (Frings et al. 1955a). Pearson et al. (1967) subsequently used distress calls to effectively disperse 3 starling roosts in Denver during 1963 and 1964. These roosts contained an estimated 1500 to 10,000 birds, mostly starlings but also about 10% grackles (Quiscalus quiscula). Distress calls were recorded on phonograph records and played by 20 to 40 residents having starlings roosting by their homes. Roosts were abandoned after 3 to 4 evenings of hazing, with fewer birds returning each evening. The program was considered a success. Block (1976) also successfully dispersed 2 urban starling roosts in Connecticut and Massachusetts by broadcasting distress calls. These roosts contained about 2500 to 4500 starlings and a small number of grackles. Both roosts were abandoned after 4 to 5 nights of hazing.

Brough (1963, 1969) and Currie et al. (1977) reported on the use of distress calls to repel starlings from rural, woodland roosts in the United Kingdom. Such roosts can contain up to 1.5 million starlings. Thirty-one of 33 roosts monitored by Brough (1969) were successfully cleared after an average of 3 evenings of hazing. Complete dispersal was achieved after only one evening at 2 roosts. Although other scaring techniques supplemented the playing of distress calls at most roosts, starlings dispersed within 3 days from the 9 roosts where only distress calls were used. The calls were directed at birds as they approached the roost but were played as sparingly as possible to alleviate possible habituation. Brough (1969) considers distress calls to be highly effective and one of the easiest bird-dispersal techniques to implement. Operating costs also were considerably less than for pyrotechnics or shooting.

Distress calls have also been used to frighten starlings feeding in agricultural fields. Although methods were not discussed, starlings reportedly were repelled from a 50-acre German vineyard for 7 weeks by broadcasting calls from 6 loud speakers (Nelson and Seubert 1966). In the early 1960s, members of the California Department of Agriculture, in conjunction with certain County Agricultural Commissioners, used broadcast starling distress calls to repel starlings from cattle feedlots and other agricultural situations. Field trials in California fig orchards and vineyards in 1964 and 1965 also showed that distress calls broadcast at 10-minute intervals throughout the day could effectively repel depredating starlings (Schwab 1964, Seibe 1965). In one trial, about 1000 starlings were repelled from a 69-acre orchard after 1 week. An estimated 2500 starlings were repelled from a 5.5-acre fig orchard after 2 days in another test.

deCalesta and Hayes (1979) effectively repelled starlings from 4 blueberry fields in Oregon in 1977. Calls were broadcast for a minimum of 30 seconds on a cassette-amplifier system whenever 5 or more starlings entered a field during a 6-week period. Starlings departed from fields on 93% of the occasions that calls were played. Other bird species, including robins (_Turdus migratorius_), did not respond to the starling distress calls, however.

Summers (1985) tested distress calls against starlings in fruit orchards in the U. K. Fifteen loudspeakers were used in 2 orchards encompassing about 20 acres. Calls were broadcast for 80 seconds every 11 to 12 minutes throughout the day during a 3-week period. Starling reactions were assessed by counting arriving and departing flocks during and between playbacks and monitoring the location of 22 individuals fitted with radio transmitters. Calls effectively repelled starlings during the first week when significantly more flocks departed during broadcasts than between broadcasts. Starlings apparently habituated to the calls, however. Radio-collared birds visited the orchards daily, and after the first week few birds departed when calls were played. If distress calls are to be used for extended periods, some type of reinforcement with other danger stimuli may be needed to alleviate habituation (Fitzwater 1970).

Brough (1968) discussed the use of distress calls against starlings at 5 airfields in the U. K. in 1965. Effectiveness was deemed "good" only 57% of the time out of 118 tests. In contrast, shell crackers alone (15 tests) produced good results 93% of the time, and the combination of calls and shell crackers (18 tests) worked well 94% of the time.

Biosonics continue to be used as a repelling technique to frighten starlings from unwanted areas.

Gulls

Distress calls have been used with varying degrees of success against nuisance gulls at airports and garbage dumps. Frings et al. (1955b) repelled about 300 gulls during a 2-day trial at a dump in Maine. A herring gull alarm call effectively repelled herring gulls and great black-backed gulls (*Larus marinus*) for periods varying from 10 minutes to 3.5 hours. Laughing gulls (*L. atricilla*) at another dump also responded to the herring gull alarm call. Calls were broadcast in 1-minute bursts on the first day, but bursts of only 10 to 20 seconds on the second day were equally effective.

Hardenberg (1963) reported on a trial at an airfield in the Netherlands where thousands of gulls roosted on a runway, mainly at night. Thirty-two loudspeakers, each elevated approximately 8 inches off the ground, were situated to provide complete sound coverage of the runway. An initial test using a taped distress call of a herring gull recorded in the United States was not successful, presumably due to a regional difference in dialect. Subsequent tests with calls recorded from locally captured herring gulls, black-headed gulls (Larus ridibundus), and common gulls (L. canus) were "very encouraging". When calls of each species were broadcast for 20 seconds sequentially, gulls rose from the runway, flew toward the source of calls, circled for 15 to 20 seconds at a height of 60 to 90 feet, and finally departed. No evidence of habituation was noted during this trial, although its duration was not specified.

Distress calls of the glaucous-winged gull (Larus glaucescens) and ring-billed gull (L. delawarensis) were tested against gull aggregations on and near runways at air force bases in Alaska and Texas (Stout et al. 1974). In Alaska, 5 types of calls (distress, alarm, mew, choke, trumpet) of glaucous-winged gulls were tested on runways and along a nearby shoreline in 1973. Calls were broadcast for 15 seconds from a pickup truck located 33 to 220 yards from the birds. All 5 types of calls dispersed the gulls from runways. Along the shoreline, however, distress calls produced the best results. Only 12% of the gulls remained when distress calls were broadcast, versus 26 to 28% for alarm and mew calls and 38 to 53% for choke and trumpet calls. Most gulls reacted to the distress calls by rising, circling towards the sound source for about 2 minutes, and departing. No evidence of habituation of distress calls was noted during 120 broadcasts. Gulls usually returned, however, after an hour or more after each broadcast. The same method was used against 31 to 400 ring-billed gulls in Texas in 1974, but only a distress call was used. In 15 of 16 broadcasts, all gulls dispersed, and the trials were deemed highly successful.

Distress calls alone were not highly effective for repelling gulls from 2 airfields in the U. K. (Brough 1963). Distress calls of herring gulls, common gulls, and black-headed gulls were broadcast sequentially for 1.5 minutes or more in attempts to disperse 200 to 500 gulls at one site. Reactions of the gulls were unpredictable, and they dispersed only about 65% of the time calls were played. When calls were supplemented with shooting smoke puffs, flares, or shell crackers, gulls dispersed 94% of the time. At a second airfield, calls were broadcast from a mobile unit upwind of the birds or while driving toward them. Gulls departed only during 16% of these broadcasts. Better results were again obtained when broadcasts were supplemented by pyrotechnics. In trials at 5 airfields in 1965, distress calls alone produced good results 85% of the time in 202 tests (Brough 1968). Supplemented by shell crackers in 153 tests, gulls were repelled 92% of the time. By 1969, the combination of gull distress calls and pyrotechnics was being used at more than 50 airfields in the U. K. (Wright 1969).

Gull distress calls broadcast regularly at an airbase in Scotland indicated long-term use may result in habituation (Heighway 1969). Loudspeakers arranged along both sides of a runway effectively repelled gulls for about 5 months, but thereafter the birds became indifferent to the broadcasts. The trial was discontinued in favor of using trained raptors.

Gulls rapidly habituated to distress calls played at 2 garbage dumps in the United States (Seubert 1963). About 1000 gulls were present at each site. A combination of distress calls and shooting shell crackers successfully repelled gulls for the 3-week test period, but at the second site they were repelled for only about 1 week. Calls alone were effective for only a few days at either site. Seubert (1963) speculated that the failure of distress calls to repel gulls under these circumstances might have been due to a strong attraction to the feeding sites and possibly also by the stage of the annual cycle.

Other Species

Distress calls have occasionally been tested against species other than starlings and gulls. Seubert (1963) reported that red-winged blackbirds (Agelaius phoeniceus) were effectively repelled for 25 days from a corn field in South Dakota, and numbers of blackbirds and starlings were reduced 91% at a 20-acre feedlot after 80 days of broadcasting blackbird distress calls. Trials using both alarm and distress calls of the house sparrow

(Passer domesticus) had some effect at deterring feeding sparrows from 2 grain fields, but crop damage was reduced only in a limited area (0.25 acres) around the loudspeaker (Bridgman 1976). deCalesta and Hayes (1979) had only limited success in repelling cedar waxwings (Bombycilla cedrorum) from 4 blueberry fields in Oregon during a 6-week test period. Waxwings left the fields during only 37.5% of the broadcasts.

Distress calls also were tested against blackbirds damaging corn fields near Sand Lake, South Dakota in the early 1960s (De Grazio 1964). Stationary and mobile ground units and a portable unit in a low-flying airplane were tested. Few details were provided, but the stationary unit playing blackbird distress calls reduced damage 15 to 85% in 3 fields with a history of heavy bird damage. Distress calls were said to be more efficacious than alarm calls. Tests with aircraft had some initial effect in repelling birds but nearly constant harassment was required for satisfactory protection.

Tests with corvid distress calls began as early as 1955 in France and were considered promising for dispersing roosts and feeding birds (Frings and Frings 1967). Rooks (Corvus frugilegus), jackdaws (C. monedula), and carrion crows (C. corone) could all be repelled from agricultural fields for up to 2 weeks by broadcasting distress calls of any one species (Nelson and Seubert 1966). Naef-Daenzer (1983) also found that distress calls broadcast for 20 to 30 seconds every 25 minutes from dawn to dusk were effective for repelling carrion crows from sprouting corn fields in Switzerland. Damage was significantly less in 12 treated fields than in 12 untreated fields, although damage was extremely low in all fields.

Corvid distress calls have been used with varying success at British airfields. In one trial, corvids, mainly rooks and jackdaws, departed only during 43% of the broadcasts (Brough 1963). They were highly effective at five other airfields, however, where corvids dispersed 93% of the time distress calls were played in 181 tests (Brough 1968).

Brough (1963, 1968) also reported on tests with lapwings (Vanellus vanellus) at U. K. airfields. Distress calls alone dispersed lapwings 83% of the time at one site. At five other airfields, lapwings departed during only 71% of broadcasts (97 tests), but supplementing the calls with shell crackers increased their effectiveness to 90%.

Mott and Timbrook (1988) used a 2-speaker broadcast system mounted on top of a car to repel Canada geese from lakeshore campgrounds at a Tennessee reservoir. Calls were either broadcast alone or in combination with shooting racket bombs. Goose numbers decreased an average of 71% when calls were used alone and by 96% when supplemented by 1 to 6 racket bombs fired immediately after a broadcast. Geese responded by flying or swimming to safe areas in the middle of the lake, but they returned soon after treatment. The authors concluded that continual harassment is necessary for effective protection of the campgrounds.

Distress calls of the night heron were tested as a means of repelling these fish-eating birds from fish ponds in Israel (Spanier 1980). Attempts to repel the herons by other methods were not successful. Calls were broadcast for 2 minutes every 20 minutes throughout the night for several months. More than 80% of the herons reacted to calls by flying away from the ponds, although most settled in nearby trees. They often eventually returned to the ponds but were repelled by subsequent broadcasts. The trial was considered successful, because fish losses were greatly reduced even after several months of broadcasts.

About 350 bayas (Ploceus philippinus) were successfully repelled from a roost in India (Swamy et al. 1980). Recorded calls were broadcast for 30 to 40 seconds at 5-minute intervals every 2 to 3 days as birds entered the roost. All birds abandoned the roost after 6 nights of hazing during a 13-day period.

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COMMERCIAL SUPPLIERS OF DISTRESS/ALARM CALLS*

Applied Electronics Corp., 3003 County Line Road, Little Rock, AR 72201

Signal Broadcasting Co., 2314 Broadway Street, Denver, CO 80205

Smith's Game Calls, P.O. Box 236, Summerville, PA 15864

*Compiled from: Schmidt and Johnson 1982; Timm 1983.

SCARECROWS AND PREDATOR MODELS

Predator models used to frighten birds include scarecrows (human effigies) and raptor models, especially hawks and owls. Model snakes and cat silhouettes are commonly sold to gardeners. Scarecrows have a long history of use against pest birds (Frings and Frings 1967, Achiron 1988). Often, however, the traditional motionless scarecrows provide only short-term protection or are ineffective (National Pest Control Assoc. 1982). Some birds may even utilize them as perches (DeHaven 1971), or associate them with favorable conditions (Inglis 1980). Hawk and owl models in some circumstances may be more effective than scarecrows, but birds can rapidly habituate to their presence (Conover 1982). For best results, scarecrow and raptor models should appear lifelike, be highly visible, and be moved frequently at the site to help alleviate habituation (Neff n.d., Vaudry 1979). Dangling streamers or reflectors from scarecrows and using brightly colored loose clothing may help increase their effectiveness because they move in the wind and birds react more readily to colored and moving objects (Vaudry 1979, National Pest Control Assoc. 1982). Snake and cat models are rarely of any value.

In most situations, traditional scarecrows and models of perched raptors do not closely enough resemble a situation that is alarming or threatening to birds (Inglis 1980). Reinforcement with shooting or supplementing models with other bird-scaring techniques is, however, highly recommended to increase their effectiveness. More recent field studies have indicated that mechanically incorporating movement or sound stimuli into the models may greatly enhance their effectiveness. Howard et al. (1985) suggested designing models that display action or produce sound, which is somehow triggered by the pest birds when they first enter an area, before they have a chance to land and feed. Such action or sound should be discontinued when the birds leave. This would result in the birds habituating much less rapidly. There is one such triggering device that does turn on frightening equipment when the birds approach.

