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DECRESCENDO VOCALIZATIONS OF FEMALE MALLARDS AND MIMICRY BY DUCK CALLERS

By

James Thomas Callicutt

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DECRESCENDO VOCALIZATIONS OF FEMALE MALLARDS

AND MIMICRY BY DUCK CALLERS

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Female mallard ducks (*Anas platyrhynchos*) exhibit diverse vocalizations. Duck hunters mimic these vocalizations using artificial calls made from hardwoods or plastics. Hardness of these calls and extent to which humans can mimic live mallards using an artificial call were unknown before this study. I compared hardness of 7 species of hardwoods and cast acrylic and found acrylic, cocobolo (*Dalbergia retusa*), bocote (*Cordia alliodora*), osage orange (*Maclura pomifera*), and pecan (*Carya* sp.) were the hardest materials tested. I also compared acoustic metrics of field recordings of vocalizing female mallards to those of experienced duck callers using calls of these materials equipped with single or double reeds. I found that cocobolo, osage orange, pecan, acrylic, and bocote calls with double reeds were acoustically most similar to female mallards. I recommend that duck call manufacturers use acrylics and harder wood species with single or double reeds, recognizing that double reed calls generally performed superior in this study.

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CHAPTER I

HARDNESS OF SEVEN HARDWOOD SPECIES AND CAST ACRYLIC USED TO MAKE DUCK CALLS

Commercially produced duck calls have existed since the mid-1800s and have been made of a variety of materials and designs (Harlan and Anderson 1988). Today, mass manufactured duck calls are primarily made of 5 materials. These are poly-carbonate and cast acrylic plastics and 3 species of hardwoods. Hardwoods used are North American osage orange (*Maclura pomifera*) and bocote (*Cordia alliodora*) and cocobolo (*Dalbergia retusa)* from South America and Central America, respectively (Glenn and Keats 2005). Duck call makers often choose dense materials that are resistant to swelling when exposed to wet and harsh environmental conditions (Thompson 1970, Siau 1995). Materials also are likely selected to produce possible variations in sounds and quality that can be associated with wood or plastic properties (e.g., density, hardness, and volume), similar to fabrication of musical instruments (Bucur 1995). To my knowledge, no comparison has been made among properties of various duck call materials. Hardness is a good indicator of density (Rowell 2005), which is the single best predictor of other wood properties (e.g., workability, strength, etc.; Amstrong et al. 1984). Herein, I evaluate hardness of 7 hardwood species and cast acrylic used to make duck calls.

METHODS

Hardness Test

Hardness tests were conducted by staff members of the Forest and Wildlife Research Center, Department of Forest Products, Mississippi State University, in August 2009. Hardness tests were conducted using the Janka modified ball test (ASTM 1996). The 5 native species tested were osage orange, yellow poplar (*Liriodendron tulipifera*), black walnut (*Juglans nigra*), pecan (*Carya sp.),* and red oak (*Quercus* sp.). The two exotic species tested were bocote and cocobolo. With the exception of the exotics all test pieces were cut from a single tree of each species. Each of the7 species and acrylic was cut into pieces 5 cm x 5 cm x 16cm. Then, each piece was penetrated with an 11.3 mm diameter hemispherical steel fixture. Testing involved 8-16 penetrations for each species except for acrylic which shattered after the initial penetration. Variation in numbers of penetrations per species was due to amount of material available of each species. Maximum force loadings (Newtons) were recorded when the hemispherical fixture was penetrated fully into the material.

Statistical Analysis

I subjected hardness values to analysis of variance (ANOVA; PROC GLM, SAS Institute Inc. 2003) to test the null hypothesis of no differen6e (6$\alpha = 0.05$) in hardness 6 among the 7 species of hardwoods. Subsequently, I made *a posteriori* comparisons of means using Fisher's least squared differences (PROC GLM, SAS institute Inc. 2003).

RESULTS

Hardness values varied among species of hardwood trees (ANOVA, $F_{6,6} = 150.71$, $P \leq 0.001$). 6Cocobolo and bocote were hardest and harder than all other species (Table 1.1). Osage orange and pecan had similar hardness but were less hard than the two exotic woods but harder than black walnut, red oak, and yellow poplar which did not differ in hardness (Table 1.1). The acrylic shattered after the first penetration but the loading at which it shattered was much greater than the loadings recorded for all 7 species of hardwoods (≈26,689 N). 6

DISCUSSION

Custom duck call makers use a wide variety of materials to fabricate calls, ranging from various plastic and rubber materials to dozens of species of hard- and soft woods. However, mass manufactured calls are limited primarily to acrylic, cocobolo, bocote, and osage orange (Glenn and Keats 2005). To my knowledge, no one has investigated differences in wood properties of materials used commonly by duck call manufacturers with those less common. My results indicate that the hardwood most used commonly by duck call manufacturers nowadays (i.e., bocote, cocobolo, and osage orange) are harder than less commonly used materials (Table 1.1). However, I found that pecan, a species not typically used by call manufacturers, did not differ in hardness from osage orange which is used commonly. Presumably duck call manufacturers use these harder woods because of their tone qualities, resonance, volume, and other acoustic qualities (Chapter II). Thus, duck call manufacturers would be wise to use woods that share similar properties and are easier and more economical to obtain than exotic woods.

