

Vocal individuality as a potential long-term monitoring tool for Western Screech-owls, *Megascops kennicottii*

T.M. Tripp and K.A. Otter

Abstract: Recent studies suggest that individually distinctive vocalizations found in many avian species can be used in population monitoring. In this study we assessed whether vocal identification of male Western Screech-owls (*Megascops kennicottii* (Elliot, 1867)) was possible, and if it could be applied as a long-term monitoring tool. Recordings were collected between 2001 and 2003 from 28 territories on southern and central Vancouver Island. As a quantitative descriptor of the calls, a total of 17 variables were measured from each of 1125 calls. A discriminant function analysis resulted in 92.3% of calls being correctly classified to individual territories within one season and 87.3% of calls in a cross-validation of the model. Variables that showed the greatest discriminant ability included length of call, internote distance between first note and second note, and number of notes per call. Of the 14 territories that had owl calls recorded over 2 years, 4 appeared to be occupied by a different individual in the 2nd year, 7 had calls that were consistent between years, and 3 had calls that were ambiguously classified between years. Our results suggest that Western Screech-owl calls have enough individually recognizable characteristics to aid in the tracking of individuals both within and between years, allowing for long-term monitoring of individuals.

Résumé : Des études récentes laissent croire que les vocalises individuelles distinctes qui existent chez plusieurs espèces d'oiseaux pourraient servir à la surveillance des populations. Nous évaluons dans notre étude la possibilité d'identifier par leurs vocalises les mâles du petit-duc des montagnes (*Megascops kennicottii* (Elliot, 1867)) et d'utiliser ces vocalises comme outil de surveillance à long terme. Des enregistrements ont été réalisés de 2001 à 2003 dans 28 territoires dans le sud et le centre de l'île de Vancouver. Pour décrire quantitativement ces vocalises, nous avons mesuré un ensemble de 17 variables dans chacun des 1125 appels. Une analyse des fonctions discriminantes associe correctement 92,3 % des appels faits dans une même saison à leur territoire correspondant et 87,3 % des appels dans un essai de validation croisée du modèle. Les variables qui offrent la plus grande valeur discriminante sont, entre autres, la longueur de l'appel, l'intervalle entre les deux premières notes et le nombre de notes par appel. Parmi les 14 territoires dans lesquels des appels du petit-duc ont été enregistrés au cours de 2 années, 4 sites semblent être occupés par un individu différent la 2^{ème} année, 7 ont des appels qui concordent pendant les 2 années et 3 ont des classifications ambiguës d'une année à l'autre. Nos résultats indiquent que les appels des petits-ducs possèdent suffisamment de caractéristiques individuelles identifiables pour servir à suivre les individus au cours d'une année et d'une année à l'autre, ce qui rend possible une surveillance à long terme des individus.

[Traduit par la Rédaction]

Introduction

The use of avian vocalizations to identify individual birds has become a well-established research method for studying secretive non-passerines (e.g., Galeotti and Pavan 1991; McGregor and Byle 1992; Galeotti et al. 1993; Appleby and Redpath 1996; Otter 1996; Peake et al. 1998; Delpont et al. 2002). Results have shown that vocal signatures can provide a reliable means of identifying individuals, with correct re-identification of individuals between observations

(based solely on primary territorial songs or calls) often exceeding 80% accuracy. These results suggest that long-term monitoring of some species may be possible using such naturally occurring variation.

There are a number of benefits to identifying individual birds through their vocalizations. First, by being able to identify individuals through song, a larger number of individuals can often be monitored than can be accomplished with other, more labour-intensive marking methods (McGregor et al. 2000). Although radiotelemetry and banding may provide higher (100%) confidence in individual re-identification, the potential of monitoring a greater number of males efficiently and economically with song makes vocal "tagging" attractive, especially when individuality is sufficient to approximate the same level of re-identification confidence. Vocal tagging is also less invasive than methods that require individual capture and handling, making it preferable if the species is difficult to capture or sensitive to handling (McGregor and Peake 1998; Terry et al. 2005). Identification of individuals can also provide increased accuracy during cen-

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suses in high-density regions over merely assuming each singer is a distinct individual, although this must be weighed against the extra time required for analysis (Gilbert et al. 1994). Finally, in combination with monitoring song rates of individuals, vocal behaviour can provide information about a bird's condition, which may provide an indirect measure of habitat quality (Godfrey 2003).