SCARECROWS (HUMAN EFFIGIES)

The use of traditional scarecrows to deter grain-eating and fish-eating birds has provided variable success. Simple scarecrows made of black plastic bags attached to wooden stakes are used to deter waterfowl from grain fields in North Dakota and South Dakota (Knittle and Porter 1988). This has also been tried in California to keep birds from contaminated waters. The key to their success is to place them out before waterfowl begin arriving in newly swathed fields. DeHaven (1971), however, considers scarecrows to be of little value in deterring blackbirds from rice fields unless they are used with other devices, such as exploders. Lagler (1939) stated that scarecrows placed along pond walls provided good protection at a fish hatchery in Utah, but they were not effective at a hatchery in West Virginia. A scarecrow mounted on a float was 80% effective in deterring birds from circular ponds, but kingfishers were not repelled (Lagler 1939). One of 14 fish-rearing facilities surveyed by Parkhurst et al. (1987) reported successful bird control with scarecrows, whereas 13 facilities rated them of limited or no success.

Boag and Lewin (1980) evaluated the effectiveness of a floating human effigy for deterring waterfowl from natural and artificial (contaminated) ponds in Alberta, Canada. The effigy was a commercial manikin clothed in bright orange coveralls and a knee-length bright yellow plastic overcoat, and it was mounted on a floating platform. In 1975 a single effigy was placed in the center of a small pond, and waterfowl were counted on the pond and on two untreated ponds to determine their effectiveness. As a follow-up study in 1976, 27 manikins were placed on a contaminated 375-acre pond. In this study effectiveness was evaluated by comparing the number of dead birds located on the pond in 1976 versus the number found in the previous year when no control was used.

The human effigy was more effective in deterring waterfowl than were a floating raptor model and a series of floating reflectors. The number of waterfowl on the small treated pond in 1975 was 75% less than on control ponds. Significantly fewer dead birds were found on the contaminated pond in 1976 than in 1975. Resident birds, however, gradually habituated to the model, but nonresidents did not. Boag and Lewin (1980) concluded that human effigies can be effective in deterring waterfowl from ponds, although not all birds will be excluded.

Craven and Lev (1985) assessed the use of scarecrows to repel double-crested cormorants (*Phalacrocorax auritus*) damaging commercial fisheries in Wisconsin. Scarecrows hung from net poles were effective for about 1 month, but cormorants then began to habituate to the models and returned to perch on the poles. A scarecrow placed in a boat provided protection for about 5 weeks.

A variety of scarecrow models has been tested against various birds in Europe. One promising model consists of a 3-dimensional human effigy whose head and outstretched arms move periodically (Inglis 1980). The movement presumably more realistically mimics an alarming situation than does an unanimated model. A mobile scarecrow unit also has been developed in Scotland but details are lacking. This consists of an inflated human effigy placed on a 3-wheeled cart that is guided along cables in fields and orchards (Achiron 1988). Propane exploders and taped distress calls supplement the deterrence provided by the moving effigy.

Pop-up scarecrow units that work in synchrony with propane exploders also have been developed and evaluated in agricultural fields. One version consists of a head and torso of a human effigy mounted on an exploder (Achiron 1988). When the exploder blasts, the effigy shoots 3 feet into the air and spirals back down with fringes fluttering from its outstretched arms. One such unit is operated by a solar-powered cell and is marketed locally in North Dakota for about $500 (1988 cost). The Razzo Missile® is an action device that produces both acoustical and optical stimuli. The device sends a visual scaring projectile up a pole when activated by a propane exploder.

Another version of the pop-up scarecrow was developed and tested by the Denver Wildlife Research Center (Cummings et al. 1986). The effigy consists of the upper torso of an inflatable plastic scarecrow injected with polyurethane foam. It is mounted on a CO_2-operated pop-up device set so the scarecrow pops up 15 to 30 seconds prior to two explosions (at 10-minute intervals) from a propane exploder. The unit is mounted on a tripod, but the scarecrow is visible above the sunflower heads only when the scarecrow is in the upright position. Units were tested against blackbirds damaging five sunflower fields (4 to 48 acres) in North Dakota in 1981 and 1982. Each unit covered 8 to 10 acres in 1981 and 4 to 6 acres in 1982. Sunflower damage was assessed to determine their effectiveness. The units were effective for deterring blackbirds, but efficacy varied among the test fields.

They were less effective in fields where birds had an established feeding pattern and in fields located near roosts. Cost per unit, excluding labor, was about $900, but the cost per acre was estimated at $14 based on the expected life (10 years) of each unit.

RAPTOR MODELS (HAWKS AND OWLS)

Boag and Lewin (1980) also attempted deterring waterfowl from small ponds by using a model falcon mounted on floats. The wooden model simulated a flying falcon with a 16-inch wingspan. It was attached to a 12-foot tall pole bolted to the platform and floated in the center of a small pond. Wind and waves caused the model to move back and forth in a small arc. The number of birds counted on the pond declined 69% after the model was installed, and they declined 47% compared with the decline in numbers on two untreated ponds. The falcon model, however, was not as effective as the human effigy model tested on other ponds.

The use of raptor perches and perching kestrel models on some of the perches was found ineffective in significantly repelling pest birds from vineyards (Howard et al. 1985). Craven and Lev (1985) found that stationary owl decoys were not effective for repelling double-crested cormorants that perched on nets and poles of commercial fishermen. Cormorants were observed perching next to the decoys within 2 days after their placement.

Will (1985) also noted that stuffed owls placed on beams and overhead ledges in aircraft hangars had little or no effect in dispersing roosting birds.

Models of owls are often promoted and used unsuccessfully in an attempt to repel pest birds. Like any new object placed in the environment, they may be avoided by other birds for a few hours or days. However, the pest species soon learns that the models are no threat and pay no attention to them. They often even perch on top of the model owls.

Conover and Perito (1981) evaluated the response of starlings (Sturnus vulgaris) to predator models holding conspecific prey. The model was a great horned owl (Bubo virginianus) used alone, accompanied by a taped distress call, or grasping a "captured" starling. Observations were conducted at open silage troughs on two dairy farms where starlings fed regularly. Starlings usually responded to the models by delaying their return to the feeding trough and by feeding at the end of the trough opposite the model. Starlings fled the area when distress calls were played. They were most wary of the owl model when it was holding a live tethered starling. They were also more wary of the model after the starling was removed than before it was attached. Tethering a dead starling to the model was less effective than attaching a live starling.

Conover (1979) evaluated the response of birds to raptor models at five artificial feeding stations and a small (0.15-acre) blueberry plot. The models were museum mounts of a sharp-shinned hawk (Accipiter striatus) and a goshawk (A. gentilis). More than 10 bird species used the feeders, which consisted of wooden platforms 3 to 4 feet off the ground baited with corn and sunflower seeds. The models were evaluated for up to 7 days each. They initially deterred birds but most habituated to the models after only 5 to 8 hours. Blue jays (Cyanocitta cristata) and starlings were deterred more than mockingbirds (Mimus polyglottos), mourning doves (Zenaida macroura), and house finches (Carpodacus mexicanus). Although the hawk models significantly reduced the number of feeding birds, they were not as effective as a hawk kite suspended from a helium-filled balloon. Conover (1979) believes that movement of models or their "captured" prey is critical for frightening birds.

At least one mechanical hawk model has been marketed and is powered by battery. It can be suspended from poles where it continuously flaps its wings. A timer can be installed to control and vary the times of operation. Other raptor models available have outstretched wings and are generally suspended from poles or overhead wires.

Conover (1985) also evaluated a great horned owl model for protecting vegetable crops from crow (Corvus brachyrhynchos) depredations. Three versions of the model were tested in 33 x 66-foot tomato and cantaloupe plots. The first test used an unanimated plastic model. The second test used the same model, but it was grasping a crow model in its talons and was mounted on a weathervane so it moved in a wind or breeze. The crow model had wings that also moved in the wind. The third test was similar to the second except that the model crow's wings were moved by a battery-operated motor, thus they moved even in the absence of a wind or breeze. Damage to fruit was assessed during each treatment and compared to damage levels in an untreated plot. The unanimated owl model was ineffective. Both animated versions reduced damage by 81% when compared to the control plot, and they were equally effective under the conditions tested. Models were inexpensive and easily built. Costs of the owl decoy and crow model in 1981 were $6 and $4, respectively. Other materials cost $20 for the wind-operated version and $60 for constructing the motor-operated model.

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SOURCES OF MATERIALS*

Bird-X, Inc., 730 W. Lake Street, Chicago, IL 60606 (Life-sized plastic model hawk).

Birdmaster, 2100 Llano, Bldg. N-5, Santa Rosa, CA 95401 (Hawk site and teather rig).

W. Atlee Burpee Seed Co., Warminster, PA 18974 (Scarecrow "Farmer Fred").

Brookstone Company (Mail Order Catalog Sales), 127 Vose Farm Rd., Peterborough, NH 03458 (Inflatable life-sized scarecrow, owl models).

David Kay (Mail Order Catalog Sales), Terrace Suite 114, 921 Eastwind Drive, Westerville, OH 43081-5306 (Inflatable life-sized scarecrow).

The Plow & Hearth (Mail Order Catalog Sales), 560 Main Street, Madison, VI 22727 (Inflatable life-sized scarecrow, inflatable owl and snake models).

Robert Royal, P.O. Box 108, Midnight, MS 39115 (Automatic pop-up air-inflated scarecrow "Scarey man").

Terso Kasei Co., Ltd., 350 South Figueroa Street, Suite 350, Los Angeles, CA 90071 (Automatic propane-activated acoustical and optical animal-scarer "Razzo Missile," life-sized, mechanical wing-flapping hawk model).

Tisara Enterprises, P.O. Box 2006, Fremont, CA 94536 (Hawk silhouette "Wonder Bird Scarer").

Williams-Sonoma (Mail Order Garden Catalog Sales), P.O. Box 7307, San Francisco, CA 94120-7307 (Inflatable life-sized scarecrow, inflatable snake, inflatable owls).

*Compiled from: Timm 1983, various others.

THE AV-ALARM® AND OTHER SONIC DEVICES

Various types of sonic devices are marketed for repelling birds from agricultural crops and other situations. These devices emit loud noises (<18,000 to 20,000 cycles per second) that are audible to humans and birds (Fitzwater 1970). Conflicting claims exist as to their effectiveness under field conditions (Bomford 1990). The Av-Alarm[R], probably the most widely used of these devices, has been marketed for pest control since 1967 (Stewart 1974). A noise synthesizer designed after the Av-Alarm has recently been tested for repelling birds from runways at Paris-Orly Airport in France (Briot 1987). Other sonic units also have been experimentally tested (Woronecki 1988, Bomford 1990). Most units are designed to be sufficiently irritating to birds that they leave the immediate area (National Pest Control Association 1982). Like other noises, they may temporarily scare species like starlings and pigeons from the area, but most field evidence suggests that this method is less effective than the use of actual distress calls (biosonics). Because these devices are relatively loud, their use is best confined to areas away from human habitation. The noise emitted, however, is generally not as objectionable as that produced by gas exploders.

AV-ALARM AND RELATED DEVICES

The original Av-Alarm units emitted loud, intermittent, electronically synthesized sounds that were similar to the noisy chirping of a large number of birds. These were sometimes referred to as synthetic bird alarm sounds. Such sounds were supposed to cause psychological "jamming" in birds and other pest animals (Av-Alarm Corporation n.d.). To date there is little basis in fact for this claim (Boudreau 1975). Present units, however, can generate many different electronically produced synthesized sound combinations within a sound range of about 2,000 to 5,000 cycles per second (Martin 1976, National Pest Control Association 1982). The loud pulsed noises produced may interfere with the birds' normal sound communication (although scientific support is lacking for this).

The Av-Alarm consists of a noise-generating unit, speakers to broadcast the sounds, and a power supply. Power is usually provided by a 12-volt car battery, although a separate AC power supply is available if needed. Each unit can operate unattended for several days or more on a single charge of the battery. A photocell circuit is present to allow the unit to turn on automatically at dawn or dusk as desired. Each unit also contains a timer so that noise is generated in 6- to 10-second increments (4 bursts per second) each minute (Av-Alarm Corporation n.d., Holcomb 1977). A 10-second warning is issued before each outburst of noise (National Pest Control Association 1982).

An Av-Alarm unit operated in the open produces a sound level of about 70 decibels and has a range of about 700 feet when used with a standard 30-watt speaker (Stewart 1974). A somewhat larger area of coverage can be expected at night when ambient sound levels are reduced. Each speaker covers a 90- to 120-degree sector with an effective area of coverage of about 8 to 10 acres (Av-Alarm Corporation n.d.). As many as four speakers can be attached to a single large unit. Multiple installations are said to have a synergistic rather than additive effect. Supplementing the Av-Alarm with propane exploders, gunfire, pyrotechnics, or other bird-frightening devices also is believed to enhance its effectiveness (Stewart 1974).