However, before this study, there have been no attempts to evaluate the acoustical performance of duck calls made of these materials and blown by callers with vocalizations of live ducks. This evaluation follows in Chapter II.

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Table 1.1 Means ($\bar{x}$) and standard deviations (SD) of hardness measured in Newtons (N) for 7 species of hardwood tested at the Department of Forest Products, Mississippi State University in August 2009.

Hardwood species	$\bar{x}$	SD (*n*)
Cocobolo	16,180.41 A[a]	2,990.46 (8)
Bocote	14,178.71 B	1,169.36 (8)
Pecan	11,454.17 C	1,525.85 (16)
Osage orange	11,259.56 C	1,638.43 (8)
Black walnut	5,184.96 D	543.08 (16)
Red oak	5,164.11 D	439.17 (16)
Yellow poplar	4,837.44 D	250.32 (16)

[a] Means followed by unlike letters differ significantly ($P<0.05$)

CHAPTER II

ACOUSTIC COMPARISONS BETWEEN DECRESCENDO CALLS OF FEMALE MALLARDS (*Anas platyrhynchos*) AND CALLING MIMICRY BY HUMANS USING DUCK CALLS

Female mallards exhibit a diverse repertoire of vocalizations (Abraham 1974). They include decrescendos, incitation, repulsion, pre-flight, alarm, feeding (i.e., murmurs), and single and multiple quacks (Abraham 1971). The decrescendo is a common vocalization of female mallards and other female dabbling ducks (*Anas* spp.) that begins with force and loudness but gradually decreases (Morris 1982). Generally, the decrescendo consists of 5-6 notes and is onomatopoeically described as, "Quack, Quack, quack, quack, quack" with greatest amplitude in the first or second note and decreasing thereafter (Abraham 1974). Hochbaum (1955) termed it the "hail" call, perhaps having a greeting function among conspecifics on the water and in flight (Lockner and Phillips 1969). The decrescendo, feeding murmurs, and quacks often are mimicked by humans using artificial calls made of hardwood or plastic during hunting and calling events (Abraham 1971). However, extent to which mimicked calls acoustically compare to vocalizations of wild female mallards is unknown.

Duck calls originated in the 1850s and initially were simple handmade wooden or metal instruments with reeds (Harlan and Anderson 1988). Subsequently, duck call manufacturing has become a multi-million dollar industry (Young 2002). Nowadays, duck calls are available in a variety of models, styles, and colors and are made of hardwood, plastic, and rubber (Harlan and Anderson 1988, Young 2002). The most commonly used call today is the Arkansas style; a four-component design consisting of a barrel, insert, reed, and cork or rubber wedge to secure the reed to the insert (Figure 2.1). The insert is the main component of this style and sets it apart from earlier designs. The insert of the Arkansas style call has the stopper (i.e., the posterior piece that fits into the barrel) and the toneboard (i.e., part of a stopper that contains the surface on which lay the reed[s]; Christensen 1994). This style has existed since the early 1900s, but didn't gain popularity until the 1940s (Harlan and Anderson 1988, Christensen 1994). The style is often referred to as the J-frame call which derives its name from the J-shape of the toneboard (Knight and Hale 1989, Christensen 1994; Figure 2.1).

Duck call makers choose dense materials that are resistant to swelling during wet and cold conditions (Thompson 1970, Siau 1995). Materials also are selected to produce possible variations in sounds and quality associated with wood or plastic properties (e.g., porosity, density, hardness), much like the production of musical instruments (Bucur 1995).

Most past studies of mallard vocalizations have been qualitative and focused on behavioral significance of different vocalizations (e.g., Lorenz 1953; Johnsgard 1965; Maley 1969; McKinney 1969, 1992). However, quantitative studies of female mallard vocalizations are rare and have focused on variation in call structure (i.e., note length and interval, number of notes), sonographic display, and seasonal frequency (Lockner and Phillips 1969, Johnsgard 1971, Caswell 1972, Abraham 1974). I am unaware of any studies that have compared acoustic metrics of vocalizations from wild female mallards with vocalizations mimicked by humans using duck calls. Therefore, I compared acoustic metrics of field recordings of wild female mallards to recordings of experienced callers using wooden and acrylic duck calls to mimic wild females. I included and analyzed recordings of decrescendos only, because this vocalization is frequently mimicked by waterfowl hunters and competition callers and is the most difficult to master (Abraham 1971).

STUDY AREA

I recorded decrescendos of female mallards that used private and public wetlands in the Interior Flatwoods Region of east-central Mississippi and in the Mississippi Alluvial Valley (MAV) in western Mississippi and Tennessee. The Interior Flatwoods contains hardwood bottomland and emergent wetlands and is an important area for wintering waterfowl (Wehrle et al. 1995). The MAV also is an important region for wintering waterfowl, especially mallards (Reinecke et al. 1989). Today, dominant waterfowl habitats in the MAV include flooded croplands, moist-soil wetlands, forested wetlands, and catfish ponds (Reinecke et al. 1988).

