On 23 August 1971, an adult Goshawk (*Accipiter gentilis*) was observed chasing teal (*Anas crecca, Anas discors*) and Wood Ducks (*Aix sponsa*) on a 5.1-ha beaver flowage at 0620. At 0635 an adult female kingfisher arrived and the Goshawk gave chase as the kingfisher flew within 20 m. When the hawk closed to within 1 m after a few wingbeats and thrust its legs forward, the kingfisher dove into the water from a height of approximately 3 m. The kingfisher emerged immediately, rattled, and rapidly flew away. The Goshawk turned quickly when it had flown past the splash made by the diving bird and was within striking distance before the kingfisher had flown more than 50 m downstream. The kingfisher dove again, emerged at right angles to its previous course and flew directly to a dead snag on the edge of the flowage, after which the Goshawk returned to a branch immediately above the ducks. Although quiet after landing in the dead tree, the kingfisher began calling when the Goshawk landed. It then flew within 1 m of the hawk, again initiating a chase sequence. The kingfisher dived into the water three times before landing on a perch after the second chase. This series of interactions was repeated three times. During the last chase, the kingfisher called continuously, flew out of view, and returned without the hawk in pursuit. The Goshawk was not seen again.

These observations and those in the literature illustrate encounters where the hawk initiates the pursuit in a typical predator-prey relationship and where the kingfisher initiates an attack by its persistent approaches toward the hawk. McCabe and McCabe (1928) described these approaches by the kingfisher in terms of "amusement" behavior. This kind of behavior may be better explained as mobbing behavior, since the kingfisher's actions result in a thwarting of predatory activities (Cully and Ligon 1976: 123). Since the hawks left the kingfisher's areas of activity after these encounters, we suggest that the purpose of this behavior is similar to that espoused for mobbing in general, an increase in fitness for either the mobbing bird, its mate, or kin. Observations by Kirby at beaver flowages and by Mic Hamas (pers. comm.) in other areas of north-central Minnesota suggest that kingfishers maintain feeding territories throughout the summer months. Benefits thus accrue to a bird if the mobbing behavior subsequently allows uninterrupted feeding behavior on a feeding territory, a result that was in fact observed. Mobbing behavior makes information regarding the presence and nature of a predator available to both conspecifics and extraspecifics. By informing other potential prey of the raptor's presence and location, the hawk's probability of capturing any prey within the kingfisher's territory would be reduced; therefore it would be more efficient for the hawk to leave the area and search elsewhere for more vulnerable prey.

We thus suggest that the kingfisher's ability to mob a hawk in its territory reduces the incidence of predation by raptors, increases the potential efficiency of the bird's food gathering process, and accounts for the behavioral series discussed here and in earlier literature.

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Acoustical Properties of the Swoop-and-soar Call of the Ring-billed Gull

Michael R. Conover and Don E. Miller
Department of Zoology, Washington State University, Pullman, Washington 99164 USA

When a predator enters a gull colony, nearby gulls take flight and some may dive at the predator by flying rapidly downward toward it and then suddenly swinging upward in an arcing swoop, occasionally defecating when overhead (Tinbergen 1953, Moynihan 1955, 1956, Manley 1960, Kruuk 1964). This diving pattern has been labeled the "swoop-and-soar" and may serve to intimidate or distract predators from their search for chicks and eggs (Tinbergen 1952, Kruuk 1964). Just before reaching the nadir of the swoop, the gull begins a loud call, transcribed as "*K-waarh*," "*Koowaarh*," or "*K-wow*" (Moynihan 1956, Manley 1960), which continues as the gull passes through the nadir. Apparently this call makes the swoop more effective in distracting the predator by drawing attention to the swooping bird.

To examine the acoustical characteristics of this call in the Ring-billed Gull (*Larus delawarensis*) we tape recorded and spectrographically analyzed the call. We also made movie films of gulls swooping to estimate their speed. The filming and recording were carried out in a gull colony located on an island in Sprague Lake near Sprague, Washington. Swooping was induced by one of us standing near a nest situated on the perimeter of the colony while the other, kneeling, filmed 40 m away or recorded 15–20 m away along the perimeter.

A Kodak super-8 movie camera was used for filming. The individual serving as the swoop-object held a 1-m stick horizontally at a right angle to the camera view to provide a reference for measuring distances in projected images. Only swoops made parallel to the meter stick were filmed. As the movies were taken at a known speed, a gull's speed could be determined from single frame analysis yielding the distance traveled between frames. The mean speed of 25 such swoops filmed was 13.33 m/s. The highest measured speed was 15.19 m/s.

Tape recordings were obtained using a Uher 4000 Report-L tape recorder and a parabolic reflector directed at an angle away from the colony to minimize background noise of other birds. Only swoops made perpendicularly across the reception cone of the reflector were recorded so that the change in the bird's distance relative to the reflector would be minimal. Twenty *K-wow* calls were recorded in this manner and their frequency pattern later analyzed on a Kay 6061-B Sonagraph. Amplitude characteristics of the 20 calls were also examined using the Kay 6076-C Amplitude Display.

