ACOUSTIC EVIDENCE OF RELATIONSHIP IN NORTH AMERICAN CROWS

BY L. IRBY DAVIS

THERE has been much difference of opinion as to how the crows of North America should be classified. The Northwestern Crow (*Corvus caurinus*) was originally described as a distinct species, but later (1931) listed as a race of the Common Crow (*Corvus brachyrhynchos*) by the American Ornithologists' Union Committee. After retaining that classification for many years, the latest "Checklist" (1957) again elevates the Northwestern Crow to full specific rank. (In the meantime it had been listed as a race of the Fish Crow, *C. ossifragus*, by Hellmayr, 1934.) In a similar manner there has been considerable discussion as to whether or not isolated populations, such as the Fish Crow of the eastern United States and the Mexican crows should be considered conspecific. (*C. imparatus* was listed as a race of *C. ossifragus* by Blake in 1953). When one reads the published data on various forms in museum collections, it becomes apparent why there is so much difficulty in trying to set up a classification based upon such morphological findings as are revealed by the skins. Using the data published by Ridgway (1904:266–275), one will find that (with the exception of the tarsus) the measurements given for the Common Crow overlap completely those of the other two species with which it comes in contact. The longest tarsus reported for a male Fish Crow is 47 mm., and the longest for a male Northwestern Crow is 53 mm., whereas the shortest tarsus given for a male of the western race of the Common Crow (*C. b. hesperis*) is 54.3 mm. However, when it is seen that the longest tarsus of *hesperis* is 58.5 mm. and the shortest for a male of *C. b. brachyrhynchos* is 60.0 mm., it becomes evident that there may be no overlapping in this character in the races within a species; hence, the specific taxonomic importance of that point becomes doubtful. Since there is so much variation in the measurements of different individuals, it was thought that perhaps ratios might give a better picture of certain characters. With this in mind, measurements were obtained from skins of random samples representing various populations, and the ratios of wing-length to tail-length calculated. The results are shown in Table 1. Disregarding the sexes and races the total variation in the Common Crow was from 1.63 to 1.82, the Northwestern Crow from 1.65 to 1.85, and the Fish Crow from 1.69 to 1.83. Hence it is seen that this ratio is essentially the same in all these species.

The western race of the Common Crow is more glossy on the back than the Northwestern Crow with which it comes in contact. Also, the plumage of the Fish Crow is more glossy than that of the races of the Common Crow which it meets. In some cases this difference is so slight as to be hardly noticed;

hence, it would not likely in itself serve as an effective barrier to interbreeding of the species.

One trait which is different in these species is the voice. Field students have repeatedly pointed out these differences in areas where the Common Crow comes in contact with the Northwestern Crow, and with the Fish Crow. Brooks (1942) was quite emphatic in pointing out that the distinctive voice had greater significance than measurements of skins in the Northwestern Crow. Studies have produced information tending to show that in genera, such as the forest thrushes, *Catharus,* in which the species all appear rather similar, the voice is of prime importance in species recognition (Dilger, 1956). Since it is quite possible that in North American crows, difference in voice is the main barrier to interbreeding, it was thought that a study of the calls might throw light on the taxonomic problems. Accordingly, the usual calls of the various species were analysed and the results reported herein.

Acknowledgments

I would like to express my appreciation to the members of the staff of the Laboratory of Ornithology at Cornell University for their valuable assistance and advice. I am especially indebted to Dr. Paul Kellogg for making spectrograms of the call of the Northwestern Crow in my absence, and to David G. Allen for making the photographs of the audio-spectrograms.

Materials and Methods

All the tape recordings of the voices of crows in the Library of Natural Sounds at the Laboratory of Ornithology at Cornell University were reviewed and what seemed to be representative examples of the typical or usual call of each species were selected for analysis. Audio-spectrograms were made of these calls and photographs then made of the audio-spectrograms. The use of the audio-spectrograph has been explained in detail by Potter (1947), and its use in the analyses of bird song discussed by Kellogg and Stein (1953). In the present study it was found desirable to use two different tape speeds for feeding the voice recordings into the audio-spectrograph machine in order to demonstrate different features of the calls. The "fast" tape speed used was double that at which the original recording was made and the "slow" speed was one half that at which the original recording was made.

Discussion

Common Crow. *Corvus brachyrhynchos.*—By far the widest ranging of any North American species, this crow is found over most of the United States and southern Canada. It comes in contact with the Northwestern Crow in the northwestern part of its range (coastal British Columbia), and with the Fish Crow in the southeastern part of its range. The usual call may be described as a short "caah" with a quick rise in inflection at the beginning and almost as quick a fall at the end. There is a slight difference in pitch between the sexes but otherwise the sound is the same. (Since it has been observed in the field

TABLE 1
RATIO OF WING LENGTH TO TAIL LENGTH IN SELECTED POPULATIONS OF NORTH AMERICAN CROWS[1]

Species or race	Range of ratios in males		Range of ratio in females
Corvus b. brachyrhynchos	1.67 to 1.77	:	1.65 to 1.82
Corvus b. pascuus	1.69 - 1.82	:	1.76 - 1.79
Corvus b. hesperis	1.71 - 1.79	:	1.63 - 1.79
Corvus caurinus	1.65 - 1.85	:	1.70 - 1.85
Corvus ossifragus	1.69 - 1.82	:	1.71 - 1.83

[1] Measurements from Ridgway, 1902.

that the larger of a pair of crows has the lower-pitched voice, it is assumed in this discussion that the lower-pitched member of a pair of birds is the male.)