One recent application of vocal individuality to avian conservation biology is the identification of individuals over multiple years (long-term monitoring) (e.g., Peake et al. 1998; Galeotti and Sacchi 2001; Delpont et al. 2002; Terry and McGregor 2002). The use of vocal individuality as a means of monitoring site fidelity, turnover rates, and annual survival estimates has provided an opportunity that would otherwise be difficult for many species (Terry et al. 2005). This technique may be especially useful in studies of secretive or nocturnal birds where visual tags are of limited value and radiotelemetry can be limited by battery life and by difficulty in catching individuals. The Western Screech-owl (*Megascops kennicottii* (Elliot, 1867)) is such a species.

The Western Screech-owl is a nocturnal, secretive, long-lived, non-migratory species that is fairly common throughout most of its range in the Pacific northwest coast of the US and Canada (Johnsgard 1988; Cannings and Angell 2001). Capturing individuals is fairly time-consuming, limiting the number of males available for telemetry studies. In addition, the small size of the birds (<140 g, on average, for males; Gehlbach 2003) precludes the use of transmitters that have battery lives greater than a few months; this requires multiple recaptures for long-term monitoring of site occupancy. These owls, however, are highly vocal, especially during the breeding season, and readily respond to call broadcast surveys (e.g., Hardy and Morrison 2000; Cannings and Angell 2001, Herting and Belthoff 2001). These characteristics make the Western Screech-owl well suited for bioacoustic research, because little is known about populations, life history, and effects of land development on Western Screech-owls in Canada (Fraser et al. 1999; Cannings and Angell 2001; Chaundy-Smart 2002). Furthermore, several subspecies, such as *Megascops kennicottii macfarlanei* Brewster, 1891 in the south-central Okanagan region of British Columbia, are considered endangered because of habitat loss (Chaundy-Smart 2002). Techniques that allow long-term monitoring of populations, especially the turnover rate of individual territories in relation to habitat alteration, are essential for the conservation of the species.

The primary objectives of this study were (i) to determine the feasibility of individually identifying adult male Western Screech-owls using territorial vocalizations within a single breeding season and (ii) to determine whether vocal individuality could be used to estimate turnover rates at known territories between seasons (long-term monitoring). To achieve these objectives, we repeatedly recorded the singing behaviour of male owls resident on multiple territories on Vancouver Island, British Columbia, over a single breeding season to compare within-season variability in call characteristics. We then returned to these sites over three successive breed-

ing seasons and recorded the vocal activity of resident males to determine whether vocalizations remained stable between years at the same territories.

Materials and methods

Between 2001 and 2003, males were recorded from 28 sites on southern (Victoria and Duncan) and central (Campbell River) Vancouver Island, British Columbia (48°N, 123°W). The elevation ranged from 50 to 450 m and the sites are in a northern hemisphere coastal rainforest (coniferous and mixed) habitat, with varying levels of development. A Marantz PMD430 cassette recorder (Marantz, Scarborough, Ontario), and Sennheiser MKH70 or ME67 microphone (Sennheiser, Pointe Claire, Quebec) were used to collect recordings during the breeding seasons (mid-February to mid-May each year), between 1700 and 0300, and at optimal conditions (low wind, no rain).

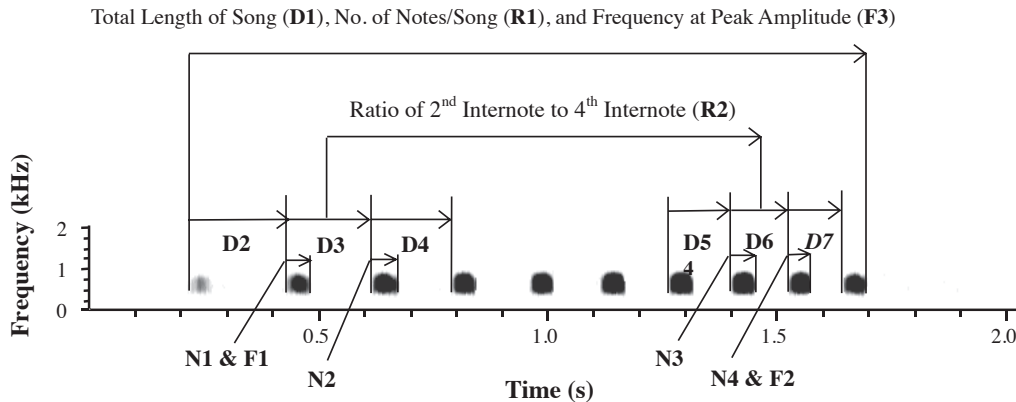
Initial surveys were conducted each year to confirm the presence of calling males at each of the known territories. A standardized call broadcast was used to elicit a response from territorial males. The broadcast consisted of five territorial calls of a conspecific that were evenly spaced over 1 min and was followed by a 2 min listening period. This procedure was repeated up to three times for a total of 3 min of broadcast (15 calls). If a bird was detected, broadcast was stopped after the 1 min interval was completed. A minimum of 15 min was spent at each site to maximize the likelihood of detection.