In October – February of 2008-2009, I recorded decrescendos of female mallards within moist-soil and forested wetlands at Noxubee National Wildlife Refuge (NWR; 33°15'34.20"N, 88°47'42.87"W), Trim-Cane Wildlife Management Area (WMA; 33°31'28.31"N, 88°50'48.67"W), Dixie Hunting Club (33°41'48.52"N, 88°58'12.29"W), and Blocker’s Bottom (33°19'22"N, 88°49'18"W) in east-central Mississippi and moist-soil wetlands, forested wetlands, and flooded croplands in the MAV at Coldwater NWR

(34° 6'19.19"N, 90° 8'8.54"W), Yazoo NWR (33° 7'21.38"N, 91° 0'55.56"W), Hatchie NWR (35°30'19.45"N, 89°24'24.26"W), White Lake WMA (36° 7'9.78"N, 89°33'1.71"W), Panther Swamp NWR (32°46'21.07"N, 90°32'49.59"W), and York Woods (34° 3'55.61"N, 90° 9'32.69"W). I was unable to obtain an adequate sample of calls from individual females in each of the 3 types of aforementioned habitats ($n \geq 30$; 6 Johnson 1981). Thus, I did not attempt to partition analysis of calls by habitat. However, the majority (95%) of decrescendos I recorded were emitted by female mallards that used emergent wetlands.

I recorded mimicked decrescendos produced by an experimental panel of duck callers situated outdoors at a single location at the R. Rodney Foil Plant Science Research Center (hereafter referred to as North Farm; 33°28'16.47"N, 88°46'58.81"W) on the campus of Mississippi State University. North Farm is an open agricultural area with minimal traffic and other sources of background noise that could contaminate recordings. I processed and analyzed mallard and human recordings at the Forest and Wildlife Research Center (i.e., Thompson Hall) at Mississippi State University.

METHODS

Collection of Mallard Vocalizations

I recorded 620 decrescendos emitted by female mallards during winters 2008-2009 using a portable Marantz PMD-222 cassette recorder (Marantz America Inc., Mahwah, N.J.) with a Sennheiser ME-67 shotgun microphone (Sennheiser Electronic Co., Wedemark, Germany; Cramer and Price 2007). I only analyzed vocalizations free of other sounds and greatest signal to noise ratio (i.e., the level of desired sound to the level of background noise; Baker and Logue 2003). I used decrescendos from 38 females whose calls were clearly discrete and not overlapping with vocalizations of ducks or other animals.

I collected decrescendos in the morning and late afternoon, when mallards are most vocal (Abraham 1974). I collected recordings in only clement weather when winds were ≤4 on the Beaufort scale. When wind was between 2 and 4 on the Beaufort scale, I6 equipped the microphone with a blimp style windshield (Sennheiser Electronic Co., Wedemark, Germany). I observed vocal hens while recording them to estimate recording distance. If multiple vocal hens were present and recorded, one randomly selected decrescendo was used from the group for analysis.

Hardwood and Acrylic Duck Calls

I used duck calls made from acrylic and 7 different hardwoods by Pro-Cut Laser & Machine, SP (Sedalia, Missouri). I used native osage orange (*Maclura pomifera*), yellow poplar (*Liriodendron tulipifera*), black walnut (*Juglans nigra*), pecan (*Carya sp.),* and red oak (*Quercus* sp.). I used exotic bocote (*Cordia alliodora*) and cocobolo (*Dalbergia retusa*) from South America and Central America, respectively. I used a bocote prototype Arkansas style call with single and double reed patterns supplied by Hardwoods Waterfowl Calls, GP (New Albany, Mississippi). The machinist at Pro-Cut Laser & Machine measured the exterior and interior dimensions of the components of the prototype and then digitally mapped them. When components were mapped, their dimensions were used to produce 3 identical calls (CV = 0%) from each of the aforementioned materials using an automated lathe (Table 2.1). The tone boards were shaped using an automated mill. I measured a prototype reed to make a template and used it to produce identical reeds from sheets of 0.254-mm thick mylar. I hand cut a cork wedge for each call to hold single or double reeds tightly in place (Figure 2.1).

Experimental Duck Calling Panel

I assembled an experimental panel of 38 duck callers, equal to the number of discrete female mallard vocalizations recorded. I solicited callers through newspaper advertisements in *The Reflector* and bulletin board postings at Mississippi State University and at local waterfowl conservation venues. I asked prospective callers if they considered themselves an average to good caller, and I assumed the 38 callers represented a reasonable cross-section of duck hunters capable of calling ducks in the field. I maintained identification of callers confidential in compliance with the Mississippi State University Institutional Review Board for the Protection of Human Subjects in Research (IRB). I escorted each caller to the North Farm for a recording session. Before recording each caller, I randomized the order that each duck caller would blow each of the 8 different hardwood and the acrylic calls, so sequence of call use and type of call were not confounded. I used 3 replicate calls of each type and randomly selected one of these for each caller. Additionally, I determined randomly the sequence that callers used single or double reeds in each of the 8 calls. Next, I asked each caller to listen to a tape recording of the decrescendo of a randomly selected female from the group of 38 mallards and mimic the recording using each of the 16 combinations of experimental calls (i.e., 7 hardwoods and 1 acrylic [$n = 8$], each blown with a single and double reed [$n = 2$]). I located callers approximately 46 m from the microphone for recording, because most female mallard decrescendos were recorded near this distance. I used the same equipment and weather criteria for recording callers and female mallards in the field.

