

VOCALIZATIONS OF THE BLUE-FRONTED AMAZON (*AMAZONA AESTIVA*) IN THE CHANCANÍ RESERVE, CÓRDOBA, ARGENTINA

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ABSTRACT.—The calls of the Blue-fronted Amazon (*Amazona aestiva*) are described and their possible function within the social organization of the species during breeding and non-breeding seasons are discussed. We identified 9 vocalizations; six (“wak-wak”, “wa-wawawa”, transitions, “gu-gugu”, guturals, “ka-kaka”) were nonspecific and were given in several circumstances: alarm, contact, feeding, and flying. The remaining had specific contexts: “waahh” (agonistic), “grr-uip” (contact in flight), and songs (reproduction-territorial). Vocalization rates increased in alarm contexts and during the non-breeding season, probably as a result of increasing interactions between individuals. The frequency containing the greatest amount of energy was a useful variable to characterize Blue-fronted Amazon calls, particularly at the species level. The most commonly used vocalization, “wak-wak”, has structural features that promote directionality and short-range transmission, enhancing its usefulness for the aggregation of individuals. It is suggested that songs were derived from a process of repetition and increasing variability from guttural calls. The highly contextual variability of these calls may be due to an incompletely specialized repertoire or a vocal system based upon combinations of calls for conveying messages. Received 5 May 1997, accepted 17 Mar. 1998.

The Blue-fronted Amazon (*Amazona aestiva*) is a parrot whose distribution extends over northeastern Brazil, Bolivia, Paraguay, and northern Argentina (Forshaw 1977, Darrieu 1983). Populations have declined in recent years, especially as a result of habitat destruction and over exploitation by pet trade (Bucher and Martella 1988, Bucher et al. 1992, Beissinger and Bucher 1992, Nores and Yzurieta 1994). This species is locally extinct in certain areas of southern Argentina; nevertheless, small populations survive in some isolated forest patches, such as in the Chancaní Reserve, province of Córdoba (Bucher et al. 1992, Fernández-Juricic et al. 1998).

Blue-fronted Amazons feed on fruits and seed and they can attack crops, especially citrus (Forshaw 1977, Navarro et al. 1991, Saud et al. 1991a). During the non-breeding season, flocks fly from roost sites in the morning to feeding areas, returning in the afternoon (Forshaw 1977, Saud et al. 1991b, Mosa et al. 1992). In the breeding season (September–March), isolated pairs nest in cavities of ma-

ture trees such as the quebracho blanco (*Aspidosperma quebracho-blanco*) and the palo blanco (*Calycophyllum multiflorum*; Bucher and Martella 1988, Nuñez et al. 1991). Because these cryptically colored parrots spend most of their time in tree canopies, their presence is generally detected only by their loud vocalizations. Although Vielliard (1994, 1995) analyzed some vocalizations of the Blue-fronted Amazon for phylogenetic comparisons, the vocal repertoire of this species has not been studied comprehensively.

The objectives of this work were to identify the vocalizations of the Blue-fronted Amazon and analyze their functions within the social organization of this species.

METHODS

The study was carried out in the Natural Provincial Park and Natural Reserve of Chancaní, Córdoba, Argentina (6° 26' W; 30° 22' S), which encompasses 4920 ha of undisturbed Chaco forest and where the dominant plant community is the quebracho-blanco forest. Annual precipitation ranges from 300–550 mm (Capitanelli 1979).

We visited the reserve during breeding and non-breeding seasons (December 1993, March, May, August and October 1994), accumulating 100 sampling hours. In each visit, we first determined the areas within the reserve where the parrots were most actively seen or heard to concentrate our sampling efforts. We recorded vocalizations during the morning (from 30 minutes before sunrise to mid-morning) and in the af-

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ternoon (3 hours before sunset until sunset). Behavioral observations were accomplished according to focal sampling techniques (Altmann 1974). Sexes were not distinguishable because the Blue-fronted Amazon is sexually monomorphic.

