1983

Bird Dispersal Recordings: An Overview

Robert H. Schmidt
University of California, Davis

Ron J. Johnson
University of Nebraska-Lincoln, ronj@clemson.edu

Robert H. Schmidt[1] *and Ron J. Johnson*[2]

Bird Dispersal Recordings: An Overview

REFERENCE: Schmidt, R. H. and Johnson, R. J., "**Bird Dispersal Recordings: An Overview,**" *Vertebrate Pest Control and Management Materials: Fourth Symposium, ASTM STP 817*, D. E. Kaukeinen, Ed., American Society for Testing and Materials, Philadelphia, 1983, pp. 43-65.

ABSTRACT: Bird damage control often involves dispersing birds from areas where they cause problems. Dispersal techniques have been used at airfields, rural and urban bird roosts, livestock facilities, fruit orchards, grain fields, and other locations. Certain avian vocalizations have evolved as alarm or distress calls, and these calls can be exploited as a means of dispersing birds. The behavioral response to such calls, however, varies. Certain species may disperse with the appropriate call, whereas others show little or no reaction. The efficacy of this technique is not well documented at present, but its potential for development as a management tool seems great.

Visual warning signals may increase the effectiveness of bird dispersal recordings by decreasing the habituation rate, increasing realism, or decreasing the fright threshold of the birds causing problems, or by a combination of these factors. Habitat manipulation, which reduces the attractiveness of an area to birds, complements dispersal efforts. It appears that a combination of management techniques is the most effective strategy. In addition, pretreatment evaluation of the problem and situation plus records of field results are helpful parts of a dispersal effort.

Evolutionary, theoretical, and applied aspects of bird communication are discussed as they relate to bird dispersal, the repellency of recorded sounds, habituation rate, and effects of regional dialects. A review of the vocalization and hearing ranges of birds is included; this may help define the frequency and type of sounds most likely to disperse birds. The characteristics of recording and broadcasting equipment are detailed in relation to component selection, and suggestions are made for effective use. A section on field application of bird dispersal recordings provides guidelines for duration and spacing of playbacks and recommends using an integrated approach. Continued refinement of bird dispersal recordings and associated techniques can increase considerably our effectiveness in solving bird damage problems.

KEY WORDS: vertebrate pest control, birds, dispersal recordings, bird communication, alarm calls, distress calls, auditory repellents, habituation, regional dialects, recording equipment, broadcasting equipment, playback considerations, biological control, airport management

[1]Research technologist, Department of Forestry, Fisheries and Wildlife, University of Nebraska, Lincoln, Neb. 68583-0819; presently graduate student in Ecology, Wildlife and Fisheries Biology, University of California, Davis, Calif. 95616.

[2]Extension wildlife specialist, Department of Forestry, Fisheries and Wildlife, University of Nebraska, Lincoln, Neb. 68583-0819.

Twelve years after Thomas A. Edison first displayed his tinfoil phonograph to the American public in 1877, a German, Ludwid Koch, made what is believed to have been the first recording of a bird's voice [*1*]. In 1900, the first recording of a bird in the wild was made, and by 1946 bird sounds were being recorded on magnetic tape [*2*].

As more recordings and better equipment became available, biologists around the world began to use these recordings to learn more about avian taxonomy, ecology, and behavior. In 1953, Hubert Frings and Joseph Jumber found that starlings (*Sturnus vulgaris*) emitted a "piercing shriek" when handled. They reported that "this 'distress call' caused other starlings to fly out of the barns immediately, even in the dark, and they did not return, even after some months" (Ref *3*, p. 318). It occurred to them that a recorded distress call could be used as a repellent, and they successfully used those recordings to clear starling roosts in two towns in central Pennsylvania. Frings continued his work [*4–7*], and various European researchers also began recording bird sounds and testing their effectiveness in dispersing birds [*8–10*]. They were generally successful and found that a wide variety of birds responded to distress or alarm sounds, or both. From these pioneering beginnings, the use of bird dispersal recordings has now become a common technique used in many integrated bird damage control programs.

For convenience and clarity, we will define bird dispersal recordings as electronic reproductions of sounds, usually on magnetic tape, which are intended to disperse birds when broadcast. These sounds can have either natural or artificial origin, but currently most of the recordings available are of natural sounds (Schmidt and Johnson, unpublished data).

Bird Damage Problems and Dispersal Recordings

Damage Problems

During the course of history, man has hunted, tamed, and even worshiped birds. In today's modern world, we find ourselves more and more in conflict with some species of birds for the use of the same food and space resources [*11*]. With the world human population projected to be 6 billion to 7 billion by the year 2000 [*12*], the demand for food and fiber production can only increase. In addition, land use changes have favored certain wild bird species. Some of these, such as starlings and blackbirds, are economically important and are generally on the increase across much of North America [*13*]. Kozicky and McCabe [*14*] listed some areas of conflict that exist between humans and birds: (1) consumption or destruction of foodstuffs, (2) economic losses to nonfoodstuffs, (3) hazards to aircraft, (4) transmission of disease to man and domestic animals, and (5) negative effects on man's comfort, aesthetics, and sporting values. It is very unlikely that these conflicts will be decreasing in the foreseeable future. Bird dispersal recordings have potential applications in all of these areas.

Because of advances in technology, some problems that did not exist 50 years ago are severe today. Bird hazards to aircraft is an example. In separate essays on the economic impact of birds in relation to man, Henderson [*15*] stated that gulls are "practically harmless" and Du Pay [*16*] agreed that they were "seldom harmful to man." But with man's increasing presence in the skies and the advent of turbine engines on aircraft, gulls now account for 40% of the world's reported bird/aircraft strikes [*17*]. Actually, the first reported instance of a fatal bird/aircraft strike occurred in 1912, when Cal Rodgers, the first man to fly across the United States, died after a gull became entangled in the control wires of his aircraft, causing it to crash [*18*]. Although birds may cause human death indirectly by consumption or destruction of foodstuffs or through transmission of disease, they are a direct and obvious danger when they interfere with the normal operation of aircraft. In 1960, an Electra in Boston collided with a flock of starlings soon after takeoff, resulting in a crash landing and 62 fatalities [*19*]. Harrison [*20*] noted that from 1966 to 1976, the U.S. Air Force experienced 3851 bird strikes which resulted in damage or loss of aircraft, with 9 fatalities and 18 aircraft lost. The estimated monetary loss was at least $81.1 million, not including the man-hours required for repair. Clearly, birds can cause significant problems whenever there is competition for the same airspace [*21-24*].

Approaches to Bird Dispersal

Numerous techniques have been employed for dispersing nuisance, depredating, or dangerous birds. These include shouting, arm-flapping, banging sticks against metal pans, scarecrows, bird decoys, raptor kites or balloons, falconry, shooting, propane exploders, pyrotechnics, synthetic alarm devices, recorded bird sounds, rock music, microwave radiation, ultrasonic sounds, chemical repellents and frightening agents, changes in cultural practices, and habitat manipulation [*23,25-27*]. Although using a single technique has been effective in some situations, generally the best approach to bird damage problems is to use several complementary techniques together [*14,23,24,26*]. No one technique works best for all locations, weather conditions, and species.

Zabadal and Hothem [*28*] reviewed some of the disadvantages of many bird dispersal techniques. These include (1) the small range of influence for many devices, (2) the ability of birds to habituate to certain audio and visual stimuli, (3) the fact that many techniques are labor intensive, and (4) the annoyance factor caused by the disturbance to the human environment.

Bird dispersal recordings have a number of advantages over other dispersal techniques. When used properly, they can be a valuable and useful technique for dealing with problem birds around airports [*23*], agricultural concerns [*29-31*], urban and rural structures [*32,33*], and in other problem situations

[7,34]. Generally, the initial cost of the system is the only major expenditure, and this cost can be prorated over the length of the control program. The equipment necessary is readily available and can be operated manually or automatically. Because the recordings are usually distress or alarm sounds, the biological or natural basis of the sounds may decrease the chance of habituation before the operation is completed. With increasing public concern over the treatment of animals, nonlethal control methods, such as bird dispersal recordings, are likely to receive more public acceptance than lethal techniques [35,36]. However, the limited range of bird dispersal recordings may limit their cost-effectiveness in protecting very large areas.