Sound Analysis

I converted analog sound data from cassette recordings of live female mallards and duck callers to digital format at a sampling rate of 44.1 kHz. I used Audacity ® software to select and extract individual decrescendos of female mallards and mimics of callers for analysis. I conducted analysis at the syllable or "note" level (Baker and Logue 2003). Female mallard decrescendos may emit 1 – 20 notes (Abraham 1974), but I only analyzed the first 5 notes of decrescendos because this number of notes most frequently vocalized in decrescendos by the 38 recorded females (i.e., 42%; Figure 2.2).

I used multi-taper spectral analysis (MTSA) to evaluate the following 5 acoustic metrics of each note using SOUND ANALYSIS PRO ® software: (1) Wiener entropy, (2) pitch goodness, (3) pitch, (4) mean frequency, and (5) frequency modulation. Wiener entropy measures the randomness or amount of variation in a wave of a sound or in the case of a mallard decrescendo, "the degree of rasp" (Ho et al. 1998). Pitch goodness is the derivative-cepstrum calculated for harmonic pitch. Pitch Goodness can be defined more simply as a measure of how periodic a sound is (Tchernichovski et al. 2000, Day et al. 2008). Pitch is the fundamental frequency of a sound (Tchernichovski et al. 2000). Frequency modulation is a measurement of the slope of the frequency contour (Tchernichovski et al. 2000, Baker and Logue 2003). I isolated and removed background noises (i.e., other bird vocalizations, frogs, etc.) from each sample before obtaining values of these metrics for the notes by adjusting the amplitude and entropy scales in Sound Analysis Pro ® until only the notes produced by the callers or mallards were recognized. I obtained values for each of the metrics by highlighting each note in Sound Analysis Pro®. I then averaged each of the metrics across the 5 notes for each mallard and caller for statistical analysis.

Statistical Analyses

I assessed multicollinearity among acoustic metrics of all 16 caller groups and the group of female mallards using Pearson's correlation coefficients (PROC CORR, SAS Institute Inc. 2003) and variance inflation factors (VIF; PROC REG, SAS Institute Inc. 2003). Multicollinearity is evident when VIF is ≥ 10 (Meyers 1990, Dubovsky and Kaminski 1992, Freund and Littell 2000). I evaluated data for multivariate normality by examining histograms, residual plots, and Shapiro-Wilk's goodness-of-fit test and determined the data did not follow a multivariate normal distribution. I transformed data by squaring values and using Box-Cox and $\log_{10}$ procedures (Johnson and Wichern 2007). I compared outcomes of statistical analyses using transformed and untreated data. I subjected acoustic metrics for all 16 duck call-reed combinations and female mallards to discriminant function analysis (PROC DISCRIM, DFA; SAS Institute Inc. 2003). I used a chi-square test to determine if variance-covariance matrices were homogeneous among groups ($\alpha = 0.10$, PROC DISCRIM; SAS Institute In6. 2003). The chi-square value was significant ($P<0.001$), thus I used the within covariance matrices in the DFA. I used multivariate analysis of variance (MANOVA) in DFA to test the null hypothesis of no differen6e 6($\alpha = 0.05$) in a6oustic6 metrics among the 16 call-reed groups and the reference group of female mallards. Considering the16 groups of duck call-reed combinations, each with 38 duck callers, plus the reference group of 38 female mallards, I amassed 646 analytical units (i.e., 17 treatment groups x 38 replicates = 646), which is considered an adequately large sample size for use of DFA (Wahl and Kronmal 1977, Johnson 1981, Williams and Titus 1988). To determine which duck call-reed combinations were most similar acoustically to female mallards, I determined the frequency of occurrence of observations from each call-reed group that was classified by DFA as being a member of the mallard group and pair-wise generalized square distances of each call-reed group to the group of female mallards. Additionally, I plotted a discriminant function scatter plot using Systat ® to depict female mallard and call-reed groups. I used the first 2 DFs as the axes to plot group positions in discriminant space, because 89.48% of the variation in acoustic metrics among mallard and call groups was explained by these functions. I also plotted a 95% confidence ellipse around the group of female mallards to depict variability in acoustic metrics among female mallards. I used the standardized canonical coefficients (CC) to determine relative importance of different acoustic metrics in determining group position and separation along axes (McGarigal et al. 2000).

