The Ivory-billed Woodpecker: audio evidence and analyses from Southeast United States 2022

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Ivory-billed Woodpecker, Campephilus, Campephilus principalis, spectrogram, earbirding, kents, double-knocks, Allen-Kellogg, Dan Mennill, John Dennis, bioacoustics, harmonics, dissonance

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Abstract

Audio recordings were obtained from the owner at one undisclosed location in the Southeast United States, in different months of 2022, that upon analyses exhibit strong spectrogram matching with existing data for birds thought to be the Ivory-billed Woodpecker (IBWO) from numerous professional sources, and with similar data from other members of the genus Campephilus. The previously noted idea that the "kent" sound has harmonic structure, and can be differentiated from other similar sounds, is also reinforced. It is put forth here that the harmonic structure is only in the form of octaves for the IBWO voice. For the first time since 1935, "wokawoka" sounds were captured, and these match well with the Cornell Allen-Kellogg sounds which accompany their video of the IBWO. Because "earbirding" is used for positive identification of bird species, it is suggested that the more exact data presented here be sufficient to identify the Ivory-billed Woodpecker and demonstrate its continued existence. The demand "extraordinary claims require extraordinary evidence" is met with advancements in technology and precision.

Introduction

The Ivory-billed Woodpecker (Campephilus principalis) has been observed sporadically for over two hundred years. Individual observations by prominent scientists and explorers, naturalists, hunters, and other individuals, differ and are sometimes contradictory. There is much that is not known about this iconic species, its inter- and intraspecific behavior, and ecological needs. It is not well-documented in photographic images, videos, and audio recordings. Although there is a body of evidence (treated scientifically, forensically, and with morphometric analyses and peer review) since 2000 from a number of serious search efforts, their results are not considered conclusive enough to generally consider the species to be extant [1].

Methods and Materials

Between March and December 2022, the field observer (owner) provided a number of audio files to the author, supporting the idea that there were observed Ivory-billed Woodpeckers during this time. The observer reported the birds from a location and habitat that agrees with modern ideas for the ecology of this species [1]. The location is kept as simply Southeast United States to respect rights, legal and ethical, of both the birds and the observer who wishes to remain anonymous.

The audio information from four of the observer's files is the subject of this paper. Information was recorded on an iPhone and submitted in both WAV and MOV forms. None of the MOV forms show any birds that can be interpreted as Ivory-billed Woodpeckers.

For each file, two website programs, Sonic Visualizer [2] and Audacity [3], were used to create and examine spectrograms. Sonic Visualizer was chosen to present information from for this paper, because of ease of use and clarity. To examine the possible Ivory-billed Woodpecker calls, adjustments were made to the x and y axes to better align with length of calls and known and suspected Hz frequency ranges. In all cases, the two programs allowed the creation of spectrograms that agreed with each other in quantification of data.

Comparisons were made to existing data from various sources that are accepted by science to be from Ivory-billed Woodpeckers, and from other sources where sound files were obtained on searches, during which professional groups had visual encounters with Ivory-billed Woodpeckers. Comparisons were also made with other members of the same genus Campephilus by using the sound libraries Macauley Library [4] and Xeno-canto [5].

The program Online Tone Generator [6] was used for matching the kent sounds, by the author's ear, to Hz. An estimate is that this gives an accuracy of +/- 10 Hz, and this is precise enough to use reason for ideas involving tonality, harmony, and dissonance.

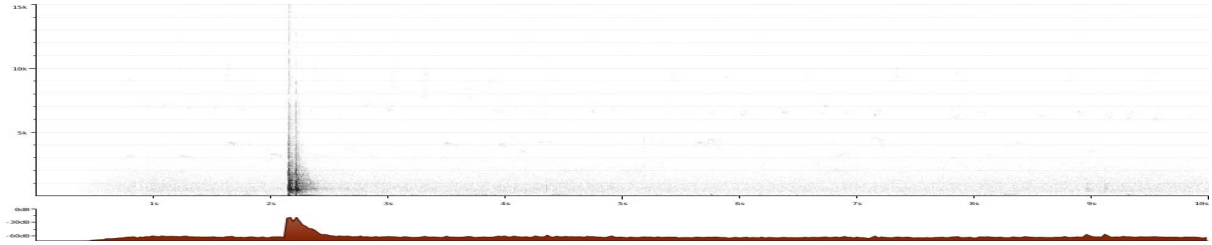
June 2022 “SK-DK-DK-SK” Audio Recording (2022 SE US 1)

In June 2022, the field observer obtained a video with sounds like a woodpecker knocking. No woodpeckers are visible on the video. Upon audio examination, one can hear four events that agree with published observations from putative Ivory-billed Woodpeckers.

The audio files made from this video reveal a “single knock” (SK), then a “double knock” (DK), then a fainter DK as if from another object farther away, then a louder (interpreted as closer) SK. The file is found below. The first SK is around 0.5 seconds, the first DK at approximately 1.8 seconds, the second DK near 4.6 seconds, and the last SK at 7.5 seconds:

https://drive.google.com/file/d/1JcVEhPwL22evN1-8EW71ydOxkaCEdbx2/view?usp=sharing

The double knock is considered to be an audio field mark, used for earbirding identification, of this genus Campephilus [1]. It appears thus (as the vertical lines) on a spectrogram:



(Xeno-canto XC48886 Magellanic Woodpecker by Bernabe Lopez-Lanus) [5]

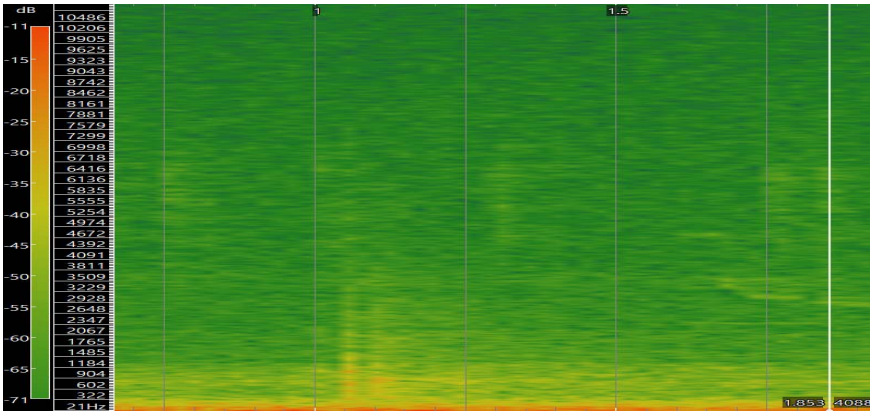
The 2022 SE US 1 double knocks match well with many of the double knocks (which are sometimes called “drumming” on Xeno-canto) from Campephilus species. Here is an audio example, including a spectrogram, provided for the Magellanic Woodpecker, Campephilus magellanicus [5]:

https://xeno-canto.org/75311

The 2022 audio also agrees well with an extensive dataset by Dan Mennill of University of Ontario. This audio was done with Auburn University’s Geoff Hill Choctawatchee River Florida IBWO studies, 2005-2006. Numerous visual reports by ornithologists were made during this expedition [7]. The dataset at Mennill’s site is the most extensive for sounds attributed to the Ivory-billed Woodpecker [8]:

https://web2.uwindsor.ca/courses/biology/dmennill/IBWO/IBWOsounds.php

From this Mennill dataset, an example is shown here, the double knock spectrogram structure appearing as orange vertical lines at the bottom:



(DK 2006 01 19 0625h.wav) [8]

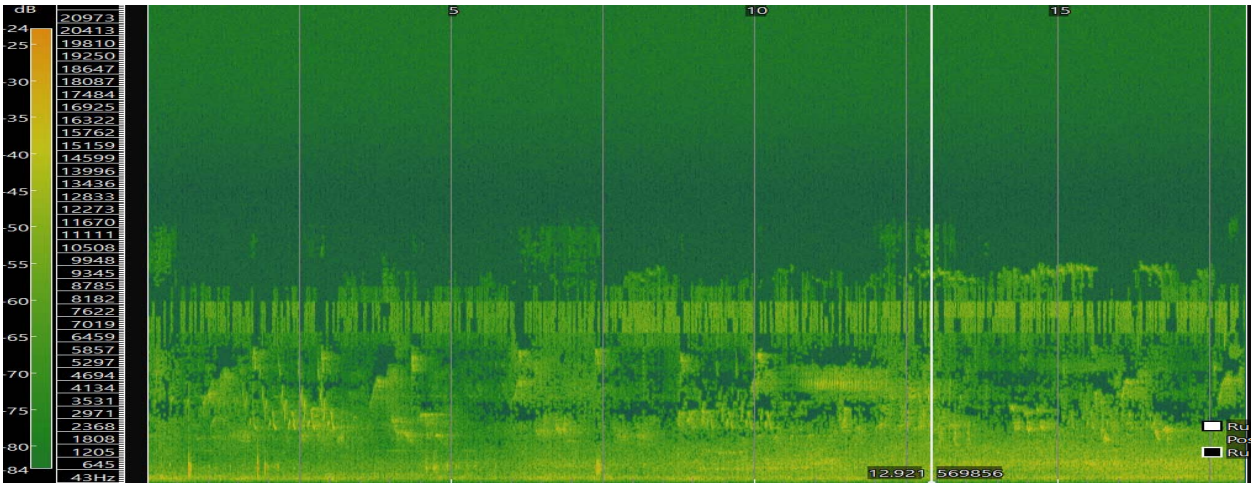
Stating that the 2022 SE US 1 data agrees with both Xeno-canto and Mennill is quantitative.