Mention should be made of dispersal recordings other than alarm and distress calls. Work on developing a superstimulus through the analysis of alarm and distress sounds [9,37] has not proven fruitful. Synthetic sounds may lack biological significance, thus habituation may be more rapid [38,39]. Music has received some support as a dispersal tool [28,40,41], but it may not elicit a response too different from that of other sounds that are nonbiological in origin.

Methods

Primarily four methods were used to review and evaluate bird dispersal recordings and to locate current sources. First, we reviewed the literature. Second, we requested information through correspondence. A questionnaire was sent to 285 individuals or agencies, and letters of inquiry were mailed to 42 potential commercial sources of bird dispersal recordings. The questionnaire asked for information including sources of recordings, resource people to contact, techniques to use, and comments or opinions. It was mailed to Cooperative Extension Service personnel in all 50 states, all U.S. Fish and Wildlife Service-Division of Animal Damage Control state offices, all participants in the Bird Hazards to Aircraft Training Seminar and Workshop held 8-9 Sept. 1976 at Clemson University, and other selected biologists from the United States, Canada, and Great Britain. Of the 285 questionnaires mailed, 131 (46%) were completed and returned; the actual number of respondents was probably higher, because many agencies coordinated their responses through one individual, thus eliminating duplication. Third, two poster displays were used to elicit information about bird dispersal recordings and their potential uses. One was presented at the 42nd Midwest Fish and Wildlife Conference, 7-10 Dec. 1980, in St. Paul, Minn.; the other was presented at the 1981 Midwest Regional Animal Behavior Meetings held 27-29 March 1981, in Ames, Iowa. Fourth, we traveled to visit in person with 21 professionals experienced with bird dispersal recordings and to view tape library facilities.

Characteristics of Bird Sounds

Bird Communication

Sound is only one segment of a bird's communication repertoire. Other communication systems include visual, tactile, and possibly other signaling devices [*42*]. One reason communication systems exist is because they are energy efficient; for example, it takes less energy for a male bird to attract a female by singing than by flying out, locating, and bringing a female back.

Acoustical signals have the advantage of being invisible and easily produced, and they do not require special lighting conditions or media. Acoustical signals travel fast and do not linger or clutter the sensory environment because they dissipate rapidly. One disadvantage of acoustical signals is that they can be exploited by predators [*43*].

The vocalizations of birds have been intensively studied for many years; birds are a popular behavioral subject and have an extensive "vocabulary" of sounds. In comparison, other vertebrate animals generally do not have as varied an acoustical repertoire [*44*]. As an example of the potential complexity of avian vocalizations, the red-winged blackbird (*Agelaius phoeniceus*) has 20 adult vocalizations [*45*]. Within this repertoire various vocalizations have specific meanings and functions. Marler [*46*] found that the vocabulary of the European chaffinch (*Fringilla coelebs*) included a flight call, a social call, an injury call, an aggressive call, three distinct and separate escape (alarm) calls, three courtship calls, song, and subsong. Clearly, the acoustical communication system of birds (even excluding nonvocal sounds) can be quite complicated.

How Birds Produce Sound

Some understanding of the mechanisms and limits of avian vocalizations is helpful in working with them effectively. Birds have a unique sound-producing organ called the syrinx, located at the junction of the bronchi and the trachea [*47*]. Greenwalt [*48*] reviewed many of the hypotheses on the mechanisms and operation of bird vocalizations. Briefly, as air is forced out of the lung/air-sac system that forms a bird's respiratory apparatus, membranes located in the syrinx (the internal and external tympaniform membranes) vibrate and produce sound. Muscles connected to the syrinx control the tension of the membranes and thus affect the characteristics of the fundamental frequency [*47,49*]. Some birds are capable of producing sounds separately from each bronchial passage [*47,48*]. Birds with a more complex syrinx structure generally have a greater frequency range but not necessarily a more complex song [*48*].

Vocalization Ranges

There are limits to the frequency ranges of vocal sounds produced by birds. Greenwalt [*48*] reported that for the birds in his study, the frequency ranges of songs free of harmonic content varied from a low of 80 to 90 Hz for the spruce grouse (*Dendragapus canadensis*) to a high of 10 700 Hz for the brown-headed cowbird (*Molothrus ater*). Brand [*50*] found the average frequency for 59 different species of birds to be 4280 Hz, with the highest song noted belonging to the blackpoll warbler (*Dendroica striata*), which had a high note of 10 225 Hz. For comparison, the lowest C note on a piano has a frequency of 32.7 Hz and the highest C is 4186 Hz [*49*].

Following are the frequency ranges reported by Brand [*50*] of some species that are considered a hazard to aircraft.

American crow (*Corvus branchyrhynchos*)	1450 to 1650 Hz
American robin (*Turdus migratorius*)	2200 to 3300 Hz
Cedar waxwing (*Bombycilla cedrorum*)	7675 to 8950 Hz
Starling (*Sturnus vulgaris*)	1100 to 8225 Hz
Red-winged blackbird (*A. phoeniceus*)	1450 to 4375 Hz

This limited sample shows that species exhibit different frequency ranges. In his study of North American bird sounds, Greenwalt [*48*] reported the greatest range in the song of the brown-headed cowbird, embracing an interval of 700 to 10 700 Hz. Harmonics associated with the fundamental frequency can occur at even higher frequencies than reported for harmonic-free songs. Their role in avian communication is not well understood.

Hearing Ranges

In the past, reports have suggested that birds' hearing ranges are similar to man's [*48*], which is approximately 16 to 20 000 Hz [*51*]. Bremond [*52*] reported that most birds hear between 100 and 20 000 Hz. However, recent studies have shown that pigeons and probably many other birds sense frequencies as low as 0.05 Hz [*53*], well below the range of human hearing. It seems unlikely that birds hear sounds which are above the range of human hearing [*7,21,34,49,54,55*].

Thorpe [*51*] speculated that birds do not necessarily hear tones of the same range that they produce. Pumphrey [*56*] reported that "it is most unlikely ... that 10 kilocycles represents the upper limit for small birds since recognition of a specific song or call seems to require perception of at least the first few harmonics as well as the fundamental of the highest tone in the song" (p. 141). He later revised his position [*57*], stating that he "doubts whether there is any useful sensitivity above 10 kilocycles per second in birds other than owls and perhaps parrots" (p. 82), based on the physical characteristics of the avian ear. Bremond [*52*] further clarified this issue by pointing out that "perception and emission of high frequencies would be only of slight value as their range in air is limited" (p. 735).

The upper frequency of songs or calls can be increased by the generation of harmonics associated with the fundamental or first harmonic. Greenwalt [*48*] found that for a given species there is a threshold frequency below which harmonics occur and above which a harmonic-free whistled phrase is generally given. This threshold ranged from 500 to 4000 Hz. He noted that Passeriformes generally had harmonic-free songs, whereas in nonpasserines, phrases with substantial harmonic content were relatively common.

As harmonics increase in frequency, some begin to exceed the upper limit of the avian ear (greater than 20 000 Hz). Higher frequencies attenuate rapidly and become inaudible at correspondingly shorter distances from the sender. Thus, in a song with a fundamental frequency of 4000 Hz one or two harmonics may be audible to other birds, but it is unlikely that any above this would be heard because even the second and third would probably be faint [*58*]. Harmonics are limited by the upper limit of the hearing range and by the rapid loss of energy associated with high frequencies in general. This does not mean that they have no importance. For many bird species harmonics above the first predominate in at least a portion of the song [*48*] and thus play a role in species recognition. Based on the hearing ranges of birds, it is unlikely that high-frequency sounds would be effective for bird dispersal work. Additionally, we found no evidence that ultrasonic devices are effective for this purpose [*25,54,55*].