Vocalizations were recorded with an UHER 4000IC tape recorder at a speed of 19.05 cm/s and a directional microphone (Electro-Voice Model 644). We used a 16-bit stereo Sound Blaster advanced signal processor to digitize sounds at sampling rates up to 22.05 kHz to exceed Nyquist frequency (two times the upper frequency of sampled vocalizations; Evans and Evans 1994, Wilkinson 1994). Signals were filtered at the Centro de Investigaciones Acústicas y Luminotécnicas (C.I.A.L., Córdoba), removing low frequencies (<500 Hz). Sonograms were made at the Instituto de Medicina y Biología Experimental (IBYME, Buenos Aires) with the software ADDA 16 (Laboratorio de Investigaciones Sensoriales 1992). To standardize and facilitate comparisons, sonograms were displayed with an arbitrary scale of 2.5 s and two frequency scales: 0–10 kHz and 0–11.03 kHz.

We adopted the following terms to describe the calls (Kreutzer 1983, Martella 1985): note, a short sound not interrupted by a silence; syllable, a group of several different notes; and complex syllable, a group of different notes that constitute a coherent unit in the sonogram. The frequency band where most of the acoustic energy was concentrated was designated as energy concentration. Multiples of the fundamental were called harmonics. Based upon the onomatopoeias of the calls, we named each sound avoiding interpretive terms and/or discreet categories (fight calls, for instance) that might have implied some motivation of the individuals to behave in a certain way (Stirling and Roux 1987, Miller 1992).

We first performed a structural analysis to identify units and then we related them to the contexts in which vocalizations were uttered. Structurally, we measured the following variables: low frequency (the lowest frequency record, in Hz), high frequency (the highest frequency record, in Hz), frequency range (the difference between the latter variables, in Hz), energy concentration (as described above, in Hz), and duration (in ms). For each one of these variables, we calculated: mean, standard deviation (SD) and coefficient of variation (CV). The latter variability measure proved to be useful for detecting trends in individual and species recognition (Catchpole 1979, Saunders 1983, Sparling 1983). Temporal and morphological methods (see Thompson et al. 1994 for details) allowed us to classify songs, taking into account the time intervals among notes and the repetition of notes forming clear patterns.

Vocal activity (vocalization rate) was estimated as the number of notes per s in different contexts—alarm, flying, perching. Kruskal-Wallis and Mann-Whitney tests were performed to assess statistical differences among vocalization rates and among note intervals of songs. All analyses were performed using Statistica (version 4.5).

RESULTS

We identified nine vocalizations; six (“wak-wak”, “wa-wawawa”, transitions, “gugugu”, guturals, “ka-kaka”) were nonspecific and were uttered in several circumstances: alarm, contact, feeding, flying. The remaining three were given in specific contexts: “waahh” (agonistic), “grr-úip” (contact in flight) and songs (reproduction-territorial).

“*Wak-wak*”.—This is the typical vocalization of the Blue-fronted Amazon uttered all year round. It has a wide frequency range (approximately 1000–5700 Hz) with a central axis and lateral branches (Fig. 1a, Table 1). We were able to identify individuals based on differences in vocalization such as inflections in the lower bands, extra bands at 7500 or 10,000 Hz, and additional segments.

Wak-waks were given in series but without a constant temporal pattern. This vocalization was used during flight (alone or in groups), takeoff and landing, in stress situations provoking alarm (the presence of intruders), and when parrots communicated at long and short distances. Typical alarm responses (flying away uttering wak-waks) changed during the breeding season: breeding pairs remained perched giving wak-waks and then flew away quietly from intruders.

“*Wa-wawawa*”.—This vocalization was given year round, but less frequently than wak-wak, and in alternation with other calls. The fundamental warbles in frequency and has harmonics associated with it, producing a wide frequency call, while note duration is much longer than wak-waks (Fig. 1b, Table 1).

Wa-wawawa was uttered in several contexts: usually flying (alone or in a group), perching, in vocal contacts with other parrots, and during landings in response to conspecific calls. This note might have a contact function, because of its association with coordinated movements and position changes during flights.