The quantitative comparison includes ideas found by the Cornell Lab of Ornithology for their separate IBWO studies, in Arkansas in the mid-2000s [9]. The time interval between knocks, for the DK, is 0.06 to 0.12 seconds, Additionally, one of the knocks is almost always louder than the other. This can vary, either the first or second being louder. They also have a non-echoing quality that easily separates them from gunshot sounds, which attenuate due to more complex sounds involved with a bullet becoming supersonic. Cornell's extensive study of double knock sound-alikes include duck wingbeats as well, but the research shows that these are distinguishable by including other sounds such as wingbeats (note—some of the data included in the link is not at present active) [9]:

https://cornell.app.box.com/s/479gjn6lut74i4d4czwydilapomb0zd2/folder/94350187109

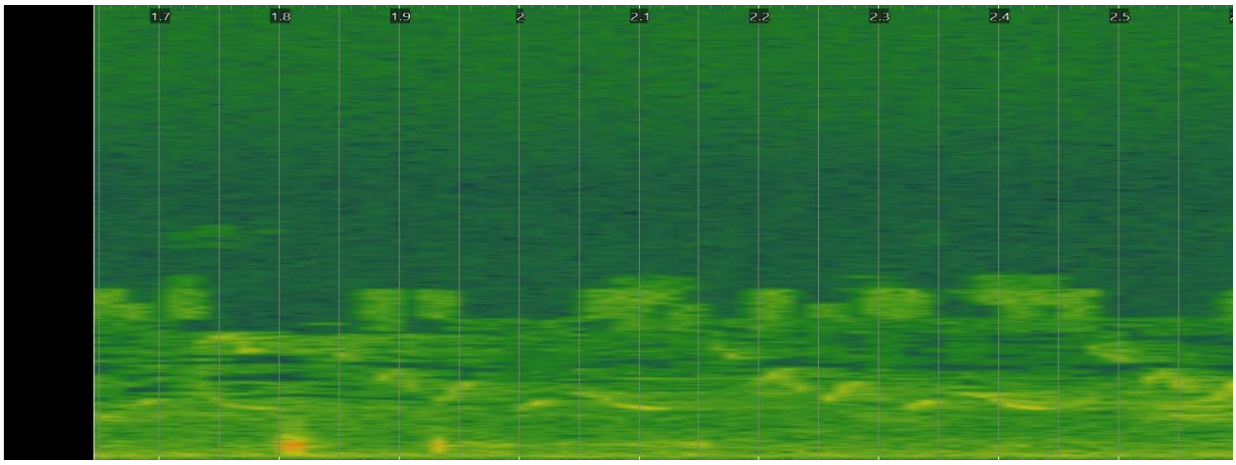
Discussion

Examination of the 2022 SE US 1 sounds using both Sonic Visualizer and Audacity, with spectrograms showing fine structure, agree with double knocks proven to be from other species of Campephilus (the Ivory-billed Woodpecker has no DKs recorded along with direct visual observation). Derived from the 2022 audio recording, the image below from Sonic Visualizer shows the knocks as orange vertical lines along the bottom edge. The first SK is around 0.5 seconds, the first DK at approximately 1.8 seconds, the second DK near 4.6 seconds, and the last SK at 7.5 seconds. Note that the two DKs have an interval that agrees with Cornell's findings of a 0.06 to 0.12 second interval, and that the volume is unequal as Cornell and other research states. The image may be expanded to examine:



Interestingly, because the two double knocks present in the spectrogram above seem too close together temporally for an Ivory-billed Woodpecker to move some distance to produce both of them at an equal volume, it is probable that the sounds are from two individuals. It is more unlikely that one individual produced both sets of double knocks at the same position, but with different volumes.

The first DK, at 1.8 seconds, matches well with existing data where the first knock (orange mark) is louder than the second. The interval is 0.12 seconds:



Both single knocks and double knocks were reported, from visual observation by James Tanner and others, to be communication forms by this species [10].

Because the 2022 SE US 1 audio has a single knock, followed quickly by a double knock of about the same volume, it is inferred that these are from one bird. The second double knock is not as loud—it is inferred this is from a different individual, answering. The final single knock is at the same relative volume as the first, suggesting it is from the closer bird again. All of the knocks

sound “woody” in comparison to metallic, for example. None of the knocks resonate or attenuate, as would be expected with a gunshot.

Thus the double knocks match well with existing data, acquired by professional groups who have searched for the Ivory-billed Woodpecker. A reasonable conclusion is that this 2022 audio file demonstrates the existence of Ivory-billed Woodpeckers.

It is important to state here that, although science critique can demand “extraordinary claims require extraordinary evidence”, the level of evidence presented here is at a level higher than acceptable for identifying species, according to a number of professional-level birding and conservation groups. This is referred to as earbirding [11]. Spectrograms describe more detail than earbirding can.

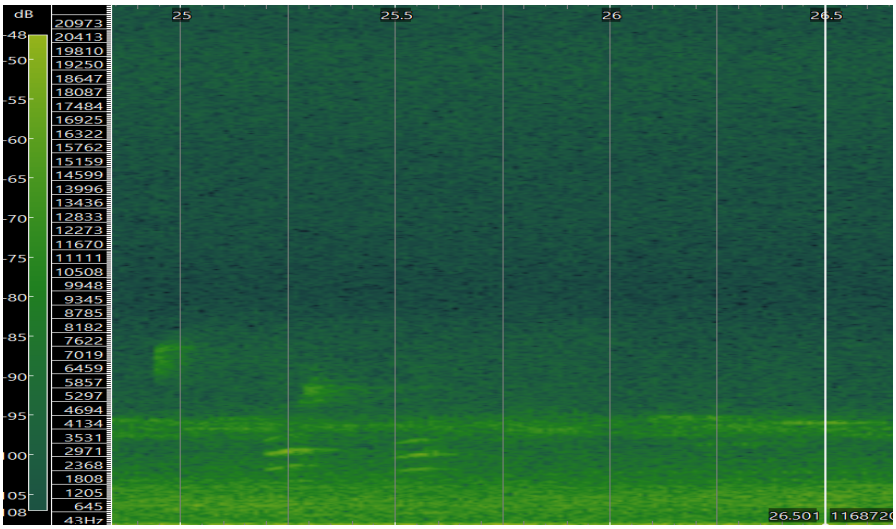
Dec 2022 Kents Audio Recording (2022 SE US 2)

On an unspecified date in December 2022, an audio recording was made by the field observer, from the same location as the double and single knocks, that includes two sets of sounds called (phonetically) “kents”. These sounds are known to be from the Ivory-billed Woodpecker [1]. They are said to sound like a toy trumpet.

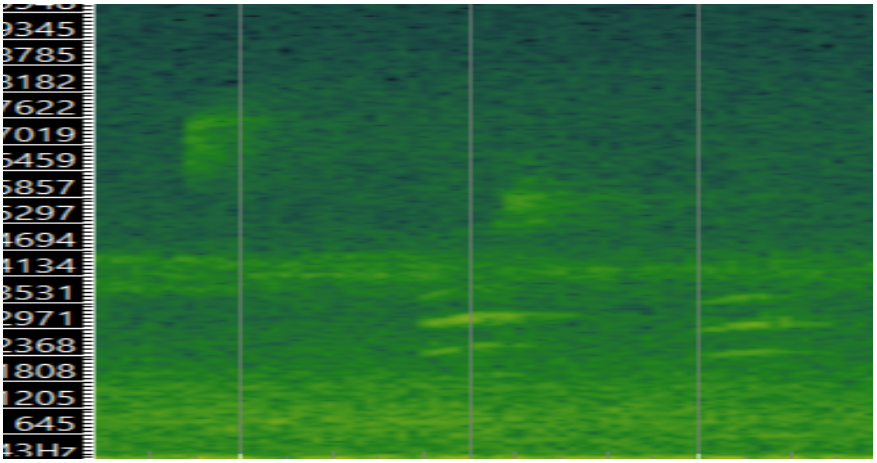
The file can be examined here. Kents are found as horizontal ladder-line line groups that appear as a light green against a dark green background, to the lower part of the spectrogram. They are found between 24 and 25 seconds, and between 1:00 and 1:01 seconds. Notice that a car goes by at one point. There may be other kent sounds faintly audible during the car passing (at 37.7 seconds and 42 seconds):

https://drive.google.com/file/d/1Fh2WgWcx0NchP0xZog8J1imUGKKd8zbo/view?usp=sharing

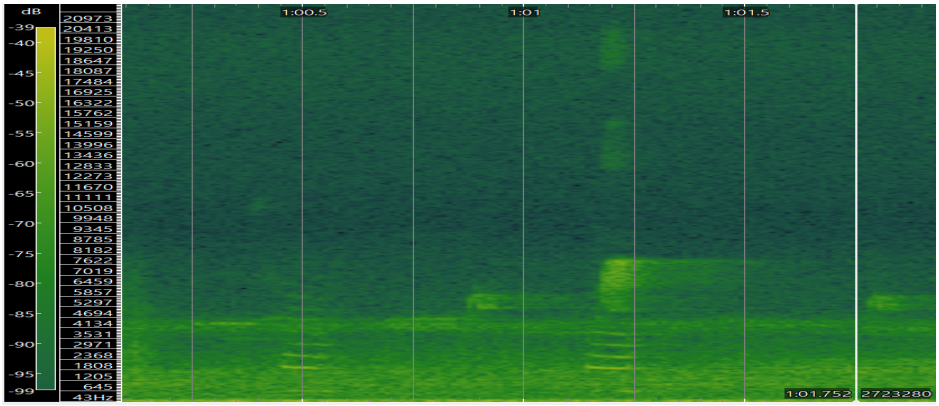
Here are spectrogram image examples from this recording. The kents appear as horizontal lines in a ladder form. The first set is shown here between 24 and 25 seconds:



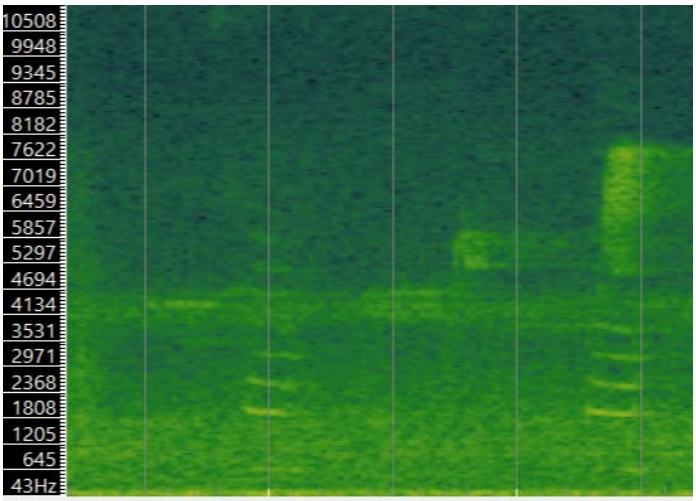
Here is the first set zoomed for the kent section:



The second set between 1:00 and 1:01 seconds:



The second set zoomed for kent section (compressed laterally):



Discussion

The program Online Tone Generator [6] was used for matching the kent sounds to Hz, which gives numerical values to sounds. For these kents, they sound to the author at approximately 686 and 631 Hz for the first set, then 631 and 631 Hz for the second set.

Notice that for the first set of kents, although the sounds are clearly at 686 then 631, spectrogram lines do not show at these Hz but do show at higher frequencies. In the second set of kents, the lines show at 631 and 631 Hz as well as at higher frequencies. A reason for this is not easy to propose, but perhaps involves the bird turning its head and “aiming” the sound [12].

The 2022 SE US 2 kents agree strongly with data from recordings by Dan Mennill, and separately from John Dennis [13], both obtained by professionals searching for the Ivory-billed

Woodpecker, and supported in Mennill's case by sightings during the same expedition. They also agree with three other professional-level datasets thought to be IBWO-generated, unpublished and acquired since 2000 [14]. Numerous examples of this kent sound from Mennill's studies are found below, at the same website for the IBWO double-knock data referenced previously [8]:

https://web2.uwindsor.ca/courses/biology/dmennill/IBWO/IBWOsounds.php

These sounds are thought to be conversational for the Ivory-billed Woodpecker. Qualities that kents have, and comparable spectrograms, are discussed here in a Project Principalis writing, in the section Vocalizations [15]. Again the information here matches well with the 2022 SE US 2 kent recordings:

https://web.archive.org/web/20211018120417/https://www.aviary.org/conservation/project-principalis/natural-history/sounds/

Quantifying Kent-type Calls

In order for these sounds to be considered as kents from Ivory-billed Woodpecker(s), it is necessary to distinguish them from other species that make similar sounds. A line of critical thinking is that it is not easy to tell IBWO kents from similar sounds made by nuthatches (genus Sitta), Bluejay (Cyanocitta cristata), or a small number of other species.