Time discrimination (temporal resolving power) refers to the ability of an organism to distinguish between separate successive sounds which can be heard as distinct within a given time interval [*51*]. Pumphrey [*57*] reported that time discrimination in birds was at least ten times better than in humans. Greenwalt [*48*] believes that this figure is low and argues that time discrimination is 50 to 100 times better in birds than in humans. He concludes that "there is then the strong presumption that birds hear *as such* the rapid modulations so characteristic of their songs, and that the information content even in relatively simple songs must be enormous" (p. 142).

In summary, bird vocalizations free of harmonics generally fall between 100 and 11 000 Hz, or within the hearing range of most birds. Harmonics increase the frequency range of the sounds produced, but birds may not hear harmonics above 20 000 Hz. Birds apparently hear frequency ranges similar to those heard by humans, except that birds are also capable of sensing very low frequency sounds. Additionally, birds apparently distinguish between separate successive sounds (time discrimination) much better than humans. Because of the sensory differences between humans and birds, caution should be used in interpreting bird sounds and their significance.

Dispersal Sounds

Evolutionary Concepts

It is unlikely that bird sounds exist to satisfy an aesthetic sense in the birds themselves [*59*]. Instead, through an evolutionary process over time, certain vocalizations have elicited specific responses which have increased or decreased the genetic fitness of the caller. Those vocalizations that increase fitness would be selected over ones that did not, assuming everything else is equal. In other words, bird vocalizations generally have a function that relates to the propagation of genetic material and thus to survival [*60*].

Theoretical Aspects

Of all the avian vocalizations that have evolved through time, alarm and distress sounds have shown the most promise for dispersing birds from areas where they cause problems. Feeding calls have been suggested as a method of attracting birds to lure crops or locations where birds can be controlled or tolerated, but this has received little attention [*5,51,61*].

Warning calls are generally of two rather distinct types: alarm and distress calls. Distress calls are given when a bird is restrained or captured [*62,63*] or when a bird is subjected to unfavorable situations such as cold, isolation, or hunger [*51*]. On the other hand, alarm calls generally are given in response to the presence of a predator or an unknown and sudden stimulus [*21,26,37*] or when a bird is excited or angry [*64*]. Starkey and Starkey [*65*] described the characteristics of the alarm and distress vocalizations of mallard (*Anas platyrhynchos*) ducklings and showed that they differed in frequency, duration, and repetition rate. These results demonstrate that distress and alarm sounds can be fundamentally different. The distinction is not as obvious in all birds. Boudreau [*37*] concluded that the starling distress call was actually a modified alarm sound, given both when the bird was in danger and when it was suffering physical distress. Other researchers have reported separate alarm and distress sounds for starlings [*66,67*]. Theoretically, however, distress and alarm calls are distinct sounds initiated by different sets of stimuli.

There is a continuum of sounds that can be considered dispersal calls. Armstrong [*68*] stated that birds may possess a gradation of calls of varying intensity, depending upon the circumstances surrounding the stimulus. He asserted that the nature of the call was influenced by both the internal and external environments and that other factors, such as suddenness of disturbance and stage of the breeding cycle, also contributed. Marler [*69*] summarized this point, noting that "a bird that is alert or nervous is more likely to give alarm when danger threatens than one that is sleepy or relaxed. Thus, the physiological state at the time of the confrontation with a predator cannot be ignored if we are to understand the process of alarm call production" (p. 53). He mentioned also that the response of another bird to an alarm call would vary according to its physiological state and its previous learning experiences. Fretwell [*70*] and Spanier [*39*] state that residents are more likely to give distress calls than migrants. The logical conclusion from this, then, is that the reaction of a bird to an external stimulus cannot be fully understood without taking its current physiological state and past experiences into account.

Applied Aspects

Some controversy exists over which type of call, alarm or distress, is best suited for bird dispersal work. There are three main areas, however, which affect the utility of these calls as a bird dispersal tool. These are (1) the repellency of the call, (2) the habituation rate, and (3) the effect of regional dialects. Additionally, because the information contained in these sounds generally has biological significance to the receiver, the quality of the broadcast is important and will be addressed later in this paper.

Repellency—Distress sounds have been used as attractants [*71*] and as repellents [*32*]. Thorpe [*51*] noted that "it has been part of the lore of bird snarers from time immemorial that distress squeals of birds held in the hand (particularly young birds) will have a very strong attractive effect on members of the same and sometimes of other species" (p. 21). However, the repellency of a distress call generally is the quality most useful with bird damage problems.

Perrone [*63*] reviewed some of the current hypotheses for a bird vocalizing distress calls when captured. The distress call may be a call for help, a warning to other birds, or a mechanism that could either startle the predator into loosening its grip or bring a second predator to the site, thus increasing the possibility of escape. If the call has evolved as a mechanism to bring help, it may function as an attractant. If the call has evolved as a warning, it may function as a repellent. Similarly, if the call has evolved as a startle mechanism, it may function as neither a repellent nor an attractant. Thorpe [*51*] noted that the distress call of herring gull (*Larus argentatus*) chicks seemed to have no effect on other chicks of the same age, although it may have an effect on the hen. Last, a single distress call may serve more than one function; for example, it may startle a predator and at the same time repel or attract other birds.

Just as there is variability among species in their responses to distress calls (positive or negative attraction), there also appears to be individual variability within a species. Morgan and Howse [*72*] reported that three out of nine jackdaws (*Corvus monedula*) did not learn to avoid or terminate distress calls during behavioral tests. They questioned "whether distress calls act as negative reinforcers for all individuals, and whether they are equally effective negative reinforcers for those individuals which did learn to respond" (p. 489).

Thus, reactions to distress calls vary both with the species and with the individual. Some species or individuals respond well and others do not [*7*]. Such variation may be a function of previous experience, age, sex, and resident or migratory status.

Alarm sounds have not been tested as thoroughly as distress calls, primarily because true alarm sounds are difficult to record [*34*]. Because alarm calls are given in response to sudden danger, they may trigger an innate reaction in the caller or in other birds nearby [*37,68*]. This reaction may be either to flee or to crouch down and hide [*73,74*]. Thorpe [*51*] cautioned that although some bird calls may be based on a strong innate foundation, there can be considerable leeway for learning in determining a reaction. Accordingly, Marler [*46*] reported that hand-reared chaffinches gave a complete escape response to an imitation of their alarm call heard for the first time, and they also learned to respond to the alarm calls of other species.

Alarm sounds, therefore, at times may be superior to distress sounds for dispersing or repelling birds, assuming that valid alarm sounds exist for the species in question. However, alarm sounds may be more complicated than distress sounds and therefore less predictable [*7*]. Alarm sounds may also need the accompaniment of other vocalizations, such as the attention call preceding the alarm call proper with the herring gull [*5*].

Habituation Rate—Habituation refers to the gradual learning of an animal not to respond to an unimportant repeated stimulus [*42*]. Optimally, a dispersal device such as a warning call should have so definite a biological meaning for the species in question that reactions persist without habituation or else the birds abandon the area altogether [*26*]. This biological meaning can be either from innate programming or from learned experience. Although a bird's physiological state will influence the habituation rate [*37*], it appears logical that the more realistic a broadcast warning sound is, the greater the biological significance and time until habituation. Noise without biological significance should more quickly be accepted as part of the environment. Accordingly, Thompson et al [*75*] reported 8.1 repetitions of distress calls to a starling before habituation, compared with 2.5 to 2.9 repetitions before habituation when using a human voice, escape call, or drug-induced call. Shalter [*38*] found that a recorded human whistle would not elicit a fear response in breeding blue tits (*Parus caeruleus*) even when broadcast at similar sound pressure levels and durations as recorded alarm calls, which provoked immediate responses. Spanier [*39*] reported rapid habituation to recordings of propane exploders by night herons (*Nycticorax nycticorax*), but no habituation to the playback of natural distress calls was observed. Frings [*76*] has stated that "it is not enough just to go out and make a racket. The birds have to be able to recognize this sound" (p. 110). Therefore, it could be expected that birds would habituate to their distress and alarm sounds at a slower rate than to sounds that have no biological significance.

