J. Raptor Res. 34(2):85–92

IDENTIFICATION OF INDIVIDUAL BARRED OWLS USING SPECTROGRAM ANALYSIS AND AUDITORY CUES

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ABSTRACT.—To determine if individual male Barred Owls (*Strix varia*) could be identified using spectrogram analysis, I recorded vocalizations from mid-February through May at 17 different field locations in Minnesota. In 1997, 134 calls from seven locations were analyzed; in 1998, 531 calls from 15 locations were analyzed. The final four notes of the Legato hoot, which consisted of five-to-nine evenly accented notes, were used in the analyses. On each spectrogram, I measured 10 temporal and 12 frequency measures, then used stepwise logistic regression to select the seven most influential variables. A discriminate function analysis (DFA) separated and identified spectrograms from different locations in 1998 with an overall accuracy of 84.5%. Sortspects, a multimedia-based program, was developed and used to determine whether observers could discriminate unmeasured calls using only visual and auditory cues. Discrimination of 1997 calls (four locations with two nights each) was 100% for all four observers. The observers were able to correctly discriminate 1998 calls (15 locations, each with three nights) 38, 58, 76 and 87% of the time.

KEY WORDS: *Barred Owl*; Strix varia; *vocalizations*; *songs*; *individual identification*.

Identificación individual de *Strix varia* mediante la utilización de análisis de espectogramas y señas auditivas

RESUMEN.—Para determinar si un individuo macho de *Strix varia* puede ser identificado mediante un análisis de espectogramas, grabé sus vocalizaciones desde mediados de Febrero hasta Mayo 17 en distintas localidades de Minnesota. En 1997, 134 vocalizaciones de siete localidades fueron analizadas; en 1998 531 vocalizaciones de 15 localidades fueron analizadas. Las cuatro notas finales de la secuencia de buhos ululando, la cual consistió de cinco a nueve notas igualmente acentuadas fueron utilizadas en el análisis. En cada análisis de espectograma tomé las medidas temporales y 12 frecuencias, utilicé una regresión logística para selecionar las siete variables mas influyentes. Un análisis de función discriminatorio separó e identificó los espectogramas con una exactitud del 84.5%. Mediante el desarrollo del "Sportspecs" un programa de multimedia se determinó si los observadores podían discriminar las vocalizaciones no medidas mediante la utilización de señas visuales y auditivas solamente. La discriminación de las vocalizaciones de 1997 (cuatro localidades con dos noches cada una) fue del 100% para los cuatro observadores. Los observadores fueron capaces de discriminar correctamente las vocalizaciones de 1998 (15 localidades cada una y tres noches) 38, 58, 76 y un 87% del tiempo.

[Traducción de César Márquez]

Acoustical identification of individuals in songbirds and seabirds has been documented extensively over the last several decades (Beer 1970, Falls 1982); however, only recently has it been investigated in raptors (Eakle et al. 1989, Galeotti and Pavan 1991, Galeotti et al. 1993, Telford 1996, Otter 1996, Appleby and Redpath 1997, Kuntz and Stacey 1997). Recognition of individuals by auditory cues is likely where vision is impaired due to darkness, topography, congested colony sites, or thick vegetation (Beer 1970, Falls 1982), and in species with repeated neighbor contact or long-term pair bonds (Falls 1982). Individual variation, therefore, may be particularly important in nocturnal owls, especially in species that occupy large territories of varying topography and vegetation.

Although the Barred Owl (*Strix varia*), an indicator species (U.S. Department of Agriculture 1985, 1986, 1987), is common throughout much of its range, its vocalizations have been little studied. The ability to identify individuals using characteristics of calls potentially provides a new approach to the study and census of this species. Voice analysis could potentially permit identification of individuals without having to capture or band birds.

I investigated the consistency and variability of Barred Owl vocalizations recorded at different locations over two years, and determined whether human observers were able to distinguish between calls of birds recorded at different locations. Barred Owls are sedentary, long-lived and territorial (Nicholls and Fuller 1987, Mazur et al. 1998). Telemetry studies in Minnesota and Saskatchewan indicate that Barred Owls defend large (228–971 ha) exclusive areas (Nicholls and Warner 1972, Mazur et al. 1998) and spend little time outside them (Nicholls and Fuller 1987). Therefore, if the vocalizations of individual Barred Owls are distinct, vocalizations recorded in one territory should be distinguishable from those recorded in other territories.