Transitions.—These vocalizations were heard during nearly all of the study period. We distinguished two types: transition toward wak-wak (more frequent; Fig. 1c) and transition toward wa-wawawa (Fig. 1d). Transitions look like incomplete wak-waks or wa-wawawas, respectively, indicating that they keep

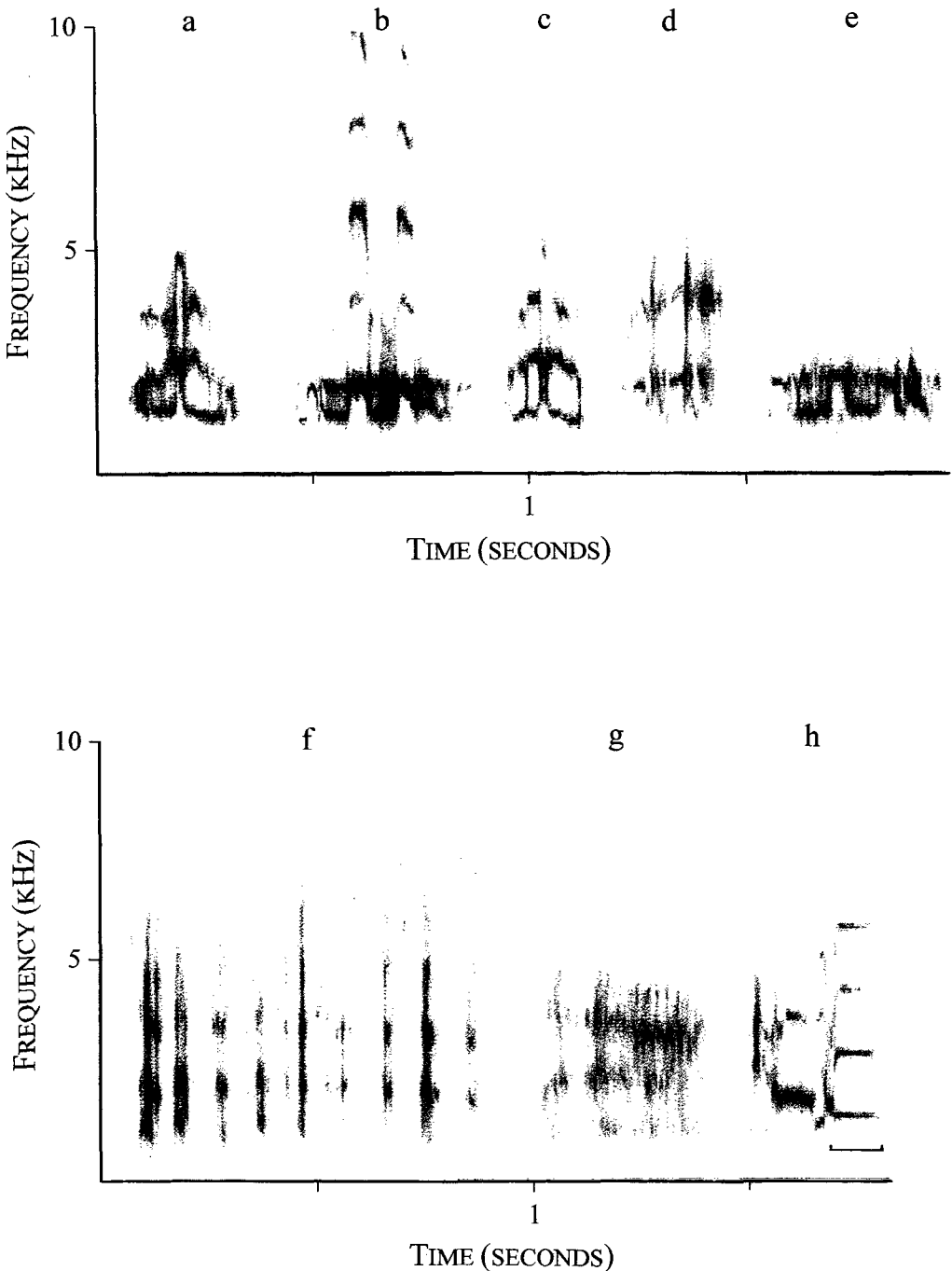


FIG. 1. Blue-fronted Amazon vocalizations identified in the Chancaní Reserve, Córdoba, Argentina (and the usual contexts in which they were observed): (a) “wak-wak” (the call most frequently used in several situations), (b) “wa-wawawa” (coordination of position changes during flight), (c) transition to “wak-wak” (alarm), (d) transition to “wa-wawawa” (prior to the emission of “wak-waks”), (e) “gu-gugu” (contacts of flying and perching parrots), (f) “kakaka” (feeding), (g) “waahh” (agonistic situations), (h) “grr-uíp” (contact in flight; the most common syllable is indicated).