Male Western Screech-owls are known to occupy their territories year-round (non-migratory) (Cannings and Angell 2001); therefore, it is extremely likely that once a territory was located, the same male would occupy it for at least a single season. We were confident that we had recorded the same male within and between nights at the same site within a season because of (i) repeated presence of a calling bird at the same location, generally within 100 m of previous calling locations, (ii) identification of nest and (or) roost trees, (iii) distance between recording sites exceeded the average territory diameter for the species (recording sites were separated by a mean of 2.92 km, with a range from 0.90 to 8.42 km), (iv) low likelihood of changes in territory occupancy (turnover) within a season based on banded population studies (J. Belthoff, personal communication (2004)), and (v) unique vocal characteristics among some males that could be easily distinguished by the observer (e.g., presence of unusual syllables in the call). As part of a separate study, two male Western Screech-owls included in our data sets that were captured in 2003 were monitored via back-pack-mounted radio transmitters over a single breeding season. Subsequent relocations confirmed that both males remained within the same area where they were captured (data in Doyle and Pendergast 2004²), thereby lending support to our assumption that the same bird occupied the same territory within a breeding season.

To account for potential seasonal variation in territorial call structure, we attempted to record males at each known territory on multiple occasions within a single season (2001:

²D. Doyle and S.R. Pendergast. 2004. Radio-telemetry studies of Western Screech-Owl and Northern Saw-whet Owls in the Campbell River Watersheds. Unpublished report for the British Columbia Conservation Foundation, Nanaimo, and Ministry of Water, Land and Air Protection, Nanaimo.

Fig. 1. Spectrogram of a Western Screech-owl's (*Megascops kennicottii*) primary territorial call with variables measured for vocal individuality: D1 (total length of call), D2–D7 (internote distances), N1–N4 (note length 1–4), R1 (number of notes per call), R2 (ratio D3/D6), and R3 (number of notes per second; not shown). Frequency measurements included F1 (mean frequency of second note), F2 (mean frequency of second-to-last note), and F3 (frequency at peak amplitude).



mean = 2.25 recording nights/territory, range = 1–6, $n = 8$; 2002: mean = 2.81 recording nights/territory, range = 1–8, $n = 22$; 2003: mean = 1.63 recording nights/territory, range = 1–6, $n = 22$). Overall, 13 of the 28 sites used for the vocal individuality analysis were recorded more than once within a single season (2001–2003: mean = 2.17 recording nights/territory, range = 1–6, $n = 28$). The two radio-tagged males were among this group and were recorded on at least two nights to compare vocalizations from known individuals for seasonal variation.

Spectrographic analysis and measured variables

Recordings were reviewed for high-quality calls from each territory (typically <25 m from the bird). The territorial calls were then digitized for vocal individuality analysis using Avisoft SAS-Lab Pro version 2.6 (Specht 1993). To reduce background noise, calls were filtered above 1000 Hz and below 300 Hz for all individuals, thus avoiding the actual call frequency range of males (400–750 Hz). Variables were measured on screen using spectrogram parameters for frequency variables set at a resolution of 20 Hz, Faus-Fourier transform (FFT) length of 512, bandwidth of 56 Hz, and temporal resolution of 2.9 ms. Temporal variables were measured using the wide bandwidth setting (324 Hz).

The territorial call was selected for analysis because it was the most frequently heard vocalization from this species in response to a conspecific broadcast. This vocalization consists of a series of 6–20 notes, with note spacing speeding up towards the end to create the “bouncing ball” effect (Johnsgard 1988; Cannings and Angell 2001). A total of 17 variables was measured for each territorial call, including the number of notes per call (R1), call speed (a ratio of the second internote distance (i.e., D3) to the penultimate internote distance (i.e., D6) measured, R2), number of notes per second (R3), total length of call in milliseconds (D1), six internote distance measurements (D2–D7), four note length measurements (N1–N4), average frequency at start of call (F1), average frequency at end of call (F2), and frequency at peak amplitude of call (F3) (measured in Hertz) (Fig. 1).