RESULTS

None of the acoustic metrics were very correlated with each other ($-0.15 \leq r \leq$ 6 0.61; 1.104 ≤ VIF ≤ 1.703; Table 2.2). Transformation did not normalize acoustical data 6 ($P < 0.05$; Shapiro-Wilk's Test). Nevertheless, MANOVA and DFA produced the same outcomes with transformed and untransformed data; therefore, the following results are based on analyses of untransformed data.

The female mallard group and the 16 duck call-reed combinations differed based on the 5 acoustic metrics (MANOVA, Wilks' $\lambda = 0.76$; $F_{17, 80} = 2.20$; $P \leq 0.001$). 6 Pitch (CC = 0.64, along DF 1, frequency modulation (CC = -0.96 along DF 1), Pitch goodness (CC = -0.77, along DF 2), and mean frequency (CC = 1.02, along DF 2) were important in separating groups (Figure 2.3). Female mallards were classified correctly by DFA (i.e., classification error = 3%), whereas call-reed groups generally were misclassified (i.e., classification error = 84%; Figure 2.3). Additionally, 96% of the 38 female mallard decrescendos were within a 95% confidence ellipse of the acoustic metrics for the mallard group (Figure 2.3). Except for oak calls, calls produced with double reeds were classified more frequently as mallard calls than calls with single reeds within a material type (Table 2.3). The pair-wise generalized squared distances from the mallard group were used to rank call-reed groups when ties in frequency of occurrence occurred (Table 2.3). Based on DFA classification statistics, the top 10 call-reed combinations in acoustic similarity to female mallards were cocobolo double reed, osage orange double and single reeds, pecan double reed, acrylic double reed, bocote double reed, oak double reed, cocobolo single reed, oak single reed, and walnut double reed (Table 2.3).

DISCUSSION

Duck calls are known to have existed since the late 1800s (Harlan and Anderson 1988). Since use of live ducks as decoys was outlawed in 1935, duck call manufacturers have strived to fabricate calls that can produce realistic sounds when properly blown by humans (Glenn and Keats 2005). However, to my knowledge, no research has compared acoustic similarities between vocalizations by live female mallards and mimics produced by humans using duck calls. Apparently, my research is first to provide a ranking in acoustical similarity between 16 combinations of hardwood and acrylic calls, with single and double reeds, blown by a panel of humans (hereafter referred to as duck callers) and decrescendo calls of wild female mallards. The following discussion focuses on my arbitrary selection of the top 10 calls in acoustical similarity to live mallards (Table 2.3).

One may argue that calling ability could play a more significant role in successfully mimicking female mallards than material type. However, in compliance with IRB, I did not collect or analyze any data from the duck callers on their calling ability (e.g., calling and hunting experience, age). I merely assumed the 38 duck callers represented a typical cross-section of duck callers and hunters capable of vocally attracting ducks in the field. Therefore, perhaps the top 10 call-reed types facilitate mimicry of "mallard-like" sounds by duck callers, given that all call types tested in this study were capable of mimicking sounds acoustically similar (i.e., observations classified as mallards) to female mallards but not in as great a frequency as the top 10 calls.

Given that the materials used to fabricate calls in top 10 were harder materials, material type may influence callers' ability to mimic sounds acoustically similar to those emitted by female mallards. Composition of materials used to make the top 10 calls were denser and harder (See Chapter I), especially the top 6 calls which were made of the hardest of all 8 materials used in the study (i.e., acrylic, cocobolo, bocote, pecan, and osage orange; see Chapter I). Red oak was one of the only calls in the top 10 that did not share these properties; however, the roughness of the tone board and the barrel interior, due to pore structure (i.e., distribution and size of pores [Hoadley 1990]) of red oak, likely affected vibration of the reed(s) and female mallard-like sound quality when blown by callers. Hardness is a good indicator of density (Rowell 2005), which is the single best predictor of other wood properties (e.g., workability, strength, etc.; Amstrong et al. 1984). Thus, call makers could use other wood species to manufacture duck calls possibly with similar or better results than mine. For example, duck call manufacturers in North America may be wise to seek and use wood species with similar density and hardness values to the 5 species that performed well in this study (e.g., persimmon; *Diospyros virginiana*). Additionally, wood species could be sought that may exhibit superior acoustic performance or superior moisture stability, aesthetics, durability, and other attributes. These are issues for further investigation beyond the scope of this study.

Another question for future research is to identify what other wood properties may be influencing the acoustic performance of calls, such as pore structure. Pore structure could play a significant role in acoustic performance. Two species in this study that performed well but were of different rankings were osage orange and red oak, both of which are ring porous (i.e., hardwoods with large pores in the springwood and small pores in heartwood). However, osage orange pores are packed with tyloses (i.e., bubble-like structures in the vessels) which are mostly absent in red oak pores (Hoadley 1990). The absence of tyloses in red oak may influence the call to absorb more sound, causing it to be harder to blow and affecting sounds produced.