METHODS

Sound Recording. The study was conducted at Itasca State Park in northcentral Minnesota, U.S.A. (47°12'N, 95°12'E). I recorded male Barred Owl vocalizations from mid-February through May in 1997 and 1998.

To locate owls, I provoked responses by broadcasting conspecific calls. The tapes used for broadcasts contained 5–6-min segments, with calls every 25 sec. My goal was to maximize rather than standardize the number of recorded vocalizations, so I used one to three different vocalizations at each location: (1) Legato calls from a captive female recorded at the Raptor Research Center at the University of Minnesota, (2) Legato and Cook calls from a male recorded at Itasca State Park and (3) a short segment of a pre-recorded male-female duet (National Geographic Society 1983).

Recordings of responses were made between 1600–0730 H with a Sony TCM 5000 EV or Marantz PMD 221 tape recorder, and either a Sennheiser directional or a 45 cm parabolic microphone. To allow for comparisons of call structure under different conditions, I did not standardize for time of day, temperature, distance from the microphone or background noise level. However, calls were not recorded on nights with constant precipitation or wind speeds over 10 km/hr.

After the initial recording, I used the same location for all subsequent recordings and noted the direction and distance of any individual that answered. Recording locations ranged from 0.4–4.0 km apart ($\bar{x}$ = 1.75 km). Since Barred Owls are highly sedentary, the likelihood of recording the same individual on more than one occasion at the same location was high. Neighboring birds were determined to be different individuals because they called simultaneously and consistently from a different location and direction than the one being recorded.

Observer Discrimination. For all analyses, I used only calls with spectrograms that were clearly visible despite background noise, and which were recorded in response to broadcasts. Sortspects, a multimedia-based program developed by G. Nuechterlein at North Dakota State University, was used to determine if observers could distinguish calls from different locations using only visual and auditory cues.

The 15 locations in 1998 were each represented by three computer "folders" (45 folders total). Each folder represented a different recording night at a location and contained the sounds and spectrograms of three randomly selected calls from that night. The Sortspects program randomly and anonymously displayed the spectrograms and played the sounds within each folder. All 45 folders were simultaneously visible, and the goal of the observer was to place the calls into like groups using visual and auditory clues. The observer was not provided any quantitative measurement. Once sorting was finished, I checked the identities and scored the trial. In 1998, the maximum score for an observer was 45 correct. Sample sizes were smaller in 1997 with only four locations and two recording nights per location (eight folders). The maximum score for an observer was 8 correct.

Four observers were used in the Sortspects discrimination process. To assess if spectrogram experience would be necessary for this procedure, I used two experienced and two inexperienced spectrogram readers. For each Sortspects task, a Monte Carlo simulation with 10 000 trials was run to determine the probability of randomly attaining scores using the Sortspects program. Points for the Monte Carlo were assigned in the same fashion as in the Sortspects program.

Spectrogram Measurements. The most common vocalization heard in response to broadcast calls was the male's Legato hoot, five to nine evenly accented hoots ending with a "hoo-aw" (Freeman 1999). For analyses, I randomly selected complete Legato hoots from each recording session at each location and analyzed spectrograms and spectra (filter bandwidth = 88 Hz) using CANARY 1.2 software (Cornell Laboratory of Ornithology, Ithaca, New York U.S.A).

All but two of the 22 variables studied were taken from the final four notes of the Legato vocalization. I focused on this segment of the call because it showed more consistency within a call sequence and more variability between locations than did the introductory notes. CANARY provided quantitative measurements of the last four notes from each spectrogram, which included peak amplitude frequency of each note from the spectrum (FTR1, FTR2, FTR3 and FTR4) and spectrogram (FGR1, FGR2, FGR3 and FGR4); duration of each note (D1, D2, D3 and D4); length of intervals between notes (I1, I2 and I3) measured from the end of one note to the beginning of the next note; and peak amplitude interval (PI1, PI2, and PI3) measured between peak amplitude of successive notes (Fig. 1). Other measurements from the call were peak amplitude frequency of the last four notes together from the spectrum and spectrogram (FTRALL4 and FGRALL4) and peak amplitude of the entire call from the spectrum and spectrogram (FTROV and FGROV).