Martin (1976) tested the Av-Alarm in a cereal-crop scheme in the Sudan in 1975. The trial site measured approximately 1400 x 500 feet. Bird species causing damage were the red bishop (*Euplectes oryx*), golden sparrow (*Passer luteus*), and house sparrow (*Passer domesticus*). Two stationary units were mounted on 10-foot high platforms approximately 250 feet apart, and three speakers were attached to each unit. The units operated alternately. A mobile unit with three speakers also was mounted on a Landrover to enable rapid movement toward feeding flocks. The three bird species initially were deterred from the site but returned within 4 days to resume feeding throughout the site. The Av-Alarm was considered ineffective for reducing bird damage at the site. Damage was actually somewhat more severe near the units than away from them.

Holcomb (1977), in contrast, found that the Av-Alarm was effective in reducing damage to rice by red-billed quelea (Quelea quelea) in Somalia. One Av-Alarm unit with three speakers was placed in a 90-acre rice field in 1975 and 1976. Efficacy was based on twice-weekly bird counts and damage assessments conducted in 55-yard wide bands radiating outward from the speakers. The bird counts were too variable to analyze. Damage was less within 165 yards of the speakers than farther away, indicating the noise deterred quelea. The few red bishops present, however, did not seem to respond. Some bishops were observed feeding within 11 yards of speakers and did not cease feeding when bursts of noise were emitted.

J. Jackson (cited in Holcomb 1977) tried using the Av-Alarm to interfere with reproduction of red-billed quelea in a nesting colony in Sudan. The synthesized noise had no apparent effects on the birds.

The Av-Alarm was used with other noise-producing devices (propane exploders, taped distress calls, whistle bombs) to frighten birds loafing on an industrial waste pond in central

California (Martin 1979, 1980). Six Av-Alarm units were placed on 10- to 20-foot tall tripods around the 40-acre pond. Two units were operated at night and four during the day. Additionally, six propane exploders were spaced around the pond, taped distress calls were played on a portable biosonics unit when gulls were present, and whistle bombs were fired at passing flocks of blackbirds and starlings. The program was conducted from November 1978 through February 1979 and was deemed a success. Fewer birds inhabited the pond and fewer dead birds (killed by the toxic water) were found than in the previous year when no bird-scaring devices were employed. The effectiveness of the Av-Alarm in relation to the other noise-producing devices could not be evaluated. Martin (1979, 1980) believes success was due to the integration of several types of sound rather than any one alone.

The Av-Alarm was also tested against double-crested cormorants (Phalacrocorax auritus) impacting commercial fisheries in the Apostle Islands, Wisconsin (Craven and Lev 1985). A unit was tested for one week in an attempt to repel these fish-eating birds. The noise emitted did not deter cormorants, which were observed feeding within 7 feet of the speaker.

Thompson et al. (1979) measured physiological and behavioral reactions of 24 adult European starlings (Sturnus vulgaris) exposed to the Av-Alarm and starling alarm and distress calls.

Heart rates of the captive birds were measured with sensors and radio transmitters. Keypeck responses to food also were recorded when the different sounds were broadcast. Reactions to the Av-Alarm were slight, almost negligible, and much less marked than reactions to the biological calls. The authors conclude that the synthesized noises produced by the Av-Alarm have little potential for repelling starlings.

Little other information is available concerning the effectiveness of the Av-Alarm under field conditions. Boudreau (1975) states that it temporarily scares starlings and may have limited use for dispersing starling roosts, but it has little effect on other bird species. McCracken (1972) reported excellent success in protecting vineyards from starlings in California, but no data were provided. Fitzwater (1970) used an Av-Alarm for 2 days in an attempt to repel swallows constructing nests on a building in Davis, California, but with no success. Palmer (1976), however, believes the Av-Alarm is useful for repelling birds from feedlots providing it is used in an integrated program combining a variety of bird-scaring techniques.

A noise synthesizer designed after the Av-Alarm was recently tested for repelling black-headed gulls (Larus ridibundus), lapwings (Vanellus vanellus), pigeons, and starlings at Paris-Orly Airport (Briot 1987). The noise produced by this device is reported to be similar to that emitted by the Av-Alarm. Thirty-watt loudspeakers were placed at 500-foot intervals along the airport runways. Sequences were broadcast randomly and had to exceed 70 decibels to be effective. During an 8-month test period, bird strikes at the airport were reduced by 80%. No evidence of habituation to the noise was apparent during the trial.

Attributes of this noise synthesizer include full automation and low cost (Briot 1987). Major drawbacks, however, are an individual unit's small area of effective coverage and potential noise disturbance to people living near the airport. Because only the runways and adjacent shoulders were protected, some birds remained in the vicinity and occasionally flew across runways when disturbed. Although not tested, saturating the area with more units might have solved this problem. Despite the drawbacks, the device was deemed efficacious and will be used at other French airports having bird problems.

OTHER SONIC DEVICES

Bomford (1990) tested the effectiveness of the Electronic Scarecrow® against European starlings feeding in an open field baited with bread and fruit. This device consists of a control unit, programmable timer, individual speakers, and is powered by a 12-volt battery. According to the manufacturer, each speaker provides coverage of about 10 acres. Starling numbers and feeding activity were assessed in a 1650-yard radius around the unit. Treated, untreated, and buffer segments of equal size alternated around the circle. A speaker was elevated 1 yard above ground in each of the 3 treated segments. The unit was operated for 12 days during daylight hours. The noise produced by the device is audible to humans as a high-pitched whine that rapidly changes pitch and is accompanied by a loud hiss. The sound level measured 10 yards from the source ranged from 88 to 95 dB but decreased to <71 dB at 55 yards distance. The noise emitted had no effect on starling numbers or their feeding activity. Starlings often landed within 2 yards of the speakers without being alarmed. Starling numbers actually increased during the treatment period and were 57% higher than during the pretreatment period.

Woronecki (1988) tested the effectiveness of a sonic device (Deva-Megastress II) against pigeons (*Columba livia*) roosting and nesting in a vacant building. The unit has a photo-electric cell to switch it on and off, 4 speakers, including 3 on 82- to 165-foot leads, and operates with a 12-volt battery. It reportedly produces 56 randomly selected sound variations. Measured output was 8 to 9 bursts, each lasting 6 to 17 seconds, every 3 to 4 minutes, with a 4- to 7-minute interval between sequences. Sound measurements 3.3 yards from the source ranged from 102 to 108 dB. The unit was tested in 3 treatments (unit operated 2, 6, or 8 hours per day among treatments), with each treatment lasting 10 days. An average of 81 pigeons was present in the building during pretreatment counts. Pigeon numbers ranged from an average of 72 to 101 during the 3 treatments. Numbers were reduced for only 2 days during the first treatment, although pigeon behavior was altered for 10 days. Most birds left the building when noise was emitted and returned only when the unit was not operating. During the two subsequent trials, however, pigeons remained in the building during the outbursts and others entered even when the unit was operating. Thus, habituation was too rapid for the unit to provide adequate protection.

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AERIAL VISUAL DEVICES

Aerial visual devices that have been tested for repelling birds include colored balloons, hawk-shaped kites, and balloon-supported hawk kites. Tests have been conducted to determine the effectiveness of these methods in reducing bird damage to agricultural crops (Conover 1979, 1983a, 1984; Hothem and DeHaven 1982) or dispersing large aggregations of roosting birds (Mott 1985). However, apparently relatively few appear in the literature. These devices have not been widely explored or used to frighten birds away from other types of locations. Free-flying kites work best in a breeze or moderate wind but may not be suitable in calm conditions or in strong winds. Lighter-than-air balloons work in calm conditions, breezes, or light winds. Some birds may habituate to the presence of balloons and hawk kites exposed for long periods. Some wind movement of the balloons or kites suspended from balloons is preferred as the motion increases the fright responses of birds. Their effectiveness likely would be improved by using them with a variety of other bird-scaring techniques, such as gas (propane) exploders, cracker shells, distress calls, and others.

BALLOONS

Colored balloons have been tested in several situations to determine their potential for repelling birds from agricultural crops or roosting aggregations. The balloons used were plain colored or had imitation eyespots painted on them. Some studies suggest that eyespots illicit an alarm response in many animals, including some birds (Inglis et al. 1983). Balloons are either air-filled and tied to long poles or to vegetation so they will bob in the wind, or are filled with helium and floated above the area intended to be protected. With tethered air-filled balloons, a breeze or moderate wind will move the balloons and add to their effectiveness. However, helium balloons and tethered air balloons may be damaged by strong winds or the tether lines may become entangled with one another or in vegetation.

Helium balloons require a considerable amount of servicing. To alleviate bird habituation, they probably should be occasionally (every 3 - 5 days) moved about in fields and/or elevated or lowered as to distance from the ground rather than left in the same location for long periods (Hothem and DeHaven 1982). They also must be refilled as needed, which may be every 3 to 4 days, and should be taken down if strong winds are anticipated (Conover 1984). Vandalism can be a problem if balloons are near roads or areas with public access (Conover 1983a). Depending on type and size, individual balloons cost $16-$35 and require $4-$7.50 of helium to inflate. These represent early 1980's cost figures.

Mott (1985) dispersed common grackles (Quiscalus quiscula), red-winged blackbirds (Agelaius phoeniceus), brown-headed cowbirds (Molothrus ater), and European starlings (Sturnus vulgaris) by floating colored helium-filled balloons 26 ft above roosting vegetation as the birds were returning to roosts in the evening. White, yellow, red, and blue balloons (47-in diameter) were used at five sites ranging in size from 0.1 to 0.7 acres. The density of balloons ranged from 2 to 10 per 2 1/2 acres of roost. Estimated numbers of birds prior to placement of balloons ranged from 85,000 to 178,000 per roost. The balloons were floated in the evening but removed during the day when birds were away from the roost. During the three evenings balloons were exposed along the edge and within the roosts, bird numbers declined 82%. When wind speed exceeded 10 miles per hour, balloons were blown around and became tangled in the roosting vegetation. Although the balloons were effective, they were less effective than the shell crackers and noise bombs used at other roosts to disperse blackbirds and starlings (Mott 1980).

Helium-filled mylar balloons were used as one of nine techniques tested against double-crested cormorants (Phalacrocorax auritus) preying on fish at a commercial fishery in Wisconsin (Craven and Lev 1985). The balloons were not effective when used alone during a 2-week trial, but they provided some protection when used with a scarecrow.

Shirota et al. (1983) used a helium-filled balloon to protect 8.8 acres of grapes, cherries, and peaches on an experimental farm in Japan. The 8 1/2-ft-diameter balloon with five imitation eyespots was floated about 49 ft above the fields and provided effective protection against grey starling (<u>Sturnus cineraceus</u>) depredations.

Air-filled balloons were tested in a flight pen to determine their effectiveness in deterring captive great-tailed grackles (<u>Quiscalus mexicanus</u>) from citrus trees (Avery et al. 1988). Balloons with and without eyespots were tested separately by attaching them to poles for 2-week periods. None of the balloons provided complete protection, but grackles used the orange trees less often when eyespot balloons were present. Further tests under field conditions were recommended.

Air-filled beach balls (20-inch diameter) were subsequently tested for repelling great-tailed grackles from citrus groves in Texas (Tipton et al. 1989). Four groves, each paired with an untreated grove, were treated. Damage to fruit was assessed to determine efficacy. Balls with white backgrounds upon which were painted three large eyespots (black irises with bright red pupils) were placed in three groves. A fourth grove was treated with multicolored (red, blue, green, yellow) balls lacking eyespots. Balls were attached to poles about 1 yard above tree tops at densities of one ball per 4 to 10 trees. Damage was only slightly less in treated than untreated groves, and further tests are needed before their effectiveness in repelling grackles can be determined.

HAWK KITES

Hawk kites are plastic kites with a color image of a soaring raptor imprinted on them. The kites often simulate soaring hawks in general shape. The kite is tethered to a pole or suspended beneath a helium-filled balloon and flown above the area needing protection. The technique presumes that birds will flee from an overhead imagine of a potential aerial predator. Kites, costing $2 to $7 each, are marketed with life-size images of soaring hawks, eagles, or falcons (Conover 1979, 1983a,b; Hothem and DeHaven 1982). Effectiveness may be improved by selecting a model that closely resembles a raptor species occurring in the local area. Kites fly best in a breeze or moderate wind; wind speeds exceeding 5 miles per hour may blow down kites (Hothem and DeHaven 1982).

Conover (1983a) tested four types of pole-tethered hawk kites for protecting corn from blackbirds in Connecticut. The kites were tethered to poles driven in the ground in 5- to 15-acre fields. Four to eight kites were placed on half of each field and the remaining half was left unprotected. Damage levels in treated and untreated sections of the fields were not significantly different. Kites were often damaged or became entangled in the support poles.

The effectiveness of hawk kites can be increased by suspending them from helium-filled balloons floated above the area needing protection. The kite is tethered by a line to the aloft balloon, which is tethered to a stake or post at ground level. Using the hawk kite and balloon together is usually more effective than using either alone.

Conover (1979) compared the effectiveness of a balloon-supported hawk kite to perched raptor models at artificial feeding stations in Connecticut. A hawk kite with an image of an eagle was flown about 66 to 100 ft above the feeding site by tethering it to a helium-filled balloon 132 to 200 ft off the ground. The balloon and hawk kite was more effective in repelling birds than were perched raptor models, presumably because of the movement of the kite. Some individual birds began habituating to the hawk kite after only 5 to 8 hours of exposure, however, and different bird species responded differently to the model.

Conover (1983a) also tested a hawk kite over three .13 to 2.0-acre blueberry plots in Connecticut. The kite was flown 100 ft above the plots by suspending it from a helium balloon, tethered with monofilament line, 200 ft above ground. Bird counts and damage assessments were conducted in treated and control plots to evaluate its effectiveness. Damage was reduced by 35% on the treated plots, but the effectiveness of the hawk kite varied among bird species. Robins, starlings, and northern orioles were deterred from the plots but mockingbirds and brown thrashers were not.