However, on spectrograms, nuthatch species show lines that are non-harmonic (see Table 1 below). For human singers, this is the equivalent of dissonance, or "bad singing". This has implications suggesting that for nuthatches, "kents" serve as alarm calls because dissonant sounds are used in Kingdom Animalia for this purpose [16].

The IBWO shows lines that are of "good singing"-- harmonic, and furthermore, in octaves. An example—if the audible sound is at 472 Hz, the lowest spectrogram line would show at 472, and the next line higher will show at close to twice this, an octave, at around 950 Hz. A third line will be present an octave above at 950 + 472, or near 1400 Hz. Michael Collins notes this doubling in his spectrogram analysis of 'high-pitched" calls obtained during observations of an Ivory-billed Woodpecker being harassed by crows in 2006 [17]. This is "good singing" and is also comparable to a human singer with a harmony singer who sings an octave, or two, above.

This pattern for the IBWO is true for multiple data, again derived from the excellent Dan Mennill dataset, as shown below. The program Online Tone Generator was again used for matching the kent sounds to Hz:

Table 1: Comparison of "Kent" Harmonics From Ivory-billed Woodpecker, White-breasted Nuthatch, Red-breasted Nuthatch, Bluejay

Hz	K108A	K206A	K206B	Ke1353	Ke1018	WBNH	RBNH	BJ	BJ
4200		4200							
4000	3800								
3500	3400	3600					3500		
3000	3000	3200		3100	3200	3200	3100	3200	
2500	2300	2400	2400	2700	2500	2800	2500		2500
2000		1800	1800	2200		2000	2200	2300	
1500	1700			1500	1600		1600	1600	1600low
1300						1400			
1200		1200	1200						
1100	1100			1100			1100		
1000									
900									
800					836				845low
700								794low	
600		600	613faint						
500	553			546					
Sounds Like >	553	600	613	546	836	1400	1100	794	845

Table represents spectrogram values in Hz. IBWO info used with permission from Dan Mennill [8]. K and Ke represent putative IBWO kents. WBNH= White-breasted Nuthatch RBNH= Red-breasted Nuthatch BJ= Bluejay

Octave harmonics in yellow. WBNH and RBNH have Hz spectrogram line between first octave (red).

Below is additional data from the Dan Mennill audio recordings. All of these sounds are reported to be from the Ivory-billed Woodpecker. Again the pattern of octave harmonics is dominant (but not absolute):

Table 2: Dan Mennill Kent Recordings from Ivory-billed Woodpecker [8]

Hz	Kent 3-13 1046	Kent 3-15 1007 (1)	Kent 3-15 1007 (2)	Kent 3-15 1007 (3)	Kent 3-15 1007 (4)	Kent 3-16 1626	Kent 3-18 1124 (1)	Kent 3-18 1124 (2)	Kent 3-18 1124 (3)
4200									
4000			4250	4250					
3500	3596								
3000			3400	3400					
2500	2850		2500	2500	2900	2550		2600	2600
2000	2200	2400			2200		2100		
1500			1600	1600		1900		1950	1700
1400					1400		1400		
1300						1300		1300	
1200		1200							1200
1100									
1000									
900									
800			838	838					882
	700				700		730		
600						missing		660	
500		550faint							
400									
Sounds like >	741	660	838	838	736	660	730	660	851

Table represents spectrogram values in Hz. Octave harmonics in yellow.

An independent researcher could verify this pattern of octave harmonics using more data from the Mennill sound files.

In 1968, the ornithologist John Dennis recorded sounds attributed to the Ivory-billed Woodpecker [13]. Examining these kents with the same processes adds the data below. There are a total of 18 kents with these same values. The 18 kents show variation in amplitude for the spectrogram lines, but no other lines. Again this shows harmonic octave structure:

Table 3: John Dennis kent recordings (the values below occur 18 times in the recording) [13]:

Hz
2650 to 3000
2300
2000
1700
1200
588 Hz (sounds like)

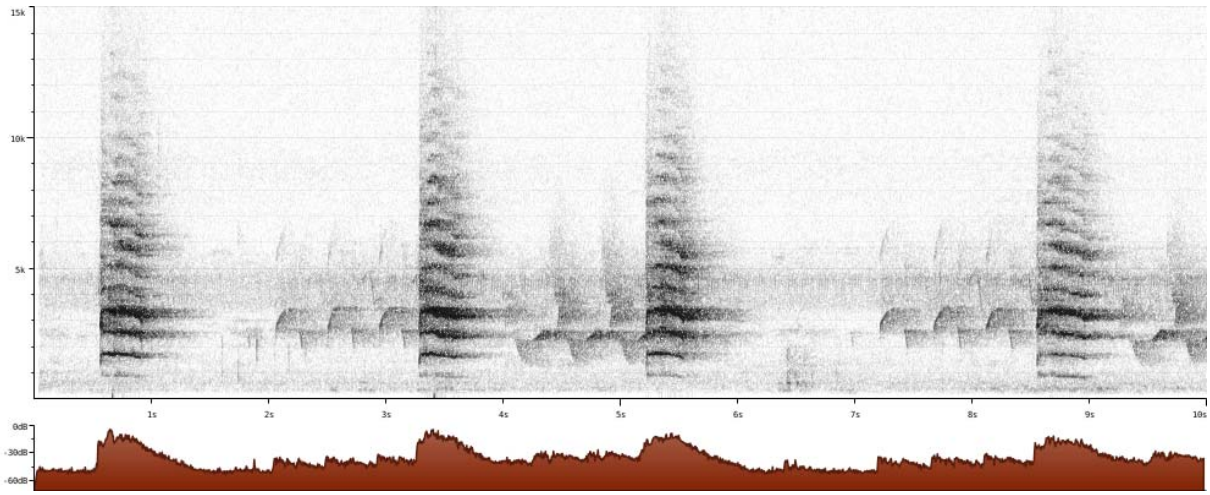
Table represents spectrogram values in Hz.

Octave harmonics in yellow.

Thus, it is a strong hypothesis, supported by internal agreement between different professional efforts, and supported by visual data (sight reports from Geoff Hill's group) that kents from the Ivory-billed Woodpecker show octave harmonics, and that the audible value can be strong on a spectrogram, with some variability in this. Variability may be caused by distance, "aiming" of sound, or some unknown factor.

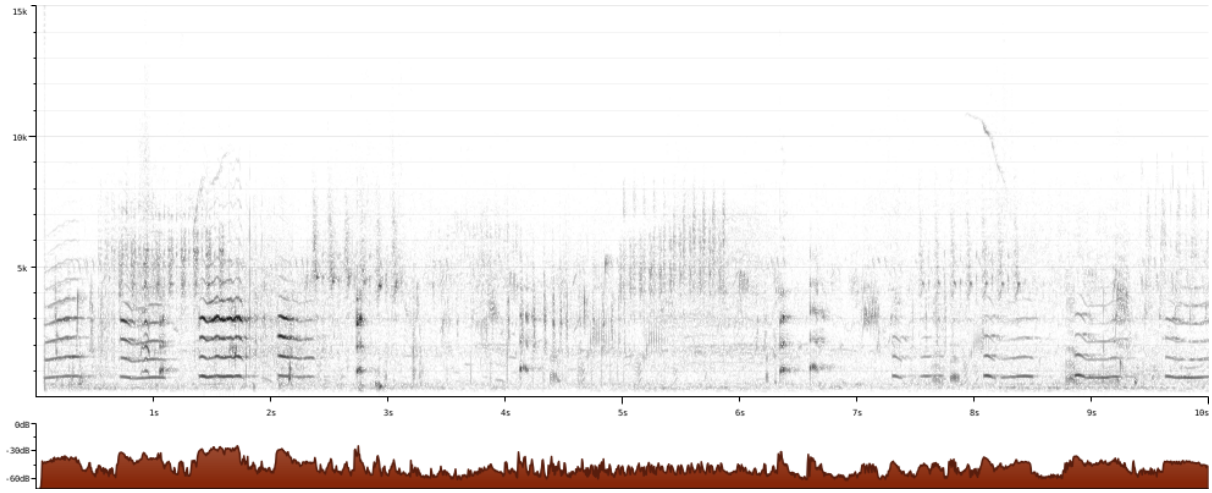
On a spectrogram, the IBWO kents sampled from both Mennill and Dennis average 0.3 seconds in length. This agrees with the 2022 SE US 2 data. Samples examined from White-breasted Nuthatch (Sitta carolinensis) and Red-Breasted Nuthatch (Sitta canadensis) are shorter, around 0.1 seconds.

To compare to Bluejay, here is a Xeno-canto spectrogram representative of many other Bluejay spectrograms found at the same website that resemble kents. The fundamentals are never below around 800 Hz, there are more total lines for each sound, and the lines are not as flat:



(Xeno canto XC712978 Blue Jay by Bruce Lagerquist) [5]

Another comparison is with American Coot (Fulica americana), who are said to have kents. Coots have two sounds on this representative image below. These lines have consistent wavers which makes them not as flat as the kent spectrograms suspected to be from Ivory-billed Woodpeckers, and the audible fundamental cannot be found to be less than 724 Hz:



(Xeno canto XC546223 American Coot by Richard E Webster) [5]

Other species such as grackles (Quiscalus group) and Great Blue Heron (Ardia herodias) are said to produce kent sounds, but on examination, there are significant differences in spectrogram structure, accompanying sounds, and context, that can more easily be observed.

The 2022 SE US 2 kents sound to the author at approximately 686 and 631 Hz for the first set, then 631 and 631 Hz for the second set. On a spectrogram, the second set of kents does indeed show faint marks near 631 Hz, does not show a clear one-octave harmonic mark, but shows a two-octave mark near 1900 Hz. The four kent sounds show no dissonant spectrogram lines. To distinguish from Bluejay, the audible sounds are well below 800 Hz. Thus, it agrees with previous IBWO-thought “kents”. This pattern also holds for other kents from other species of Campephilus, notably the Magellanic Woodpecker (C. magellenicus) as can be found on Xeno-Canto.

With all the data for kents considered, a pattern emerges of kents from Ivory-billed Woodpeckers showing spectrogram structure that

1. is not dissonant

2. shows harmonics in the form of octaves (multiples of the fundamental)

3. has an audible sound to humans lower than approximately 700 Hz, often in the 600 +/- Hz range, sometimes in the 400+ Hz range [26]. (Note that some of Mennill's data may possibly be Bluejay with fundamentals above 800 Hz.)

4. the audible sound is often 0.3 seconds long.

The 2022 SE US 2 kents agree with these ideas, and it is reasonable to state that this sound file again demonstrates the presence of the Ivory-billed Woodpecker at this location. It is also important to state that this dataset is additive to the double-knock 2022 SE US 1 audio, from the same location and same year, as reinforcement of this IBWO presence.