Temporal and frequency variables included in the analysis were typical of those measured in other vocal individuality studies of non-passerines (e.g., Galeotti and Pavan 1991;

Appleby and Redpath 1996; Otter 1996; Delport et al. 2002). To capture one of the common call characteristics of the territorial call, R2 was included to provide the greatest contrast of distance between notes at the start and finish. We chose the second and penultimate internote distances, rather than the first and last, to improve accuracy; the first, and sometimes the last, notes of the call are often quieter than the remaining notes, and as such can be subject to loss or degradation in more distant recordings.

Statistical analyses

Vocal individuality within a season

To investigate within-season vocal individuality in territorial male Western Screech-owls, a forward stepwise discriminant function analysis (DFA) (p -to-enter = 0.05) was conducted on the variables measured from each male's call using STATISTICA[®] version 6.0 (StatSoft Inc. 2002). A general lack of model cross-validation was considered to be a weak point in previous vocal individuality DFAs (Terry et al. 2001). We addressed this issue by using two data sets, one subset of calls from all individuals to build the model (learning set) and another subset to test it (test set). The use of a test set lends support to the ability of the model to accurately classify individual calls, as none of the test calls were included in the learning set that derived the discriminant equation. While this often lowers the percentage of individuals with correctly classified calls, the cross-validation provides for a more robust assessment of the model's discriminant ability.

Within the DFA, all 17 territorial call variables were assessed for their ability to correctly classify individuals to their territory of origin. The DFA selected the most significant variables and added them sequentially until it determined that adding extra variables did not result in significantly better discrimination (Manly 1994; Quinn and Keough 2002). Variables that were highly correlated and that did not provide additive variability were excluded from the resultant model (StatSoft Inc. 2002).

Calls were randomly selected for analysis from high-quality recordings. A mean of 29.9 territorial calls (range 28–30) per site ($n = 28$ birds in total), representing a single season

of recording, was included in the analysis for a total of 837 territorial calls. To provide enough cases to develop a test set for cross-validation of the model, we aimed for a larger sample size than earlier bioacoustic research (e.g., mean = 19.5 calls/male (range of 10–35 calls for each of 10 Eurasian Pygmy-Owls, *Glaucidium passerinum* (L., 1758); Galeotti et al. 1993); mean = 8 calls/male (range of 4–30 calls from each of 17 Tawny Owls, *Strix aluco* L., 1758; Galeotti and Pavan 1991); mean = 20.5 calls/male (range 7–30 calls from each of 24 Eastern Screech-Owls, *Megascops asio* (L., 1758); Cavanagh and Ritchison 1987)). A subset of the calls (561 in total, 18–20 calls/individual) was used in the learning set to derive the discriminant model, with the remaining calls forming the test set. Where possible, the learning set included calls recorded at the same territory from different nights within the same breeding season. The use of calls from different nights and bouts of recording was intended to account for the potential variability that might exist within an individual's call throughout the breeding season. A bout of calling was defined as complete when greater than 1 min of silence was observed between two successive territorial calls.

As the majority of owls included in the study were unbanded, there is the possibility that territorial turnovers within a season would add to variation in our data set; i.e., two different males occupying the same site could be classified as the same bird. Based on the criteria outlined previously, this scenario was probably unlikely but still feasible. To account for this potential, we conducted two DFAs — one on territories with multiple recording nights ($n = 13$ birds, 390 call samples, mean = 30 calls/site) and a second on territories with a single recording night ($n = 15$ birds, 447 call samples, mean = 29 calls/site). In the latter data set, the calls were recorded during continuous tracking of a single individual, so the identity of the caller had nearly 100% confidence; if results of identifying individuals in the two analyses are similar, it would suggest high stability within season. F -to-enter was increased to 5.0 to reflect the reduced number of territories in the analysis (smaller sample size) in relation to number of variables ($p = 0.05$).

For territories that had multiple recordings (mean = 3.61, range = 2–6 recording nights/site) within a single breeding season, calls from a different recording night, not included in the learning set, were used to test the model. This enabled us to examine whether call structure of birds from territories with multiple recording nights in the model were comparable to re-identify (similar correct classifications) birds from territories with only a single recording sample. This also provided a means by which to test whether calls recorded on a different day, week, or month varied enough to affect the overall discriminant ability of the model for a given territory.