Examination of spectrograms of the call revealed that although some features varied, there were some consistent elements (Fig. 1 shows four randomly sampled sonagrams). On almost all of the recorded spectrograms, two distinct notes were apparent. The first was relatively constant in frequency, but in many cases it showed a gradual rise at its beginning. The second note usually started just before the end of the first note, although occasionally it began after a short pause (e.g. spectrogram B in Fig. 1). In all of the recorded calls, the second note was consistent in featuring a decline in frequency. The mean frequency decrease of the 20 recorded calls was 24.5% from the beginning to the end of the second note.

The notable aspect of this changing frequency pattern is that it resembles the auditory pattern expected from the Doppler effect. The Doppler effect occurs when a sound source and listener are moving relative to each other so that the sound frequency heard differs from the frequency emitted at the source. The relation between the frequency received by the observer (f') and the frequency (f) at the source is given by the expression: $f' = f(1 \pm Vos/V)$ where V is the speed of sound (343 m/s at 20°C), Vos is the speed of the source relative to the listener, and the plus or minus signifies whether the source is approaching or receding from the listener, respectively. This particular form of the Doppler equation holds when the speed of the source is very small relative to the speed of sound (Alonso and Finn 1970: 550–552), which is true in this case. The Doppler effect is the reason for the sound of passing cars, planes or trains seeming to drop in frequency.

That the call heard as a gull swoops overhead should auditorily decrease in frequency would thus be expected, since the gull's velocity relative to the predator reverses in direction. However, calculations based on the highest measured speed (15.19 m/s) indicate that the object of the swoop would hear an 8.9% drop in frequency owing strictly to the Doppler effect, and that the drop in frequency in the spectrographically analyzed calls recorded from the side of the swoop would only be 1.1%. As the mean decrease of the recorded calls was 24.5%, the gull evidently decreases the frequency vocally as it passes overhead. Indeed, the decrease is nearly three times the actual Doppler effect that would be heard from beneath the swoop. Combined, the vocally mediated decrease and actual Doppler effect produce a total frequency drop of 32.3%, equal to that produced by the Doppler effect of a constant sound source traveling at a speed of 55.4 m/s, or 3.6 times greater than the maximum measured from our film.

In 15 of the 20 calls, the sound amplitude increased during the middle of the call, and then decreased towards the end. Much of the enhanced mid-call amplitude resulted from greater energy in high-frequency overtones, which are particularly affected by a change in distance. This amplitude and overtone pattern also resembles that of a uniform sound source that is rapidly approaching and then receding. As with the decrease in frequency, these patterns are vocally produced since our method of recording precluded any great change in distance that could affect amplitude.

Spectrographic analysis of other common calls given by the Ring-billed Gull while in flight showed some variation but none were similar to the swoop-and-soar call. These calls usually featured a single

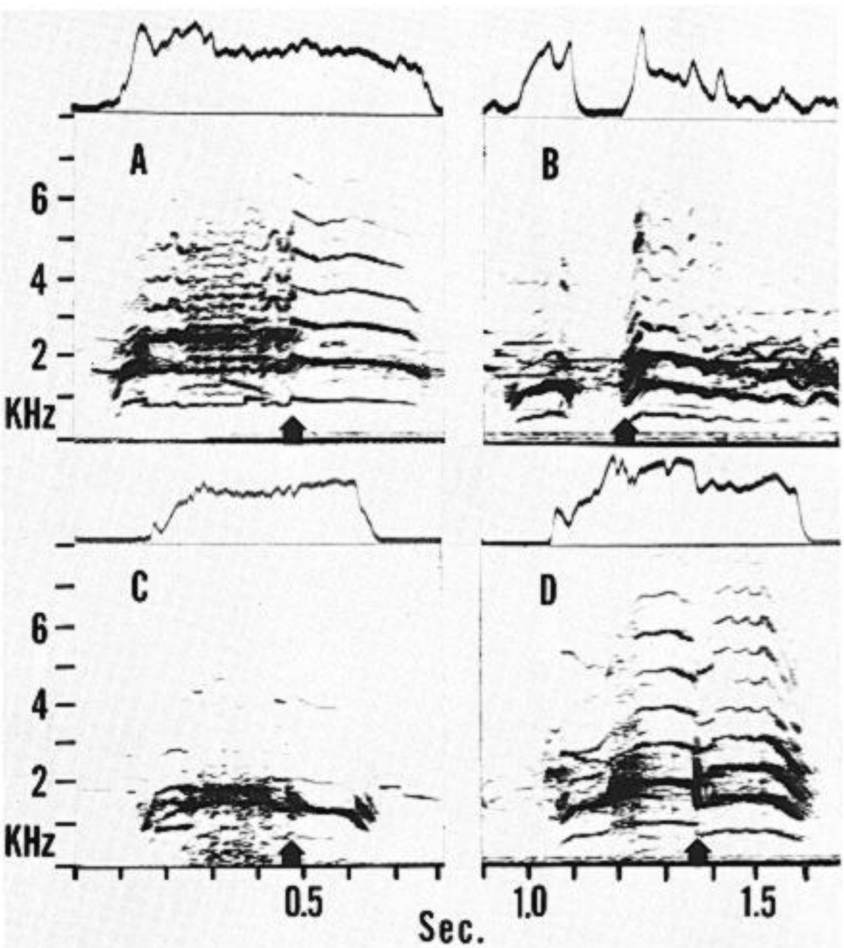

Fig. 1. Spectrograms of four swoop-and-soar calls of the Ring-billed Gull. The arrow points to where the second note begins. The graph above each sonagram plots mean amplitude of all frequencies over time.