In 1997, I analyzed 134 calls from seven locations. The number of recording nights per location varied from 1–6 with a total of 4–59 ($\bar{x}$ = 19.1) spectrograms per location. In 1998, the number of successful recording nights per location varied from 3–6 with 29–42 ($\bar{x}$ = 35.4) spectrograms per location, for a total of 531 calls in 1998.

Statistical Analyses. The 22 spectrogram variables were subjected to univariate and multivariate analyses. I first

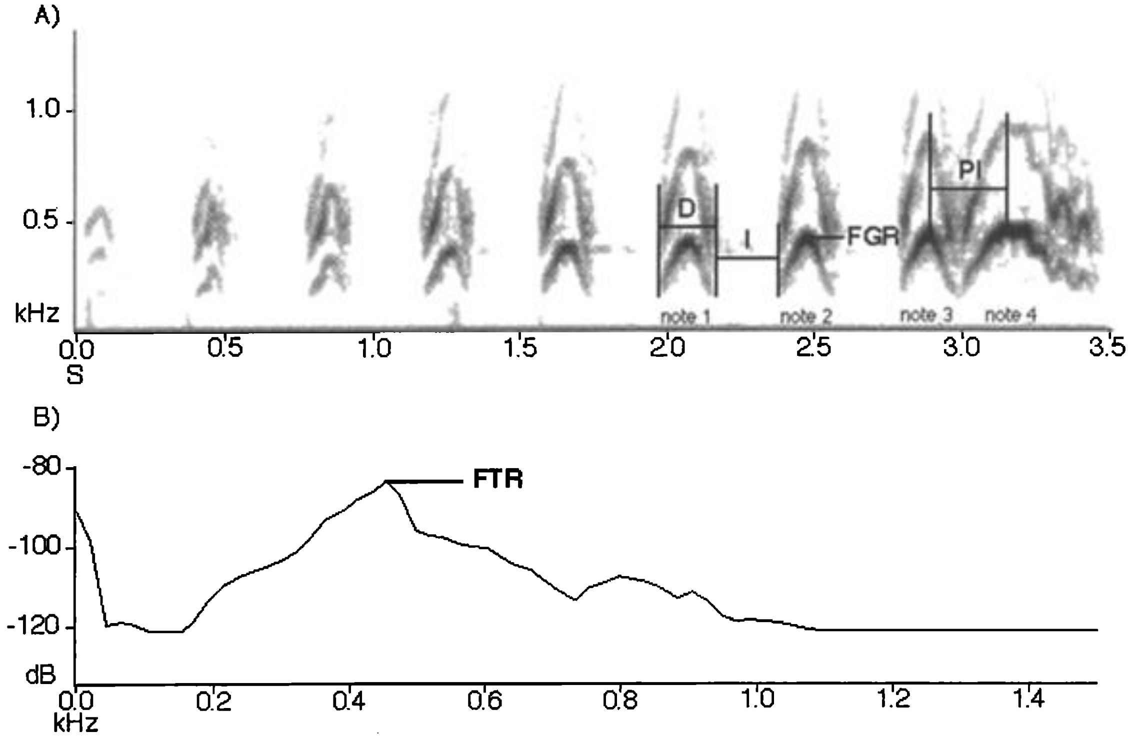

Figure 1. Spectrogram and spectrum of a Legato call from a male Barred Owl (Location K) showing examples of measurements. (a) Spectrogram measurements: D = note duration, I = note interval, PI = peak amplitude interval and FGR = peak amplitude frequency. (b) Spectrum of the entire call showing FTR = peak amplitude frequency.

conducted a separate analysis of variance (ANOVA) on each variable to determine if significant differences existed within and between locations. Variables were also plotted against recording dates to determine if characteristics of vocalizations changed over the breeding season.