For sites that were only recorded once, a mean of 20 calls were randomly selected for use in the learning set. The remaining third of the cases was used as a test set (9–10 calls/site, for a total of 276). Following the two DFAs, a regression analysis was conducted to determine if there was a relationship between the number of nights of recording included in the DFA model and the percent classification that resulted. A regression analysis was also conducted to test for the percentage correctly classified in relation to the number

of bouts included in the DFA model (i.e., did the number of calling bouts recorded in a given night influence the classification of calls from that territory in the DFA model).

Re-identification among seasons

We used the data for within-season cross-classification of calls to a particular territory to determine the upper threshold for assigning calls recorded across seasons as originating from the same individual. If the variation is high enough for the individualization of calls, however, the calls of two different individuals at the same territory should randomly cross-assign at low rates. To test this theory, the 28 sites used in the within-season analysis (above) were randomly cross-assigned to create 14 sites in a learning set and 14 different sites as a test set. This control test was conducted twice for a total of 28 different territory combinations (i.e., to mimic the 28 sites in the within-season DFA used to establish the upper threshold). The lower threshold criterion, used to indicate turnover between years, was determined based on these results.

A forward stepwise DFA was used to investigate whether vocal identification of individuals could be applied to determine territory turnover between years. Fourteen territories were successfully recorded over more than one breeding season. Data from the larger sample size year were used as the learning set to derive the discriminant model (28–30 calls/individual, 408 in total), and these were typically recorded in 2001 or 2002. Calls recorded from a 2nd year were used to test the model. An additional 288 calls (mean = 20.85 calls/individual, range 15–30) were measured from a 2nd year of recording to build the test set. In three cases, between-year comparisons were not in chronological order (sites 1, 7, and 21). For example, in 2002, site 1 had a sample size of 21 calls, but in 2003 a larger sample size of 30 calls was obtained; therefore, year 2003 was used as “year 1” in the model and 2002 was “year 2” in the test set. If calls were stable between years, then returning males should have had relatively high cross-classification between breeding seasons. We then proceeded to run a forward stepwise DFA ($n = 14$ sites, F -to-enter = 1.0, $p = 0.05$).

Twelve additional territories were included in a separate DFA as a form of control to test the classification performance of the model for sites that were known to contain different birds between years. Including control cases was intended to demonstrate that two randomly assigned territories would have low cross-classification that was similar to the within-year control set used to set lower limits (above), thus confirming the ability of the model to recognize individual territory occupants that differed between years. The control set was created by randomly selecting 12 territories not already used in the cross-year comparisons, and then randomly assigning two territories to each other. This design created six known false matches between years. We then proceeded to run a forward stepwise DFA ($n = 6$ sites, F -to-enter = 5.0, $p = 0.05$).

Results

Accounting for seasonal variation

The discriminant function analysis that was conducted to investigate consistency in calls within a single recording ses-

Table 1. Results of within-year discriminant function analysis for vocal individuality in the male Western Screech-owl (*Megascops kennicottii*) territorial call within a single breeding season on southern Vancouver Island ($n = 28$).

Site No.	Year	No. of days/ no. of bouts	No. of calls sampled	Percentage of calls correctly classified (learning set)	Percentage of calls correctly classified (test set)
1	2003	4/4	30	95.0	100.0
2	2002	3/6	30	100.0	60.0
3	2002	4/6	30	100.0	80.0
4	2001	2/3	30	95.0	100.0
5	2002	1/5	30	75.0	80.0
6	2002	1/2	29	100.0	77.8
7	2003	1/1	30	100.0	90.0
8	2002	1/1	30	75.0	70.0
9	2001	1/1	30	85.0	80.0
10	2001	1/3	30	100.0	90.0
11	2002	1/1	30	100.0	100.0
12	2002	1/3	30	100.0	100.0
13*	2003	2/3	30	95.0	80.0
14*	2003	2/5	30	100.0	80.0
15	2003	1/2	30	95.0	100.0
16	2002	1/3	30	100.0	100.0
17	2002	6/12	30	75.0	60.0
18	2002	6/8	30	80.0	100.0
19	2002	5/6	30	100.0	100.0
20	2003	1/2	30	95.0	70.0
21	2001	6/6	30	95.0	100.0
22	2002	2/2	30	85.0	70.0
23	2002	2/2	30	90.0	90.0
24	2001	1/1	28	90.0	100.0
25	2003	1/1	30	100.0	100.0
26	2001	3/3	30	75.0	80.0
27	2001	1/2	30	90.0	90.0
28	2003	1/1	30	95.0	100.0
Total		61/93	837		
Mean		2.2/3.3	29.9	92.3	87.3