Figures (1) through (6) in Plate 1, represent a series of calls of a pair of Common Crows. (The tape was not edited or altered and the spacing is just as it was arranged by the birds.) Here, as in all other plates, the intervals between the graduations on the horizontal scale represent 1/10 second, and the vertical scale shows the frequency in cycles per second. Calls (1), (2), and (5) were made by the presumed female and (3), (4), and (6) by the male. One call of the male and one of the female, (4) and (5), were selected for detailed study. The calls are made up of a series of harmonic bands which are almost exactly duplicated each time the call is repeated. In each case the fundamental is weak and appears as a light smudge in the area between 500 and 1000 cycles. The second harmonic in each case is strongly resonated, the third is considerably weaker than the second, and the fourth is again quite weak. The steepness of the rise and fall in inflection of each succeeding harmonic appears to be exaggerated because of the linear frequency scale used in the spectrograms. In order to facilitate the discussion and to make comparison of different calls easier, the use of two terms should be defined.

Since, in these short calls, the loudest part is thought to be that which affects the ear for the most part, the center of the darkest part of each harmonic band will be called the *effective frequency* of that harmonic. And, since the loudest or most strongly resonated harmonic is the one which most affects the ear, the effective frequency of that harmonic will be designated the *pitch* of the call. This spectrogram was made with a wide (300-cycle) filter, which, in this case, resolves the calls into distinct harmonic bands. The curvature of the harmonic bands indicates the rise and fall in inflection used by this species in its call. Hence, it is seen that the spectrogram gives a picture of the form, harmonic make-up, pitch, and duration of the calls. When a tape recording

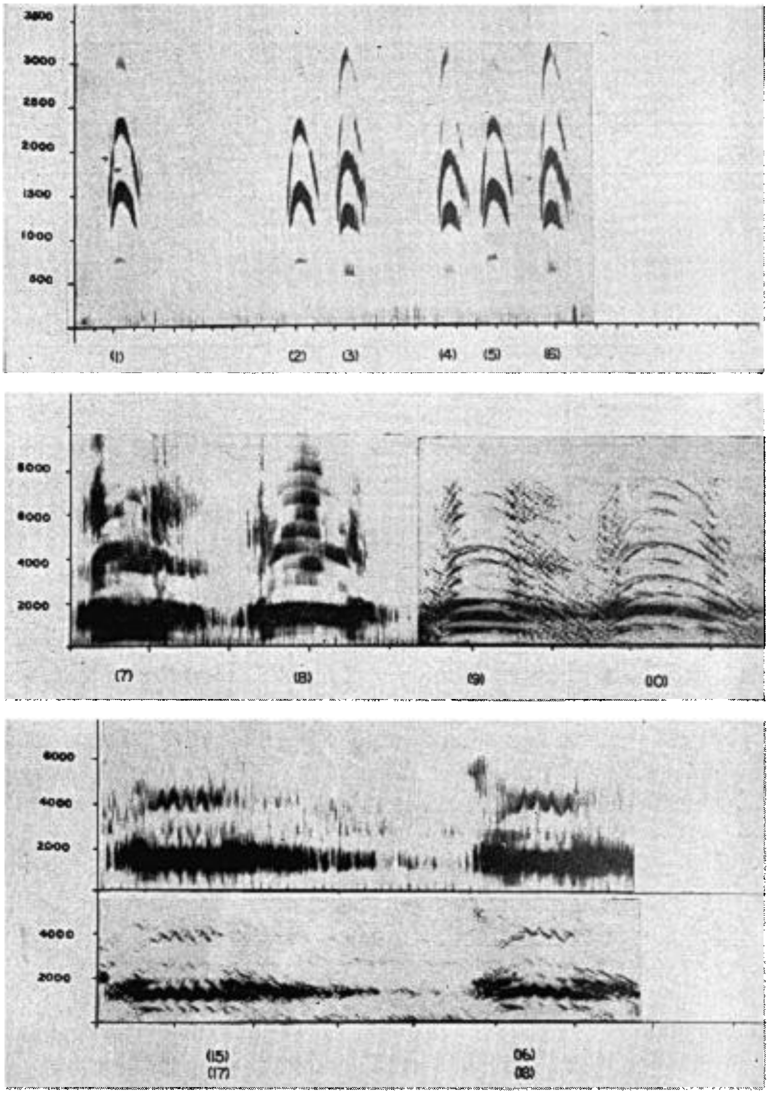

Plate 1. Sound spectrograms of the Common Crow (Figs. 1–18) See text for explanation.