TABLE 1. Structural characteristics of "WAK-WAK," "WA-WAWAWA," transition to "WAK-WAK," transition to "WA-WAWAWA," "GU-GUGU," "KA-KAKA," "WAAHH" and guttural calls of the Blue-fronted Amazon in the Chancaní Reserve, Córdoba, Argentina.

Vocalization (sample size)	Low freq. (Hz)	High freq. (Hz)	Freq. range (Hz)	Energy concn. (Hz)	Duration (ms)
"WAK-WAK"					
(n = 30)					
Mean	920.60	5706.90	4802.50	2402.80	243.20
SD	179.20	511.31	565.91	84.20	50.76
CV	19.47	8.96	11.78	3.50	20.87
"WA-WAWAWA"					
(n = 20)					
Mean	1005	5808.50	4805.30	2190.40	353.95
SD	166.33	764.12	725.31	272.01	79.078
CV	16.55	13.16	15.09	12.42	22.34
Transition to "WAK-WAK"					
(n = 9)					
Mean	1141.40	4854.80	3635.9	2373.40	147.44
SD	87.42	791.50	911.35	126.04	49.02
CV	7.66	16.30	25.07	5.31	33.25
Transition to "WA-WAWAWA"					
(n = 3)					
Mean	1008.3	5857	4884	2237.70	232.33
SD	123.27	823.18	847.48	56	2.31
CV	12.23	14.06	17.35	2.50	6.99
"GU-GUGU"					
(n = 12)					
Mean	1077.90	2474.40	1405.2	2056.80	253.17
SD	108.65	232.49	210.01	126.71	84.10
CV	10.08	9.40	14.95	6.16	33.22
"KAKAKA"					
(n = 62)					
Mean	247.32	5555.60	5308.30	3566	43.60
SD	228.28	795.48	889.21	219.52	8.09
CV	92.30	14.319	16.75	6.16	18.56
"WAAHH"					
(n = 15)					
Mean	492.67	7000.10	6507.50	2492.50	247.13
SD	243.87	1473.60	1550.80	197.92	170.86
CV	49.50	21.05	23.83	7.9409	8.27
Gutturals					
(n = 76)					
Mean	860.49	3968.30	3068.40	1855.80	127.58
SD	330.01	1402.50	1649	429.39	50.16
CV	38.35	35.34	53.74	23.138	39.32

Abbreviations: Freq. = frequency; Conc. = concentration; SD = standard deviation; CV = coefficient of variation; Hz = Hertz; ms = milliseconds.

their basic shape, but are shorter and lack 1 or 2 of the characteristic frequency bands (usually the lower and the upper; Table 1). Transitions were recorded sporadically before wak-waks or wa-wawawas, when perching

flocks vocalized repeatedly, and in alarm situations involving pairs.

"Gu-gugu".—This note was recorded at the end of the breeding season (March) and during the non-breeding season (May). It is a

TABLE 2. Physical characteristics of the most common sector of "GRR-UÍP" calls of the Blue-fronted Amazon in the Chancaní Reserve, Córdoba, Argentina.

(n = 7)	Low freq. (Hz)	High freq. (Hz)	Freq. range (Hz)	Energy conc. (Hz)	Harm. 2 (Hz)	Harm. 3 (Hz)	Harm. 4 (Hz)	Duration (ms)
Mean	1148	6229.90	5081.90	1481.90	2869	4392	5758.50	122.86
SD	164	648.85	664.21	68.72	255.78	247.84	225.69	18.83
CV	14.29	10.42	13.07	4.64	8.92	5.64	3.92	15.33

Abbreviations: Freq. = frequency; Conc. = concentration; SD = standard deviation; CV = coefficient of variation; Hz = Hertz; ms = milliseconds; Harm. = harmonics.

low pitched warble with variable duration. Energy is concentrated at the peak of the warbles (approximately 2000 Hz; Fig. 1e, Table 1). This call was heard when a large number of individuals (generally more than four) were flying and during vocal contacts between perching individuals. Sometimes, gu-gugus and wa-wawawas were associated in a long series.