*Site where individual identification was confirmed by radiotelemetry during recordings.

sion at a known territory (guaranteed to be the same male) resulted in correctly classifying 96.3% of calls (range of 75%–100%) from the learning set and 91.8% of calls (range of 70%–100%) from the test set. Three variables relating to note length (N1, N3) and internote distance (D4) failed to enter the model owing to low discriminant ability. Similar high correct classifications occurred in a separate DFA analysis on territories with multiple recording sessions within a single breeding season, with 95.8% (range of 75%–100%) of calls being correctly classified in the learning set, which was used to develop the model. Cross-validation of the model with the test set of calls from different recording sessions resulted in a correct classification of 87.3% (range of 60%–100%) of the calls. Four variables (frequency at start of call (F1) and three measures of note length (N2, N3, and N4)) failed to enter the model following forward stepwise analysis.

Results of the regression analyses indicated no relationship between the number of nights of recording and the correct classification rates of individuals for either the learning ($r^2 = 0.045$, $p = 0.278$) or test ($r^2 = 0.002$, $p = 0.792$) sets. The regression analysis for the percentage of correctly classified calls in relation to the number of bouts included in the

DFA also resulted in no significant relationship ($r^2 = 0.061$, $p = 0.202$ for the learning set; $r^2 = 0.078$, $p = 0.149$ for the test set). As there appeared to be no effect of the number of nights over which recordings were collected on the percentages of correctly classified calls, the two data sets were combined for the final within-season DFA.

Vocal individuality within a season

The final discriminant function analysis was conducted for all individuals ($n = 28$ individuals, 837 calls in total, F -to-enter set = 1.0, $p = 0.05$, 17 variables). Of the 28 sites included in the analysis, the model was able to correctly classify 92.3% of the 561 calls contained within the learning set (from 75% to 100%) to the site of origin (Table 1). The cross-validation resulted in a slightly lower classification of 87.3% of the 276 calls contained in the test set (from 60% to 100%) being correctly assigned to the site of recording. For the two males with radio transmitters, a classification of 95% and 100%, respectively, occurred for the learning set (recordings from night 1; Table 1). In the test set both sites performed at 80% (all test-set cases were from a second night of recording). The main discriminating variables of the territorial call were the total length of the call (D1), number

Table 2. *F*-to-enter values of variables included in the discriminant function model for vocal individuality in the male Western Screech-owl territorial call within a single breeding season on southern Vancouver Island ($n = 28$, F -to-enter = 1.0, $df = 27$, $p = 0.05$, 17 variables entered).

Variable	<i>F</i> -to-enter	<i>p</i>
D1 (total length of call)	39.83	<0.001
R1 (no. of notes / call)	39.58	<0.001
D2 (internote distance between note 1 and note 2)	28.28	<0.001
R2 (ratio of second internote to fourth internote measure)	24.97	<0.001
D4 (internote distance between note 3 and note 4)	22.40	<0.001
R3 (no. of notes / s)	17.61	<0.001
D3 (internote distance between note 2 and note 3)	15.29	<0.001
D6 (internote distance between third from last note and second from last note)	15.20	<0.001
F3 (frequency at peak amplitude)	12.13	<0.001
F1 (mean frequency at start of call, note 2)	9.74	<0.001
D5 (internote distance between fourth from last note and third from last note)	8.20	<0.001
D7 (internote distance between last two notes)	7.54	<0.001
N1 (length of second note)	5.38	<0.001
F2 (mean frequency at end of call)	4.90	<0.001
N4 (note length of second from last note)	4.86	<0.001
N3 (note length of third from last note)	3.52	<0.001
N2 (note length of third note)	3.47	<0.001

Note: *F* values are listed in order of greatest to least in its discriminant ability in the model.

of notes per call (R1), and the internote distance between note 1 and note 2 (D2) (Table 2). The four measures of note length (N1–N4) and the mean frequency at end of call (F2) had the lowest discriminant ability (*F* values of 3.47–5.38; Table 2).

Re-identification among seasons

As 60% was the lowest correct classification among territories in the cross-validation test sets within-year, we considered $\geq 60\%$ to be a reasonable criterion (upper threshold) for re-identification between breeding seasons (years), as it would allow for minor variation across years in call structure. The 28 randomly cross-assigned control cases included in a DFA to determine turnover criterion (lower threshold) performed at a mean of 4.6% cross-classification (range 0%–50%), with 26 of 28 (93%) of the control cases classified at $\leq 30\%$ in the DFA. We therefore predicted that territories with classifications $\leq 30\%$ between years likely represented a new individual occupying the site.