To reduce the number of variables for the discriminate analysis, I performed a stepwise logistical regression (SLR) with the 15 locations from 1998. The SLR provided the concordant values and indicated the accuracy with which the regression model fit the data, or in this case, how well it could predict the location. The seven variables that were meaningful in identifying locations were then subjected to a Fisher's quadratic discriminate function analysis (DFA). A cross-validation technique was used to validate the model. The parameters from the 1997 data were not directly analyzed by a DFA owing to small sample sizes.

RESULTS

Observer Discrimination. Although spectrograms of Legato calls were easily recognizable in overall structure, there were differences between spectrograms from different locations. Examples of differences in note shape can be seen in spectrograms from locations A, C, D and H (Fig. 2). Spectrograms from location D exemplify consistency in note shape, frequency modulations and tempo between years.

When given the 1997 sample, each of the four observers successfully discriminated all eight folders into the correct four locations (100% correct, Table 1). For comparison, the Monte Carlo probability of earning a score of 4 (50% correct) or more by chance was <0.03. The ability of the four observers to discriminate the 45 folders of 1998 into their 15 locations varied from 38–87% accuracy ($\bar{x}$ = 64.8%; Table 1). For comparison, the probability of 11% or greater accuracy by chance alone was <0.03, while the probability of 22% or greater accuracy by chance alone was <0.0001. Observers reported that differences in tempo, accent, frequency, tonal quality and presence or absence of frequency modulations were important in auditory discrimination. Experienced and inexperienced spectrogram readers exhibited no apparent difference in ability to discriminate the calls.

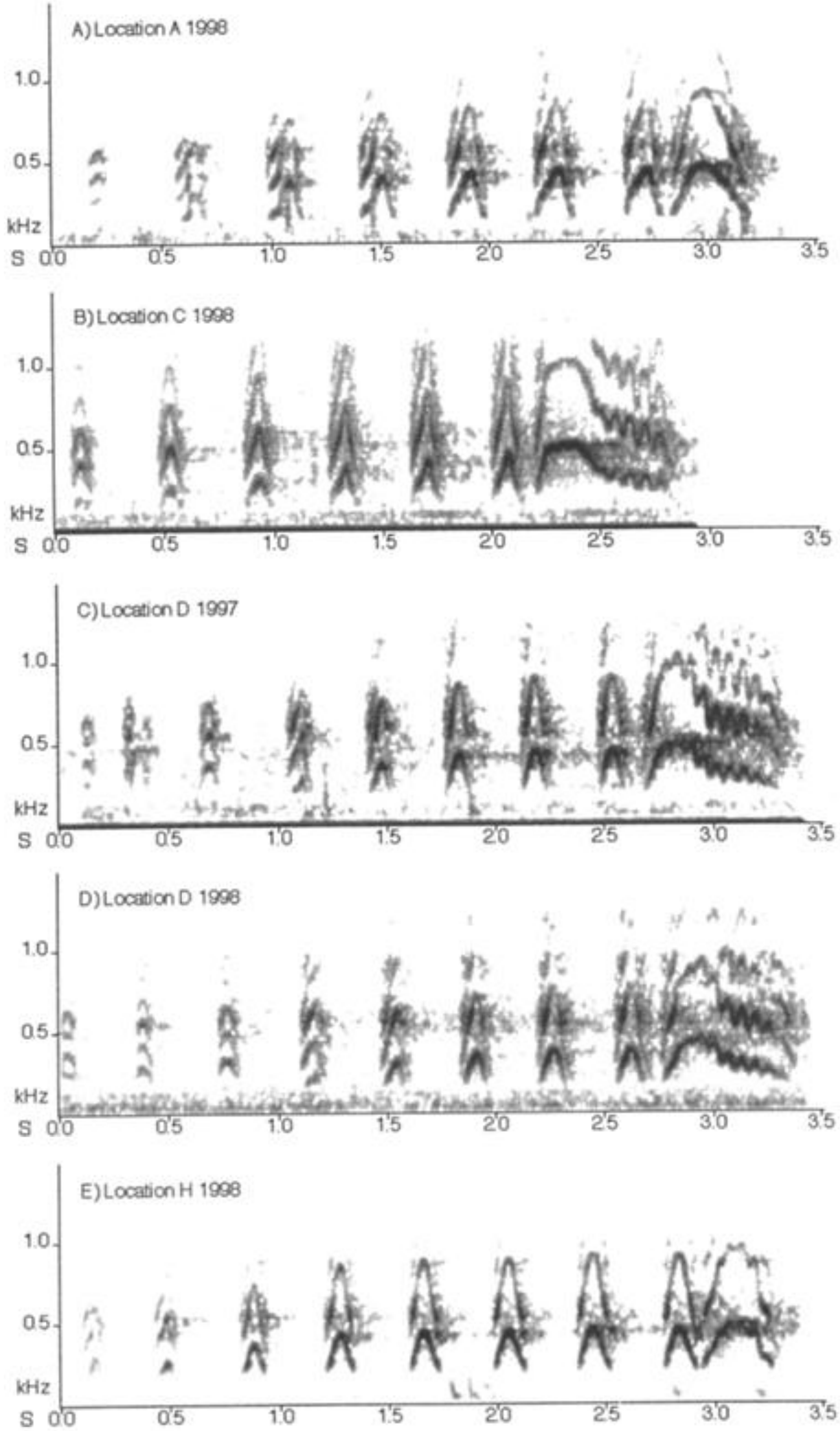
A) Location A 1998
B) Location C 1998
C) Location D 1997
D) Location D 1998
E) Location H 1998
1.0
0.5
kHz
S 0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Table 1. Human discrimination of Barred Owl calls and unmeasured spectrograms: number (%) correctly classified to four 1997 locations, each with two nights of calls; and number (%) correct for 15 locations of 1998, each with three nights of calls.