is played at one half the speed at which it was made, the time taken for a call is doubled and the pitch is reduced one octave. Such methods are used to obtain different kinds of information from an audio-spectrogram. Figures (7) and (8) were made from the same calls as (4) and (5) but the tape was run at only one fourth the speed previously used. Consequently, the distance between the 1/10 second graduations on the horizontal scale becomes four times as great, and on the vertical scale 8000 cycles are now crowded into the space formerly occupied by 2000 cycles. Since the harmonic bands are pushed down closer together, many more of them fall within the range of the spectrogram; also, since these bands are now greatly stretched out, they are also flattened. The harmonic bands are now so close together that the wide (300-cycle) filter "sees" them merely as dark, blurred bars. Calls (9) and (10) also are the same as (4) and (5) and this spectrogram was made at the same tape speed as used for (7) and (8) but a narrow (45-cycle) filter was used. The narrow filter is able to resolve the calls into distinct harmonic bands, providing a more complete picture of the whole call. The dark shadow representing the main area of resonance passes squarely over the second harmonic in both the male (9) and female (10) spectrograms. In the case of the female call the third harmonic is largely outside the area of resonance, but the extreme ends of the band are of low enough frequency to fall just within this area. Some of the upper harmonics, such as the sixth, are stressed slightly more than the others and this no doubt adds to the quality of the voice. The fundamental is now more clearly defined and is found to be of an effective frequency of 638 cycles per second in the male and 756 cycles in the female (as nearly exactly as could be measured with a mm. scale). The pitch of the male call is 1276 cycles per second and the female is 1504 cycles per second.

As well as the clear calls discussed above, the Common Crow frequently gives one of a more burry or vibratory quality. Figures (15) and (16) represent two such calls (presumably both given by the same bird). Figures (17) and (18) represent the same two calls but were made by using the narrow filter. All were made at the same "slow" speed used in (7), (8), (9), and (10); hence, the scales are the same. From the wavy form of the harmonic bands it is seen that the peculiar quality of these calls is caused by a "vibrato" in the voice. Modulating the voice with this vibrato changes the general appearence of the picture, but a comparison of (18) with (10) will show that there are no differences of a fundamental nature. Again the second harmonic is dominant, the third shows little resonance except at the extreme ends, the fundamental is quite weak, and the sixth harmonic although weak is relatively stronger than the fourth and fifth (the fifth failed to show at all in this print). (The small patch of dark marks at the upper left of Fig. 16 is not part of the call, but is "interference" by another bird.) The fact that the fundamental is quite weak and that the sixth harmonic is resonated more strongly than the seventh suggests that this call was given by a female (see Fig. 10). The end of the first call, (15), (17), is more drawled out than any of the others and this makes the call over 3/10 of a second long.

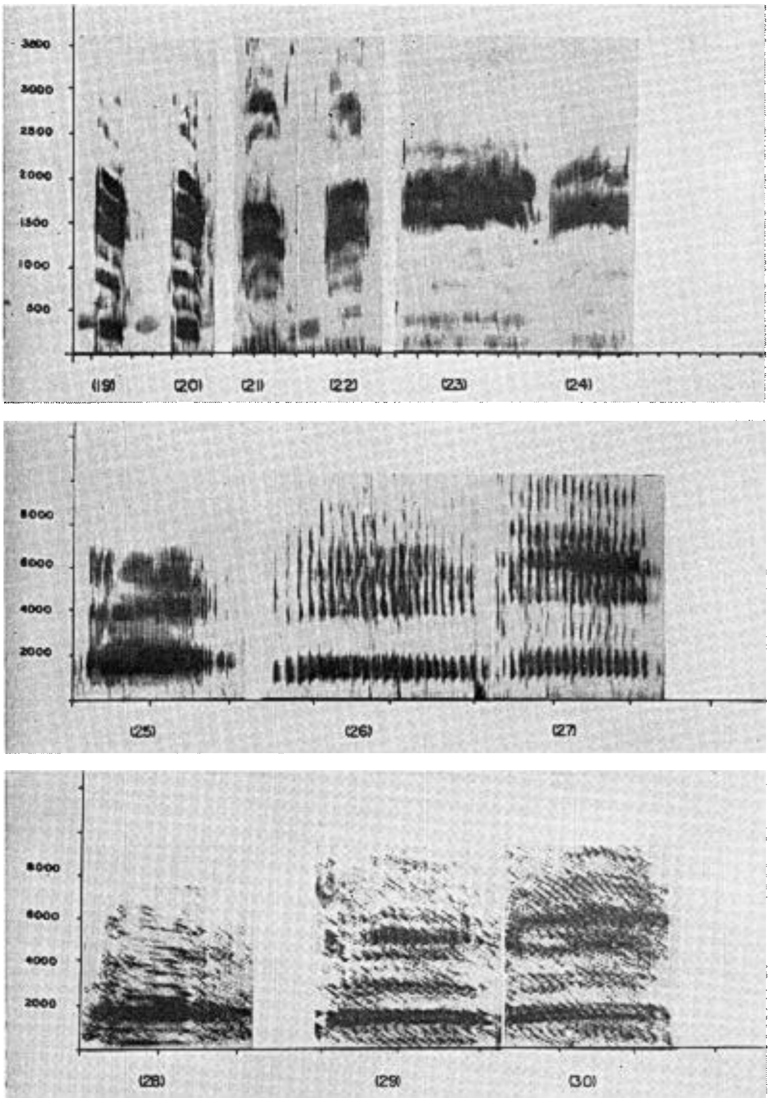

PLATE 2. Sound spectrograms of the Fish Crow (Figs. 19, 20, 25, 28) and Tamaulipas Crow (Figs. 21–24, 26, 27, 29, 30). See text for explanation.