Hawk kites suspended below helium balloons also were compared to propane exploders and Avitrol, a chemical-frightening agent, to determine which method was most efficacious and cost-effective for frightening blackbirds from corn fields (Conover 1984). Field sizes ranged from .8 to 20 acres. Treatments began when corn reached the milk stage of maturation in late August and continued until it was cut for silage in October. Birds were counted and damage assessed in each field. The hawk kite was the most effective of the three methods. Damage was reduced by 83% and the cost:benefit ratio was 3.5:1. For some reason the birds did not appear to habituate to the hawk kite in these tests. Most of the cost of the hawk kite was due to maintaining the helium balloons. The costs of operating an individual hawk kite, excluding labor, was about $63 for the duration of the tests.

Hothem and DeHaven (1982) tested hawk kites in California vineyards in 1979 and 1980. Test sites ranged from about 3 to 1(acres in size. Additional tests were conducted to determine longevity and flight characteristics of four balloon types (two spherical types, a polyurethane tetroon, and a mylar tetroon). In 1979 a kite with a color image of a golden eagle (4-ft wingspan) was tethered to a blue spherical weather balloon (4-ft diameter) tethered with 100 ft of fishing line in the center of a 2.8-acre vineyard. The device was flown for three 7-day periods, interspersed with three 7-day periods, when the balloon and kite were removed. In 1980, kite/balloons were placed in three fields at a density of approximately one per 2 1/2 acres. An orange tetroon, a tetrahedron-shaped polyurethane balloon, was also tested. Kites had either golden eagle or falcon (2 1/2-ft wingspan) images and were tethered with 50 to 200 ft of line. Damage assessments and bird counts were made in all fields.

In both years fewer birds were counted and damage was reduced in areas near the balloons. Damage was reduced by an average of 48% (32-88%) in 1980. Twenty-three to 83% fewer birds were counted in the periods when balloon-kites were present. However, not all bird species responded equally to the hawk kites. Numbers of house finches and California quail declined 87-100% but bluebirds and robins actually increased in numbers (20-92%).

One problem was keeping the balloons aloft. Tetroons were blown down when wind speeds exceeded 5 miles per hour. Spherical balloons were more stable in winds but were less durable and lasted only 2 to 2 1/2 days each. In longevity tests, polyurethane tetroons lasted an average of 7 days, which was significantly longer than the other balloon types. Kites lasted 7 to 14 days but also were blown down if wind speeds exceeded 5 miles per hour.

The trials of Conover (1979, 1983a, 1984) and Hothem and DeHaven (1982) indicate that some birds can be repelled when hawk kites are employed at a density of about one per 2 1/2 acres. However, the response appears to vary among species and also some birds habituate more rapidly than others to the presence of the hawk kites.

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SUPPLIERS OF BALLOONS AND KITES*

Atmospheric Instrumentation Research (AIR), Inc. 1880 S. Flatiron Ct., Suite A, Boulder, CO 80301 (balloons, kites)

Clow Seed Co., 1081 Harkins Rd., Salinas, CA 93901 (kites)

Cochranes of Oxford, Ltd., Leafield, Oxford, England, UK OX8 5NT (kites)

High-as-a-kite, 200 Gate Five Rd., Sausalito, CA 94965 (kites)

Raven Industries, Inc., Box 1007, Sioux Falls, SD 57117 (balloons)

R.M. Fay, Rt. 2, Box 2569, Grandview, WA 95930 (balloon-supported raptor kite)

Sutton Ag. Enterprises, 1081 Harkins Rd., Salinas, CA 93901 (kites)

Teiso Kasei Co., Ltd., 350 S. Figueroa St., Suite 350, Los Angeles, CA 90071 (kites)

Tiderider, Inc., Box 9, Eastern and Steele Blvds., Baldwin, NY 11510 (kites)

Weather Measure Corp., Box 41257, Sacramento, CA 95841 (balloons)

*Compiled from: Timm 1983.

FLAGGING, REFLECTORS, AND REFLECTING TAPE

Various types of visual devices have been used or tested as frightening stimuli to alleviate bird damage to field crops or to repel birds from contaminated ponds, trout streams, and fish-rearing facilities. These devices include Bird-scaring Reflecting Tape®, various types of reflectors and spinners, and colored flags and streamers. Rapid habituation represents their major shortcoming. The fright response of birds may wane as they become accustomed to these strange objects after prolonged exposure (Frings and Frings 1967, DeHaven 1971). Efficacy depends on the bird species present and the type and size of area that needs protection. Wind conditions also are important because motion increases their effectiveness. Most of these devices probably are not effective for any prolonged length of time if used alone. Some may, however, provide some temporary protection, which may be extended somewhat when used with other bird-scaring methods or techniques (e.g., gas exploders, pyrotechnics).

REFLECTING TAPE

Bird-scaring Reflecting Tape is marketed in Japan and used by rice growers to protect fields from depredations by Java sparrows (Padda oryzivora) (Bruggers et al. 1986). This tape also has been tested in several countries to determine its potential in repelling birds from a variety of agricultural crops. Reflecting tape is 0.43 inches wide and 0.001 inches thick and is usually suspended at parallel intervals above the crop by twisting and stretching it between erect poles. The colored mylar coating on the tape (silver and red on opposite sides) reflects sunlight, causing a flashing effect, and its vibration in a breeze produces a humming noise (Tobin et al. 1988). Under windy conditions, a "thunder-like" or "roaring" noise may be produced (Bruggers et al. 1986, Dolbeer et al. 1986). Thus, under optimum conditions, reflecting tape produces both unnatural visual and acoustical stimuli for frightening birds.

Bruggers et al. (1986) tested reflecting tape in a variety of bird-damage situations in the United States, Bangladesh, Philippines, and India. Pest situations included damage to sunflower and corn by rose-ringed parakeets (Psitticula krameri), foxtail millet by munias (Lonchura spp.), corn by crows (Corvus spp.), sorghum by European tree sparrows (Passer montanus) and munias, finger millet and corn by blackbirds (Agelaius phoeniceus, Xanthocephalus xanthocephalus), and sunflower by goldfinches (Carduelis tristis). Tape was stretched in parallel rows at intervals of 10, 16.5, and 33 feet across plots ranging in size from 2.5 to 3.3 acres. Effectiveness of treated plots was evaluated by bird counts and damage assessments. In most trials reflection tape reduced crop damage. Where untaped plots were not available as alternative feeding sites, however, some bird species seemed unaffected by the taping.

Dolbeer et al. (1986) stretched parallel strands of reflecting tape across 0.35- to 0.75-acre field crops under attack by blackbirds in the United States. Strands were spaced at intervals of 10, 16.5, and 23 feet. Damage to corn, millet, and sunflower was reduced in the taped fields. Numbers of blackbirds and house sparrows (Passer domesticus) were reduced in taped areas, but goldfinches and mourning doves (Zenaida macroura) were not deterred. The 10-foot spacing was most effective for repelling blackbirds; 16.5 and 23-foot intervals also provided some protection. Costs of installing tape at 10-foot spacings was estimated at approximately $33 per acre.

Reflecting tape was not effective for repelling starlings (Sturnus vulgaris), robins (Turdus migratorius), house finches (Carpodacus mexicanus), mockingbirds (Mimus polyglottos), and catbirds (Dumetella carolinensis) feeding in blueberry plots in New York (Tobin et al. 1988). Tape was spaced at 10-foot intervals across several 0.5- to 1.3-acre plots. Birds flew between the strands of tape and also occasionally perched briefly on them before dropping down into the vegetation to feed.

Conover and Dolbeer (1989) found that reflecting tape was not efficacious in repelling blackbirds from corn when strands were widely spaced (52-foot intervals). Trials were conducted for 4 to 5 weeks in 1985 and 1986 in Connecticut. Damage was not less in taped areas than in adjacent untaped areas or in other untreated fields. Even if effective, however, the authors believe reflecting tape probably would not have been cost effective in this situation. An average of 2.9 manhours per acre was required to install the tape and support poles. Tape also was vulnerable to high winds, and broken strands occasionally had to be replaced.

Tipton et al. (1989) discussed problems with using reflecting tape to repel great-tailed grackles (Quiscalus mexicanus) from citrus groves in Texas. Nine groves were taped at 10- to 23-foot intervals. The trial was abandoned, however, because winds exceeding 15 mph frequently broke strands or entangled them in trees. Because high winds are common in this area, reflecting tape is considered impractical for protecting citrus groves.

These studies indicate that there may be a species-specific response to reflecting tape. Dolbeer et al. (1986) speculated that tape may be most effective against flock-feeding birds, whereas those birds feeding solitarily or in small groups may be less sensitive to the visual stimuli. Reflecting tape may be most suited for protecting small fields of crops and gardens from certain depredating bird species (Bruggers et al. 1986).

REFLECTORS

Various types of homemade reflectors or spinner reflectors have been used in attempts to deter birds from agricultural crops or water containments. Foil flashers reportedly deterred great blue herons (Ardea herodias) and other wading birds feeding at fish ponds (Naggiar 1974, cited in Mott 1978). In general, however, such devices have poor or limited effectiveness unless supplemented with other scaring techniques (Frings and Frings 1967, DeHaven 1971). Only 8 of 235 fish-rearing facilities surveyed by Parkhurst et al. (1987) used tin reflectors to scare birds, mostly with little success. Reflectors usually consist of aluminum pie pans, rectangular pieces of sheet metal, or other similar shiny material suspended by a cord from an erect pole or T-bar. They dangle and rotate freely in a breeze and reflect sunlight (Uhler and Creech 1939). Eight- to 12-square-inch tins suspended from 6-foot tall poles have been used along trout streams to deter fish-eating birds, but with unreported effectiveness (Cottam and Uhler 1948).

Uhler and Creech (1939) described a spinner reflector used to frighten waterfowl from field crops in Michigan. The device was made by attaching 10- to 12-inch square tin sheets on a horizontal wheel mounted on a 4- to 5-foot tall T-bar. Units were spaced 35 to 40 yards apart throughout a field so that ducks could land no farther than 25 to 30 yards from a reflector.

Rotating reflectors with a beacon also were used at night. No efficacy data were provided, but the devices were said to be effective.

Boag and Lewin (1980) tested a series of moving reflectors for repelling waterfowl from contaminated ponds in Canada. The reflectors were suspended on a frame mounted on floats. The device consisted of aluminum pie plates suspended from varying lengths of line attached to a revolving rectangular 3.3 x 5-foot clothesline. Wind and wave action caused the pie plates to move, which produced noise and light reflections. Loon, grebe, duck, and coot numbers declined notably on the test pond but not on untreated ponds, but the device was not completely effective. Some ducks swam within 13 feet of the floating unit without being frightened, and it was less effective at scaring waterfowl than was a model of a human effigy tested on another pond.

Whirling or flashing pieces of metal suspended in fields or on buildings reportedly have been used with limited effectiveness to scare birds (Frings and Frings 1967). Habituation generally occurred, however, when reflectors were used for extended periods or over large areas.

FLAGS AND STREAMERS

Flags or streamers hung from poles or wires have occasionally been used to frighten birds from agricultural fields. Their effectiveness has usually been limited when used alone. Birds may be initially repelled, especially if the flags flutter in the wind, but in due time the birds become habituated and may even use the poles and wires as perches (DeHaven 1971). Eight of 235 fish-rearing facilities surveyed by Parkhurst et al. (1987) reported using flags to scare fish-eating predators but with little or no success.

Pigeons (*Columba livia*) inhabiting a vacant building in Ohio habituated within one day to a marketed flag device known as "Spinning Eyes" (Woronecki 1988). It consists of two bright yellow nylon flags (2 x 3 feet), both sides imprinted with an image of a red eye having an enormous black pupil. The two eye flags are attched to a spinning boom. Pretreatment pigeon numbers ranged from 54 to 69. Two spinning-eye units were installed near a roosting/nesting ledge inside the building and operated for 8 days. Pigeons rapidly departed the first day but 82 were present the next day, and an average of 62 pigeons were present during the treatment period.

Colored flags were tried as a means of reducing damage by red-billed quelea (Quelea quelea) feeding in a rice field in Africa (Manikowski and Billiet 1984). Flags (20 x 20-inch cloth pieces) were attached to 6.5-foot tall poles and placed in 30 165 x 165-foot plots. Fewer quelea were observed in flagged plots than in adjacent untreated plots, and white and red flags were more effective than black, yellow, or blue flags. Bird numbers also increased in flagged plots after the flags were removed.

Neff (1948) described two methods of flagging agricultural fields to protect crops from damage by horned larks (Eremophila alpestris). One technique involved attaching strips of cloth or paper to the top of stakes spaced at intervals of 20 to 25 feet. Flags destroyed in wind or rain were replaced as necessary. Continuous-string flagging also was described. Twine was stretched across a field in parallel rows 20 to 30 feet apart and attached to 4-foot tall poles. Paper or cloth streamers (2 to 2.5 x 20 to 24 inches) were tied to the twine at 5-foot intervals. White muslin cloth was preferred because of its durability. Neff (1948) recommended installing the streamers before larks begin attacking the crop. Although the effectiveness of these techniques was not reported, in practice they likely provide short-term protection at best.

Flags and streamers, as well as various reflective materials such as aluminum pie plates or empty TV dinner trays, are frequently used by the home gardener to frighten birds from young seedlings or from damaging maturing crops. They are also hung on berry bushes or in fruit or nut trees to prevent crop losses. They are most suitable for these situations because they are relatively inexpensive, can be made from a variety of materials readily available to the homeowner, and are easy to install. Most important, they are resonably effective in many situations.