Year (Sample per Observer)	Experienced Observers		Inexperienced Observers	
	#1	#2	#1	#2
1997 ($N = 8$)	8 (100)	8 (100)	8 (100)	8 (100)
1998 ($N = 45$)	34 (76)	26 (58)	39 (87)	17 (38)

Spectrogram Measurements. Mean values of the 22 variables were plotted against each other and many locations overlapped when only two variables were considered (Fig. 3a). However, most locations could be discriminated when additional variables were considered. For example, compare the means of locations M and L in Figs. 3a and b.

Individual ANOVAs for both years indicated significant variation in parameters between locations ($P < 0.0001$ for every parameter except 1997 FGR3, where $P = 0.0022$). No variable showed any consistent seasonal trend.

The SLR revealed high concordant values (84.8–99.7%) for all locations. The seven variables most commonly shown by the SLR were used to create the DFA: D1, D4, I2, PI3, FTR1, FTR3 and FTR4. This mix suggested that it was not just one type of variable that was important for discrimination of locations but a combination of many.

The overall accuracy of the spectrogram classification in 1998 using the DFA was 84.5%. Using the DFA, over 90% of the spectrograms from locations B, C, H, I, J and O were correctly classified (Table 2). The cross-validation prediction accuracy for the DFA was also relatively high (72.8%).

DISCUSSION

Although birds in this study were not banded or radio tagged, previous work (Nicholls and Fuller 1987, Mazur et al. 1998) and my findings support the assumption that the same bird was recorded at the same location upon each subsequent visit. Spectrogram parameters did not exhibit any trend from February through May. Similarly, Galeotti and Pavan (1988) found that the vocalization characteristics of Tawny Owls (*Strix aluco*) did not change within a season.

The hypothesis that Barred Owls are individually identifiable by voice was supported by multivariate DFA analyses. The DFA accuracy rate in my study was similar to that recorded for Pygmy Owls (*Glaucidium passerium*) (84.6%, Galeotti et al. 1993) and was less than that for Tawny Owls (98.6%, Appleby and Redpath 1997; and 99.1%, Galeotti and Pavan 1991). Increasing the number of birds in a study increases the difficulty of correct classification, and I analyzed more calls and used approximately the same number of birds as the other studies (except $N = 50$ birds in Appleby and Redpath 1997).