Fish Crow. *Corvus ossifragus.*—This species ranges along the Atlantic coast of the United States and the Gulf coast to extreme eastern Texas. It is in contact with the Common Crow throughout its range but does not meet any other species of *Corvus*. Field students have reported the call of the Fish Crow as being shorter than that of the Common Crow and more of a nasal quality. I do not know how "nasal quality" would show up on an audio-spectrogram, but the duration of the call may be readily studied. Two calls of the Fish Crow are represented by Figs. (19) and (20). This spectrogram was made to the same scale as that which showed calls (1) through (6) of the Common Crow, and it is seen that they are indeed somewhat shorter than the calls of the Common Crow. However, the most noticeable thing about the spectrograms is the striking difference in form. Possibly that is what makes the difference in quality of the sound. As in the case of the Common Crow in (4) and (5), there is a resonant area from about 1400 to about 2000 cycles per second, and here again the lowest harmonic in the area of resonance seems to be somewhat more heavily emphasized. However, all other points are quite different. The fundamental is of a much lower frequency (below 500 cycles); hence the harmonics are much closer together. In this case the harmonic bands are not strongly bowed up and down but are relatively straight with a slight tilting down, indicating that the frequency falls slightly during the call. The fundamental appears to be considerably stronger. By slowing the tape down to one fourth the previous speed a spectrogram as shown in (25) was produced (compare with Common Crow, Figs. 7 and 8). Although the general areas of resonance are similar, the Fish Crow spectrogram presents a much "coarser" picture due to the plainly visible vertical lines which represent the actual vibration rate of the voice. Call (28) is the same as (25) but the spectrogram was made with the narrow filter. In this case the narrow filter fails to resolve the harmonics into complete bands (compare with Common Crow, Figs. 9 and 10). When the harmonics are spread further apart by speeding up the tape, the narrow filter is able to resolve them into distinct bands. This same call was used to make (35), but the fast speed of (20) was used as well as the narrow filter. From (35) it was determined that the pitch was 1390 cycles per second (this is for the fifth harmonic which seems to be almost exactly equal to the sixth in this print but in some other prints seemed to be a bit stronger).

Tamaulipas Crow. *Corvus imparatus.*—Although averaging half an inch smaller, the shape and the overlapping of the measurements of the skins has led many taxonomists to consider this bird a race of the Fish Crow even though the two populations have been isolated for a very long time. Measurements made on 10 males from Tamaulipas in the U.S. National Museum give wing-to-tail ratios varying from 1.63 to 1.72, and two males from the American Museum of Natural History fell within this range. (Seven females from the U.S. National Museum had wing-to-tail ratios varying from 1.65 to 1.68.) Hence, it is seen that in this population the ratios of these measurements fall completely within the range for the various populations cited in the introduction above. However, in spite of all these similarities, these birds differ from the Fish Crow in the field in three easily apparent repsects: first, the habits and habitat are different; second, the plumage is a more lustrous violet-black; third, the voice is very different. The preferred habitat is semi-desert brushland (the towns, villages, farms, and ranch yards in the region are frequented as well as the brushy areas themselves); however, a few birds occasionally wander into open places in more humid woods at the limit of the usual habitat. Tall forests, true deserts, mountains, and the sea beach all are avoided. The species ranges from China, Nuevo Leon, eastward to the lower tip of the Rio Grande Delta and southward (via Linares, Nuevo Leon) to the area about 15 miles south of Valles, San Luis Potosí, and to the northern border of Veracruz in the vicinity of Tampico, Tamaulipas. This is a strip roughly 100 miles wide and 250 miles long mostly in the state of Tamaulipas. Most of the birds are found between 100 and 1000 feet elevation but a few occur near sea level and up to about 1400 feet.

The voice of this species is so different from those previously considered that it is hard at first for an observer to believe that the sound is made by a crow. It is burry, low-pitched, and relatively low in volume, and sounds something like a frog croaking softly or someone plucking on a "Jew's-harp." Spectrograms of two typical calls are shown in (21) and (22). These represent male and female, respectively, and were recorded in a brushy pasture east of El Mante, Tamaulipas. The tape was played at the same "fast" speed as was used for Fish Crow call (20) and hence all have the same scale. These spectrograms present a coarser picture than any previous ones; no harmonic bands are resolved; and only blurred resonant areas are shown, with the fundamental more or less lost in the "noise" of the base line. Figures (23) and (24) represent longer calls that are less often heard; these were recorded about 15 miles southeast of El Mante. From the pitch it is presumed that they were made by females. Aside from the greater length, these spectrograms present the same form and structure as those of the shorter calls. Figures (26) and (27) represent the same calls as (21) and (22) but were made with the tape moving only one-fourth as fast, which gives them the same scale as Fish Crow call (25) and makes them directly comparable. It is seen that the calls of the Tamaulipas Crow give a much coarser picture than that of the Fish Crow; that the resonant areas are different; and that even the shorter calls are longer than that of the Fish Crow. Figures (29) and (30) represent the same two calls analyzed with the narrow filter. Whereas in the Fish Crow (28) there was some slight resolution of harmonic bands, there is none at all in (29) and (30), but only dark resonant bars. Even with the fine filter there is still evidence of the vertical sound pulse lines. This again indicates that it is necessary to use a much faster speed in order to show the harmonics. By going back to the fastest