Frings and Frings (1967) found that a 3 x 12-foot banner stretched between two 30-foot poles effectively altered the flight path of Laysan albatross (Diomedea immutabilis) on Midway Island. They speculated that such banners might be useful for deterring albatross from airport runways where they are a hazard to aircraft, but efficacy data were not obtained.

Various types of streamers also have been used in Europe to reduce crop damage by birds (Frings and Frings 1967). In vineyards, for example, colored or black-and-white masses of nylon threads were used to frighten birds consuming grapes. The nylon masses served as partial barriers as well as visual deterrents. Habituation occurred rapidly, but some protection was provided if the thread masses were placed sufficiently close together and moved in the wind.

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WATER-SPRAYING DEVICES

Water-spray systems have been used for some time on reservoirs in Tacoma, Washington, to reduce potable water contamination by gulls that used the reservoirs (Emigh 1962). These studies of several different systems concluded that at least 50% of the water surface area should be covered with spray, and the spray system should be operated in a cyclic pattern. Based on behavioral observations of the gulls, it was concluded that the best cycle was 5 minutes on and 35 to 45 minutes off, which was automatically controlled (Emigh 1962). The system needed only to be operated during daylight hours as the gulls did not use the site at night.

Water sprays from rotating sprinklers can also be used to deter some fish-eating bird species from fish ponds. Such devices are probably most effective and economical for protecting small rearing ponds (Svensson 1976). To be effective, the water spray must cover most or all of the pond or birds may feed between the spraying water. Because birds may habituate to a continuous spray, best results occur when sprinklers are operated on an on-off cycle (Anon. n.d.). The start-up noise and sudden spray of water helps startle and frighten the birds.

The use of water-spraying devices for hazing birds has been limited. None of 235 fish-rearing facilities surveyed by

Parkhurst et al. (1987) reported using this technique to deter predators. The Swedish Salmon Institute, however, developed a rotator to protect small (30-ft diameter) fish ponds from bird predators (Svensson 1976). The rotators provide a water spray 6 to 6 1/2 feet high that effectively deters gulls and terns (Laridae) when the spray covers the entire pond. The rotator is made of galvanized steel pipe and has four arms with nozzles to deliver the spray. The arms are short (2 1/4 to 5 ft long) to produce sufficient speed as they revolve. Pipes can be tapered toward the end to reduce weight. To deter gulls and terns, the rotating arms must revolve at 20 rpm; if slower, the birds may descend between the arms. Water (20 gal/min) is delivered by gravity feed through a hose. These rotators can be easily disassembled to facilitate other operations on the ponds. Material costs were low, but expenses would depend on the sizes of ponds needing protection.

There is a process whereby pond water is pumped through a large number of elevated sprinkler heads to increase water evaporation. This patented process was developed in Israel by Ormat Engineering, Inc., to concentrate brine waters for mineral recovery (Bradford et al. 1989). Observations of its use in Israel indicate that waterbirds prefer not to enter the shower spray. This may be a potential method to both increase evaporation and keep birds from using the ponds. Although Emigh (1962) found that the spray need only cover about 50% of the surface to move gulls, it is suspected that more coverage would be needed to repel all water-loving species and that the spray patterns would have to be nearly overlapping and cover most of the entire pond surface to effectively reduce the bird numbers. If the Ormat process was ever to be considered for use on the evaporation ponds, then it should be set up to maximize its value to reduce bird use of the pond. This combined approach may deserve some consideration in the future.

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UNDERWATER SOUNDS

Underwater acoustical devices currently being used or experimentally tested for deterring marine mammals may be worthy of investigation for repelling waterbirds from containment ponds or to deter feeding at ponds. The potential advantage of underwater sounds is that they are conducted more efficiently than sounds in air. Sound velocity approaches 1800 yards/sec in seawater compared to only about 400 yards/sec in air, and attenuation is lower (Myrberg 1990). Underwater sounds of appropriate frequencies and loudness might be disturbing to diving birds (e.g., diving ducks, grebes, etc.) and waders (e.g., avocets, stilts, dowitchers) that submerge their heads below the water surface to obtain food. If effective in causing the birds to leave the pond area or to deter their feeing at contaminated ponds, the devices could be used singly or alternately to provide variety to a hazing program by intermittently combining underwater sound with other scare methods (e.g., propane exploders, shell crackers, etc.), thereby furthering the concept of variability in negative reinforcement.

Underwater sound has several important advantages over airborne sound. When used near residences, it would not be disturbing when used around the clock (24 hrs/day); secondly, the sound and its projection are not influenced by strong winds. However, the shallowness of the water in some agricultural evaporation ponds may work against its potential effectiveness. The effects of disturbing the pond bottom sedimentation would also have to be considered.

Ambient underwater noises resulting from human activities are known to have deleterious effects on some marine mammals and fish (Myrberg 1990). Ship-traffic noise, for example, has been found to disturb and deter cetaceans in Arctic waters, especially when sudden changes occur in the noise level. High-energy tonals generated by ship engines, including some frequencies exceeding 1500 Hz, are believed to be important cues stimulating avoidance behavior.

Two underwater sound devices currently are used to repel mammals from fisheries. One device, the seal bomb, has been successfully used in some situations to frighten pinnipeds away from fishing areas (Geiger and Jeffries 1987, Mate and Harvey 1987). Seal bombs are somewhat analogous to underwater shell crackers. Weighted with sand, lit and dropped into the water, they explode with a flash of light and high-amplitude sound at a depth of about 3 yards. Sound output is about 190 dB at the source, with a frequency less than 2 kHz. Seal bombs are class C explosives and are registered as agricultural fireworks by the State of California (Geiger and Jeffries 1987). The auditory characteristics of seal bomb underwater explosions have been described by Awbrey and Thomas (1984). Because of their explosive nature, seal bombs can be dangerous if improperly handled. Seal bombs are relatively inexpensive, costing about $0.30 each, and are considered somewhat labor intensive for repelling marine mammals.

An acoustical harassment device (AHD) was recently developed specifically for harassing harbor seals in Pacific Northwest fisheries (Mate and Harvey 1987). This device, sometimes referred to as the "sealchaser," consists of a sound unit and dual transducers that are suspended below water level. The unit can be powered by a generator or a 12-volt battery. It produces 60-millisecond bursts of pulsed sound at random or predetermined intervals of about 1 burst per second (Geiger and Jeffries 1987). Sound output at the source is 195 dB. Pulses are in the frequency range of 12 to 17 kHz, which is the range of maximum sensitivity for pinnipeds. Cost of the device in 1986 was $3500.

The AHD or AAD (acoustic aversion device) has not to our knowledge been tested as a bird-repelling device, but Mate et al. (1987) noted no reactions by marine birds, such as gulls, shearwaters, ducks, and cormorants, within 100 yards of a unit used against pinnipeds. It was not stated whether the birds were just loafing in the area or fed within the range of the unit. Present commercial units may not be effective against birds because the most appropriate frequencies for repelling birds are not produced. The most highly sensitive range of hearing in birds is in the 1 to 5 kHz range (Dooling 1982), although they can hear over a wide range of frequencies similar to those heard by humans. Research seems warranted, however, to determine if an AHD or acoustic aversion device (AAD) producing sounds to which birds are most sensitive could effectively deter waterbirds from an area, or at the minimum deter some feeding.

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BIRD AVOIDANCE IN RESPONSE TO COLORED WATER

Virtually every method imaginable has been considered to keep birds from using specific ponds or containment sites. Coloring the water with various dyes is one method that has received some very limited research attention, specifically for saving birds from oil spills (Lipcius et al. 1980).

Birds, unlike some mammals, generally have relatively good color vision, and a number of studies on various species have been conducted (Hess 1956, Kovach and Hickox 1971).

Colors have also been examined as to those preferred and those shunned or avoided by ducks and geese (Hess 1956, Davies 1961). They both found red and blue to be avoided and green and yellow preferred. Kear (1964) evaluated the color preferences of some 40 species of ducks and geese. A general preference for green was found among these species, and there was a tendency to avoid red and orange, which are found at the end of the color spectrum. Similar color preferences and avoidance were found by Oppenheim (1968).

Lipcius and his colleagues (1980) evaluated eight different colors--red, orange, yellow, green, blue, indigo, violet and black--on captive mallard ducks and measured the time it took for hungry birds to enter the colored water to gain access to feed. They concluded that orange was the color that most consistently elicited an aversive response. Yellow was ranked next for latency and hesitation times by the ducks but was not significantly different from the other colors. Red and black were the least effective in their study, but it was believed that the lack of avoidance of red may have been because of previous exposures to red-colored drinking fountains. Kear (1964) found red to be avoided to approximately the same degree as orange.

Lipcius and his associates (1980) concluded that no single color would have a dramatic effect on pond avoidance by ducks, but they believed their results were sufficiently noteworthy that further experiments were warranted.

The dyeing of water has been used for some time for other purposes. In artificial pools and ponds in landscaped areas it can make them look more natural or cause water in reflecting pools to be more reflective. Dye in water is also used to inhibit growth of algae and make it more difficult for avian predators to see and prey upon fish. Black dyes have been successfully used in ornamental pools and in shallow lily ponds to discourage children from wading and playing in them.

The use of dyes in evaporating ponds to block sunlight penetration, thus reducing aquatic vegetation and the invertebrates that feed upon this plant life, has been discussed previously as a means of limiting the food base for birds (Bradford et al. 1989). Should this be instigated in the future as an approach to reduce bird use of the ponds, some consideration might be given to coloring the water orange, at least as an experiment. The birds might habituate to the orange colored water if the ponds contained ample food; however, if orange water was always or frequently associated with a lack of food, the birds might eventually visually discriminate between dyed and undyed ponds. From what is known about bird behavior, the two approaches, i.e., limiting the food base and coloring the water, in combination might be a significant improvement over either method used alone.

An area that to our knowledge has not been explored is the use of dyed water in conjunction with other hazing methods (e.g., patrols firing cracker shells). Since colored ponds would be visible to the birds from some distance in the air, the birds may learn that orange-colored water is to be avoided because of other frightening stimuli or perceived danger associated with that pond or cell. Such learned behavior would have area-wide implications if all or most intensely hazed cells or ponds were also dyed orange.

The feasibility and practicality of coloring the water of the larger pond seems questionable from a cost basis. A possible alternative would be to strategically place brightly painted floating styrofoam rafts throughout the pond. These would probably have to be large enough (10 to 20-ft diameter) and numerous enough (1 per 5 to 10 acres) to give the conspicuousness needed.

While coloring the pond water is highly speculative with regard to results, it is often through some type of innovative approach that new methods or techniques are developed.

The deliberate addition of a repellent substance directly into the water has also been explored experimentally as a repelling method. Fraser and Hristienko (1982) tested a variety of chemicals or substances to discourage moose from drinking from roadside pools or puddles containing residues of salt applied to the highways in winter. Their efforts were directed at reducing moose-vehicle accidents in Canada, which were associated with the moose's frequent use of roadside pools.

Recently reported preliminary research by the USDA, APHIS, Denver Wildlife Research Center (Sandusky, Ohio Field Station) directed at repelling birds from ponds with the use of methyl anthranilate is most encouraging. The repellency to birds of dimethyl anthranilate and methyl anthranilate for other purposes has received considerable research attention (Askham and Fellman 1989, Glahn et al. 1989, Mason et al. 1991). A link between taste aversion and color aversion has been established in birds, which favors the combination of the two (i.e., colored water and chemical taste repellents) to achieve superior results (Martin et al. 1977, Gillette et al. 1980, Mason and Reidinger 1983, Greig-Smith and Rowney 1987).

The use of chemical repellents in the water to deter birds' use or feeding from the pond has not been researched enough to be even considered at this time. The large size and amount of water contained in the evaporation pond systems make the use of chemical repellent-laden water relatively impractical.

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ELECTRIC SHOCKERS

Electrified wires providing nonlethal shocks have been used as a repelling tactile stimulus to deter pest birds. Although operating on high voltages, they are not lethal because of low amperages (Fitzwater 1978). Electrical shocking systems of different types have been used to mostly deter birds from loafing, roosting, and nesting on building ledges, and certain firms specialize in their installations (Fitzwater 1978, National Pest Control Association 1982). Electrified wires have also been used to prevent damage by birds to agricultural crops (Pfeifer 1956, 1957; Zajanc 1962) and to reduce depredation on fish in small ponds and lakes (Craven and Lev 1985, Anon. 1989). The birds must come into direct contact with the charged wires in order to be repelled, and this proves to be the major limiting factor in their usefulness. Hawks and owls also have been deterred from certain areas by installing an electric pole shocker (Hygnstrom and Craven 1982). Electrified wires as a deterrent to pest birds can be relatively expensive to install but often last many years with minimal maintenance (Fitzwater 1978).

Pfeifer (1956, 1957) developed an electric shocking perch to reduce damage by blackbirds and sparrows on grain plots at the Wyoming Experiment Station. The perch consisted of two wires (no. 18, galvanized) spaced 2 to 2 1/2 inches apart and suspended

10 to 14 feet above ground across the entire length of a plot. Recommended spacing of each pair of wires was 25 yards. Wire spacer insulators were placed at 12-ft intervals along the wires to minimize vibration. A 15,000-volt neon sign transformer connected to a time clock switch provided good service when powered by a gasoline generator. For nonlethal shocking, a 15- or 30-milliampere transformer is sufficient if less than 2,000 ft of perch wire is used. A 60-milliampere transformer may be needed if more wire is used. When the electric perch is operating properly, wires arc and snap periodically. Severe grain damage occurred in plots prior to installation of the perches. After installation, however, no blackbird damage was recorded within 50 yards and none occurred within 25 yards.