The overall accuracy of human observers listening to calls and viewing unmeasured spectrograms was similar to the accuracy of the DFA for the quantified spectrograms. However, locations accurately discriminated by observers using Sortspects were not necessarily accurately classified by the DFA of measured spectrograms, and *vice versa*. This suggested that the two different techniques discriminated different characteristics. Some combination of qualitative and quantitative techniques (e.g., length of notes, tonal quality and appearance of notes) may yield higher accuracy.

Implications. Vocalizations of individual Barred Owls are distinctive. Individual identification probably allows birds to recognize and locate mates (Beer 1970). Birds that recognize their neighbors can also save time and energy because they do not have to continuously reestablish territory boundaries, which could increase the chance of injury or predation (Falls 1982). Such adaptations have been suggested for Tawny (Galeotti and Pavan 1991, 1993) and Pygmy Owls (Galeotti et al. 1993). Although I did not test the abilities of Barred Owls, I suspect that mates and neighbors recognize one another far more accurately than did the techniques of my study. Playback studies could perhaps determine the call components actually used by owls for discrimination.

In a preliminary study, I tried to determine if, from year to year, call components were retained

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Figure 2. Spectrograms of Legato calls from different locations and years. (a) Location A 1998. (b) Location C 1998. (c) Location D 1997. (d) Location D 1998. (e) Location H 1998.

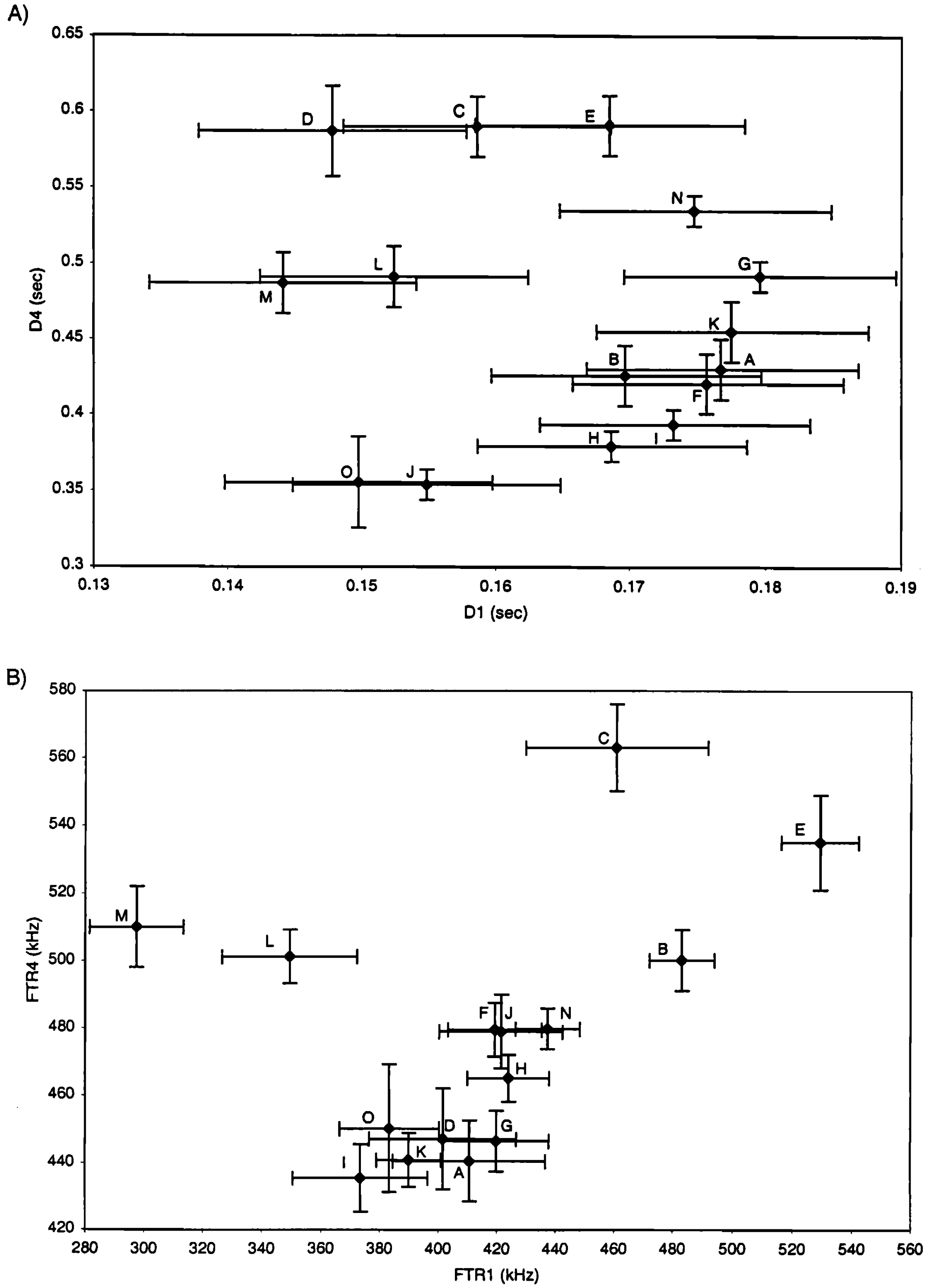
A)
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
D4 (sec)
0.13
0.14
0.15
0.16
0.17
0.18
0.19
D1 (sec)
D
C
E
N
L
M
G
K
B
A
F
H
I
O
J
B)
580
560
540
520
500
480
460
440
420
FTR4 (kHz)
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
FTR1 (kHz)
C
E
M
L
B
F
J
N
H
O
D
G
K
I
A