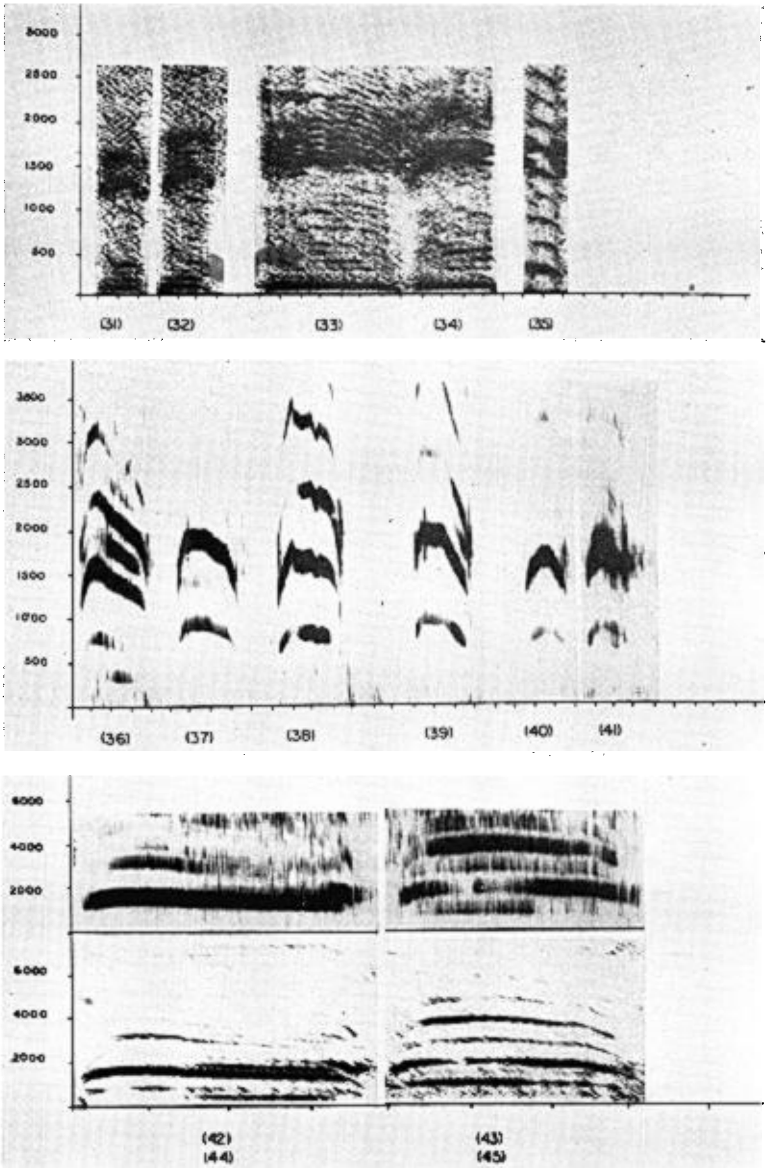

PLATE 3. Sound spectrograms of the Tamaulipas Crow (Figs. 31–34), Fish Crow (Fig. 35) and Sinaloa Crow (Figs. 36–45). See text for explanation.

speed used in this study and making spectrograms with the narrow filter, figures (31) and (32) were made with the same calls as used in (21) and (22),

(26) and (27), and (29) and (30). The fundamental now shows well although it is of such low frequency that it is almost on the base line. Above this there is a long series of harmonic bands that are quite close together and not completely resolved at any point even at the high speed used. By using multiples of the fundamental frequency, however, it is possible to calculate which harmonic would fall in the densest part of the resonance area between 1000 and 1500 cycles per second. The fundamental frequency is 82.3 cycles per second in the male and 90.0 in the female; the pitch of the male call is 1235 cycles per second, and the female, 1350 cycles, with the fifteenth harmonic being dominant in each case. The longer calls, shown in (33) and (34), since they show more horizontal area, give a picture in which it is easier to follow the incompletely resolved harmonics. Figure (33) discloses that the broad general area of resonance just above 1500 cycles is really composed of a number of very narrow resonant bars which do not exactly follow the contour of the harmonics. This causes what appear to be vertical fault lines. These "fault lines" appear to be caused by a given harmonic passing out of the area of resonance and its place being taken by another harmonic immediately thereafter. The harmonic band when outside the narrow resonant bar shows very weakly or not at all. These spectrograms are to be compared with that of the Fish Crow (35). It is seen that there is a tremendous difference in the form and structure, as well as in the frequency of the fundamental. The extremely low fundamental of this species is quite unique among North American crows.