Tests in Canada indicated that electric wires could provide partial protection of sunflower plots from some depredating bird species but not others (Chubb 1959, cited in Zajanc 1962). Following the design of Pfeifer's (1956, 1957) electric perch, two wires spaced 2 1/2 in apart were suspended 14 ft above ground across the middle of a small (49 x 69-ft) isolated sunflower plot. Wires were charged with 15,000 volts of electricity. Sparrows and finches decreased in number on the plot, but blackbirds did not.

Zajanc (1962) noted that occasionally nontarget birds, especially doves, were accidentally killed at some electric wire installations, and their use was discontinued at some sites. Due consideration must be given to incidental kills of nontarget or protected bird species even if such kills rarely occur.

The Glenn County Mosquito Abatement District installed electric wires in 1988 to reduce depredations by fish-eating birds, especially common egrets (Casmerodius albus) and snowy egrets (Egretta thula) (Anon. 1989). Other protection methods had been ineffective (e.g., exploders, scarecrows) or uneconomical (e.g., netting). They required a method that was economical, effective, and nonlethal. Two of three small ponds were treated. Pond sizes were 367 x 160 ft and 512 x 123 ft. Wires were crossed over each pond in a zig-zag pattern and were supported by metal stakes around the perimeter. Electricity was provided by two 12-volt batteries, which provide 3 months of continuous service before needing recharging. Since installation in September 1988, the electric wires have been completely effective in excluding all fish-eating birds from the ponds. Material costs, excluding labor, were approximately $230. The loss of fish prior to installation of the wires was estimated to range from $36,000 to $72,000 annually.

Electric wires also have been tested for protecting fish from bird depredations. Naggiar (1974, as cited in Mott 1978) found that a single strand electric wire placed around a pond provided some protection against fish-eating birds, but some bird mortality occurred. Double-crested cormorants (Phalacrocorax auritus) were successfully prevented from perching on nets and poles of commercial fishermen when electric wires were installed (Craven and Lev 1985). Few fish-rearing facilities in the United States, however, reported using electrical wires to repel fish-eating birds (Parkhurst et al. 1987).

Hygnstrom and Craven (1982) described an electric pole shocker designed to repel hawks and owls. The device consists of two electric wires placed 1 in apart on top of a 14- to 16-ft pole. One wire is connected to an electric fence charger and the other is grounded. When a raptor perches on the pole, it receives a nonlethal shock. The device was reported to be effective in a variety of different settings in Wisconsin. The unit is energized from dusk to dawn for owl control, and during daylight hours for hawk control. Other potential perch sites should be removed or made unattractive to encourage raptors to use the shocker poles. Recommended spacing of poles is at 50- to 100-ft intervals around the area needing protection.

Jacob and Zajanc (1965) investigated the possible use of an electrical device for the population reduction of the introduced European starling (Sturnus vulgaris). In this instance they were researching methods for lethal control. Using 60-cycle alternating current, they determined that foot-to-foot shocks, as occur most commonly when perch wires are used, were usually not lethal, even with relatively high amperage. Voltages less than 5,000 to 8,000 volts were also not lethal if surfaces were dry. Shocked birds frequently uttered a fright call that scared other starlings away. The devices they experimented with never proved practical and this approach was eventually abandoned.

Electric nonlethal shocking devices for repelling birds have generally received little attention. The approach probably deserves greater consideration for special situations. The units must be engineered and designed to achieve their objective without incidental kills of protected birds.

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LIGHTS

Various types of lights have been used to deter birds such as herons and waterfowl from feeding at night at fish hatcheries and grain fields. These lights include area lights, strobes, barricade-type lights, and revolving beacons with or without reflectors (Uhler and Creech 1939, Imler 1944, Lostetter 1960). Area lights deter birds by illuminating the area where they forage at night. Strobe lights provide an extremely bright flash similar to warning lights on aircraft, and they have a blinding effect that causes confusion and diminishes the ability or inclination of birds to feed (Anon. n.d.). Flashing amber barricade lights, comparable to those used at road construction sites, also have been used along raceways and on banks of fish ponds. In general, the more barricade lights used the greater is their effect. Birds may habituate to them rapidly, however, and their long-term effectiveness is questionable (Salmon and Conte 1981). Revolving lights and beacons also have been used with varying degrees of success. The type and number of lights used and their placement depends on the size of the area to be protected and the power source available.

Lasers also have been tested experimentally to determine their potential for repelling birds from airport runways (Lustick 1973). Lasers have not yet been developed for bird control and may never be because of their dangerous aspects (Blokpoel 1976).

Lights are most commonly used at fish-rearing facilities to deter birds such as night herons and great blue herons that feed on fish at night. Many fish hatcheries use street or spot lights with varying degrees of success. Sixteen (38%) of 42 facilities rating the effectiveness of lights found them to be highly effective in reducing predation on fish, whereas 26 (62%) stations reported little or no effect (Parkhurst et al. 1987). One facility used barricade lights with limited success. At some facilities area lights repelled herons for several years, but birds subsequently returned to feed on the fish (Anon. n.d.). When strobe lights were used at one site, night herons avoided the bright flashes by landing with their backs toward the light source. Naggiar (1974) reported some short-term success in repelling herons with flashing lights and reflectors. Grey herons (Ardea cinerea) however, were not deterred from small fish ponds illuminated with a 1500-w spotlight (Draulans and Van Vessem 1985).

Imler (1944) developed a revolving electric beacon that effectively deterred ducks from feeding at night in several grain fields where the beacon was tested. An automobile spotlight or headlight was wired to a 6-volt phonograph motor altered to revolve three times per minute. Because flashing light is more effective than a constant beam, a flasher like those used in automobile tail lights was connected to the device. This caused the light to flash on and off about 70 times each minute. The revolving beacon was tested in several fields in North Dakota and Colorado where ducks were feeding on grain at night. A single beacon used for 4 to 5 nights successfully repelled ducks and reduced damage within 400 to 500 yards of the beacon. Stephen (1959) found that a single revolving searchlight of 1,000 watts discouraged ducks from feeding within a one-half-mile radius. Horn (1949) also noted that revolving lights have proven very effective for deterring waterfowl from fields at night, with one light successfully protecting an area of about 640 acres. The effectiveness of revolving lights depends on their size, proper placement in the field, size of the field, and number of units used (Lostetter 1960). Blind spots can occur if trees or other obstructions block the beams (Horn 1949).

Imler and Creech (1939) described an early homemade revolving beacon with reflectors they used to repel waterfowl from a grain field in Michigan. The device was made by mounting two small electric reflecting lanterns on a bicycle wheel mounted on a 1-inch iron pipe driven into the ground in the center of the field. Curved sheet metal wings were attached to the outer rim of the wheel, which was rotated by wind or, if conditions were calm, by a small electric fan. The lanterns provided about an 800-ft beam of light. The beam was reflected off the spinning reflectors, causing a series of flashes that effectively frightened ducks from the field throughout the harvest season.

Cottam and Uhler (1948) also found that an automobile headlight mounted on the frame of an oscillating electric fan was effective in deterring nocturnal birds feeding at fish-rearing facilities. If electricity is not available, a carbide searchlight can be mounted on a small disk and rotated on a clockwork mechanism similar to that used in revolving barber poles. Lights should be placed in a strategic position where the beam can move back and forth across the area to be protected.

Blinking road-flasher lights were used by Lostetter (1960) to protect a 10-acre alfalfa field being damaged by widgeon (Anas americanus) in California. Twenty-four lights were elevated slightly above crop level by placing them on irrigation levees and field borders. The lights operated continuously for 33 days, and no subsequent damage was observed.

Lights have also been used inside aircraft hangars and other buildings to repel roosting or nesting birds but with little success (Spear 1966, Bivings 1985, Will 1985). One airforce base estimated the annual cost of using rotating beacons as more than $9,600. Birds quickly became accustomed to the lights, and even strobes were ineffective.

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SUPPLIERS OF REVOLVING AND FLASHING LIGHTS*

Bird-X, 325 W. Huron St., Chicago, IL 60610

R.E. Dietz Co., 225 Wilkinson St., Syracuse, NY 13201

The Huge Co., 7625 Page Blvd., St. Louis, MO 63133

Tripp-Lite Manufacturing Co., 500 N. Orleans, Chicago, IL 60610

*Compiled from: Timm 1983.

TRAINED FALCONS AND HAWKS

Trained falcons or hawks occasionally have been used at airports to frighten birds from runways, flight paths of landing and departing aircraft, and inside hangars. Peregrine falcons (*Falco peregrinus*), gyrfalcons (*F. rusticolus*), and goshawks (*Accipiter gentilis*) are the species most frequently used (Heighway 1969, Blokpoel 1976). They are most often used to disperse gulls (Larus spp.) on or near runways. To be effective the falcons or hawks must be well trained. Their success against other bird species may vary. Birds not normally included as prey may not perceive the falcon or hawk to be a danger and may not flee upon its approach (Inglis 1980, Burger 1983). Falcons will not attack birds on the ground (Heighway 1969), although the presence of nearby falcons may cause the birds to take flight. Firing shell crackers or exploders may be necessary to move loafing or roosting birds on or near runways.

Blokpoel (1976) reviewed the use of trained raptors to alleviate bird problems at airports. The first reported use of falcons was by Royal Naval Air Station in Scotland in the late 1940s. Peregrine falcons were successful in frightening gulls from runways when used in addition to firing of shell crackers and exploders. Falcons had to be flown daily to be effective or the gulls would return within 2 days. Experiments with peregrines and gyrfalcons were conducted at Victoria Airport on

Vancouver Island, Canada, in the early to mid-1960s. Gulls dispersed when a falcon was airborne but frequently returned soon after the falcon was caged.

The Dutch military tried using goshawks to deter gulls from an airfield in 1968 (Blokpoel 1976). A trained falconer with three assistants and six hawks patrolled the airfield in a jeep. The gulls occasionally moved a short distance down the runway when the jeep approached. When this happened, shell crackers and smoke puffs were fired to make the gulls rise off the ground. Initial results with the hawks were satisfactory, but it could not be determined if the gulls dispersed because of the hawk or because of the presence of the patrol team.

Peregrine falcons were effective in dispersing little bustards at airbases in Spain (Blokpoel 1976). Thousands of little bustards (*Tetrax tetrax*) were dispersed at one base where six falcons were used for 3 months. Continued use of the falcons was required, however, to prevent the return of the bustards. At a second base, little bustards, curlews (*Numenius arquata*) and mallards (*Anas platyrhynchos*) were dispersed after 6 months. Encouraged by these results, the U.S. Air Force employed falcons at six airbases in Europe. The falcons supplemented other bird-scaring methods, including firing of shell crackers and live ammunition with patrols and dogs. The falcons were used for only

20% of the control operations but were considered essential for effective dispersal.

Falcons and hawks also were used to disperse gulls at other European airbases. Peregrine falcons were deemed highly effective at dispersing gulls at a base in Scotland where other bird-frightening methods, including shotgun patrols, bird distress calls, and colored fabric placed on the ground, had not been effective (Heighway 1969). After 2 years, the number of birds at the base had decreased markedly. Because falcons can be flown only in daylight, shell crackers were fired at night and exploders were used at the end of runways whenever aircraft were landing or departing. At Leeuwarden airbase in The Netherlands, goshawks effectively dispersed birds, especially gulls (Mikx 1969). The presence of the patrol team also likely added to the deterrent effects of the hawks. Because the effectiveness of hawks was limited when many birds were circling overhead, the use of shell crackers was still necessary when this occurred. Effective control also was reported at Charles de Gaulle airport in Paris, France (Briot 1987). Eleven falcons and four goshawks were used successfully to frighten gulls, pigeons, and lapwings (<u>Vanellus vanellus</u>) from runways.

Blokpoel and Tessier (1987) attempted to prevent ring-billed gulls (<u>L</u>. <u>delawarensis</u>) from nesting at Toronto Outer Harbor, Canada, by using flying or tethered raptors supplemented with other bird-scaring methods. Tethered raptors included a ferruginous hawk (Buteo regalis), an eagle owl (B. bubo), and a prairie falcon (F. mexicanus). A ferruginous hawk, Harris' hawk (Parabuteo unicinctus), and saker falcon (F. cherrug) were flown in one area by a trained falconer. Additional techniques including firing shell crackers, playing taped distress calls, and using dead gulls as a visual deterrent. After 3 years of hazing, the number of nesting pairs was reduced from 75,000-80,000 to about 40,000.

Little information is available on the effectiveness of falcons and hawks in other situations. The U.S. Air Force has sometimes used them to disperse birds roosting at night in aircraft hangars (Will 1985). One base reported that pigeons could be kept out of hangars for 2 to 3 months after a falcon was placed in a hangar overnight. In England Kenwood (1978) examined the influence of human and goshawk activity on wood pigeons (Columba palumbus) feeding in cabbage and brussel sprout fields. Most pigeons dispersed when a goshawk was flying over the field but the effects were temporary and most pigeons returned to feed in the field. The presence of a person in the field was more of a deterrent than was the goshawk.