"*Ka-kaka*".—It was given only during the non-breeding season. Structurally, it is formed by a series of an average of 15 notes (± 4.73 SD), each with a wide frequency range (5300 Hz) and short duration (about 45 ms), separated by 50 ms intervals (Fig. 1f, Table 1). Kakas were heard in foraging contexts (parrots in the canopy of quebracho blancos moving through branches, eating sprouts) and when large flocks were displaying continuous vocal activities in dense forests.

"*Waahh*".—This vocalization was uttered during March and August; however, for its analysis we used recordings taken at the Zoological Garden of Córdoba (Argentina) in order to obtain better sound quality. Waahhs are typically harsh sounding and have a wide bandwidth. Energy is concentrated at two frequency bands: 2500 and 3800 Hz (Fig. 1g, Table 1). The call was given in threat and fight contexts among conspecifics. When several parrots (>10) were in trees, some aggressive interactions took place. Usually one parrot moved its head toward another individual behind it, displayed its wings, and vocalized a single waahh. If the approach continued, the other parrot left or began fighting. As individuals came closer, call intensity and duration increased.

"*Grr-uíp*".—This call was given in March (post-breeding season) and in May (non-breeding season). It is a complex vocalization formed by two or three different syllables.

The most common syllable spans nearly 120 ms and is distinguished by the presence of multiple harmonics. The average syllable has its greatest amplitude at 2100 Hz, lasting 390 ms (Fig. 1h, Table 2). Grr-uíp corresponded closely to flight movements which required certain coordination; for instance, when parrots changed their positions within flocks or when they displayed intricate maneuvers while landing in trees.

Gutural.—A very common vocalization throughout the year. Structurally, guturals are highly variable in their bandwidth, duration, and intensity (Fig. 2a, Table 1). They were associated with a variety of contexts: alarm, takeoff, flight, contact between members of a pair and among perching individuals. Moreover, they were given in series or combined with other vocalizations (particularly wak-wak, wa-wawawa and gu-gugu).

Songs.—They were recorded exclusively at the beginning of the breeding season (August). Structurally, songs constitute a series of different notes given in long succession and with a specific pattern. Based upon a sample from 1 individual and 6 complete songs, we identified 17 different notes, designated as Note 1 to 17. Physical characteristics and sonograms of the most common notes (Notes 1 to 6) are shown in Table 3 and Fig. 2b, respectively.

Songs are made up by two successive sets (Set 1 and 2). Set 1 is less variable than Set 2 and is formed by the sequence of Notes 4, 5, 6, and 1. Set 2 is more variable in relation to the type and number of notes (Notes 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17). However, certain syntactic rules can be established: (1) Note 2 was the most frequently used, and generally alternated with the other notes in the following way: $Nx_N2_Nx_N2_Nx \dots$; where N2 is Note 2, Nx