The habituation rate of alarm as compared to distress calls is not clear. Keil (in Ref *26*) reported habituation to playbacks of alarm calls but not to those of distress calls. In contrast, G. W. Boudreau[3] believed that alarm sounds were effective longer than distress calls because repetitions of the sound are not required as often. Whichever type of call is used, however, it appears that technique is very important for delaying habituation as long as possible. This will be discussed in further detail in a later section.

Regional Dialects—A number of authors have commented on the problem associated with regional dialects [*40, 77–79*]. Vaudry [*40*], in describing bird dispersal work in British Columbia, stated "it must be emphasized that birds will usually respond only to calls of their own species and sometimes only to those from the same region" (p. 11). Marler [*46, 73*], on the other hand, showed that bird alarm calls for many species are similar and have probably evolved in response to selection for both a common language and a call which is difficult to locate. So even though variation in most bird vocalizations is the rule rather than the exception [*44*], alarm sounds of different species show some similarity. Frings et al [*5*] found that the alarm calls of herring gulls were also effective with black-backed gulls (*Larus marinus*) and vice versa. Boudreau [*37*] suggested that regional dialects in alarm sounds were not likely, based on his analysis of resident and migrant birds in the southwest United States. It may be that few regional differences exist between alarm calls, whereas distress calls have observable response differences between populations.

It appears that alarm calls may be more likely than distress calls to elicit responses in a variety of species and in different regions. Birds that encounter other races or species may learn to react to their distress calls [*51*]. However, evolutionary convergence of alarm calls may make them more useful over a larger area.

In general, it appears that both alarm and distress sounds have promise as bird dispersal tools. Alarm sounds may be less likely to result in rapid habituation and may be more likely to elicit a response across species and regions. However, alarm sounds are less tested and are generally more difficult to record. Additional research is needed to find under what circumstances either alarm or distress sounds may be most effective in dispersing birds.

Equipment

The equipment used in a bird dispersal program is important to the ultimate success of the operation [*76, 80–84*]. Brough [*10*] stated that bird recordings and broadcasts should be made with attention to accuracy, signal strength, and clarity. He continued that "any reduction in the standards of any component in the playback equipment is likely to degrade the calls from the level of a recognizable signal to that of a meaningless noise, thus lessen-

[3]Director, Wildlife Technology, Clements, Calif., personal communication, 1981.

ing the response obtained from the birds" (Ref *10*, p. 408). Since the importance of biologically meaningful signals has been emphasized by several authors [*5,10,14,34*], the acquisition of proper equipment should be a first consideration in a bird dispersal program.

It is beyond the scope of this paper to evaluate effectively all of the equipment that has been recommended for use with wildlife recordings. Such an evaluation would require rigorous testing under various environmental conditions, using many different types of equipment. Therefore, only a short review of bird dispersal recording equipment will follow.

Sound energy is transformed by the microphone into electrical energy and then by a tape recorder into a permanent medium on magnetic tape. When broadcasting, the recording is transferred from the tape to an amplifier and then to a speaker, where the electrical energy is transformed back into sound energy. This entire process should be accomplished without any reduction in the integrity or accuracy of the original song or call.

All the components in both the recording and broadcasting systems should have a frequency response that overlaps the frequency range of the song or call of the species in question. In addition, all the components should be matched in terms of their respective specifications.

Microphones

Andrieu [*85*] listed some of the factors that should be considered when choosing a microphone for recording animal sounds. These include the qualities of the sonic field itself or the characteristics of the sound to be recorded, the qualities of the microphone such as voltage output and frequency response curve, and the physical characteristics of the environment such as terrain, surrounding noise, and weather. Fisher [*86*] considers the transformation of sound energy into electrical energy one of the weaker links in an audio system and, therefore, considers selection of a good microphone important. Two types of microphones are often suggested for outdoor wildlife sound recording. These are the moving coil (dynamic) microphone and the condenser (capacitor or electrostatic) microphone [*1,85–89*]. For further information about various kinds of microphones and their relative advantages and disadvantages, refer to Andrieu [*85*], Fisher [*86*], and Simms [*1*].

Reflectors

Parabolic reflectors are commonly used for recording wildlife sounds, but their use should be approached with caution. Many authors have noted problems associated with using parabolic reflectors [*1,48,85,86,90*]. Depending upon the diameter and focal point of the reflector, both high and (especially) low frequencies can be underrepresented in a recording. Parabolic reflectors are useful tools for recording bird sounds. However, an understanding of their limitations is needed for proper interpretation and application of the sounds recorded.

Recorders

Both reel-to-reel and cassette tape recorders have been used to record bird sounds. Boudreau [*34*] hypothesized that cassette recorders were adequate for birds with lower-pitched sounds, but for birds with higher-pitched sounds, the higher tape speeds associated with reel-to-reel machines were required. Both Fisher [*86*] and Simms [*1*] recognize the ease of using a cassette recorder, but both consider the reel-to-reel recorder more versatile as well as cost- and time-effective. Cassette recordings must be copied onto standard tape before editing and are similar in price to comparable reel-to-reel machines.

For broadcasting bird dispersal recordings, the cassette recorder is a very convenient device to use in the field. Cassettes are easily stored and loaded and do not require detailed instruction for proper use. Kolz and Johnson [*91*] compared the frequency response curve of ten portable cassette recorders in relation to their usefulness with bird dispersal recordings. They rated the recorders primarily according to their ability to reproduce a flat frequency response. Some of the recorders showed good reproductive fidelity between 100 and 12 000 Hz. This frequency range would include the vocal range of most birds in the United States.

Tape

Bird dispersal sounds may be recorded and broadcast using magnetic tapes in reel-to-reel, cassette, and endless-loop cassette formats. The tape selected should be of sufficient quality to produce a good frequency response and low noise [*86*]. It is easy to overlook the importance of tape selection, but Kolz and Johnson [*91*] have commented that "the frequency response obtained from any biosonics system is necessarily limited by its poorest quality component, and it is a common error to overemphasize the frequency response of the amplification system and neglect the quality of the input magnetic tape" (p. 8). In addition, since the thickness of a cassette tape is related to strength, the long, thin C-120 sizes are best avoided [*86*].[4]

Recording and Playback Considerations

Currently, there are no complete or universal guidelines to use when recording or broadcasting dispersal sounds. However, several individuals have reported observations and experiences that should be considered.

Perrone and Paulson [*92*] reported that the percentages of mist-netted

[4]A. L. Kolz, electronic engineer, U.S. Fish and Wildlife Service, Denver, Colo., personal communication, 1981.

birds giving distress calls varied significantly with different handlers. They speculated that the differences in handling may have included "length of time in the net, duration of handling, position of birds during handling or gentleness of handling" (p. 424). Since handlers affect the incidence of calling, they may also affect the intensity or other qualities of the calls. Kuhring [*93*] reported success in eliciting distress sounds from birds by using electric shocks. Further observation and research could help determine whether particular handling procedures, circumstances, or stimuli would elicit a more effective dispersal call.

The elimination of unnecessary background noise from the recording is important for clarity. Background noises can include man-made noises, wind, and electrical noise [*87*]. A windbreak can help eliminate wind noise [*87*], and a microphone held high will help avoid reflection, absorption, or echo problems from the ground [*85*]. A filter that eliminates the lower frequencies may reduce some of the electrical noise [*48*] without adversely affecting the dispersal qualities of the call [*72*]. However, birds sense low frequencies [*53*], so these filters should be avoided unless electrical noise is a problem.

One point that cannot be overemphasized is the importance of good field notes, both when recording a call and when conducting a dispersal operation. Sellar [*94*] gives an example of a standard field note format for use when recording sounds. Playback trials require field notes also. Stockdale [*95*] reported that starlings seemed to respond more to the splice in an endless-loop cassette than to the distress call itself, and G. R. Dudderar[5] believes that a 20 to 30% reduction in resolution may have a greater frightening effect than a more perfectly recorded distress call. R. L. Thompson[6] suggests that hunting calls of avian predators, integrated with alarm calls, may increase their effectiveness, and F. L. Boyd[7] reports that bird dispersal recordings are more effective if they have spaces with no sound instead of continuous noise. Observations such as these should be accurately detailed in field notes to help understand the processes and variables involved.