The use of falcons and hawks is limited by several factors including cost, availability, weather conditions, and others. Falcons are no longer used at Canadian airports despite some early success at dispersing birds because of such limitations (Solman 1973, Pearson 1967). Falcons and hawks cannot be flown at night, when molting, during strong winds, or in rain or fog (Heighway 1969, Blokpoel 1976). The use of falcons or hawks requires a trained and licensed falconer and assistants. They can be difficult to handle and sometimes refuse to fly altogether (Burger 1983). They work best when reasonably hungry. Several are required to ensure that one is always available to fly when needed. When used for prolonged periods at the same site, they become familiar with the surrounding area and may leave and not return. At one airbase where eight falcons were used, turnover due to loss and mortality averaged two birds per year (Heighway 1969). At most facilities where falcons or hawks have been used, other methods, including patrols and firing of shell crackers and exploders, have still been necessary to augment dispersal by the raptors.

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HIGH FREQUENCY SOUND DEVICES

Ultrasonic frequencies are those exceeding 20,000 cycles per second (cps) (Spear 1966, Fitzwater 1970). Devices emitting such sounds occasionally have been recommended by some (mostly manufacturers and distributors) for discouraging nuisance birds. Their main attraction for pest control is that ultrasonic sounds are not audible nor disturbing to man (Frings and Frings 1967). Despite user testimonials and unsubstantiated claims of advertizers, however, ultrasonic devices have not been proven efficacious for repelling birds (Griffiths 1987, Woronecki 1988).

Hearing ranges for several bird species have been measured in the laboratory by Brand and Kellogg (1939a,b) and Edwards (1943). Values ranged from 60 to 15,000 cps (Table 1), which is well within the hearing range of man (20 to 20,000 cps; Spear 1966) and below ultrasonic frequencies. Even if such sounds were heard by birds, they might not be practical for use over large areas. Power requirements are probably too high because ultrasonic frequencies diminish much more rapidly than audible sounds with increasing distance from their source (Spear 1966, Stewart 1974, Blokpoel 1976). Ultrasonic frequencies also leave "shadows" if sound waves are obstructed (Spear 1966, Fitzwater 1970).

Table 1. Hearing ranges of bird species as determined by laboratory trials.

Species	Hearing range (cycles per second)	Source
Canvasback (Nyroca valisineria)	190 - 5,200	Edwards 1943
Great Horned Owl (Bubo virginianus)	60 - 7,000	Edwards 1943
Horned Lark (Otocoris alpestris)	350 - 7,600	Edwards 1943
Snow Bunting (Plectophenax nivalis)	400 - 7,200	Edwards 1943
Starling (Sturnus vulgaris)	700 - 15,000	Brand and Kellogg 1939a
House Sparrow (Passer domesticus)	650 - 11,500	Brand and Kellogg 1939a
Pigeon (Columba livia)	200 - 7,500	Brand and Kellogg 1939a
Canary	1,100 - 10,000	Brand and Kellogg 1939b

Laboratory and field tests have demonstrated that ultrasonic frequencies do not disturb birds. Woronecki (1988) tested an ultrasonic device (Ultrason ET-360) against pigeons (Columba livia) inhabiting a vacant power house in Ohio. The unit tested could produce either continuous or pulsed output sounds and was mounted on a turntable rotating twice per minute. The device was placed near a ledge used by the birds for roosting and nesting.

Pigeon numbers and nesting activity were monitored during the study. The unit was operated in the continuous mode for 10 days and in the pulsed mode for an additional 10 days. The pretreatment number of pigeons was 64 to 66. Postreatment numbers ranged from 75 for the continuous mode to 73 for the pulsed mode. Pigeons did not avoid areas where ultrasonic waves were strongest, and they built nests and laid clutches within 7 to 20 m from the operating unit. Woronecki (1988) concluded that ultrasonic sound has no value for repelling pigeons.

Griffiths (1987) tested a commercial ultrasonic unit (unspecified) against several bird species in Maryland and Virginia. One site along forest edge was baited with sunflower seeds to attract birds. The feeding station was visited by several species, especially the house finch (*Carpodacus mexicanus*), dark-eyed junco (*Junco hyemalis*), white-breasted nuthatch (*Sitta carolinensis*), tufted titmouse (*Parus bicolor*), black-capped chickadee (*Parus atricapillus*), and blue jay (*Cyanocitta cristata*). The unit was also tested against house sparrows (*Passer domesticus*) perching on electrical wires prior to entering a warehouse to roost. The device produced an output of 20,000 to 50,000 cps and was located 10 to 30 feet from the sites. According to the manufacturer, the unit provides coverage over an area approximately 100 x 72 feet. The ultrasonic sounds had no apparent effect on bird activity at either site, and use of the unit was not recommended by Griffiths (1987) for bird control.

Several tests were conducted in England to determine if ultrasonic sounds could deter birds (Wright 1963). In one test a sound generator producing 22,000 cps and having a range of 150 feet was used to attempt repelling starlings from a building. The birds did not respond to the sounds. In another test with roosting pigeons and starlings, sound at 18,500 cps, bordering ultrasonic frequency, had no effect. One company marketing a unit claimed that their ultrasonic unit, operating at 40,000 cps, was effective for dispersing birds. When their unit was tested, however, the sound produced had no discernable effect on the birds, even those present within a few feet of the sound source.

Martin and Martin (1984) evaluated the effectiveness of an ultrasonic device for repelling birds roosting on a pier tower in California. The birds included 30 to 55 cormorants, 10 to 15 gulls, and 5 to 11 pigeons. The amount and distribution of fecal pellets deposited on a rooftop below the tower was assessed before and after control to determine the effectiveness of ultrasonic sound, propane exploders, and taped distress calls. The ultrasonic unit was tested for 2 weeks and had little if any effect in dispersing the birds. The other noise-making devices, especially exploders, were found to be more effective.

Other tests also indicated that ultrasonic frequencies do not deter birds. Kerns (1985 as cited in Griffiths 1987) unsuccessfully attempted deterring cliff swallows (Hirundo pyrrhonata) from nesting under eaves of aircraft hangars in Alaska by operating a 21,000 cps rotating ultrasonic unit (Ultrason ET). Thiessen and Shaw (1957) found that Peking ducks were sensitive only to low-frequency sounds. The ducks did not respond to ultrasonic frequencies (20,000 cps) at intensities up to 130 decibels. Spurlock (1962) reported that starlings responded to sounds in the range of 1 to 10,000 cps, but no aversive effect was noted with sounds in the range of 20,000 to 30,000 cps.

Meylan (1978) reported that an ultrasonic device (Vitigard) was successful in reducing damage to sunflower by greenfinches (Carduelis chloris) in Switzerland in 1977. Damage was low during the one month the unit was operating but increased considerably after the unit was removed. As reported by Woronecki (1988) and Griffiths (1987), however, Meylan subsequently noted that the unit operated at only about 16,000 cps. Thus, the sound waves that deterred the birds were considerably below ultrasonic frequency.

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OVERHEAD WIRES

Networks of overhead wires have been used with varying degrees of success for excluding birds from reservoirs, fish-hatchery ponds, sanitary landfills, agricultural fields, and other sites (Amling 1980, Solman et al. 1983, Laidlaw et al. 1987, Pochop et al. 1990). The wires are suspended horizontally in one direction or criss-crossed to form a grid or irregularly shaped network of lines above the area needing protection (McAtee and Piper 1936, Salmon and Conte 1981, Blokpoel and Tessier 1984). They are most effective at excluding seagulls (*Larus* spp.) but also have been used with varying success against waterfowl and other bird species (Terry 1984, Pochop et al. 1990). Overhead wire networks can be expensive to install, but they generally require little maintenance other than replacing an occasional broken wire (Lagler 1939, Amling 1980). In some situations, however, depending on wire spacings and species present, birds may become entangled in wires, necessitating periodic inspections to release them (Blokpoel and Tessier 1987).

Monofilament fishing line or stainless steel or other types of nonrusting wire are most commonly used for overhead wiring. The wire must be sufficiently strong to withstand strong winds and occasional bird impacts. The network can be attached to existing structures (e.g., buildings, fences) or to poles or frames anchored around the perimeter of the area needing protection (Blokpoel and Tessier 1984, Tipton et al. 1989). At landfills, fish hatcheries, or in public areas, the wires can be elevated sufficiently high that boat, vehicle, or foot traffic is not impeded. Perimeter wires or fencing may be needed at some sites to prevent birds from landing and walking into a protected area from the side. This type of learned entrance behavior frequently occurs with some bird species (McAtee and Piper 1936, Barlow and Bock 1984).

USE ON RESERVOIRS AND PONDS

McAtee and Piper (1936) first described the use of overhead wires for excluding birds from reservoirs and fish ponds. The technique was probably developed in British Columbia, and it is still successfully used at some Canadian fish hatcheries (Solman et al. 1983). Fifteen percent of 235 fish hatcheries responding to a recent survey in the United States reported using overhead wires to deter fish-eating predators (Parkhurst et al. 1987). Of the 30 facilities that rated the effectiveness of installing such wiring, 19 (63%) found them to be highly effective, 10 (33%) found them somewhat effective, and only one (3%) considered wires ineffective. The bird species effectively repelled were not specified, however.

The installation of overhead wires effectively excluded gulls from two water supply reservoirs in southern California

(Amling 1980). Coated stainless steel wires (0.015-in diameter) were stretched between existing chain-link fences at both sites. Lines were elevated 8 to 10 feet above water and spaced at either 50 or 80-ft intervals. Wires were stretched up to 1,000 ft without midpoint supports. Gull flocks were excluded immediately after the lines were installed, and few gulls have subsequently used the reservoirs. Strong winds occasionally broke wires, but most of the original lines were still in place after 8 years. Several duck species continued to use the reservoirs, but numbers decreased after the lines were installed.

Ostergaard (1981) reported success at excluding herring gulls (L. argentatus) from fish ponds at Allegheny National Fish Hatchery in Pennsylvania. Other frightening techniques and preventive measures, including exploders, netting, and shell crackers, had not effectively deterred the gulls. Monofilament fishing line (50-lb test) was spaced at 16-in intervals and stretched across the 80-foot-wide ponds. Lines were suspended 8 in above the water level and attached to S-hooks so they could be detached as needed to facilitate hatchery operations.

Wires installed in 40 x 40-ft grids about 1 ft above water level also successfully repelled gulls from three municipal reservoirs in San Francisco in the 1920s (McAtee and Piper 1936). The reservoirs ranged in size from 200 ft square to 1,000 x 600 ft.

Campbell (1979) found overhead wires effective for excluding gulls from 60 100 x 100-ft trout-rearing ponds at a fish hatchery near Sacramento, California. Herons, however, were not deterred by the wires at the spacings (unspecified) used. The hatchery subsequently abandoned overhead wires in favor of covering ponds with screens.

Great blue herons (Ardea herodias), terns (Sterna spp.), and mergansers have been excluded from water containments by suspending overhead wires in parallel rows without cross wires (Anonymous n.d.). Spacing intervals of 4 ft for gulls, 2 ft for mergansers and terns, and 1 ft for blue herons were recommended. In another trial, Cottam and Uhler (1948) were able to exclude great blue herons from a 2-acre hatchery pond when wires were spaced 2 ft apart and 2 ft above water level.

In Reno, Nevada, a small urban lake of unspecified size was covered with an overhead wire grid to exclude Canada geese (Branta canadensis) creating a hazard to aircraft at a nearby airport (Reno-Sparks Canada Goose Task Force 1989). Wires (10- and 15-gauge plastic wire) were spaced at 30-ft intervals and attached to an existing chain-link fence around the perimeter. The grid was erected in March 1989. Canada geese have been excluded from the lake, and duck numbers also have decreased considerably. Materials cost approximately $2,550, and 386 man-hours were needed at an additional expense of $8,500. The Task Force considers the project to be a complete success.

Overhead wires were tested against ducks and geese on 1 of 3 sewage ponds at Dulles International Airport, Virginia in 1982 and 1983 (Terry 1984). Wire patterns tested included parallel spacings at 20-ft intervals, a 20 x 20-ft grid, and a 10 x 10-ft grid. The 0.015-in diameter stainless steel wires were attached to fence posts erected at 20-ft intervals around the pond's perimeter. Snap swivels were used to minimize wire kinks. Costs of installing overhead wires on the 14-acre pond included $1,119 for materials and an additional 3 man-hours to erect each wire.

Success varied with species, pattern, and grid size. Wires spaced in rows 20 ft apart effectively repelled Canada geese but few ducks. Geese flared as they approached the wires and either flew to untreated ponds or left the area. Bufflehead (Bucephala albeola) were observed flying between the wires. Numbers of wigeon (Anas americana), lesser scaup (Aythya affinis), and canvasback (A. valisinera) decreased appreciably when the 20 x 20-ft grid was installed. Mallards (Anas platyrhynchos) and wood ducks (Aix sponsa) flew between the wires, possibly because they had broods on the pond. The 10 x 10-ft grid was most effective and reduced pond use by mallards, black ducks (Anas rubipes), green-winged (A. crecca) and blue-winged (A. discors) teal, ring-necked (Aythya collaris) and ruddy (Oxyura jamaicensis) ducks, and hooded mergansers (Lophodytes cucullatus). Wood ducks and bufflehead were not deterred. Solman (1966) also reported success in excluding ducks from a drainage ditch on an airport in Canada, but the spacings used and species repelled were not specified.

Terry (1984) observed several waterfowl impacts on wires during his trials. One evening after sunset, 140 Canada geese landed on the pond when the 10 x 10-ft grid was in place. Apparently they did not see the wires. Some geese appeared confused but unharmed after landing. He suggested installing a lighting system to illuminate wires after dark; this would, however, add considerably to costs.