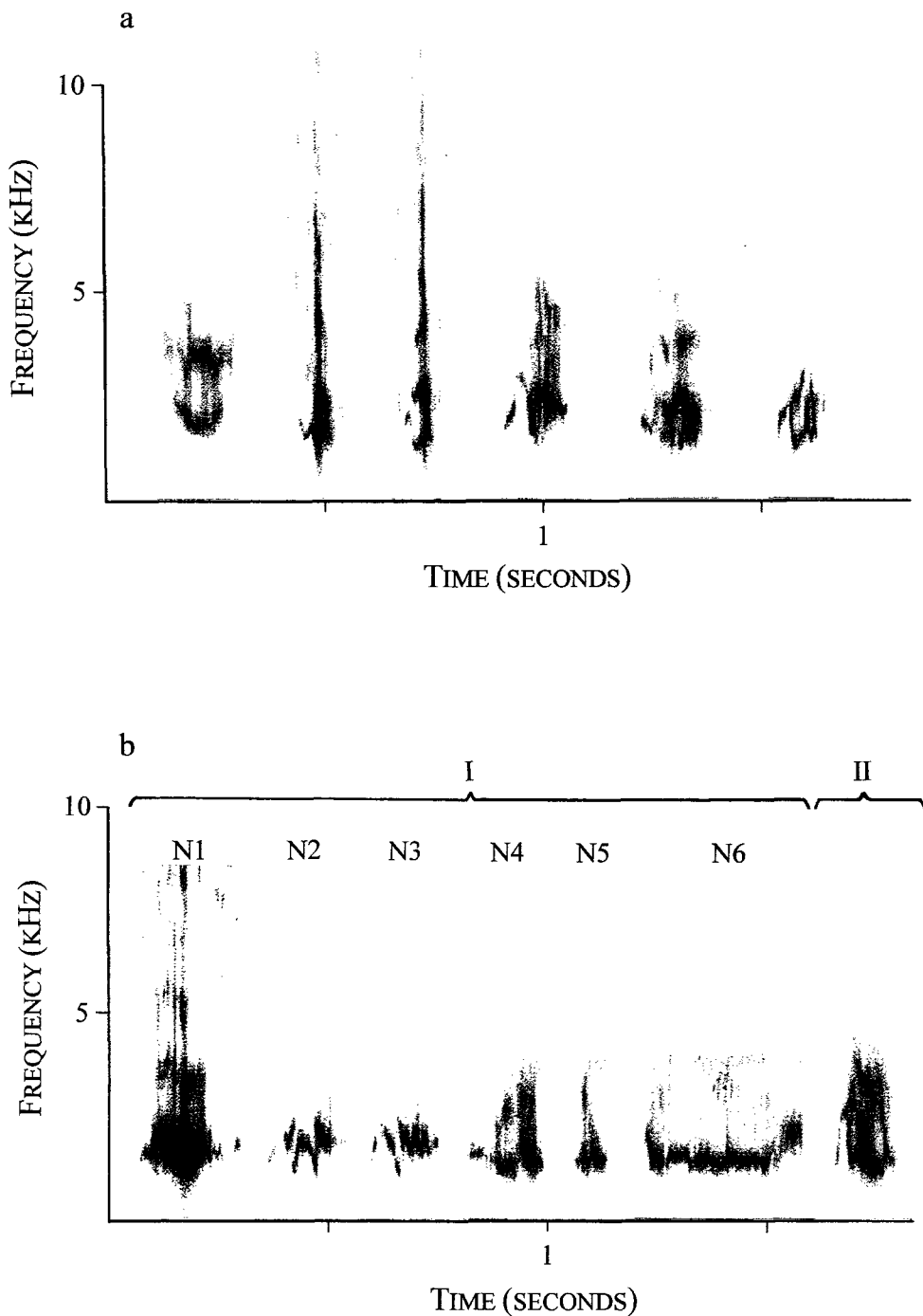


FIG. 2. Blue-fronted Amazon vocalizations recorded in the Chancaní Reserve, Córdoba, Argentina (and the usual contexts in which they were observed): (a) guturals (interaction between conspecifics), (b) songs (reproduction-territorial): I = notes commonly uttered, II = the only note vocalized by a hidden individual.

TABLE 3. Physical characteristics of the most common notes (Notes 1 to 6) of the songs of the Blue-fronted Amazon in the Chancaní Reserve, Córdoba, Argentina.