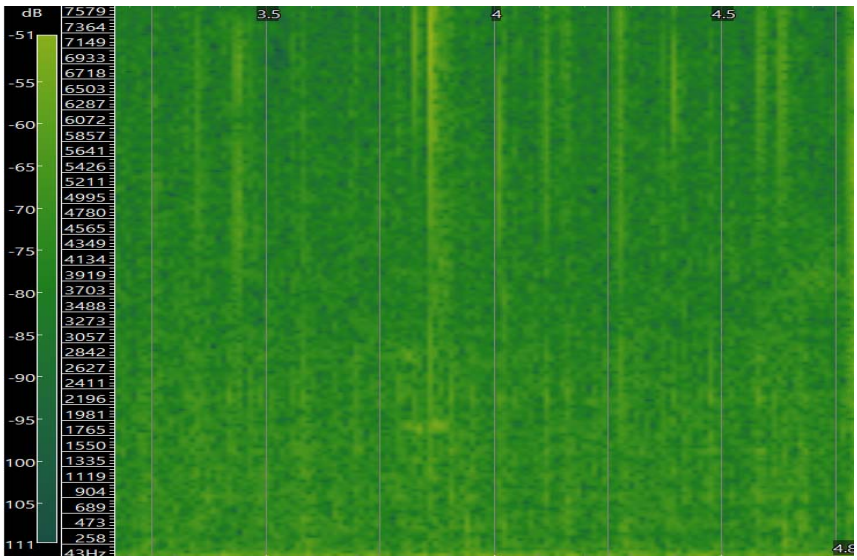
11 Dec 2022 Modified Kents Audio Recording (2022 SE US 3)

On this date, the field observer recorded a pair of Ivory-billed Woodpeckers and reported seeing that they were beginning to react to the presence of a Red-shouldered Hawk (Buteo lineatus). This event occurred during rain and was at the same location as the two previous sound recordings discussed in this paper.

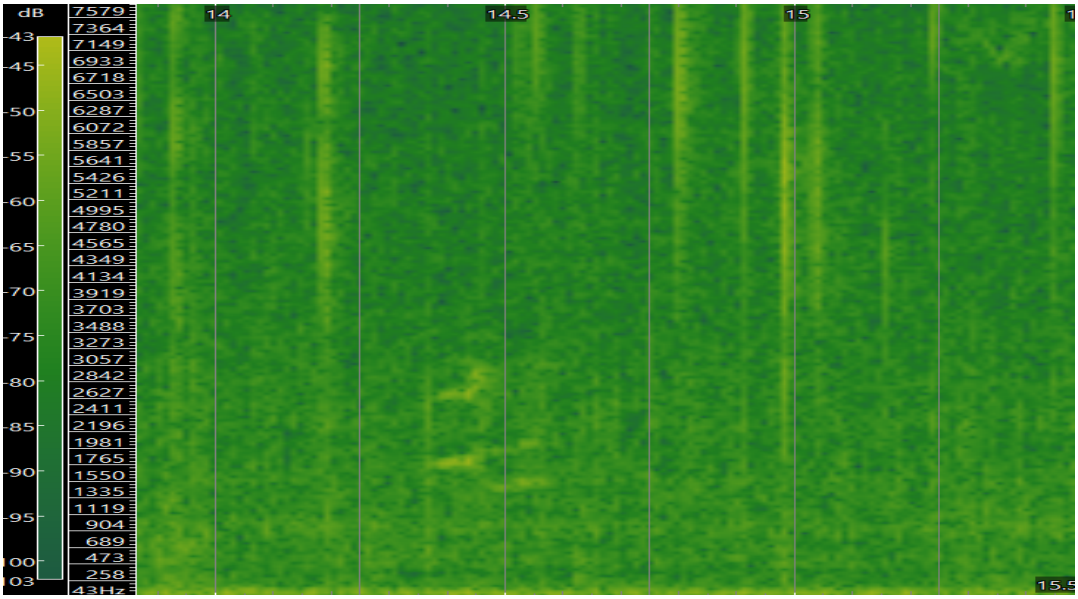
The resulting sound file was examined, and spectrograms made on Sonic Visualizer. During the file, what sound like Ivory-billed Woodpecker kents begin to change to a modified form. The file is linked below:

https://drive.google.com/file/d/1ulirvX23KkjIhauC-wjhiERcrblL-WiC/view?usp=sharing

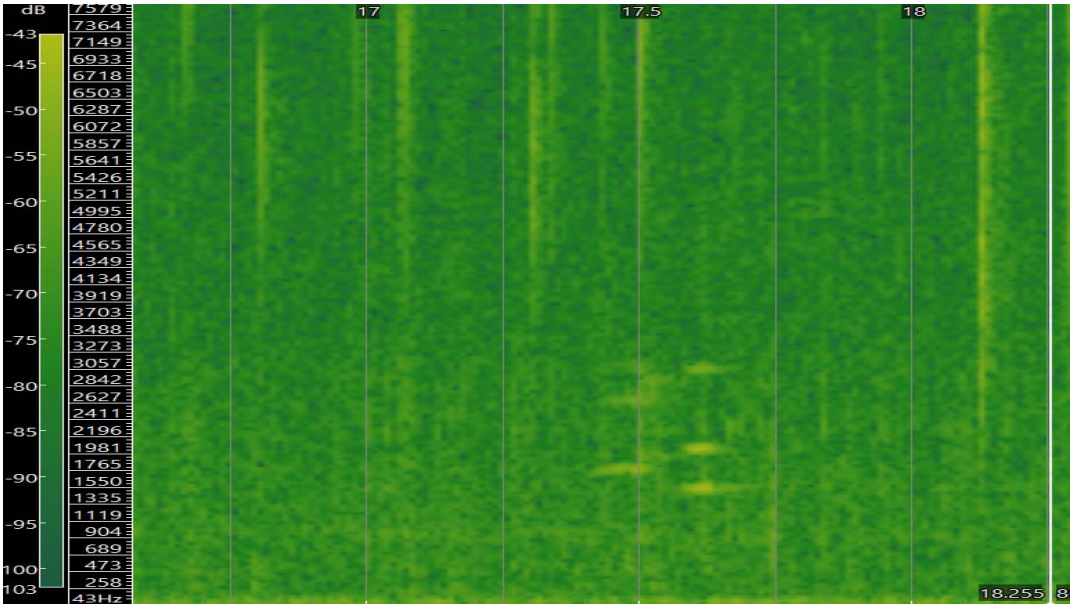
At 3.8 seconds, a faint kentlike sound is audible at about 465 Hz (using Online Tone Generator). This sound appears as faint horizontal lines:



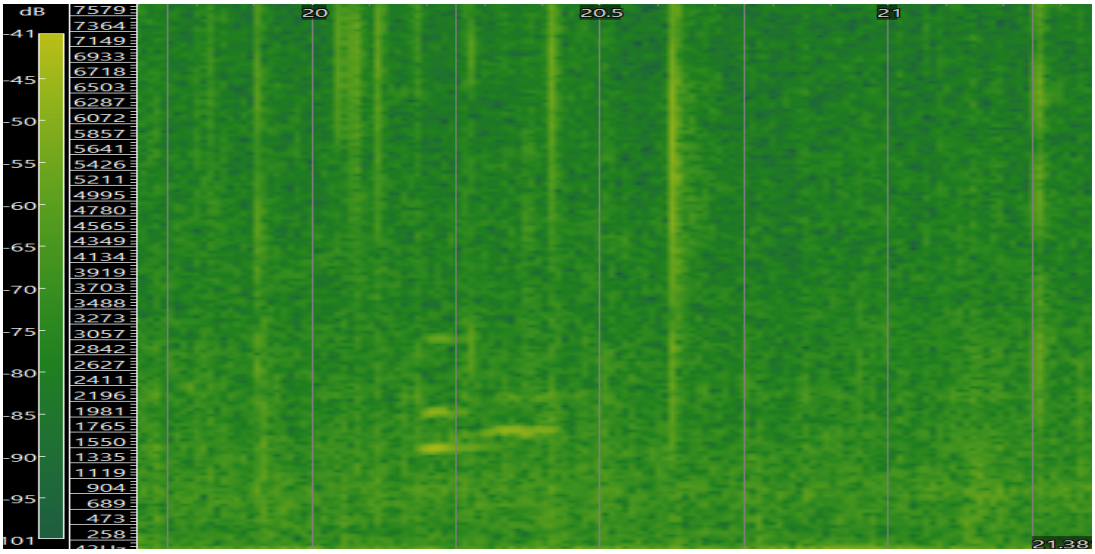
At 14.5 seconds, one can hear two separate kentlike sounds, the first at 465 Hz, the second at 506 Hz. These sounds almost overlap in time:



At 17.5 seconds, this pattern is repeated. There are two separate kentlike sounds, the first audible at 465 Hz, the second at 506 Hz. Again, they almost overlap temporally:



At 20.3 seconds, the two kentlike sounds are heard with the same cadence, but the Hz are reversed, the first at 506 Hz, the second at 465 Hz. They again almost overlap temporally:



These sounds do not show clear spectrogram lines that match with what is audible. The best example is using the first sound at 20.3 seconds, which is audible at 506 Hz, but the first clear line on the spectrogram showing at a third octave of this, near 1500 Hz, and another at 2000 Hz. All the sounds in this “modified kent” section show this quality.

In addition, except for the first kent, the sounds are paired and in each group are different Hz.

Discussion

In many ways, these sounds are similar to the kents attributed to the IBWO. Thus, they are similar to sounds by other groups who have reported them to be associated with Ivory-billed Woodpeckers. The 2022 SE US 3 file was reported by the field observer to be a pair of sighted Ivory-billed Woodpeckers, one male and one female, who are beginning to become agitated, and reacting together to a nearby Red-shouldered Hawk. They are making sounds that are together temporally, but from different birds. A hypothesis is that in the second and third set, one of the birds initiates, and in the fourth set it is the other bird initiating. The idea of the birds being agitated and producing these sounds agrees with direct observations of Ivory-billed Woodpeckers made in the 1930s by a Cornell expedition [19]. They are directly comparable.

As shown in the previous section, a growing dataset for IBWO kent sounds demonstrates that they are octave-harmonic. A working hypothesis is, because the Ivory-billed Woodpecker cannot physically make dissonant sounds, they rely on making somewhat different sounds, from each individual, together to achieve dissonance, which is used in Kingdom Animalia for antagonistic situations. This relates to the next section.

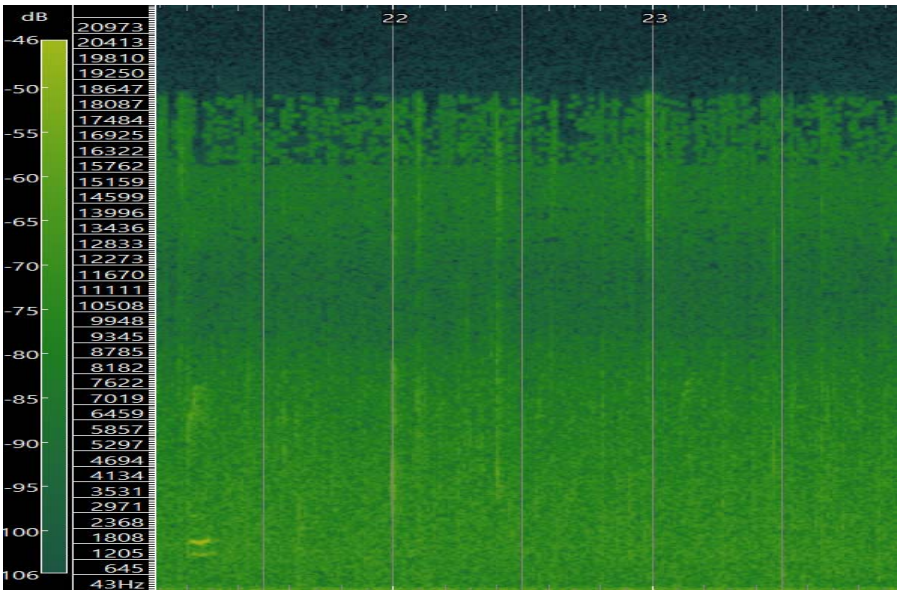
11 Dec 2022 “Wokawoka” Sounds Audio Recording (2022 SE US 4)

Soon after, on the same day and in the same location as the sound recordings of the “modified kents”, the field observer sighted and recorded the same birds reacting more directly to the presence of a Red-shouldered Hawk. This was again in rain.