Lastly, given that duck calls equipped with double reeds performed acoustically superior within a material type than those equipped with single reeds suggests that reed type influences performance of a duck call. Based upon my results I would recommend that duck call manufacturers use acrylics and the harder wood species (i.e., cocobolo, osage orange, pecan, oak, and bocote) with single or double reeds for callers' choice, recognizing that double reed calls generally performed better in this study. I also would recommend that further investigation be made to determine other mechanical properties (e.g., porosity) or reed designs that influence the acoustic performance of artificial duck calls.

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Table 2.1 Measurements (mm) of duck calls (n = 3) of different hardwood and acrylic materials taken at Mississippi State University in 2008.

	Acrylic	Bocote	Cocobolo	Osage orange	Pecan	Poplar	Red Oak	Walnut
Component	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Barrel length	69	69	69	69	69	69	69	69
Cork notch	4	4	4	4	4	4	4	4
Inside diameter of insert	9	9	9	9	9	9	9	9
Insert length	95	95	95	95	95	95	95	95
Inside diameter of barrel	15	15	15	15	15	15	15	15
Tone board length	46	46	46	46	46	46	46	46

Table 2.2 Simple correlation coefficients (r) and variance inflation factors (VIF) for all possible pairs of acoustic metrics from recordings of 38 female mallards (*Anas platyrhynchos*) recorded in Mississippi and Tennessee in winters 2007-2009 and 38 duck callers recorded at Mississippi State University in spring 2009.

Acoustic metrics	*R*	VIF
Pitch and frequency modulation	0.31	1.156
Pitch and entropy	-0.15	1.703
Pitch and pitch-goodness	-0.60	1.104
Pitch and mean frequency	-0.12	1.619
Frequency modulation and entropy	0.29	1.612
Frequency modulation and Pitch-goodness	-0.15	1.599
Frequency modulation and mean frequency	0.21	1.612
Entropy and pitch-goodness	0.18	1.597
Entropy and mean frequency	0.61	1.116
Mean frequency and pitch-goodness	0.19	1.605

Table 2.3. Frequency (*n*) that 16 call-reed combinations used by duck callers were classified by discriminant function analysis as members of the mallard (*Anas platyrhynchos*) group and their pair-wise generalized squared distances to the mallard group analyzed for duck callers recorded at Mississippi State University in spring 2009 and mallards recorded in Mississippi and Tennessee in winters 2007-2009.

Call-reed group	*n*	Distance
1. Cocobolo, double reed	9	39.02
2. Osage orange, double reed	8	36.16
3. Osage orange, single reed	7	38.54
4. Pecan, double reed	7	38.71
5. Acrylic, double reed	6	37.58
6. Bocote, double reed	6	37.68
7. Oak, double reed	6	38.25
8. Cocobolo, single reed	6	38.72
9. Oak, single reed	6	39.15
10. Walnut, double reed	6	39.19
11. Poplar, double reed	5	40.42
12. Bocote, single reed	4	41.49
13. Acrylic, single reed	3	38.63
14. Walnut, single reed	3	39.36
15. Poplar, single reed	3	41.51
16. Pecan, single reed	2	40.80