Sinaloa Crow. Amadon (1950:497) cautioned against the arbitrary conclusion that crows with widely separated ranges were necessarily conspecific just because their skins were rather similar. Field studies on the crows of Mexico indicate that it would be well to heed that warning. Two formidable mountain ranges separated by hundreds of miles of desert present three barriers to prevent the present crow population of Tamaulipas from spreading to the west coast. There are, however, crows along the Pacific coast of Mexico with the center of population in Sinaloa. They range from southern Sonora to Colima in a strip roughly 50 miles wide and 500 miles long. The skins of these Pacific coastal birds look just like those from Tamaulipas, and gross measurements vary so little from those of Tamaulipan birds that all authors (as far as I have been able to discover), from Lawrence (1874) to Blake (1953), mentioning these birds, refer them to the same monotypic species. Since the present physiographic barriers evidently have been effective for a very long time, there can not have been any interbreeding in recent geological time, and, consequently, the two populations must have had either a common ancestor in the dim past or they must have become similar in appearance through convergence due to living in a similar latitude and climate. There would seem to have been ample time for many mutations and genetic changes to have taken place, and a careful consideration of certain features does indicate both external and internal morphological differences. Even though the measurements of skins from this population discloses many characters that are almost or exactly the same as those from other populations, there is one unique difference. This is the only North American crow with a distinctive wing-to-tail ratio. Wing-to-tail ratios of 10 males (Amer. Mus. Nat. Hist.; U.S. Nat. Mus.) varied from 1.53 to 1.60, and those for 11 females, 1.47 to 1.61. None of the ratios in representatives of other populations measured fell below 1.63 (Table 1). Ridgway (*op. cit.*) gave only averages of the wing and tail measurements but, if calculations are made with these, the ratios are found to be 1.64 for the males (1.82 for females) of the Tamaulipas population, and 1.59 for males (1.58 for the females) of the Sinaloa population. Although such small variations may be of interest to those who like to deal in measurements of skins, other types of differences are most noticeable in the field.

The Sinaloa Crow is found on wet sand of the sea beach when the tide is out and along river estuaries; however, it also ranges back of the coast and up into the hills to elevations of 1000 feet or more. These birds are common in coastal towns and villages and also in the semi-desert deciduous woods some distance from the coast. The attraction to a salt water habitat, however, might suggest a closer relationship to the Northwestern Crow (of the northern Pacific coast) than to the Tamaulipas Crow. The main nesting activity of this population falls the first part of June instead of the middle of April as it does with the Tamaulipas Crows. The juvenal birds call with a voice which is lower in pitch (by ear) than that of the adults, whereas the Tamaulipas juveniles call with a higher pitch (again by ear) than the adults. The call of the adult Sinaloa Crow is so startlingly different from that of the Tamaulipas Crow that a considerable difference in the morphology of the voice-making mechanism is at once suggested. The usual call is a clear "ceow." Before making any audio-spectrographic analyses, the writer estimated by ear that the highest part of the call was about the second B above middle C (varying with some individuals down about four tones) and that the latter part of the call slurred down a full tone or a bit more. The voice lacks the low burry or croaking quality of the Tamaulipan birds, and sounds much more like the voice of a Brown Jay (*Psilorhinus morio*) than that of the Tamaulipas Crow. Audio-spectrographic analyses point out these differences which are detected by the human ear. Figures (36) and (37) represent a typical call of a male and female recorded 17 miles east of San Blas, Nayarit. These spectrograms were made to the same scale as those of the Common Crow (4) and (5), the Fish Crow (19) and (20), and the Tamaulipas Crow (21) and (22), and hence are directly comparable. It will be seen that except for duration, these calls are rather similar to those of the Common Crow, but totally different from those of the Fish Crow and the Tamaulipas Crow. Calls (38) and (39) were recorded about a mile east of Altata, Sinaloa, and calls (40) and (41) near Rosario, Sinaloa. Call (40) is shorter than the average and therefore appears still more nearly alike in form to the call of the Common Crow (5). In the case of the presumed male's spectrogram (36) the fundamental is in the area below 500 cycles, the second harmonic shows weakly, the third was too weak to print, the fourth printed heavily and is dominant in the series, not much of the fifth printed except the tail end, the sixth shows rather well, the seventh scarcely printed (only a smudge at the tail end), and finally the eighth is again a bit stronger. The peaks of the bands of the second, fourth, sixth, and eighth harmonics are visible but no peaks are shown for the third, fifth or seventh harmonics. In the higher-pitched female call (37) only the second and fourth harmonic bands printed clearly. In the male and female calls (38) and (39) only the second, fourth, sixth, and eighth harmonics printed, with the fourth again dominant in each case. The call used in Fig. (40) was made by a bird from a flock and so there was no easy way of guessing its sex; however, from a comparison of the pitch with the other calls in the series it seems probable that the bird was a male. In this case the fourth harmonic is again strongly resonated and the second and eighth show weakly. The tendency of the even-numbered harmonics to be emphasized in this series of calls seems to indicate that the resonating cavities in the voice-making mechanism of these birds are such that rather widely but evenly spaced resonance bars are produced. The call used in making Fig. (41) is thought to have been made by the same bird as made call (40) but, as is seen, the spectrogram presents a different picture. The dominant dark area is considerably wider and is blurred and somewhat distorted as though more than one harmonic band were smeared together. This represents a different type of call that is sometimes given by these birds. It sounds hoarser although it is of the same pitch and seems to be a bit distorted as though the bird was straining his voice in his excitement. The hoarseness is somewhat remindful of the call of the Common Crow in which the vibrato is used; however, it appears to be differently constructed. Spectrograms (42) and (43) represent the typical male and female calls as in (36) and (37) but were made with the tape moving only one fourth as fast; hence, we again have a spread out horizontal scale and a greatly compressed vertical scale. Consequently, these are to be compared with the Common Crow calls (7) and (8), Fish Crow calls (25), and Tamaulipas Crow calls (26) and (27). It is seen that (42) and (43) have somewhat narrower and more sharply defined resonance bars than (7) and (8). The Fish Crow call (25) is more conspicuously different, and the Tamaulipas Crow calls (26) and (27) are so radically different that there is practically no basis for comparison. When these two calls were analyzed at the slow speed with the narrow filter, spectrograms (44) and (45) were produced. When compared with the Common Crow calls (9) and (10), it is seen that although similar in general form, the resonant bars are located differently and the harmonics emphasized are not the same. The Fish Crow call (28) shows still greater differences. And again the Tamaulipas Crow calls are so entirely different as to offer no reasonable basis for comparison. When the same call as of (36) is run at high speed and the narrow filter used to make a spectrogram, the result is Fig. (51). This makes the various harmonic bands more clearly visible and shows how the second, fourth, sixth, eighth and tenth harmonics are more strongly emphasized than are the odd-numbered ones; it also shows that the fourth harmonic is clearly dominant. The effective frequency of the fundamental is 394 cycles per second and the pitch is 1504 cycles per second. Spectrograms (52) and (53) were made from two different examples of the "distorted" type of call mentioned above. The peculiar quality of these calls appears to be due to the greater number of harmonics, and the lower frequency of the fundamental. Although the basic vibrations are slower, the bird's resonating cavities give the call the same pitch; so the general form and the pitch remain the same and only the quality is changed. The fifth and tenth harmonics are now resonated, with the tenth dominant; these correspond to the second and fourth in the smooth type of call and it will be seen that the distance between the second and fourth harmonic bands in the smooth type of call is the same as the distance between the fifth and tenth harmonic band in the "distorted" call. (Because of the high pitch these last two calls, (52) and (53), are thought to have been made by females.)