Guidelines to Field Application

Pretreatment Study

A program for effective bird damage control requires a thorough understanding of the problem and situation. A pretreatment study helps provide the information needed. It should include identification of the problem

[5]Project leader and extension wildlife specialist, Michigan State University, East Lansing, Mich., personal communication, 1981.

[6]Wildlife biologist, U.S. Fish and Wildlife Service, Tallahassee, Fla., personal communication, 1981.

[7]Wildlife biologist, U.S. Fish and Wildlife Service, Nashville, Tenn., personal communication, 1981.

species, recognition of movement patterns, and determination of other parameters such as types of food eaten and sex and age composition. Information from this study would help show why the birds are attracted to the problem area and would facilitate evaluation of various control measures. Evaluation should include a determination of where the problem birds may go if they are dispersed. The direction in which they disperse and their new location are important considerations, particularly at airfields. For example, dispersing birds might fly across active runways, and they might land in another objectionable location within the airfield environment.

In conjunction with a pretreatment study, liability aspects should be established and understood by all parties involved. Additionally, local law enforcement and government agencies should be notified of planned control activities; this will help avoid potential problems such as complaints about noise. Finally, the legal status of the bird species involved should be determined and the appropriate regulatory agencies contacted [*24*].

An Integrated Approach

No single technique for bird damage control is effective at all times in all situations. An integrated approach employs a variety of complementary techniques; this may increase the number of senses stimulated and thereby enhance dispersal efforts as well as decrease the habituation rate. Thus, bird dispersal recordings used in conjunction with other techniques are likely to be more effective than recordings used alone. Murton [*21*] predicted that future developments would center on finding a combination of sound and other stimuli which would lead to the slowest practical rate of habituation while being effective and economically realistic.

Habitat Manipulation—An important first step in many bird dispersal efforts is to remove all sources of food, water, and shelter used by the target species wherever possible [*31*]. This may cause nutritional or other stress for the birds and make dispersal easier. Boudreau [*34*] states that a rule in bird damage control is to look for the bird attractants, then eliminate them if possible. Once the attractant is eliminated, as long as the bird's site tenacity is not too strong, dispersal should be much easier. Therefore, manipulation of the habitat can be an effective management tool, especially when used in conjunction with other dispersal techniques. However, it must be pointed out that habitat modification usually affects other species of vertebrates [*96*]; this should be taken into consideration.

Habitat manipulation can be one or a combination of three types. The first is direct and permanent elimination of certain features that are attractive to birds, such as the elimination of a garbage disposal site [*97*] or watering area [*34*]. The second is the continual management of an area to make it unattractive to the problem species. This may include thinning a roost site [*27,98*] or managing the height of grass on airfields [*99,100*]. The third is management of an alternate area to make it attractive to birds; using a lure crop [*101*] is an example.

Visual Warning Signals—In his classic monograph on vocal communication in birds, Thorpe [*51*] commented that, although alarm sounds were common, alarm warnings could be communicated by visual cues alone in some instances. This suggests that visual alarm cues may be effective stimuli to use in conjunction with bird dispersal recordings. The combination may decrease the habituation rate and allow enough time to ensure a successful dispersal program [*21,102*]. Busnel and Giban [*9*] speculated that distress calls would be effective at lower volumes if an optical stimulus was added; this would be helpful in urban situations. The optical stimulus can be a model of a bird in a dead or dying position [*103*], a model of a predator [*9*], or other visual frightening device. Pomeroy and Heppner [*104*] found that the mean reaction times of starlings to both light and sound stimuli were very similar (76.38 ms versus 80.64 ms, respectively). Thus, birds may react to all of the alarm stimuli simultaneously, increasing the chance of sufficient fright thresholds for dispersal.

Just as distress or alarm sounds may be more effective the more accurately they are recorded and broadcast, visual cues may also require the same realism. Stout and Schwab [*103*] summarized some earlier work on the dispersal qualities of models of dead gulls, stating that "the visual features had to be almost perfect replicas of the three dimensional appearance of a gull" (p. 4). Models that lacked some visual details were less effective. Similarly, Hardenberg [*105*] reported that stuffed dead gulls displayed a wetted and disordered plumage when exposed to several days of rain, and these birds had a reduced frightening effect on live gulls.

Other Frightening Techniques—Along with audio and visual warning stimuli, other techniques have proven effective in dispersing problem birds [*93,106,107*]. Many of these were listed earlier in this report. One technique often used successfully is pyrotechnics such as shell crackers or fireworks [*40*]. Shooting several birds, where permitted, may be effective when used in conjunction with nonlethal techniques [*102*].

Using Dispersal Recordings

Speaker Location—Vaudry [*40,108*] suggested that speakers be positioned to provide sound over the entire area being protected. The direction and speed of the wind, and the locations of obstacles such as trees that can muffle or block sound, should be considered while placing the speakers [*24,40,109*]. Speakers have been mounted in vehicles, on towers, and on the ground and operated manually, by remote control, and automatically [*31*].

Playback Duration and Interval—Kozicky and McCabe [*14*] noted that the spacing of calls was important to efficacy. Thompson et al [*110*] measured the responses of starlings to broadcast distress calls. They found that the heart rate peaked within 2 or 3 s and then decelerated. It was also found that a stimulus period shorter than 10 s was effective and suggested that, where habituation is a problem, shorter broadcast periods may extend the effective period of the recording. Langowski et al [*111*] studied the behavioral responses of captive starlings to recorded distress calls. They concluded that an interrupted distress call should be more effective than one played continuously, because starlings habituated rapidly to the continuous playback.

These experiments complement other reports on the proper use of bird dispersal recordings. Vaudry [*108*] suggested that calls be played for 10 s every 8 to 10 min, with the time increasing up to 45 s every 3 min if the bird pressure is great. Boudreau [*34*] reported that bird dispersal recordings should be played intermittently, varying from 5 to 30 s at 3- to 4-min intervals. He mentioned that "a sequence with 10 seconds of sound broadcast every 8 to 10 minutes is adequate for most American pest-bird species" (p. 120). Another report [*31*] advised that the time the tape is playing should be varied from 5 to 60 s, with spaces of 1 to 10 min between playing times. Boudreau [*112*] reported that silent intervals of 3 min or more elicited good responses from horned larks (*Eremophila alpestris*) and house finches (*Carpodacus mexicanus*), whereas the birds often ignored broadcasts of alarm calls played at intervals of 2 min or less. Lucid and Slack [*24*] advised never to run the distress recording continuously. However, Erdman [*113*] advised continuous broadcasting from the time birds were in sight until no birds were approaching. This technique was apparently successful in dispersing mixed flocks of blackbirds from urban roost sites. In general, it appears that the usual technique has been to play the bird dispersal recording for 5 to 60 s at intervals of 3 to 10 min, depending upon how the birds respond.

For dispersal of roosts, the calls should be broadcast as the birds arrive [*24,34,40,109,113*]. The operation should cease when no birds are approaching [*113*] or at dark [*34*]. Roost clearance generally takes more than one evening [*32,34,113*]. For birds such as gulls loafing on a runway or starlings around buildings, the dispersal operation should be continued until the birds do not return to the area [*24*].

Potential Hazards

The loudness of bird dispersal recordings (usually greater than 100 dB) may be disturbing to nearby residents. Both avian and mammalian predators may be attracted by distress or alarm recordings and, in the case of airfields, may increase the problem. Some birds, notably gulls, circle for a while before dispersing [*5,114*] and may cause additional problems to aircraft. Birds moved from one location may cause problems at another. The possibility and consequences of these potential hazards should be evaluated during the pretreatment study and monitored throughout a dispersal program.