Note (sample size)	Low freq. (Hz)	High freq. (Hz)	Freq. range (Hz)	Energy conc. (Hz)	Duration (ms)
Note 1 (<i>n</i> = 6)					
Mean	409.67	10,390	9979	1951.80	274.17
SD	75.66	57.24	124.64	50.03	15.26
CV	18.468	0.5510	1.25	2.56	5.57
Note 2 (<i>n</i> = 7)					
Mean	869.67	2625.70	1756.10	1867.30	99.57
SD	121.32	88.44	171.17	99.69	10.74
CV	13.95	3.37	9.75	5.34	10.78
Note 3 (<i>n</i> = 7)					
Mean	943.43	2599.90	1665.40	1874.30	127.29
SD	97.42	321.59	405.58	85.76	62.69
CV	10.43	12.37	24.35	4.58	49.26
Note 4 (<i>n</i> = 6)					
Mean	931.17	3652.50	2721.30	1562.50	149.83
SD	62.46	461.42	424.47	93.54	18.78
CV	6.71	12.63	15.60	5.99	12.53
Note 5 (<i>n</i> = 5)					
Mean	1072	2552.40	1480.40	1511.80	68.40
SD	82.44	49.34	39.23	74.60	11.44
CV	7.69	1.93	2.65	4.93	16.72
Note 6 (<i>n</i> = 5)					
Mean	1044.60	2478.2	1433.6	1496.6	356.80
SD	45.50	113.79	122.43	18.84	4.02
CV	4.36	4.59	8.54	1.26	1.13

Abbreviations: Freq. = frequency; Conc. = concentration; SD = standard deviation; CV = coefficient of variation; Hz = Hertz; ms = milliseconds.

represents the remaining notes of Set 2 and Δ is a time interval. The interval prior to Note 2 was significantly longer ($302.64 \text{ ms} \pm 212.2 \text{ SD}$) than the subsequent interval ($133.45 \pm 26.8 \text{ SD}$; Mann-Whitney test: $U = -3.87$; $n = 22$; $P < 0.001$). (2) Note 3 was the second most commonly used note, and usually alternated with Note 2 (N3_N2_N3_N2_Nx ...). (3) We identified short Sets 2 ($\bar{x} = 3.25$ notes; $n = 12$) and long Sets 2 ($\bar{x} = 10$ notes; $n = 6$).

Two parrots were sampled for 5 days moving around a restricted sector of dense forest. When another pair approached within 500 m, both pairs began vocalizing songs. We focused our recordings on one pair in which the singer was perched on a conspicuous branch. Hidden within the canopy, the other member of the pair gave only one structurally different note (Fig. 2bII) at the end of each bout. Shortly before, both pairs were involved in a flying fight, vocalizing agonistic, guttural, and con-

tact calls. It is probable that the intruders were trying to locate a suitable nesting site, which suggests a territorial context.

Vocalization rates.—Blue-fronted Amazons vocalized more frequently in alarm situations (2.25 notes/s) than in perching (1.24 notes/s) or flying contexts (1.42 notes/s) (Kruskal-Wallis test: $F_{2,57} = 10.54$; $P < 0.01$). Flying vocalization rates were not significantly different between sampled months (Kruskal-Wallis test: $F_{2,20} = 1.31$; $P > 0.05$). However, perching vocalization rates showed significant differences between March (1.03 notes/s), May (1.64 notes/s), August (1.42 notes/s) and October (0.73 notes/s; Kruskal-Wallis test: $F_{3,32} = 8.09$; $P < 0.05$). Perching vocalization rates were not significantly affected by our presence (1.2 notes/s) compared to vocalization rates of birds that did not detect us (1.3 notes/s; Mann-Whitney test: $U = 0.57$; $n = 26$; $P > 0.05$).

DISCUSSION

Blue-fronted Amazons' vocalizations have most of their acoustic energy concentrated in low frequencies, which may be adaptive, because these frequencies attenuate and degrade in forest habitats less than those of higher frequencies (Morton 1975). In addition, the concentration of energy is the structural feature showing the least variability (the lowest coefficients of variation), suggesting that it transmits information about species identity (Berger and Ligon 1977, Catchpole 1979, Saunders 1983, Sparling 1983). Conversely, note duration, with a higher coefficient of variation, could convey information about the identity of each individual (Berger and Ligon 1977, Catchpole 1979, Saunders 1983). Although the analysis of coefficients of variation does not constitute a definitive proof of the outlined distinctions, we suggest that species and individual identity certainly could be transmitted by means of acoustic structural variations.