note of comparatively short duration. Some of these calls did not decrease in frequency and those that did usually had a smaller frequency drop than the swoop-and-soar call. Hence, the frequency pattern in the latter call does not appear to be simply an unavoidable result of respiratory physiology during flight.

We can, of course, only speculate about the significance of the swoop-and-soar call in terms of its effect on predators. However, the resemblance of the call's vocally mediated frequency pattern to that produced by an intensified Doppler effect and the timing of the frequency drop so that it always occurs at the same time as the true Doppler effect may not be merely coincidental. Insofar as the swoop distracts or perhaps even intimidates a predator in the colony, natural selection should enhance any feature that facilitates such effects. Accordingly, accentuation of the actual Doppler effect of the call may more effectively deceive the predator by giving the impression that the gull is diving at a faster, perhaps accelerating speed and is thus a greater threat than it actually is. The deception would also be enhanced by the other vocally mediated characteristics involving amplitude changes that augment the Doppler effect in producing an illusion of extremely rapid aerial attack. Any deception caused by this call will probably be greatest when the predator is engaged in some activity such as hunting for chicks and not viewing the swooping gull, since its only cues then available for judging the gull's speed will be auditory. That such deception actually occurs remains an hypothesis for further work examining the auditory perception and behavior of gull predators.

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Interspecific Vocal Imitation in White-eyed Vireos

CURTIS S. ADKISSON AND RICHARD N. CONNER[1]
Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061 USA

The White-eyed Vireo (*Vireo griseus*) breeds in the eastern United States, eastern Mexico, and on Bermuda (A.O.U. 1957). Throughout this range it occupies forest edge or scrubby second growth habitat that follows clearing or burning (Bent 1950, James 1971, Conner and Adkisson 1975).

This species has been reported to imitate the sounds of as many as 30 bird species (Bent 1950). However, no attempts have been made to obtain spectrographic evidence of interspecific imitation. In this paper we seek to answer these questions: (1) is there good evidence of imitation? (2) if so, how does this system differ from other examples of mimicry? and (3) what kinds of sounds are the most advantageous to mimic?

We recorded White-eyed Vireos and their suspected models from 1974 to 1976 in Montgomery County, Virginia, within a 20-km radius of Blacksburg, using a Uher 4000 IC tape recorder and a Uher microphone mounted in a 61-cm diameter fiberglas parabola. We made spectrograms of all vocalizations using a Kay Elemetrics 7029A Sona-graph, using the wide-band filter.

In addition to recording singing birds when encountered, we usually stimulated each bird with playback of its own song or that of some other individual and recorded all vocalizations made thereafter for 10–15 min. The typical response to stimulation was to speed up the rate of song production, and to sing a larger portion of the song repertoire in a shorter time. The birds showed no tendency to imitate playback songs. Many territories were visited several times a season, with the assumption that the total repertoire of a given bird could be more fully sampled. However we had no marked birds and do not know that we recorded the same bird in the same place throughout the season. At least 20 individuals were recorded during this study.

The individuals recorded had many different songs, ranging from five recorded over a short span of time to at least 20 recorded over the span of several hours. Each vireo appeared to use a large but finite number of song figures, and the number of possible permutations was thus extremely large.

Certain figures in vireo song showed close similarity to the vocalizations of some common species found in or near typical vireo scrub habitat in the summer (Fig. 1). As identified by arrows, figures nearly identical to vocalizations of the Downy and Hairy woodpeckers (*Picoides pubescens* and *P. villosus*), Common Flicker (*Colaptes auratus*), Acadian Flycatcher (*Empidonax virescens*), White-breasted Nuthatch (*Sitta carolinensis*), Carolina Chickadee (*Parus carolinensis*), Carolina Wren (*Thryothorus ludovicianus*), Gray Catbird (*Dumetella carolinensis*), Wood Thrush (*Hylocichla mustelina*), Yellow-throated Vireo (*Vireo flavifrons*), Kentucky Warbler (*Oporornis formosus*), and Rufous-sided Towhee (*Pipilo erythrophthalmus*) appeared frequently in our sample. In addition, there were descending staccato call

[1] Present address: Wildlife Habitat and Silviculture Lab., Box 7600, Stephen F. Austin State University, Nacogdoches, Texas 75962 USA.