Airport Management in Relation to Bird Dispersal Recordings

Several reports have been published concerning bird management on airfields [*8,17,21-24,26,99,100,114-119*]. In general, the normal guidelines for using bird dispersal recordings are also applicable to the airfield environment. A pretreatment evaluation is recommended, and a forecast of what the situation will be five or ten years in the future can be helpful. All bird control work should be coordinated with local law enforcement, government, and other relevant public agencies. Individuals dispersing birds should have direct communication with the flight tower, because dispersing birds may be an immediate hazard to aircraft landing or taking off.

Bird dispersal recordings can be operated by a mobile team that continuously harasses birds near the airfield or by flight control tower personnel who can operate speakers on the airfield by remote control. Records of all bird sightings and attempted dispersals should be coordinated so that daily, seasonal, and yearly activity patterns of birds can be assessed and dispersal attempts evaluated.

Bird dispersal recordings can and have been an effective tool in dispersing birds from the airfield environment. Integrated with other techniques, they should remain a valuable part of bird management programs at airfields.

Concluding Comments

Bird dispersal recordings are not a panacea for all bird problems, but they have proved a valuable tool in integrated bird damage control programs. Kozicky and McCabe [*14*] stated that "the general effectiveness of scare devices is directly proportional to the availability of alternative sources of food and to the proper application of the method ..." (p. 74). Boudreau [*34*] believed that the failure of bird dispersal recordings to control bird damage is usually traceable to their improper use. Equipment, technique, the quality of the recordings, and the willingness to adapt to a particular situation are all important in determining the success or failure of a bird dispersal operation. Much remains to be understood about bird behavior and dispersal. However, we believe the continuing refinement of bird dispersal recordings and associated techniques can increase considerably our effectiveness in solving bird damage problems.

Acknowledgments

This project was supported with funds provided by the U.S. Air Force and administered by the U.S. Fish and Wildlife Service as Cooperative Agreement No. 14-16-0006-80-924. We are grateful to the many people, too numerous to list, who responded to our questionnaires, letters, and other requests for information; without them this project would not have been possible. Special thanks are due D. Andrews, D. Borror, G. Boudreau, J. Caslick, D. deCalesta, R. DeHaven, R. Dolbeer, G. Dudderar, L. Fairchild, W. Fitzwater, J. Guarino, T. Hoffman, N. Holgerson, G. Hood, R. Hothem, W. Howard, R. Kelly, E. Knittle, L. Koltz, E. Pearson, T. Salmon, J. Seubert, T. Stockdale, and P. Woronecki for cooperation and personal consultation. Gratitude is extended to J. Hardister and D. Stiles for valuable administrative assistance; to M. Beck, R. Case, R. Timm, and anonymous reviewers in the U.S. Fish and Wildlife Service and Air Force for helpful comments on the manuscript; and to J. Andelt and M. Kirkman for assistance on the manuscript.

References

[1] Simms, E., *Wildlife Sounds and Their Recording*, Paul Elek, London, England, 1979.
[2] Boswall, J., "Some Major Events in the World History of Bird Sound Recording," *Recorded Sound*, Vol. 34, 1969, pp. 469-470.
[3] Frings, H. and Jumber, J., "Preliminary Studies on the Use of a Specific Sound to Repel Starlings (*Sturnus vulgaris*) from Objectionable Roosts," *Science*, Vol. 119, 1954, pp. 318-319.
[4] Frings, H., Frings, M., Cox, B., and Peissner, L., "Auditory and Visual Communication in the Herring Gull, *Larus argentatus*," *Anatomical Record*, Vol. 120, 1954, p. 734.
[5] Frings, H., Frings, M., Cox, B., and Peissner, L., "Recorded Calls of Herring Gulls (*Larus argentatus*) as Repellents and Attractants," *Science*, Vol. 121, 1955, pp. 340-341.
[6] Frings, H. and Frings, M., "Recorded Calls of the Eastern Crow as Attractants and Repellents," *Journal of Wildlife Management*, Vol. 21, 1957, p. 91.
[7] Frings, H. and Frings, M. in *Pest Control: Biological, Physical, and Selected Chemical Methods*, W. W. Kilgore and R. L. Doutt, Eds., Academic Press, New York, 1967, pp. 387-454.
[8] Busnel, R. G. and Giban, J., Eds., *Le Probleme des Oiseaux sur les Aerodromes*, Institut National de la Recherche Agronomique, Paris, France, 1963.
[9] Busnel, R. G. and Giban, J. in *The Problems of Birds as Pests*, R. K. Murton and E. N. Wright, Eds., Academic Press, New York, 1968, pp. 17-28.
[10] Brough, T., "The Dispersal of Starlings from Woodland Roosts and the Use of Bioacoustics," *Journal of Applied Ecology*, Vol. 6, 1969, pp. 403-410.
[11] De Grazio, J. W. in *Proceedings: Eighth Vertebrate Pest Conference*, W. E. Howard, Ed., 7-9 March 1978, Sacramento, Calif., 1978, pp. 9-24.
[12] Petersen, W., *Population*, Macmillan, New York, 1969.
[13] Dolbeer, R. A. and Stehn, R. A., "Population Trends of Blackbirds and Starlings in North America, 1966-76," Special Scientific Report-Wildlife No. 214, U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., 1979.
[14] Kozicky, E. L. and McCabe, R. A., *Principles of Plant and Animal Pest Control: Vertebrate Pests: Problems and Control*, National Academy of Sciences, Washington, D.C., 1970, pp. 58-82.
[15] Henderson, J., *The Practical Value of Birds*, Macmillan, New York, 1927.
[16] Du Pay, W. A., *Our Bird Friends and Foes*, John C. Winston Company, Philadelphia, 1925.
[17] Seubert, J. L. in *Proceedings of Bird Hazards to Aircraft Training Seminar and Workshop*, S. A. Gauthreaux, Jr., Ed., Clemson University, Clemson, S.C., 1976, pp. 1-12.
[18] Solman, V. E. F., "Gulls and Aircraft," *Environmental Conservation*, Vol. 5, 1978, pp. 277-280.
[19] Stables, E. R. and New, N. D. in *The Problems of Birds as Pests*, R. K. Murton and E. N. Wright, Eds., Academic Press, New York, 1968, pp. 3-16.

[20] Harrison, M. J. in *Proceedings of Bird Hazards to Aircraft Training Seminar and Workshop*, S. A. Gauthreaux, Jr., Ed., Clemson University, Clemson, S.C., 1976, pp. 15-22.

[21] Murton, R. K., *Man and Birds*, Collins, London, England, 1971.

[22] Solman, V. E. F., "Birds and Aircraft," *Biological Conservation*, Vol. 5, 1973, pp. 79-86.

[23] Blokpoel, H., *Bird Hazards to Aircraft*, Clarke, Irwin and Company Ltd., Toronto, Canada, 1976.

[24] Lucid, V. J. and Slack, R. S., *Handbook on Bird Management and Control*, AFESC-TR-80-01, U.S. Air Force Engineering and Services Center, Tyndall Air Force Base, Fla., 1980.

[25] Wright, E. N. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 113-119.

[26] Larkin, R. P. in *Proceedings of Bird Hazards to Aircraft Training Seminar and Workshop*, S. A. Gauthreaux, Jr., Ed., Clemson University, Clemson, S.C., 1976, pp. 61-76.

[27] Mott, D. F. in *Proceedings: Ninth Vertebrate Pest Conference*, J. P. Clark, Ed., 4-6 March 1980, Fresno, Calif., 1980, pp. 38-42.

[28] Zabadal, T. J. and Hothem, R. L., "Mesurol—It's for the Birds," *Wines and Vines*, Vol. 60, No. 11, 1979, pp. 38-41.

[29] Boudreau, G. W., "Factors Related to Bird Depredations in Vineyards," *American Journal of Enology and Viticulture*, Vol. 23, 1972, pp. 50-53.

[30] deCalesta, D. S. and Hayes, J. P., "'Frightening Devices' Prevent Bird Damage," *Pest Control*, Vol. 47, No. 9, 1979, pp. 18, 20.