Table 2. Classification summary for 1998 spectrograms using discriminate function analysis (DFA).

Actual Location	No. Spectrograms Classified into Locations																% Correct
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Total	
A	28			1			2	1			4					36	78
B		32				1				1		1				35	91
C			33		2											35	94
D	1			32	2		2							2		39	82
E		1	3		28		1							5		38	74
F		1				27	1	1	1	1					1	33	82
G	1	1			1	1	36				1			1		42	86
H								33								33	100
I								2	33				1			36	92
J						1				30						31	97
K	3						4	2			30					39	77
L				1	2							22	8		2	35	63
M				1								6	25			32	78
N		2		1	2	1	1							31		38	82
O							2								27	29	93
Total	33	37	36	36	37	31	49	39	34	32	35	29	34	39	30	531	

and individual owls could be identified (Freeman 1999). Matching locations between years using spectrogram discrimination yielded encouraging results. Research needs to be done with marked birds to determine the consistency of vocalizations of individuals across years.

If further developed, vocal identification techniques could potentially gather certain information (e.g., home range size, population density, persistence of individuals, population turn-over) without the disturbance and cost of radio tagging, banding and handling of birds. Monitoring owls in this manner may also avoid some seasonal and weather-related biases associated with broadcast surveys. Maps of owl territories have been drawn from locations of individuals identified through spectrogram analyses (Galeotti 1990, Rohner 1996). At present, vocal identification techniques for Barred Owls are still intensive, but with further development they may become more efficient and less intrusive than traditional methods.

ACKNOWLEDGMENTS

I am grateful to G. Nuechterlein and D. Buitron for their support and suggestions on earlier manuscripts. I thank J.W. Grier and R. Magel for their support, the Sortspects volunteers, individuals at the University of Minnesota, both the Itasca Field Station and the Raptor Research Center, and the Department of Zoology at North Dakota State University. I also thank D. Kroodsma, J.C. Haney and one anonymous reviewer for constructive comments on the manuscript. This project was made possible through grants from the North American Bluebird Society; American Museum of Natural History, Frank M. Chapman Memorial Fund; Association of Field Ornithologists, Bergstrum Memorial Award; and North Dakota EPSCoR through grant #OSE-9452892.

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Figure 3. Means (±2 SE) for four of the seven variables measured on the Legato calls of male Barred Owls recorded from 15 locations in 1998. (a) Duration means D1 and D4. (b) Frequency means FTR1 and FTR4.

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Received 6 June 1999; accepted 28 December 1999