Sounds that are suspected to be Ivory-billed Woodpeckers are found at 21.3, 27.5, 32, 46, and 54 seconds. The file is linked here:

https://drive.google.com/file/d/1j56XrMsklq4UqFXwC6GA9qjnw6JVsuZF/view?usp=sharing

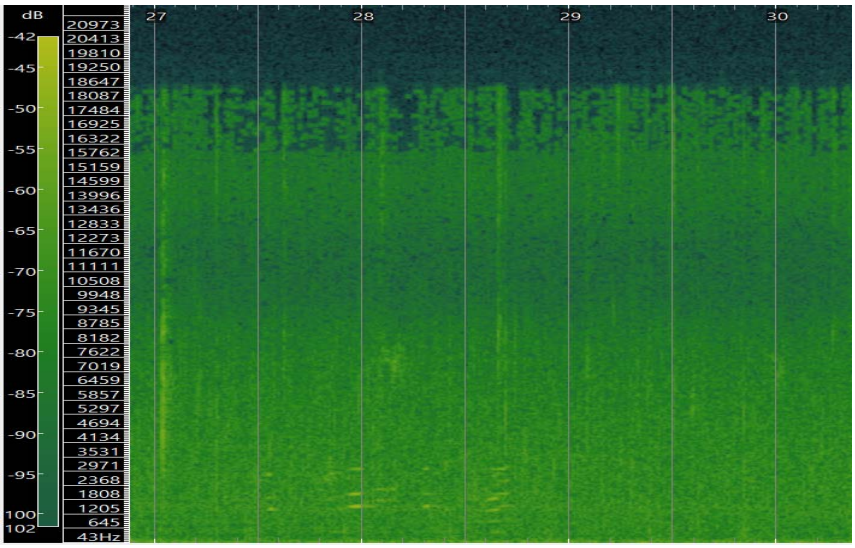
From this recording, below is the spectrogram structure for the sound at 21.3 seconds. This sounds like a kent. It is audible to a human ear at 458 Hz but does not show this line. It does not show the second harmonic at 900 Hz, but does show the third and fourth at 1360 and 1800 Hz:



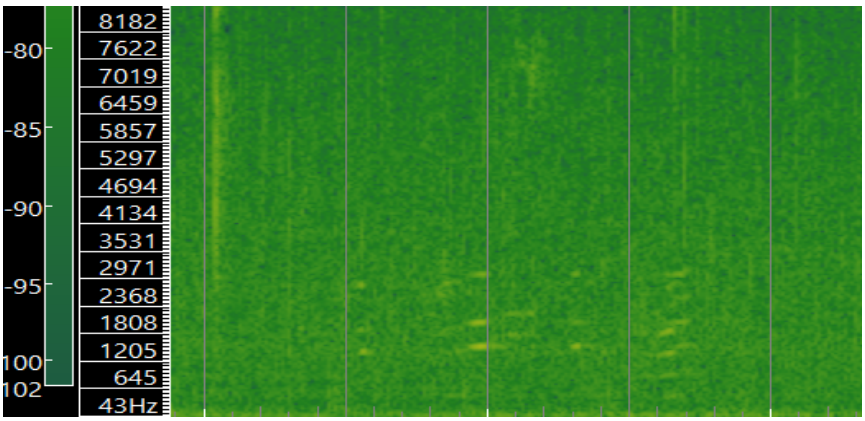
The birds begin their “wokawokas” at 27.5 seconds. These sounds are called wokawoka by many IBWO researchers to distinguish them from kents. They have been described in Ivory-billed Woodpecker observations and writings much less frequently than either kents or double-knocks, and recorded perhaps only one other time as will be discussed.

In the series beginning at 27.5 seconds, there is initially a sound at 685 Hz, then alternating sounds at 502 and 468 Hz. These audible sounds are again not shown as lines on the spectrogram, but in every case, their higher harmonics are shown. At 28.7 seconds, it can be

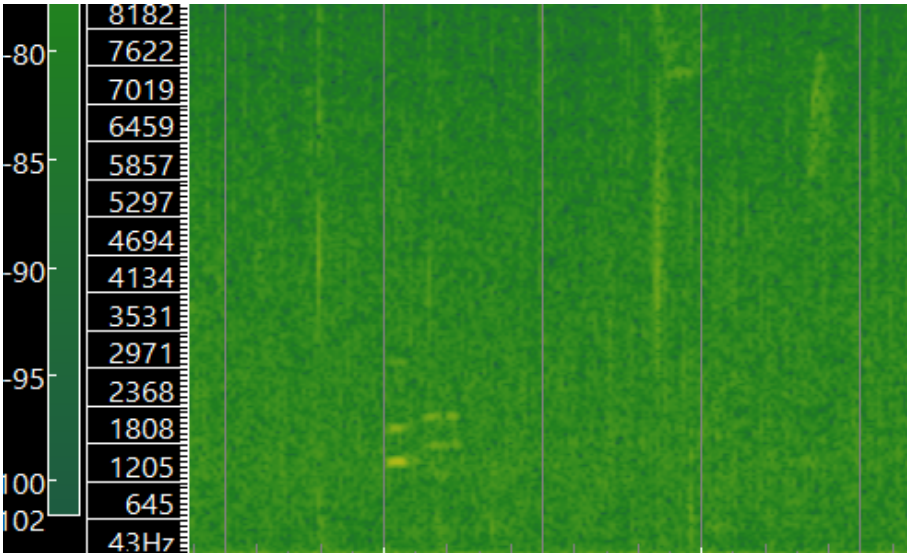
seen that the two birds reported seem to be making sounds at almost the same time—the sounds are not connected on the spectrogram-- in effect producing dissonance:



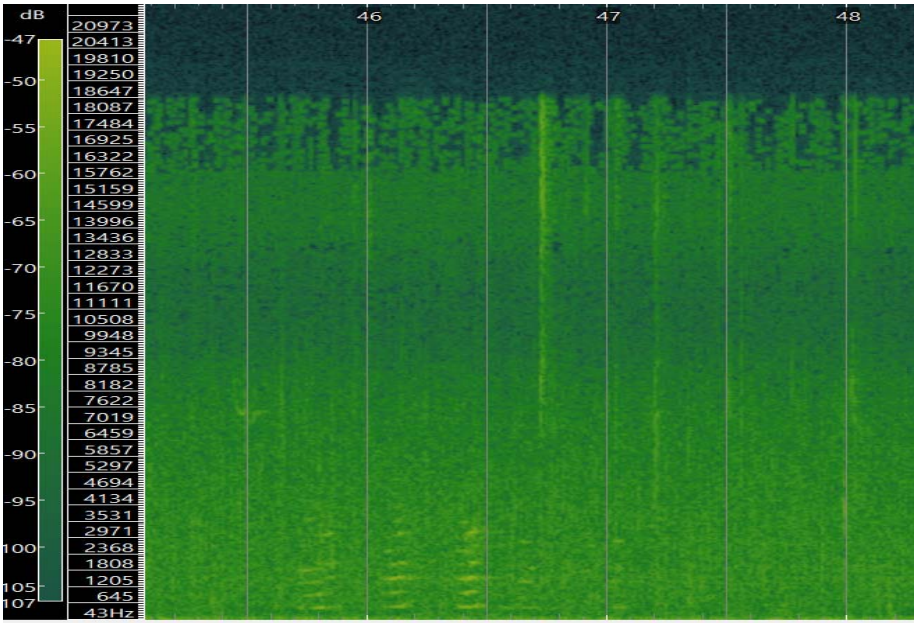
Here is a closer look at the structure of this sound group which is contained in about 1.2 seconds:



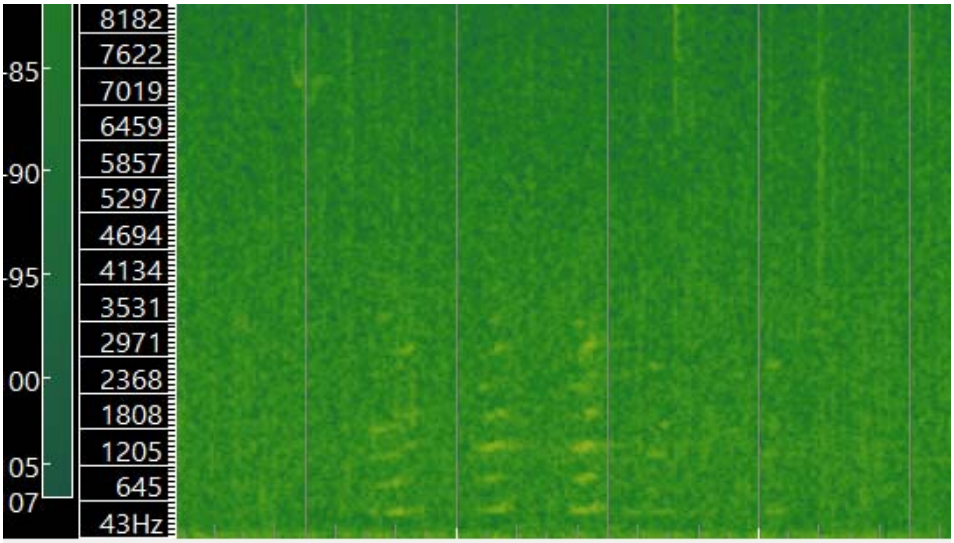
At 32 seconds, a similar pattern happens once with the first sound audible at 502 Hz and the second at 468 Hz approximately. Here is a zoom of the section:



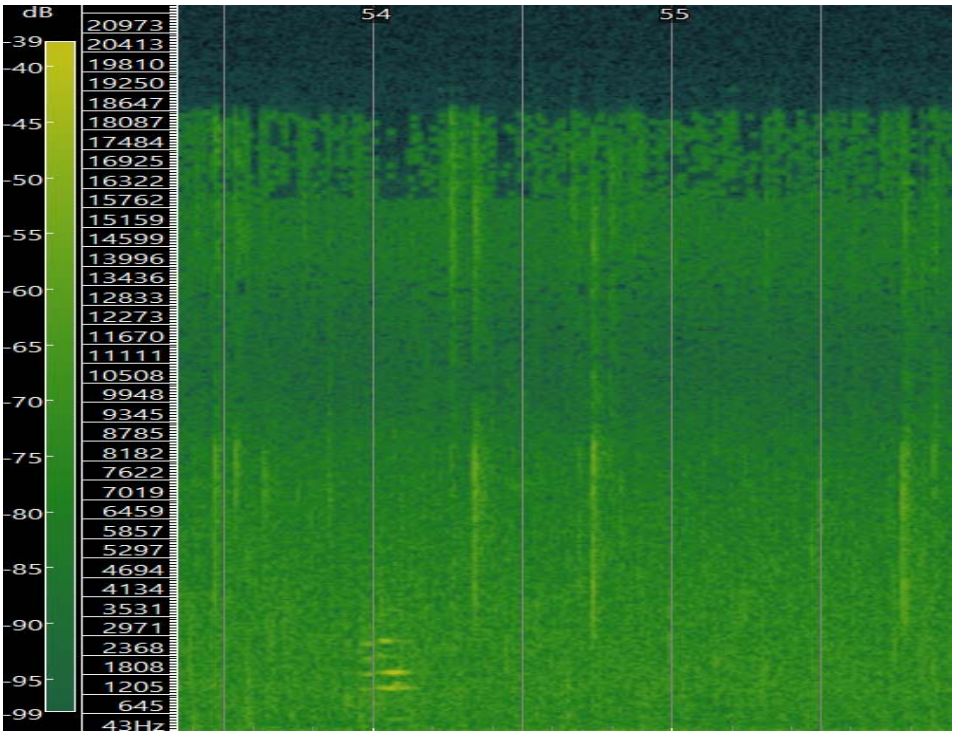
At 46 seconds, it seems that a bird produces a kent at 468 Hz, and another bird produces three audible kent sounds at 502 Hz with the first kent almost simultaneous to the first 468 Hz kent. After this, a bird makes two sounds at 468 Hz. These audible sounds now show on the spectrogram. For each of the sounds in this group, their higher harmonics also show:



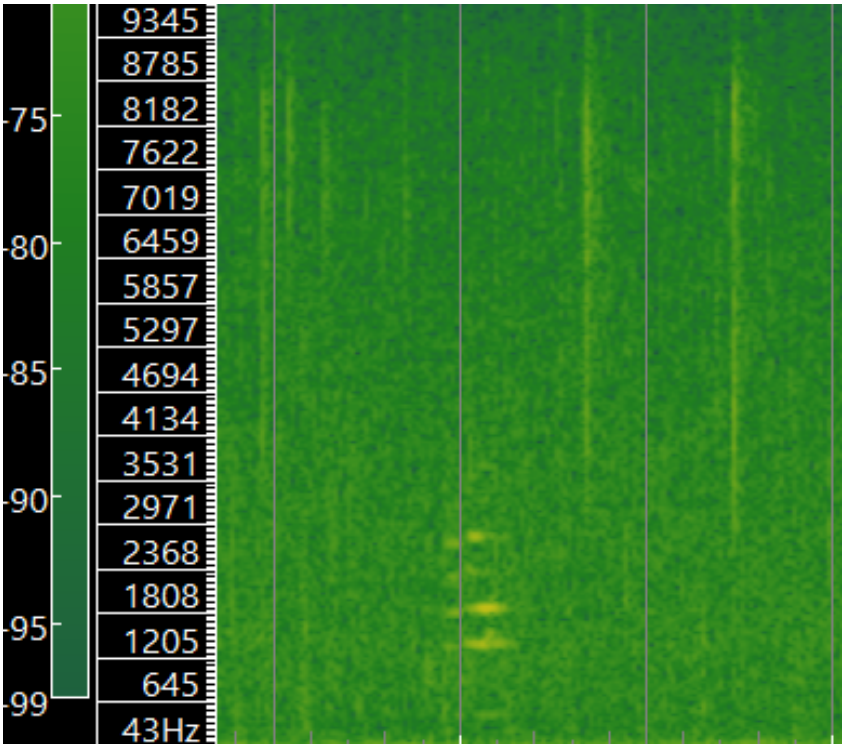
Here is a zoomed view of this group showing the overlap of the first two sounds:



At 54 seconds, a quick two sounds are produced, the first faint at 429 Hz and immediately another at 468 Hz. These sounds do not show the audible spectrogram line. The effect again is of dissonance:



Here is a zoomed view of this:



Throughout this entire 2022 SE US 4 sound file, when the birds make sounds that do not harmonize and are almost made at the same time-- in effect dissonance-- the lowest spectrogram line, audible to humans, does not show. However, in the 46 second sequence, the birds have more temporal space between three of the sounds, and the audible spectrogram line shows, as it does in many of the kent sounds discussed previously herein.

Discussion

One of the most significant aspects of the 2022 SE US 4 wokawoka sound recording is its relation to a previous recording which is the only known example of sounds with visual recording associated from the Ivory-billed Woodpecker, made 87 years prior.

The 2022 birds reported as Ivory-billed Woodpeckers make sounds that are very much like the sounds recorded by Arthur Allen and Paul Kellogg, with James Tanner along, in 1935 during a Cornell expedition to the Singer Tract in Louisiana that was focused on finding and documenting this rare species. In their field observations at the time, Allen and Kellogg wrote that they were causing nervousness and agitation in the observed IBWO pair (which were at their nest), and this caused the birds to make sounds that were a result [19].

The audio recordings of Ivory-billed Woodpeckers made by Allen and Kellogg are complex and a study unto themselves, their total time exceeding ten minutes as found here [20]:

ML6784 Ivory-billed Woodpecker (Northern) Macaulay Library

A section of these sounds, called wokawoka by IBWO researchers to distinguish them from kents, is linked here (note: because of download issues from Macaulay Library, this appears as a MOV file recorded in ambient) [4]:

https://drive.google.com/file/d/1gEABSg822Pnp4nBsONUtrUZC09OacDT9/view?usp=sharing

The 2022 SE US 4 and 1935 Allen-Kellogg files have much in common for these wokawoka sounds. Cadences are similar. The length of each sound is similar. They have octave-harmonic structure that appears as a ladder on a spectrogram. Both have Hz frequencies that are audible around 468 and 502, for 2022, and 468 to 451, varying to 491, for Allen-Kellogg. They are not simple kents but share some qualities with them. Both sound files are reported to be from agitated Ivory-billed Woodpeckers.

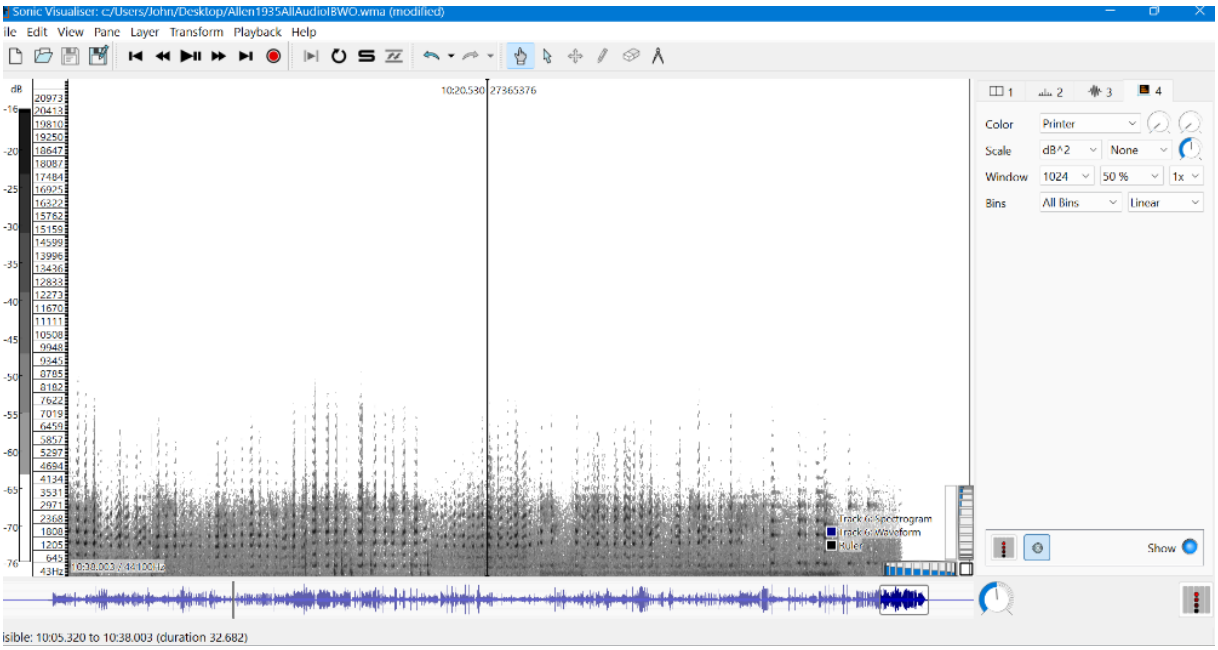
There are differences between the 2022 and 1935 recordings. The Allen-Kellogg wokawokas do show the audible fundamental spectrogram line. A hypothesis is that the birds were closer to the observers than in the 2022 observation (where distance was not reported). In the 1935 recording, the sounds do not overlap in general but are still close temporally. There are some differences in length of sound and ladder structure.

Because the 2022 SC US 4 wokawoka audio is significant, it is important to establish that it is not derived from Allen and Kellogg's—that another researcher was not playing the 1935 recordings, or a part of them, in the woods for example. In an Ivory-billed Woodpecker report that occurred at a random source and time, in the entire USA Southeast region, this idea quickly becomes absurd and can be discounted. Compare the chances that another person would happen to be playing IBWO sounds in that area (which is not woods but rural-density housing, with roads and fields included), with the much more probable idea that the observer lived at the site, had previous data for this species, as presented here, and was aware of possible sounds. The idea that a colleague of the field observer would use Allen-Kellogg's recording can be discounted by the other datasets in this paper. The chances of anthropomorphic-generated sound here approaches zero (as they would for faking any of the other sounds recorded for this species since 2000, by other professional groups using acoustic recording devices in remote areas). The 11 Dec 2022 wokawoka audio is actual, and is a significant addition to evidence that the Ivory-billed Woodpecker continues to exist.