[31] "Distress Calls Make Good Bird Control," Pest Control Notes, Agdex 685, British Columbia Ministry of Agriculture, Entomology—Plant Pathology Branch, 1980.

[32] Pearson, E. W., Skon, P. R., and Corner, G. W., "Dispersal of Urban Roosts with Records of Starling Distress Calls," *Journal of Wildlife Management*, Vol. 31, 1967, pp. 502-506.

[33] Block, B. C., "Repelling Starlings from Objectionable Roosts with Their Own Distress Calls," *Pest Control*, Vol. 44, 1976, pp. 16-18, 35.

[34] Boudreau, G. W., *How to Win the War with Pest Birds*, Wildlife Technology, Hollister, Calif., 1975.

[35] Kellert, S. R., *Public Attitudes Toward Critical Wildlife and Natural Habitat Issues: Phase I*, U.S. Department of the Interior, Fish and Wildlife Service, Yale School of Forestry and Environmental Studies, New Haven, Conn., 1979.

[36] Schmidt, R. H. and Bruner, J. G., "A Professional Attitude Toward Humaneness," *Wildlife Society Bulletin*, Vol. 9, 1981, pp. 289-291.

[37] Boudreau, G. W., "Alarm Sounds and Responses of Birds and Their Application in Controlling Problem Species," *Living Bird*, Vol. 7, 1968, pp. 27-46.

[38] Shalter, M. D., "Responses of Nesting Passerines to Alarm Calls," *Ibis*, Vol. 121, 1979, pp. 362-368.

[39] Spanier, E., "The Use of Distress Calls to Repel Night Herons (*Nycticorax nycticorax*) from Fish Ponds," *Journal of Applied Ecology*, Vol. 17, 1980, pp. 287-294.

[40] Vaudry, A. L., "Bird Control for Agricultural Lands in British Columbia," British Columbia Ministry of Agriculture, Victoria, British Columbia, Canada, 1979.

[41] "Military Flight Safety Review 1980," *Flight International*, 3 Jan. 1981, pp. 26-30.

[42] Johnsgard, P. A., *Animal Behavior*, Brown Company, Dubuque, Iowa, 1972.

[43] Otte, D., "Effects and Functions in the Evolution of Signaling Systems," *Annual Review of Ecology and Systematics*, Vol. 5, 1974, pp. 385-417.

[44] Van Tyne, J. and Berger, A. J., *Fundamentals of Ornithology*, Dover Publications, New York, 1971.

[45] Orians, G. H. and Christman, G. M., "A Comparative Study of the Behavior of Red-Winged, Tricolored, and Yellow-Headed Blackbirds," *University of California Publications in Zoology*, Vol. 84, 1968, pp. 1-81.

[46] Marler, P., "The Voice of the Chaffinch and Its Function as Language," *Ibis*, Vol. 98, 1956, pp. 231-261.

[47] Nottebohm, F. in *Avian Biology*, Vol. V, D. S. Farner and J. R. King, Eds., Academic Press, New York, 1975, pp. 287-332.
[48] Greenwalt, C. H., *Bird Song: Acoustics and Physiology*, Smithsonian Institution Press, Washington, D.C., 1968.
[49] Jellis, R., *Bird Sounds and Their Meaning*, British Broadcasting Corporation, London, England, 1977.
[50] Brand, A. R., "Vibration Frequencies of Passerine Bird Song," *Auk*, Vol. 55, 1938, pp. 263-268.
[51] Thorpe, W. H., *Bird-Song: The Biology of Vocal Communication and Expression in Birds*, University Press, Cambridge, England, 1961.
[52] Bremond, J. C. in *Acoustic Behaviour of Animals*, R. G. Busnel, Ed., Elsevier, New York, 1963, pp. 709-750.
[53] Kreithen, M. L. and Quine, D. B., "Infrasound Detection by the Homing Pigeon: A Behavioral Audiogram," *Journal of Comparative Physiology*, Vol. 129, 1979, pp. 1-4.
[54] Thiessen, G. J., Shaw, E. A. G., Harris, R. D., Gollop, J. B., and Webster, H. R., "Acoustic Irritation Threshold of Peking Ducks and Other Domestic Wild Fowl," *Journal of the Acoustical Society of America*, Vol. 29, 1957, pp. 1301-1306.
[55] Spurlock, E. M., "Control of Bird-Strike Hazard at Airports," Final Technical Report, Project No. PU-3669, Stanford Research Institute, Menlo Park, Calif., 1962.
[56] Pumphrey, R. J., "The Sense Organs of Birds," *Ibis*, Vol. 90, 1948, pp. 171-199.
[57] Pumphrey, R. J., *Biology and Comparative Physiology of Birds*, Vol. II, A. J. Marshall, Ed., Academic Press, New York, 1961, pp. 69-86.
[58] Marler, P. in *Bird Vocalizations: Their Relations to Current Problems in Biology and Psychology*, R. A. Hinde, Ed., University Press, Cambridge, England, 1969, pp. 5-18.
[59] Hartshorne, C., *Born to Sing: An Interpretation and World Survey of Bird Song*, Indiana University Press, Bloomington, Ind., 1973.
[60] Dawkins, R., *The Selfish Gene*, Oxford University Press, New York, 1976.
[61] Fitzwater, W. D., "Sonic Systems for Bird Control," *Pest Control*, Vol. 38, No. 11, 1970, pp. 9-10, 12-13, 16.
[62] Driver, P. M. and Humphries, P. A., "The Significance of the High-Intensity Alarm Call in Captured Passerines," *Ibis*, Vol. 111, 1969, pp. 243-244.
[63] Perrone, M., "Factors Affecting the Incidence of Distress Calls in Passerines," *Wilson Bulletin*, Vol. 92, 1980, pp. 404-408.
[64] Saunders, A. A., *A Guide to Bird Songs*, Doubleday, Garden City, N.Y., 1951.
[65] Starkey, E. E. and Starkey, J. F., "Description of an Aerial-Predator Alarm Call for Mallard (*Anas platyrhynchos*) Ducklings," *Condor*, Vol. 75, 1973, pp. 364-366.
[66] Schmitt, N., "Recent Outcomes of the Struggle Against Starlings in 'Rheinland-Pfalz' (Germany)," International Union for Applied Ornithology, Meeting About the Means of Protection Against Birds Harmful to Crops and Forests, Versailles, France, 9-11 Oct. 1961, p. 39 (summary only).
[67] Pfeifer, von S. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963.
[68] Armstrong, E. A., *A Study of Birdsong*, Oxford University Press, London, England, 1963.
[69] Marler, P. in *How Animals Communicate*, T. A. Sebeok, Ed., Indiana University Press, Bloomington, Ind., 1977, pp. 45-70.
[70] Fretwell, S. D., "Screaming for Help," *The Bird Watch*, Vol. 1, No. 4, Bird Population Institute, c/o Division of Biology, Kansas State University, Manhattan, Kans. 1973.
[71] Stefanski, R. A. and Falls, J. B., "A Study of Distress Calls of Song, Swamp, and White-Throated Sparrows (Aves: Fringillidae). II. Interspecific Responses and Properties Used in Recognition," *Canadian Journal of Zoology*, Vol. 50, 1972, pp. 1513-1525.
[72] Morgan, P. A. and Howse, P. E., "Avoidance Conditioning of Jackdaws (*Corvus monedula*) to Distress Calls," *Animal Behaviour*, Vol. 21, 1973, pp. 481-491.
[73] Marler, P., "Characteristics of Some Animal Calls," *Nature* (London), Vol. 176, 1955, pp. 6-8.
[74] Hinde, R. A. in *Biology and Comparative Physiology of Birds*, Vol. II, A. J. Marshall, Ed., Academic Press, New York, 1961, pp. 373-411.
[75] Thompson, R. D., Grant, C. V., Pearson, E. W., and Corner, G. W., "Differential Heart

Rate Response of Starlings to Sound Stimuli of Biological Origin," *Journal of Wildlife Management*, Vol. 32, 1968, pp. 888-893.