Since in pitch, quality, and form as indicated by the spectrograms, the voice of the Sinaloa Crow shows a greater difference from that of the Tamaulipas population than from any other North American crow, it could easily serve to keep the birds apart even though they occurred in the same region and there were no other differences that might prevent interbreeding. Since it would be helpful to field students working with these birds to have the taxonomy reflect the obvious differences in these populations, I propose that these Pacific coast birds be known as:

Corvus sinaloae sp. nov.

Type: From Escunapa, Sinaloa, Mexico. Male, no. 71674, American Museum of Natural History, collected November 16, 1895, by J. H. Batty.

Diagnosis: Similar to *Corvus imparatus* Peters of northeastern Mexico externally, but with ratio of wing length to tail length less than 1.63; voice of adult higher-pitched (the fundamental frequency, as shown by audio-spectrograms, higher) and of quite different quality (the resonance bars, as shown by audio-spectrograms, of different shape, location, and number).

Range: Pacific coastal slope of Mexico, from Sonora to Colima.

Northwestern Crow. *Corvus caurinus.*—After the present study was begun it was discovered that there were no recordings of the voice of the Northwestern Crow available. However some time after the work reported on above was completed, Dr. Ernest Booth of Walla Walla College reported that he had accidentally recorded some calls of a Northwestern Crow in the distant background while working on another species. He very kindly made this tape available and spectrograms from it were made for use in this paper. They appear as figures (56), (57), (58), (59), and (60). The last two are the same calls as the first two but were made with the narrow filter. These weak calls are of course almost below the noise level and can not be used to estimate the pitch in the manner used in the case of other species above; however, the form and relative position of the harmonic bands in these prints may be readily compared with those in the case of other species. If these calls are typical of the species, it may be said that in the form of the harmonic bands, the Northwestern Crow is intermediate between those of the Common Crow and the Sinaloa Crow. From this it would follow that the form of the harmonic bands is somewhat alike in all three species which are found on the Pacific slope, whereas they are quite different from the form found in the two species of crows which are confined to the Atlantic slope. By measuring the distance between the harmonic bands which printed in these spectrograms, it was estimated that the fundamental was about 260 cycles per second. From this it may be calculated that it is the fourth, fifth, sixth, and seventh harmonics that appear in the spectrogram; hence, it may be surmised that the dominant harmonic is below the seventh. Although it is not possible to determine the pitch by the method of measuring as was done in the species previously analyzed, by ear the pitch seems to be from a fifth to an octave below that of a series of calls of the Sinaloa Crow.

Because of the very low fundamental and the frog-like quality of the voice of the Tamaulipas Crow, it was thought it might be of interest to compare it with the voice of the American Raven (*Corvus corax*). Fig. (54) was made from a call of the Raven with the use of the wide filter; and the same call analyzed with the narrow filter is shown in (56). When (54) is compared with (21) it is seen that although the dark areas are shifted downward by the lower pitch of the Raven, that there is a noticeable resemblance. But when spectrogram (55) is compared with (31), which is the narrow filter picture of the call of the Tamaulipas Crow, the similarity becomes striking. Thus it is seen that the spectrograms of the call of the Tamaulipas Crow more closely resemble those of the American Raven than they do those of any other North American crow.