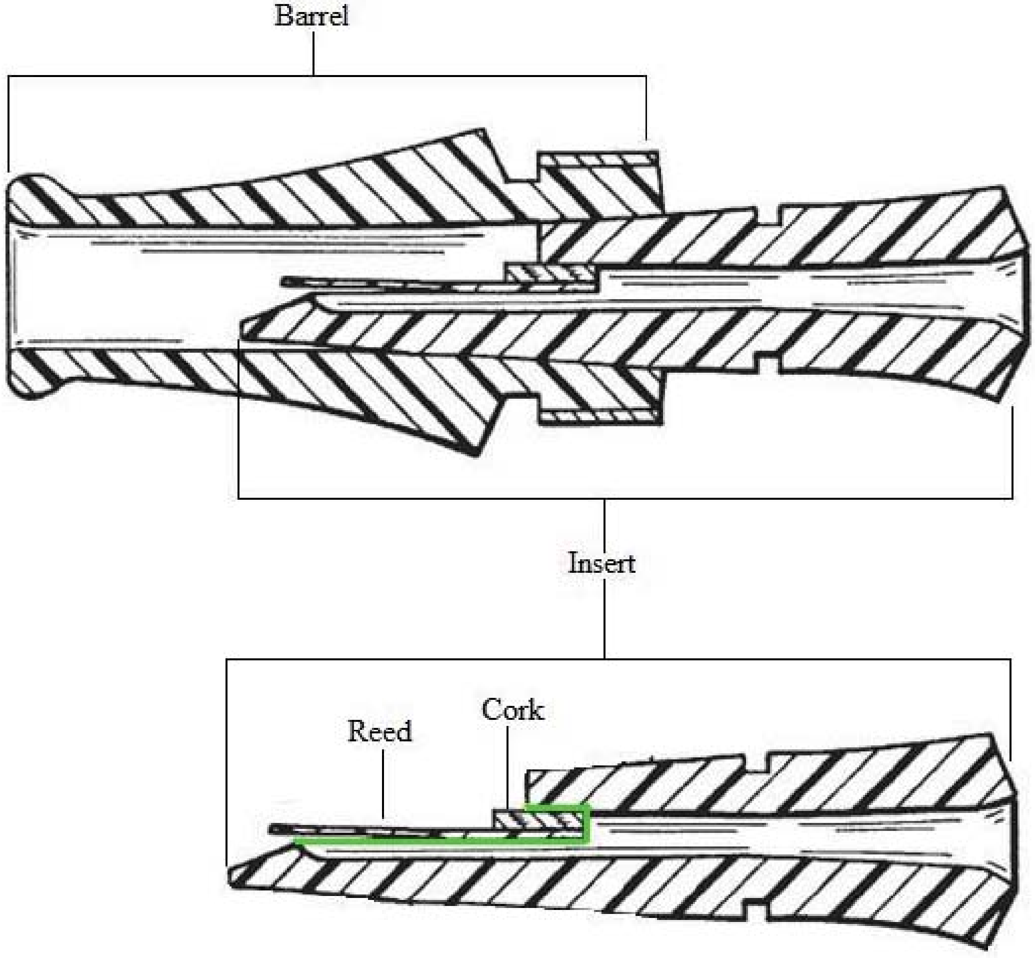

Figure 2.1. Cross-section of an Arkansas j-frame (green line) style duck call with a single reed (Rhodes 1999). Double reeds are 2 reeds atop each other.

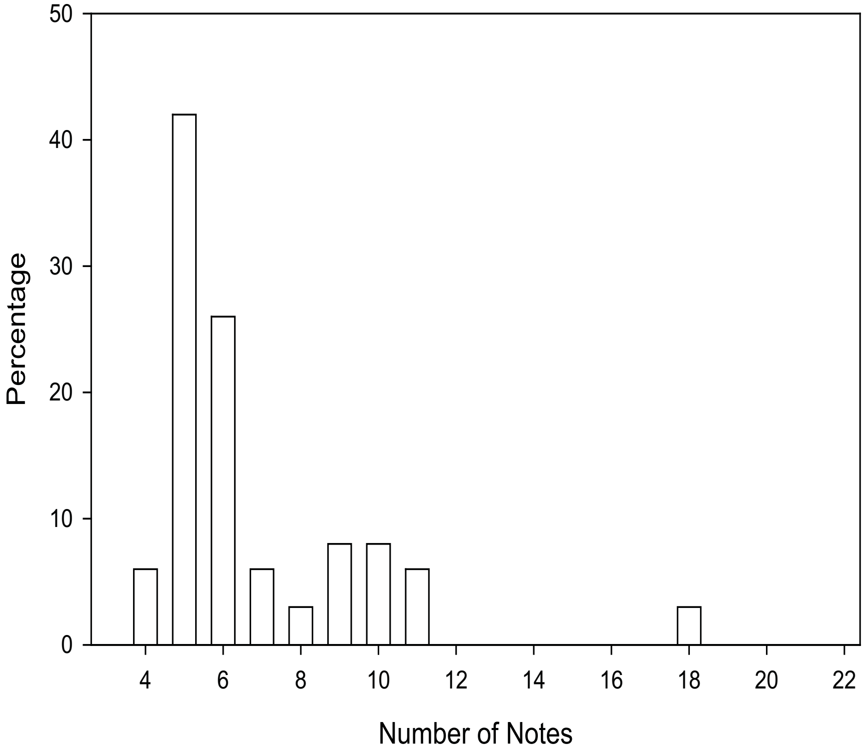

Figure 2.2. Percentage occurrence of notes emitted in decrescendos by 38 wild, free-ranging female mallards (*Anas platyrhynchos*) in Mississippi and Tennessee, winters 2007-2009.