The discriminant model for the first year of recordings correctly classified 88.8% of the calls to their territory of origin. Recordings collected from the same territories in year 2 had a similar level of discrimination within a single season (90.7% correctly classified calls) (Table 3). Use of year 1 calls as the DFA learning set, and year 2 calls from the same territories as the test set, resulted in only 52.8% of calls being classified to their territory of origin (Table 3, Fig. 2). Eleven of the 14 sites (78.6%) unambiguously fell into either the $\geq 60\%$ or the $\leq 30\%$ cross-assigned category. Four sites appeared to be occupied by a different individual in the 2nd year, based on call classifications of 0%–15% between years, which was well below the pre-set limit of $\leq 30\%$ cross-classification. In contrast, high call classification at seven additional sites suggested that the same bird was present between years (60%–100% correctly classified calls between years). Results for the remaining three sites were ambiguous: site 9 (40%) and sites 18 and 21 (45%)

(Table 3). The DFA conducted on six control sites resulted in a mean of 3.3% cross-classification (range 0%–20%), suggesting that the technique would be sensitive in detecting turnover.

Discussion

We found a high ability to discriminate individual Western Screech-owls by territorial calls within a breeding season; i.e., 87% of test calls were correctly classified against a discriminant function model that was built using a learning set of calls from the same individuals. Our results are thus comparable with several other owl species that have been tested for individual variability (e.g., 80%–96% with Wood Owls, *Strix woodfordii* (A. Smith, 1834) (Delpont et al. 2002); 84% with Eurasian Pygmy-Owls (Galeotti et al. 1993); 99% with Tawny Owls (Galeotti and Pavan 1991); 88%–92% with Scops-Owls, *Otus scops* (L., 1758) (Galeotti and Sacchi 2001); and 84% with Queen Charlotte Saw-whet Owls, *Aegolius acadicus brooksi* (J.H. Fleming, 1916) (Holschuh and Otter 2005)). As the calls being classified were not part of the data set used to build the discriminant model, it suggests that the ability to identify male owls throughout a breeding season by call alone is very robust. Discriminant ability was nearly equivalent when calls used in the classification were taken from a single night (where continuous recording allowed nearly 100% certainty that calls were from the same male) or multiple nights across the season, suggesting that call structure does not change appreciably across a single season. The fact that average call classification (87%) exceeded the between-night classifications of two radio-tracked owls (both 80% correctly classified by call alone) also suggests that the recordings taken at night can be used to accurately re-identify individuals within-season.

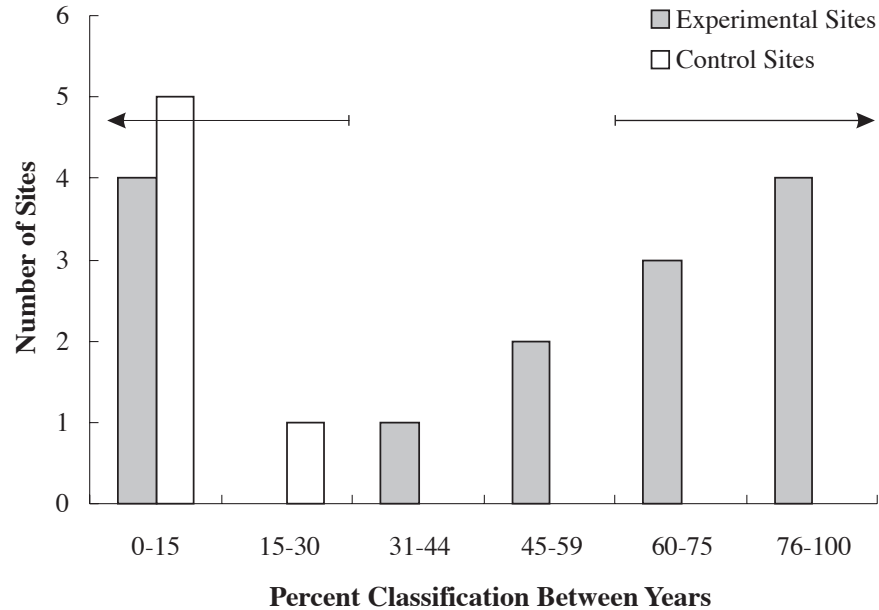
By comparison, the variability of the calls between years may be slightly greater, leading to ambiguity in a few cases

Table 3. Results of discriminant function analysis for vocal individuality between years in the male Western Screech-owl territorial call on southern Vancouver Island ($n = 14$).