Calls (47), (48), (49), and (50) represent typical calls of the Fish Crow,

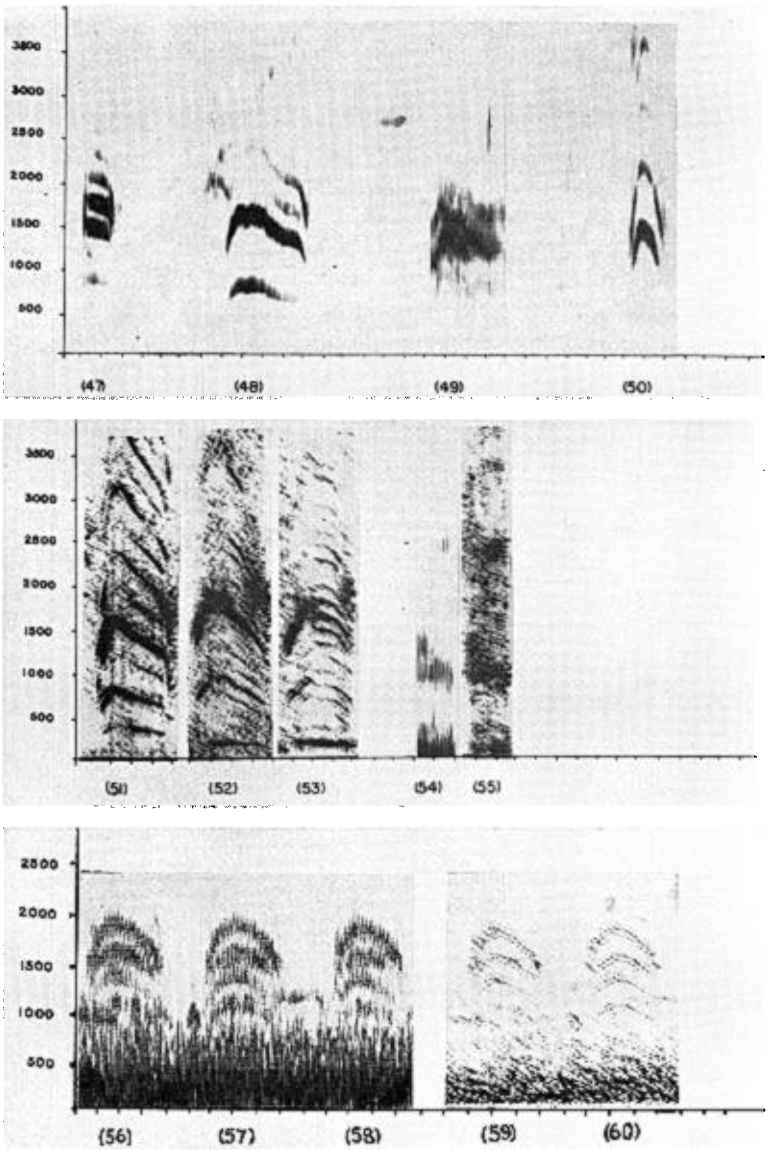

PLATE 4. Sound spectrograms of the Fish Crow (Fig. 47), Sinaloa Crow (Figs. 48, 52, 53), Tamaulipas Crow (Fig. 49), Common Crow (Fig. 50), American Raven (Fig. 54), and Northwestern Crow (Figs. 56–60).

Sinaloa Crow, Tamaulipas Crow, and Common Crow, respectively. They were all made simultaneously on a single spectrogram in order to be sure that the printing would be the same. The mark used was light and the contrast heavy in order to best show the form and the dominant features of the calls (the weaker harmonics do not print). It is seen that the dominant resonant area in each case is between 1300 and 2000 cycles, and that definite, rather sharp-cut harmonic bands are shown in all cases except one (the Tamaulipas Crow). In the Sinaloa and Common crows the spectrograms demonstrate a quite curved form to the harmonic bands, but it is not the case with those of the Fish Crow and the Tamaulipas Crow. The coarseness and generally blurred appearence of the picture in the Tamaulipas Crow was shown to be due to the very low frequency of the fundamental and the multiplicity of quite narrow resonance bars crowding together in the area of general resonance (dark region; see Fig. 33).

TABLE 2

SUMMARY OF AUDIO-SPECTROGRAPHIC ANALYSES OF SOME NORTH AMERICAN CROWS

Species	Fundamental frequency. (cycles/second)	Pitch (cycles/second)	Dominant harmonic
Sinaloa Crow	394 (male)	1575	4th
	496 (female)	1884	4th
Common Crow	638 (male)	1276	2nd
	752 (female)	1504	2nd
Fish Crow	281	1390	5th
Tamaulipas Crow	82.5 (male)	1255	15th
	90 (female)	1350	15th
American Raven	56.2	975	17th

Data developed from the analyses of typical calls are shown in Table 2 (information on the American Raven is included for comparative purposes).

SUMMARY

Audio-spectrographic analyses of typical calls of various species of North American crows were made and the results presented. It was found in the cases studied that the Sinaloa Crow had the highest pitched voice of all the species, whereas the Tamaulipas Crow had the lowest. The similarity of the form of the voice of the Tamaulipas Crow to that of the American Raven was pointed out. The Sinaloa Crow was proposed as a new species, *Corvus sinaloae,* from Escunapa, Sinaloa, Mexico.

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LABORATORY OF ORNITHOLOGY, CORNELL UNIVERSITY, ITHACA, NEW YORK, DECEMBER 18, 1957 (Submitted originally, January 10, 1957)