Wire breakage was also a problem, and considerable maintenance was required. Between 11 November and 30 March, 87 breaks occurred, presumably due to strong winds and/or bird impacts. Repairs took 30 to 60 minutes per wire per person. Heavier gauge wire was recommended to minimize this problem.

Overhead wires were not very effective at discouraging cormorants (Phalacrocorax carbo) from fish ponds in the Netherlands (Moerbeek et al. 1987). Wires were installed on several of the 27 ponds, which ranged in size from 3.75 to 27.5 acres. Nylon lines were strung between poles to form 33 x 33-ft or 66 x 66-ft grids on several ponds. Lines were located about 1 to 1.3 ft above the water level. An irregular spacing pattern was used on one pond, and one had lines stretched downward from two 33-ft high towers. Although cormorant flocks appeared to be deterred from landing on wired ponds, individual cormorants arrived frequently and continued to cause serious depredations. Several overhead wire patterns also were tested at fish-farm dams in Australia, but none were effective (Barlow and Bock 1984). They failed to discourage cormorants because of the cormorants' usual habit of landing nearby and walking to the dams rather than landing on the water.

USE OVER SANITARY LANDFILLS

Ring-billed gulls (*L. delawarensis*), fish crows (*Corvus ossifragus*), and common crows (*C. brachyrhynchos*) were successfully excluded from a landfill in South Carolina (Forsythe and Austin 1984). A 50 x 700-ft active fill area was covered with stainless steel wires spaced at 20-ft intervals. The number of gulls and crows at the site decreased by two-thirds after the wires were installed.

McLaren et al. (1984) conducted a 1-yr trial to determine if gulls, principally ring-billed gulls, could be excluded from a sanitary landfill in New York. The area covered measured approximately 1,000 x 500-600 ft. Monofilament fishing line was used initially but was replaced by wire lines because of frequent breakage. Wires were suspended 33 ft above ground between metal poles. Alternate periods with and without wires in place were monitored for gull activity. Initial wire spacings of 40 ft were not effective, but most ring-billed gulls were deterred when the spacing was reduced to 20 ft.

Limited observations at a landfill in New York indicated that parallel lines spaced 10 ft apart effectively repelled herring and great black-backed gulls (Larus marinus) that previously used the site (Dolbeer et al. 1988). Wires were suspended 80 ft above ground over 220 acres at 1 of 4 active fill sites. Installation cost $2 million. An inspection 2 to 3 weeks after installation found that about 1000 laughing gulls (L. atricilla) had penetrated the wires. Crows (Corvus brachyrhynchos), pigeons (Columba livia), and European starlings (Sturnus vulgaris) also were not excluded by the 10-ft wire spacing. About 15,000 herring and great black-backed gulls were present at a second fill site 1 mile away, suggesting that overhead wires selectively excluded them. Wing spans of these species are 25 to 60% larger than laughing gulls, and the authors speculate that the size difference may be the critical factor. Although conclusions are tentative, the Department of Sanitation considers the wires highly effective, and they recommend them for use at other fill sites to reduce gull numbers.

USE IN AGRICULTURE

Tipton et al. (1989) used fluorescent yellow monofilament fishing line (20-lb test) against great-tailed grackles (*Quiscalus mexicanus*) damaging citrus groves in Texas. In 1987, lines were suspended in a grid pattern (10-, 23-, or 36-ft spacings) about 3.2 ft above the canopy. Only the 10-ft spacing was used in 1988. Replicated treatment and control plots of about 1 acre each were assessed for damage to determine efficacy. The monofilament lines were attached to twine lines stretched between poles along the perimeter of each grove. Results suggested that damage levels must be high to justify the labor and expense of installing overhead lines to repel grackles. In 1987, damage was only 2 to 8% less in treated than untreated groves, with 10-ft spacing most effective. In 1988, damage levels were not significantly different in treated and untreated groves.

The effects of overhead wires on nesting success of native bird species, especially the mourning dove (*Zenaida macroura*), also were assessed in these citrus groves (Rappole et al. 1989). Native species were not deterred by the lines, and no reduction in nesting success was recorded. One great horned owl (*Bubo virginianus*) was killed when it impacted an overhead wire, however.

Aguero et al. (1989) conducted a variety of trials to evaluate the effectiveness of overhead wires against the house sparrow (Passer domesticus) and other species. Monofilament lines at 1- to 2-ft spacings excluded sparrows from strawberries, peaches, sprouting plants, and bait stations. Lines also stopped barn swallows (Hirundo rustica) from building nests under house eaves, but failed to protect grapes from robins (Turdus migratorius) and European starlings.

USE IN OTHER SITUATIONS

Blokpoel and Tessier (1984) evaluated the effectiveness of overhead wires for excluding ring-billed gulls from a public square and an outdoor food facility in Toronto. Stainless steel fishing line (0.1-in diameter) was stretched in rows at 8.25-ft intervals over the city square. Lines were suspended 24 to 33 ft above ground and attached to buildings. Monofilament fishing line was stretched in an irregular pattern of criss-crossing lines 10 to 16.5 ft above ground over the outdoor food facility. The wires were effective; the number of gulls using the covered areas decreased by 90%. A few gulls entered the wired area from the unprotected sides, but none were observed flying through the wires. Gulls had not habituated to the wires 1 month after installation. Pigeons, however, were not deterred by the lines at the spacings used.

Blokpoel and Tessier (1983) also evaluated the effectiveness of overhead lines for preventing ring-billed gulls from establishing nesting territories at the headlands of Toronto Harbor. Three 66 x 66-ft treatment plots were established, each with four replicates. Treated plots were covered with monofilament lines spaced at 2-ft intervals at heights of either 2 or 4 ft above ground. Control plots were not covered. All plots were monitored for nesting activity. Lines were highly effective for excluding the gulls. An average of 224 nests occurred on control plots, whereas an average of only 3 to 4 nests were established on the wired plots.

Subsequent trials at two other sites in Canada produced similar results (Blokpoel and Tessier 1987). Plot sizes were small at all sites, however, and other nesting habitat was available and heavily used in the immediate area. One major problem during these trials was that gulls occasionally became entangled in the wires, necessitating twice-daily inspections to release trapped birds. In a 2-month period, 133 gulls became entangled at one site.

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COMPLETE EXCLOSURE BY NETTING

Complete exclosure by netting or screening can be one of the most effective methods of excluding birds from a site needing protection. It is the only sure method for total exclusion. The technique is expensive, but costs may be justified in many situations where other bird-control methods are ineffective (Fitzwater 1978, Salmon and Conte 1981). Plastic or fabric netting is used more often than wire screening because it is less expensive and easier to install. Both wire and fiber netting have been used, but the development of ultraviolet (UV)-stabilized plastic netting in the early 1970s resulted in stronger, more durable material that is easier to apply or install over large areas (Stucky 1973). This netting, usually made from polypropylene plastic, is lightweight and more resistant than most other plastics to corrosion and breakdown by sunlight (Martin and Hagar 1989). It is available in large rolls from commercial suppliers and is easy to splice together as needed. Properly installed and maintained, UV-stabilized plastic netting has a life expectancy of five or more years (Fitzwater 1978, Vaudry 1979).

The use of netting or screening for excluding birds depends on several factors, including the species to be excluded, size of the area needing protection, possible damage of the netting from severe weather, and whether it will interfere with other operations at the site (Salmon and Conte 1981). Probably most uses of bird plastic netting in the United States have been to protect vineyards from bird depredations (Foster 1979). Other applications include excluding birds from containment ponds (Martin and Hagar 1989), roosting and nesting sites on or inside buildings (Anonymous 1981, Bivings 1985), and protecting blueberries (Hayne and Cardinell 1949), sunflowers (Meylan 1978), fruit crops (Stucky 1973), and trees (Campbell et al. 1981). Wire mesh has mostly been used to protect small fish-rearing ponds (Lagler 1939, Campbell 1979) and is sometimes used to protect backyard fruit trees or berry bushes.

PONDS AND FISH-REARING FACILITIES

Martin and Hagar (1989) described the techniques used to net containment ponds to exclude birds. UV-stabilized netting made of polypropylene plastic is preferred. Solid-strand netting (1-inch mesh) is recommended over diamond-shaped mesh because it is less expensive, easier to install, and can be spliced together more quickly. The netting is supported by cables attached to ground supports, either pipe embedded vertically in concrete or earth anchors. Cable diameter depends on the distance that the netting is spanned across the pond. One-eighth-inch cable is used for spans less than 100 feet, 3/16-inch cable for spans 100 to 300 feet, and 1/4-inch cable for spans exceeding 300 feet. The cable should be coated with UV-stabilized plastic to reduce netting damage from rubbing and chafing. The netting is attached to the cable with hog rings or electrical bundle ties at 6-inch intervals or less to prevent their ripping out during strong winds.

The feasibility and costs of netting a containment pond depend on its size and configuration. A rectangular basin is easier and cheaper to cover than a square basin of equivalent size because a less extensive ground-support system is needed and smaller diameter cable is used. If the span exceeds 1,000 feet, midpoint supports such as floating drums may be needed to support the interior netting and minimize cable whipping and undulation in windy conditions. Estimated costs (1990) of enclosing a rectangular 100-acre pond not requiring midpoint supports is approximately $375,000 (L. Martin, pers. comm.).

Complete exclosure with plastic netting or wire mesh is reported to be one of the most commonly used and most effective methods of reducing depredation problems at fish-rearing facilities in the United States (Parkhurst et al. 1987). Of 91 facilities rating the effectiveness of total exclosure, 74 (81%) reported complete or high success in solving their problem, including depredations by fish-eating birds. At a fish hatchery near Sacramento, California, gulls and herons were successfully excluded from 60 10 x 100-ft. trout-rearing ponds when the site was covered with overhead plastic screening (Campbell 1979).

Chicken wire also was used on the sides to prevent birds from walking in under the screening. At that time costs amounted to $10,000, but the gulls and herons had been consuming 35 to 40% of the trout produced, at an estimated annual loss of $50,000 to $60,000. In that particular situation, previous attempts to repel the birds with scarecrows, noise-making devices, and overhead wires had not been very effective.

AGRICULTURAL CROPS

Netting to completely enclose a crop is considered one of the most effective methods of protecting high-value agricultural crops from bird depredations (Anonymous 1973). Mesh size should be small (1/2-1 inch) and netting should be securely anchored at ground level to prevent birds from entering at the sides (Boudreau 1975, Vaudry 1979). A framework to support the netting is used for some crops such as blueberries, to prevent netting from snagging on the bushes and to facilitate harvesting of ripe berries (Hayne and Cardinell 1949, Stucky 1973). With certain other crops the plastic netting may be laid directly over the crop without any added supports. Maintenance of netting is required to repair holes and breaks that birds may enter (Fitzwater 1978). For seasonal crops, netting can be removed after harvest; if properly handled and stored, it is often reusable for several seasons. Costs of netting an area will depend on the extent of the crop and other factors. Stucky

(1973) estimated costs of netting vineyards at about $255 to $300 per acre, including $215 to $250 for netting and an additional $40 to $50 for installation, assuming two or three workers can install up to 20 acres per day. Foster (1979) estimated costs of netting vineyards and other fruit crops at about $167 per acre for the netting and an additional cost of 6 man-hours per acre. Present costs for labor and materials would be higher.

Meylan (1978) tested netting as a possible means of protecting sunflower crops from depredations by the greenfinch (Carduelis chloris) in Switzerland. Netting was stretched over the top of the ripening crop but did not extend to ground level. Protection was good only if alternative feeding sites were available. If not, birds soon learned to go under the netting at the sides. Some problems were encountered with the particular type of plastic netting used and method of installation. Greenfinch became trapped and died, and several birds of prey attacking trapped greenfinch also were entrapped and died. Presumably, this problem would have occurred to a lesser degree if the netting had been extended to ground level, kept taut, and securely anchored.

OTHER SITUATIONS

Netting also has been used successfully in numerous situations to exclude birds roosting and nesting on or inside buildings. For example, the U.S. Air Force uses netting to exclude birds roosting in aircraft hangars (Bivings 1985, Willis 1985). Plastic netting also was reported effective in excluding 40 to 50 pigeons roosting on a building in Fresno, California (Anonymous 1981). A problem with roosting and nesting pigeons and sparrows at a farmers' market in St. Paul, Minnesota, was solved by installing plastic netting (1/2-inch mesh) to seal the open-sided buildings (Anonymous 1990). Plastic netting and poultry wire also have been used successfully to prevent cliff swallows (Petrochelidon pyrrhonota) from nesting on buildings (Gorenzel and Salmon 1982). Proper installation was essential in each situation. Netting must be taut or its flapping in the wind may cause tangling or breakage at mounting points. Any gaps or tears must be closed or birds may enter inside the netting (Boudreau 1975, Will 1985). Mesh size also is critical and depends on the bird species to be excluded. For house sparrows (Passer domesticus), starlings (Sturnus vulgaris), and pigeons (Columba livia), mesh size should be no larger than 3/4, 1 1/4, and 2 inches, respectively (Fitzwater 1978). For cliff swallows, recommended mesh size is 1/2 to 3/4 inches, although 1-inch mesh has been used successfully in some situations (Gorenzel and Salmon 1982).

Campbell et al. (1981) designed a portable, lightweight netting exclosure for protecting individual trees up to 30 feet tall from bird damage. Each exclosure is made from 24 6 x 10-ft panels that are wired together in the field. Panels are made of PVC pipe and covered with polypropylene mesh. Approximately 37 man-hours are required to assemble and install each individual tree exclosure. Estimated cost per exclosure in 1980 was $426, and each was expected to be reused in following years.

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