[*76*] Frings, H., "Controlling Pest Birds with Sound," *Proceedings of the 30th National Shade Tree Conference*, Atlantic City, N.J., 1954, pp. 108-112.

[*77*] Frings, H., Frings, M., Jumber, J., Busnel, R. G., Giban, J., and Gramet, P., "Reactions of American and French Species of *Corvus* and *Larus* to Recorded Communication Signals Tested Reciprocally," *Ecology*, Vol. 39, 1958, pp. 126-131.

[*78*] Scheffer, V. B., *A Voice for Wildlife*, Scribner's, New York, 1974.

[*79*] Murton, R. K. and Westwood, N. J. in *Applied Biology*, Vol. I, T. H. Coaker, Ed., Academic Press, New York, 1976, pp. 89-181.

[*80*] Hardenberg, J. D. F., "Acoustical Scaring of Gulls," International Union for Applied Ornithology, Meeting About the Means of Protection Against Birds Harmful to Crops and Forests, Versailles, France, 9-11 Oct. 1961, p. 27 (summary only).

[*81*] Andrieu, A. J. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 305-320.

[*82*] Bremond, J. C. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 233-245.

[*83*] Seubert, J. L. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 144-171.

[*84*] Brough, T., "Some Theoretical Aspects of Bio-Acoustic Bird Control," *Ibis*, Vol. 111, 1969, p. 444.

[*85*] Andrieu, A. J. in *Acoustic Behaviour of Animals*, R. G. Busnel, Ed., Elsevier Publishing Company, New York, 1963, pp. 25-47.

[*86*] Fisher, J. B., *Wildlife Sound Recording*, Pelham Books, London, England, 1977.

[*87*] Tombs, D. J., "Wildlife Recording in Stereo," *Recorded Sound*, Vol. 54, 1974, pp. 278-289.

[*88*] Bondesen, P., "Lightweight Equipment for Recording in the Field," *Biophon*, Vol. 6, No. 1, 1978, p. 2.

[*89*] Hansen, P., "A Light-Weight Microphone System for Stereophonic Recording in the Field," *Biophon*, Vol. 6, No. 3, 1979, pp. 7-8.

[*90*] Lanyon, W. E. in *Bird Vocalizations: Their Relations to Current Problems in Biology and Psychology*, R. Hinde, Ed., University Press, Cambridge, England, 1969, pp. 291-310.

[*91*] Kolz, A. L. and Johnson, R. E., "Frequency Response Measurements for Cassette Tape Players," AFWL-TR-74-147, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, 1974.

[*92*] Perrone, M., Jr., and Paulson, D. R., "Incidence of Distress Calls in Mist-Netted Birds," *Condor*, Vol. 81, 1979, pp. 423-424.

[*93*] Kuhring, M. S. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 301-304.

[*94*] Sellar, P., "Notes for Contributing Recordists," *Recorded Sound*, Vol. 34, 1969, pp. 412-418.

[*95*] Stockdale, T., "Auditory Repellents," *Proceedings of the Sixth Bird Control Seminar*, H. N. Cones, Jr., and W. B. Jackson, Eds., Bowling Green, Ohio, 30 Oct.-1 Nov. 1973, pp. 271-272.

[*96*] Howard, W. E. in *Environmental Education*, T. S. Baker and Z. Naveh, Eds., Plenum, New York, 1980, pp. 205-212.

[*97*] Forsythe, D. M. in *Proceedings of Bird Hazard to Aircraft Training Seminar and Workshop*, S. A. Gauthreaux, Ed., Clemson University, Clemson, S.C., 1976, pp. 77-92.

[*98*] Good, H. B. and Johnson, D. M., "Experimental Tree Trimming to Control an Urban Winter Blackbird Roost," *Proceedings of the Seventh Bird Control Seminar*, W. B. Jackson, Ed., Bowling Green, Ohio, 9-11 Nov. 1976, pp. 54-64.

[*99*] Mead, H. and Carter, A. W., "The Management of Long Grass as a Bird Repellent on Airfields," *Journal of the British Grassland Society*, Vol. 28, 1973, pp. 219-221.

[100] Brough, T. and Bridgman, C. J., "An Evaluation of Long Grass as a Bird Deterrent on British Airfields," *Journal of Applied Ecology*, Vol. 17, 1980, pp. 243-253.
[101] Wiens, J. A. and Dyer, M. I., "Simulation Modelling of Red-Winged Blackbird Impact on Grain Crops," *Journal of Applied Ecology*, Vol. 12, 1975, pp. 63-82.
[102] Stone, C. P. and Hood, G. A. in *Introduction to Crop Protection*, W. B. Ennis, Jr., Ed., American Society of Agronomy and Crop Science Society of America, Madison, Wis., 1979, pp. 218-232.
[103] Stout, J. F. and Schwab, E. R., "Long Term Dispersal of Sea Gulls from U.S. Air Force Bases, Final Report," Andrews University, Berrien Springs, Mich., 1979.
[104] Pomeroy, H. and Heppner, F., "Laboratory Determination of Startle Reaction Time of the Starling (*Sturnus vulgaris*)," *Animal Behaviour*, Vol. 25, 1977, pp. 720-725.
[105] Hardenberg, J. D. F. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 121-126.
[106] Brough, T. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 279-286.
[107] Kuhring, M. S. in *Le Probleme des Oiseaux sur les Aerodromes*, R. G. Busnel and J. Giban, Eds., Institut National de la Recherche Agronomique, Paris, France, 1963, pp. 95-102.
[108] Vaudry, A. L., "Equipment for Portable Automatic Sound System to Broadcast Starling Distress Calls," British Columbia Ministry of Agriculture, Entomology—Plant Pathology Branch, Kelowna, British Columbia, Canada, 1980.
[109] Zajanc, A., Sprock, C. M., and Cummings, M. W., "Amplified Distress Calls for Starling Control," University of California, Agricultural Extension Service, Davis, Calif., 1966.
[110] Thompson, R. D., Grant, C. V., Pearson, E. W., and Corner, G. W., "Cardiac Response of Starlings to Sound: Effects of Lighting and Grouping," *American Journal of Physiology*, Vol. 214, 1968, pp. 41-44.
[111] Langowski, D. J., Wight, H. M., and Jacobson, J. N., "Responses of Instrumentally Conditioned Starlings to Aversive Acoustic Stimuli," *Journal of Wildlife Management*, Vol. 33, 1969, pp. 669-677.
[112] Boudreau, G. W., "Report of Bio-Acoustic Tests at Holloman Air Force Base, New Mexico," Unpublished report, U.S. Air Force, Special Weapons Laboratory, Kirtland Air Force Base, New Mexico, 1971.
[113] Erdman, S. S., "Establishing an Effective Urban Blackbird Roost Control Program," Four-and-Twenty Enterprises, Denton, Tex.
[114] Brough, T. in *The Problems of Birds as Pests*, R. K. Murton and E. N. Wright, Eds., Academic Press, New York, 1968, pp. 29-38.
[115] Aldrich, J. W., Robbins, C. S., and Dykstra, W. W., "Bird Hazard to Aircraft," Wildlife Leaflet 429, U.S. Fish and Wildlife Service, Washington, D.C., 1961.
[116] "Reducing Bird Populations on Airports," National Pest Control Association Technical Release No. 14-66, Elizabeth, N.J., 1966.
[117] "Bird Control," ATC Pamphlet No. 126-1, Air Training Command, Randolph Air Force Base, Texas, 1967.
[118] Ladd, E. R. in *Proceedings of the Fifth Bird Control Seminar*, D. L. Rintamaa and W. B. Jackson, Eds., Bowling Green, Ohio, 15-17 Sept. 1970, pp. 35-38.
[119] Seubert, J. L., "Birdstrike Hazards to Turbine-Powered Aircraft," *Proceedings of the World Conference on Bird Hazards to Aviation*, Paris, France, Vol. 3, 1977, pp. 53-67.