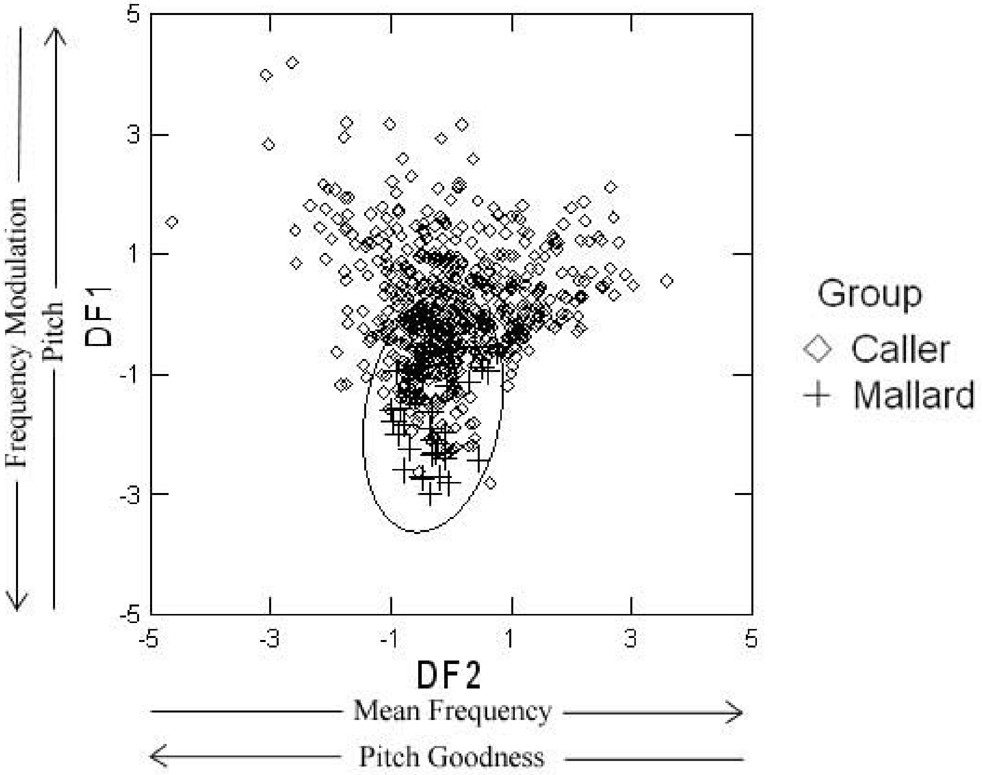

Figure 2.3. Discriminant function scores of acoustic metrics measured from decrescendos mimicked by duck callers in Mississippi in spring of 2009 and emitted by female mallards (*Anas platyrhynchos*) in Mississippi and Tennessee in winters 2007-2009, with 95% confidence ellipse around the mallard group.

CHAPTER III

SYNTHESIS

Female mallards exhibit a diverse repertoire of vocalizations (Abraham 1974). It includes decrescendos, inciting, repulsion, pre-flight, alarm, feeding (i.e., murmurs), and single and multiple quacks (Abraham 1971). The decrescendo is a common vocalization of female mallards and other dabbling ducks (*Anas* spp.). It, feeding murmurs, and quacks often are mimicked by humans using artificial calls made of hardwood or plastic during hunting and calling events (Abraham 1971). However, extent to which these mimics acoustically compare to vocalizations of wild female mallards is unknown.

In the 1800s, when waterfowl abundance was great and market hunting and live waterfowl were permitted for waterfowl hunting, artificial duck calls were not essential tools for hunters (Glenn and Keats 2005). When market hunting and use of live ducks were outlawed in the early 1900s, the commercial duck call industry emerged and makers have strived to fabricate calls that can produce realistic sounds when properly blown by humans (Christensen 1994, Glenn and Keats 2005). Today, duck call manufacturing has become a multi-million dollar annual industry, and calls are available in hundreds of models and fabricated from a variety of hardwood, plastic, and rubber materials (Harlan and Anderson 1988, Young 2002). However, I am not aware of any previous research designed to investigate differences in mechanical properties of hardwood and acrylic materials used to make duck calls and compared them acoustically to vocalizations of live female mallards.

In Chapter I, I compared Janka hardness values of 7 species of hardwoods and cast acrylic (ASTM 1996). The 7 species of hardwoods were native osage orange (*Maclura pomifera*), yellow poplar (*Liriodendron tulipifera*), black walnut (*Juglans nigra*), pecan (*Carya* sp.)*,* and red oak (*Quercus* sp.), as well as exotic bocote (*Cordia alliodora*) and cocobolo (*Dalbergia retusa*) from South and Central America, respectively. I determined that materials typically used by duck call manufacturers (i.e., acrylic, cocobolo, bocote, and osage orange) were much harder than those rarely or not used. However, I found that pecan, a hardwood rarely if ever used to make duck calls, was similar in hardness to osage orange which is used commonly.

In Chapter II, I compared acoustic metrics of field recordings of wild female mallards to mimicked recordings of a panel of experienced duck callers using calls of the 8 aforementioned materials with single or double reeds (n = 16 call-reed combinations). In descending order of acoustic similarity with female mallard vocalizations, the top 10 call-reed combinations were cocobolo double reed, osage orange double and single reeds, pecan double reed, acrylic double reed, bocote double reed, oak double reed, cocobolo single reed, oak single reed, and walnut double reed. These calls were harder and likely more dense than the other materials used in this study, especially the top 6 calls which were the hardest of the 8 materials evaluated in the study. I also found, within a material type that calls with a double reed performed better acoustically than those with single reeds. Thus, I recommend that duck call manufacturers use acrylics and the harder wood species (i.e., cocobolo, osage orange, pecan, red oak, and bocote) with single or double reeds for duck callers' choice, recognizing that double reed calls generally performed better in this study.

A conservation implication of this research is that native hardwood species that performed well in this study (i.e., osage orange, pecan, red oak, and black walnut) may be increasingly used by call manufacturers instead of exotic woods from endangered forests in the tropics (UNEP-WCMC 2005). However, this is dependent upon whether the sources of these species used by the duck call industry are in these endangered systems or sustainable tree farms. Another conservation implication to this research is one of monetary benefit. We have shown that methodology used in this research is a reliable way of testing a duck call's quality relative to live female mallard vocalization. This technology would be of great use to the duck call industry. We are in the course of securing a process patent on this methodology.

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