Wak-wak, the most used call in alarm contexts, contains many structural features that would promote directionality and short-range information transmission: abrupt beginning and end, wide frequency range, frequency variations, and note repetition (Marler 1955, Catchpole 1979, Richards 1985). These properties would allow conspecifics to quickly locate each other and confer a selective advantage in contexts where contacts between individuals are necessary for group coordination (Thorpe 1961).

Gutural calls were used to maintain contact between flying or perching individuals. The contexts in which guturals, wa-wawawas and gu-gugus were uttered (mainly during the non-breeding season) would indicate the use of the three calls for the interaction and coordination of conspecifics. The chatter of the Monk Parakeet (*Myopsitta monachus*; Martella and Bucher 1990) and the gutural calls of the Blue-fronted Amazon are structurally similar: both constitute different figures separated by short intervals. Nevertheless, it is difficult to see a functional similarity because Monk Parakeets utter these calls in more restricted circumstances, such as when social groups are perching near or within nests. Similar vocalizations are found in other sociable species, in-

cluding the Sociable Weaver (*Philetairus socius*; Channing and MacLean 1976) and the Piñon Jay (*Gymnorhinus cyanocephalus*; Berger and Ligon 1977). Blue-fronted Amazons' grr-uíps and Monk Parakeets' contact vocalizations (Martella and Bucher 1990) are complex syllables, divisible into two well distinguished sectors. Although the Monk Parakeet uses these complex vocalizations in a wide variety of situations, it shares with the Blue-fronted Amazon the fact of using them when flying parrots huddle together and when landing in trees with conspecifics.

Wide frequency range and the acoustic energy concentrated at low frequencies are two features that characterize whaa calls. Similar vocalizations are uttered in the same sort of agonistic contexts by other psittacine species, namely Orange-chinned Parakeets (*Brotogeris jugularis*; Power 1966) and Short-billed White-tailed Black Cockatoos (*Calyptorhynchus funereus latirostris*; Saunders 1974, 1983).

Parrot songs also have been observed in some Australian species, such as *Psephotus haematonotus* (Forshaw 1977), and *Melopsittacus undulatus* (Farabaugh et al. 1992). Apparently, Blue-fronted Amazons' songs have a territorial function. It is thought that this species is monogamous and keeps its pair-bonds throughout life; therefore, there would be little need for mate attraction. Instead, defending a territory that provides a critical resource (such as nest trees) turns out to be more relevant to ensure reproductive success. Furthermore, these vocalizations might also serve other subtle functions: synchronization of reproductive periods in the pair, stimulation of females to a proper physiological state for reproduction, and maintenance of pair-bonds (Catchpole 1979, McGregor 1991, Farabaugh et al. 1992).

Songs have narrow bandwidths, no harmonics, and energy concentrated at low frequencies; features allowing long distance transmission of signals in forests (Morton 1975, Wiley and Richards 1982, Richards 1985). We suggest that Blue-fronted Amazon songs evolved from a process of repetition and increased variability. The original vocalizations could have been gutural calls which structurally resemble the notes of the songs. Many bird species, including songbirds (*Parus sclateri*;

Ficken 1990), and parrots (*Melopsittacus undulatus*; Farabaugh et al. 1992), incorporate calls in their songs, a hint of this process.

We found that vocalization rates increased when individuals were alarmed. Differences in the rates of vocalization by perching parrots might imply activity variations throughout the year. May's highest value (non-breeding season) would be the result of a higher rate of interactions, since parrots spent more time together—flying in large flocks, feeding in groups and sharing communal roost sites (Fernández-Juricic 1994). The second highest value was in August, a transition period between breeding and non-breeding seasons (Fernández-Juricic et al. 1998). October and March had the lowest rates because activities are reduced to the interaction of the pair and their juveniles during the breeding season.

Only three of nine vocalizations could be associated with specific contexts; the other calls were given in a variety of situations, a fact that partially corroborates the vocal flexibility of this species in captivity (Forshaw 1977). On the whole, the high contextual variability found in the Blue-fronted Amazon calls may be partially accounted for by two possibilities: an incompletely specialized vocal repertoire (with high degrees of redundancy) or a vocal repertoire in which combinations of calls convey different messages. Neither of these prospects can be assessed with the available data and both need further testing.

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