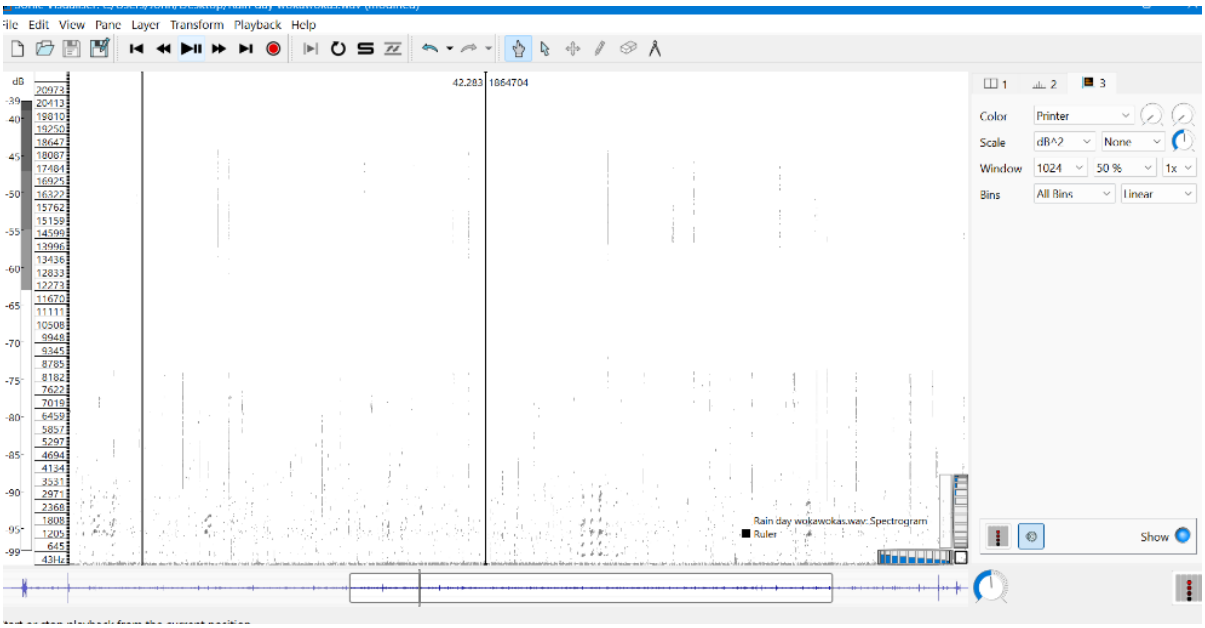
To address this extraordinary claim of the wokawoka sound being recorded in 2022, closer comparisons with the 1935 recordings were done. Sonic Visualizer settings of Spectrogram, Printer (so it is black-white), Db^2, matching X and Y axes, and zooming were used. Comparing background sounds shows the 2022 is much quieter. The 1935 has an almost constant sound that is probably the recording machine (an image of this large machine, on a wheeled cart is shown here from the Allen- Kellogg 1935 paper [19]):

Below are two images showing comparative background noise levels from 1935, using the machine above, and 2022, using an iPhone.

1935 background sound levels with wokawokas visible:



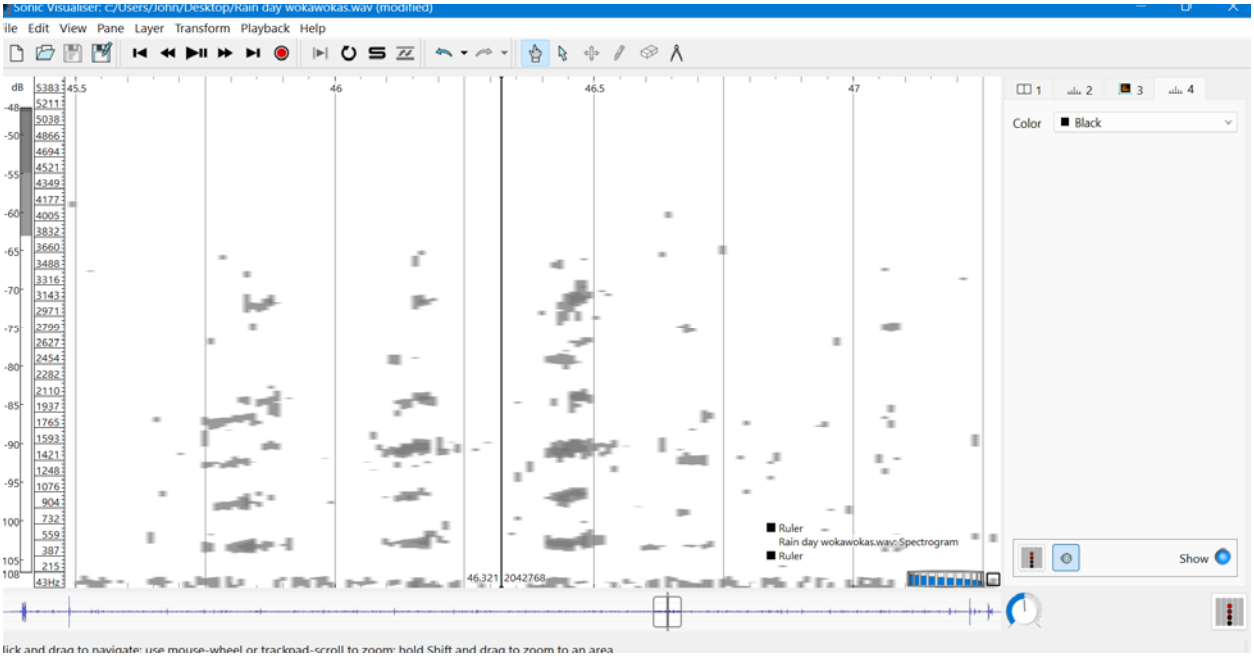
2022 background sound levels with wokawokas visible:



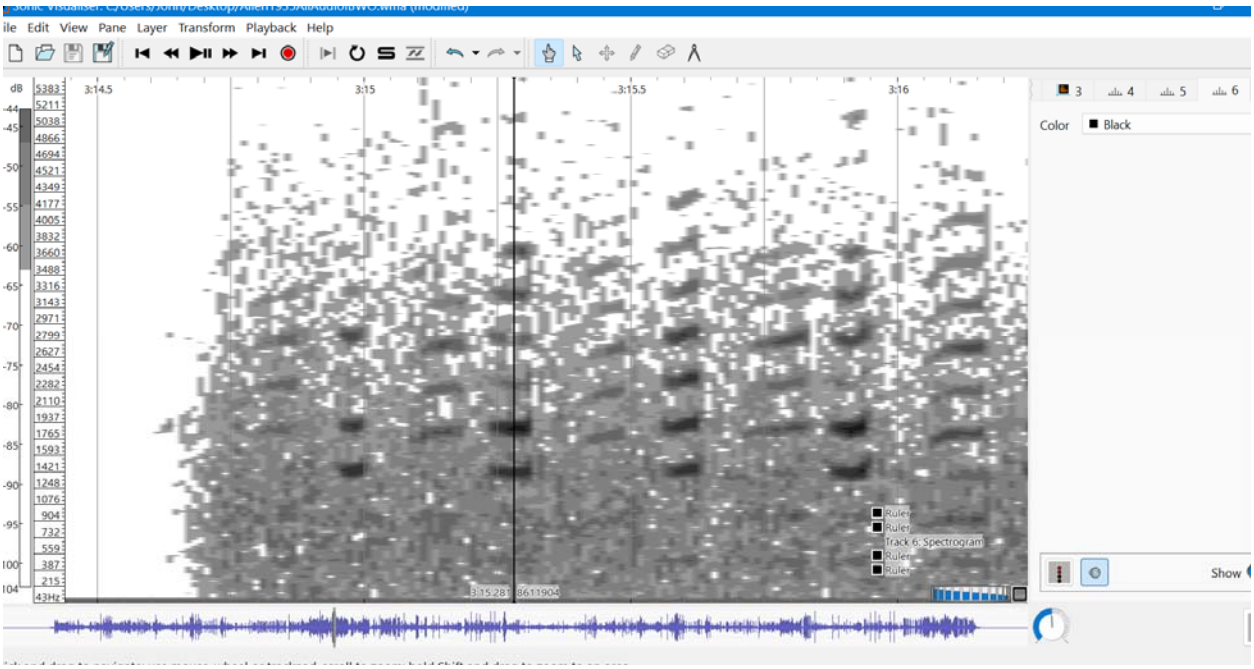
If any of the sounds from 1935 were played in 2022 SC US 4, the background sound would show up as well, as a much darker vertical rectangular area, and would be obviously seen (and most likely heard on the 2022 recording as a “splice”). No amount or type of data manipulation could remove this-- the background noise is embedded and cannot be removed from a woka sound. It would appear as this:

To further this proof of the 2022 SC US 4 wokawokas being novel, Sonic Visualizer and settings for Spectrogram, Printer, Db^2 were then used to look much closer at a sample section of wokawoka from 2022, found at 46.5 sec. Using a precision of 0.05 seconds, and the Y axis from 0 to 5383 Hz, fine shaping, length of sound, level of Hz for each ladder line, dominant line, and interval between sounds were closely examined. There are no matches to any 1935 sounds as shown here:

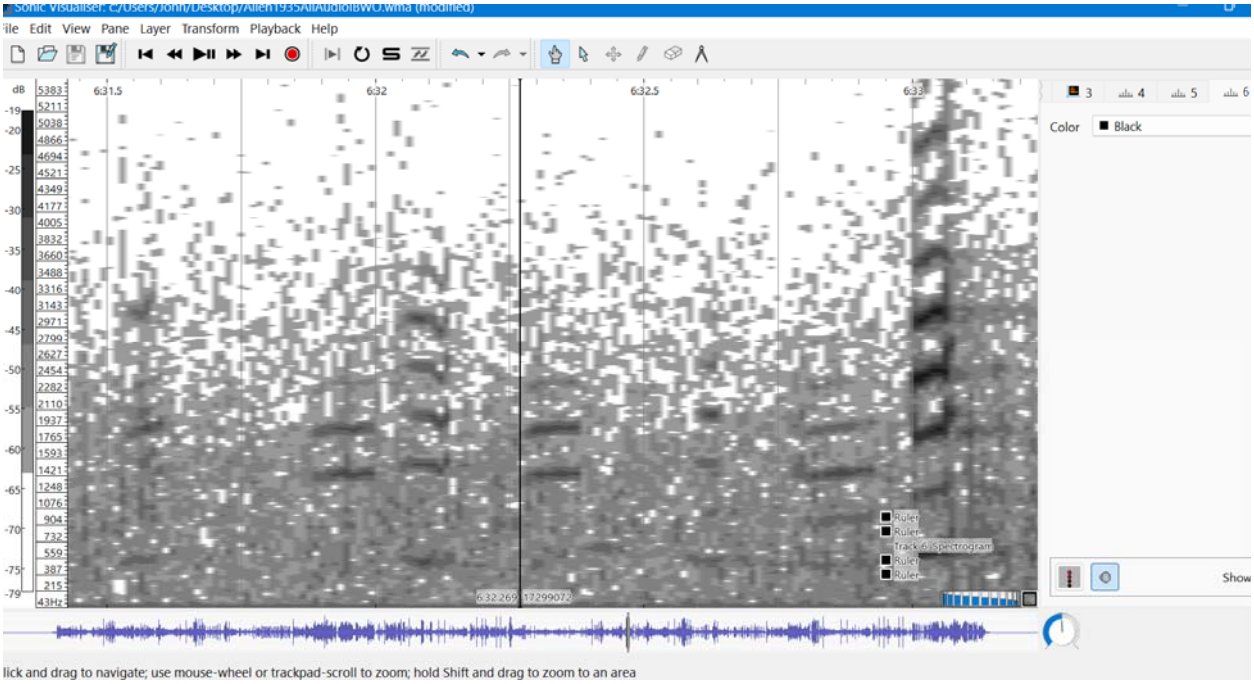
2022 SC US 4 wokawoka group at 46.5 seconds. Notice fine structure:



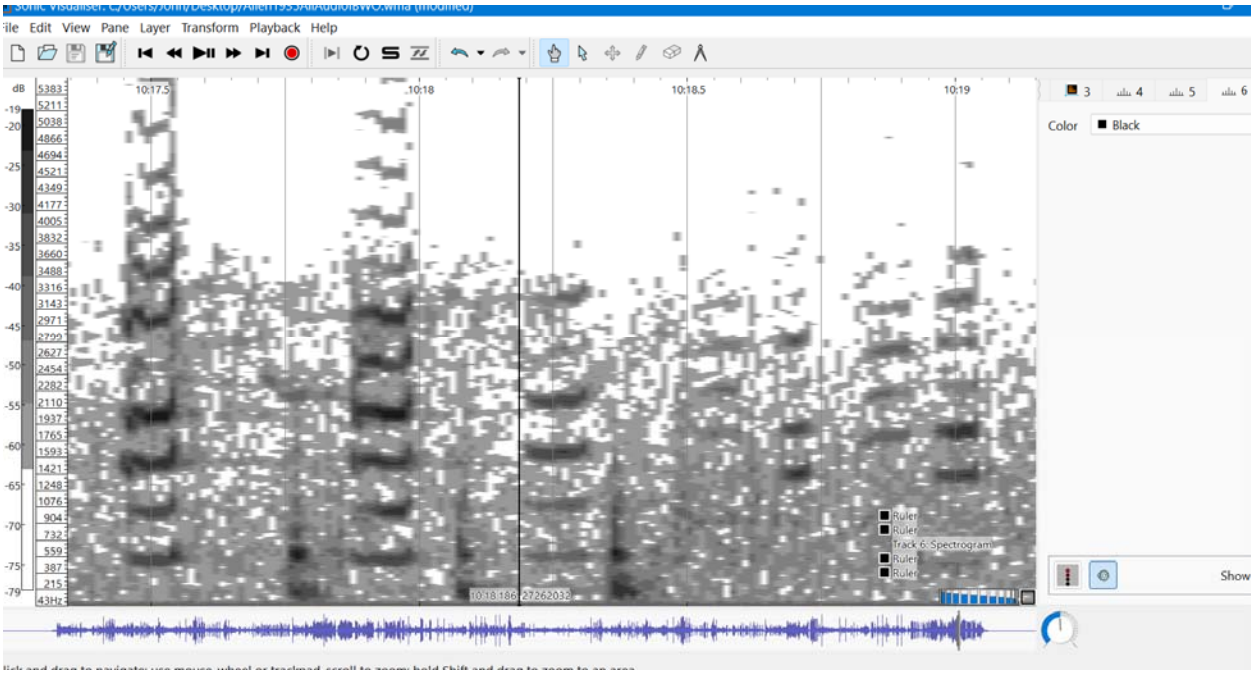
1935 wokawoka group at 3:15.6 seconds:



1935 wokawoka group at 6:31.5 seconds:



1935 wokawoka group at 10:18.25 seconds:

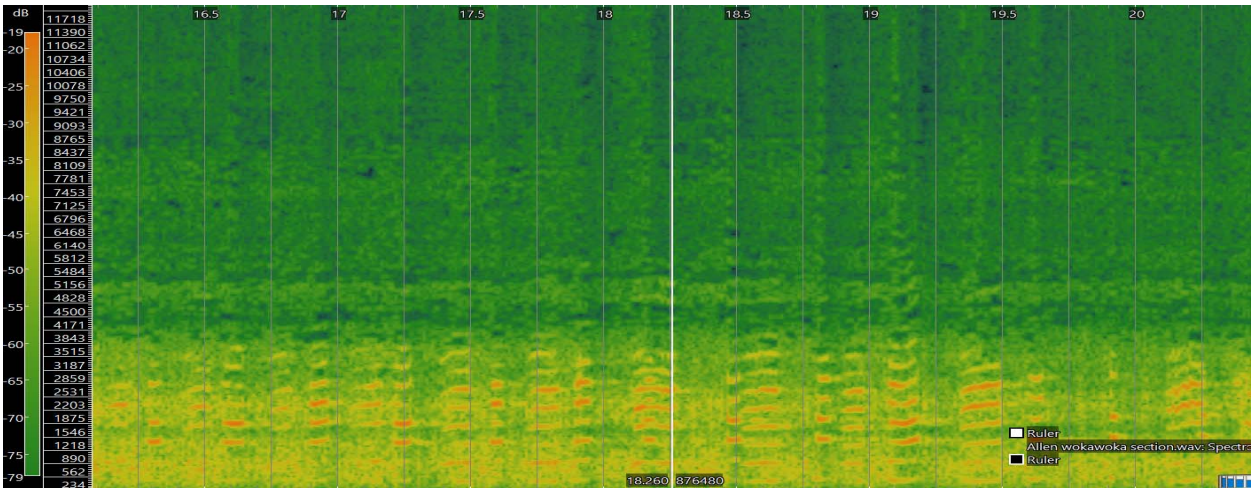


(Note too that, in the 1935 recording, louder sections that seem to be more individual kents show shorter call times and more “slurring” in the form of upward motion of the spectrogram lines. In this way, the birds are making shorter sharper calls, and attempting dissonance within

one individual call by changing it to a non-harmonic form at the end of each call. This is numerous within the 1935 dataset and is consistent with the birds being agitated.)

The 1935 recording has other sections. The matching attempt with the 46.5 second 2022 SC US 4 call included these, but no matches were found for a necessary combination of time interval between sounds with a precision of 0.05 seconds, fine shape matches, length of sound, and relation of Hz quantity to line combinations. The authors state with this level of extraordinary evidence, derived from technology, that the 2022 wokawokas are recorded directly from Ivory-billed Woodpeckers.

All in all, the differences in the 2022 and 1935 recordings are what might be expected with a same species, in a similar reaction pattern, but different individuals from different locations and times. Here is a sample from the Allen-Kellogg recordings showing a section of the wokawoka sounds:



It is noteworthy that, although putative (agreed-on) double knocks and kents exist from numerous recent IBWO research (matching well with double knocks and kents from the 2022 data presented in this paper), the wokawokas from Allen and Kellogg's 1935 expedition are the <u>only</u> Ivory-billed Woodpecker sounds ever recorded while directly observing and visually recording the birds. Wokawokas have not been obtained since, until the data offered here. This makes sense in terms of wokawokas being a more rare behavior than either DKs or kents, because response to antagonistic behavior is not as constant in a bird's life as positional (DKs) or conversational (kent) sounds.

Conclusion

The Ivory-billed Woodpecker had its population numbers reduced, perhaps drastically, in the late 1800s to early 1900s, through both hunting pressures and environmental degradation [1]. However, reports of its continued existence, including from focused scientific study, can be found in every decade since. The idea that it is now extinct is perhaps a belief more of the uninformed. A student who becomes a specialist in this species will understand that the mass of data and observations presented during this long period cannot be discounted.

One could argue that with all the seemingly valid reports, some form of proof better than what is currently offered would certainly have been obtained. The 1935 Allen-Kellogg-Tanner expedition is still the gold standard for hard data, with sound and video recordings.

But it is completely true that, since 2000, with a number of major search efforts (that were university-led in some cases) backed by more funding and better equipment, and with the advancement of technology for this equipment, more data has been obtained related to the Ivory-billed Woodpecker than at any time previous (save for the 1935 expedition which was led to an active nest). This of course would not be true for an extinct species.

One need only take the time, and study the results of Cornell's efforts in The Big Woods, David Luneau's important video, Michael Collins' extensive work in the Pearl River, Geoff Hill's expedition to the Choctawatchee River, Project Coyote-Principalis' work in Louisiana, Bobby Harrison's considerable time and effort, Mission Ivorybill's dataset—and more importantly, the results including images, video, and audio—to understand that all this data is considerable both in quantity and quality. If just one of their many recordings, videos, and images were true, it immediately reinforces all the others.

It does not stand to reason to take the view that none of the recent data is valid because the species is extinct, and not reasonable to state that every single piece of the data, in many cases from professional ornithologists, is in error.

It is more logical to presume that the growing level of technology is allowing us to get closer, so to speak, to a highly elusive, wary, and rare species.

Earbirding is a growing subset of field identification techniques for birds. There are many websites including simple apps for hobby-level birdwatchers, and more professional-level sites that intend to be comprehensive, such as Merlin [21]. In fact, there may be a new generation of conservationists who will take such applications for granted, use them exclusively, and not fully understand that in many cases the sounds offered are not a complete possibility of all the sounds a particular species can make. This would be in contrast to an individual who spends time in nature, shares space with a bird species, and hears the variety of sounds it is capable of.

It is safe to say that of this writing, the sounds of the Ivory-billed Woodpecker are not well represented on earbirding sites, with the few examples being offered including the wokawoka sounds from 1935, John Dennis' 1968 recordings of a kent series, and a recently-placed double-knock on Xeno-canto [22]. From personal experience, the author has found that having Ivory-billed Woodpecker sounds accepted at professional-level earbirding sites has been difficult, receiving statements that such evidence must be accompanied by visual confirmation. However, a general understanding is that there are many instances of accepted reports on Merlin, Macaulay Library, Xeno-canto, and even Christmas Bird Counts where audio is sufficient. Science cannot work with double standards, and perhaps with this in mind, the phrase "extraordinary claims require extraordinary evidence" might be amended to "extraordinary claims require a level of evidence sufficient to prove ordinary claims". This is more pragmatic and workable. The idea of extraordinary claims is not a moving bar, but should be set against history, where it becomes clear that the fantastic progression of technology makes possible all kinds of proof that does not involve the human eye—from exoplanets to DNA, acoustic monitoring of whales, pigment types on ancient paintings, to chemical analysis of mammoth meals from 15,000 years ago. The evidence for the Ivory-billed Woodpecker should not be regarded differently.

The idea of using spectrogram analysis to show fine detail of sounds is a more scientific level of analysis than simply the human ear, even an experienced one. Spectrograms can verify what a human who has a "good musical ear" can say—there is harmony or dissonance, a sound is staccato or legato, it is a certain "note", and even to identify a particular individual. Importantly, spectrograms are used by government agencies for identification [23].

The spectrograms presented in this paper identify the Ivory-billed Woodpecker in many ways. These have been shown to include:

1. Knocks and double-knocks that sound "woody", are non-echoing, have the correct interval of approximately 0.06 to 0.12 seconds to compare to existing data obtained and studied by Cornell, and where one of the knocks in a double-knock sequence is louder
2. Kents that are octave-harmonic, not dissonant, have a general length of 0.3 seconds, and have an audible frequency that is largely different than what is observed in other species
3. A modified kent that is similar to kents, is produced when stress is present, and is transitional between kents and the wokawoka sound. Dissonance, as a reaction to stress, is achieved not by one bird but by two birds with overlapping sounds
4. Sounds called wokawokas that are directly comparable to the only sounds recorded for the Ivory-billed Woodpecker that are proven with direct observation and video, from 1935. The 2022 wokawokas are eighty-seven years later
5. All the audio data being reinforced by visual observation from the same source, place, and general timespan, on different days between February and December 2022, suggesting a continuing presence.

The author states that, for a non-biased and objective reader, this is sufficient to declare that the species, the rare Ivory-billed Woodpecker, continues to exist. Independent examination of the data presented is welcomed.

Acknowledgements

The author wishes to thank the field observers who provided the information, including the time, effort, and level of awareness to understand the significance. As the title of the paper suggests, their privacy should be respected. All references should be considered as acknowledgements and thanks for the extensive work and time put into this species by individuals and groups.

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