Discriminant model (year 1)					Test set (year 2)						
Site No.	Year	No. of days / no. of bouts	No. of calls	Percentage of calls correctly classified	Site No.	Year	No. of days / no. of bouts	No. of calls	Percentage of calls correctly classified	Percentage of calls correctly classified between years	Turnover
1	2003	4/4	30	93.3	1	2002	1/1	21	95.2	81.0	No
2	2002	3/6	30	86.7	2	2003	1/1	20	85.0	60.0	No
3	2002	4/6	30	90.0	3	2003	2/2	20	95.0	80.0	No
4	2001	2/3	30	100.0	4	2002	4/6	30	100.0	93.0	No
5	2002	1/5	30	86.7	5	2003	3/3	20	85.0	15.0	Yes
7	2003	1/1	30	100.0	7	2002	1/5	19	100.0	5.3	Yes
8	2002	1/1	30	70.0	8	2003	4/4	20	85.0	10.0	Yes
9	2001	1/1	30	83.3	9	2003	1/1	20	65.0	40.0	?
17	2002	6/12	30	73.3	17	2003	1/1	15	100.0	66.7	No
18	2002	6/8	30	100.0	18	2003	2/2	20	95.0	45.0	?
20	2003	1/2	30	86.7	20	2002	1/1	15	86.7	66.7	No
21	2002	6/6	30	93.3	21	2003	2/2	20	95.0	40.0	?
22	2002	2/2	30	86.7	22	2003	1/1	20	100.0	0.0	Yes
24	2001	1/1	28	100.0	24	2003	1/1	28	100.0	100.0	No
<i>n</i>		39/58	418				25/31	288			
Mean		2.7/4.1	29.9	89.2			1.7/2.2	20.6	92.4	52.8	
11*	2002	1/1	30	100.0	10*	2001	1/2	20	100.0	0.0	
12*	2002	1/3	30	100.0	25*	2003	1/1	20	95.0	0.0	
15*	2003	1/2	30	100.0	16*	2002	1/3	20	100.0	20.0	
27*	2001	1/2	30	100.0	13*	2003	2/2	20	100.0	0.0	
28*	2003	1/1	30	100.0	14*	2003	2/3	20	100.0	0.0	
6*	2002	1/2	29	100.0	23*	2002	2/2	20	100.0	0.0	
<i>n</i>		6/11	179				9/13	120			
Mean		1.0/1.8	29.8	100.0			1.5/2.1	20	99.2	3.3	

*One of six control cases from different site locations and individuals between years.

Fig. 2. Distribution of classified calls between years for male Western Screech-owl territories on southern Vancouver Island. “Re-occupancy” was assigned when $\geq 60\%$ of calls recorded in the 2nd year were classified to the same territory recorded in the 1st year (arrow to the right). A potential turnover was indicated when $\leq 30\%$ of the calls were classified to the same territory (arrow to the left). Six control sites were also compared for classification of known false matches (open bars).



when attempting to monitor male return rates between years based on call structure alone. Our results indicated a turnover in territory occupancy between 28% (based on the four cases with $\leq 30\%$ cross-classification) and 50% (based on seven sites with $< 60\%$ cross-classification between years). The performance of the control cases (all at 0%–20% correctly classified calls between years) indicated that we may have set the upper threshold of $\geq 60\%$ cross-classification between years too high. Based on our knowledge of Western Screech-owl behaviour (non-migratory and territorial year-round), a low turnover rate would have been anticipated. This data set represents only a single year “snapshot”, however, and thus conclusions on rates of territorial turnover will require a greater number of sampling years; the more important result is that the use of vocal individuality may allow us to track birds across years to build such a database. In a similar study, Holschuh and Otter (2005) found that vocal individuality could be used to monitor site fidelity and turnover rates for Queen Charlotte Saw-whet Owls, with correct classification $> 60\%$.

Little is known of annual survival or site turnover rates in screech-owls. Breeding Western Screech-owls banded at nest boxes in southern Idaho were observed to have a mean life span of 1.73 years (range 1–8 years, $n = 48$) for females and 1.83 years (range 1–8 years, $n = 30$) for males (Cannings and Angell 2001). Similar studies with Eastern Screech-Owls observed annual survival of 59% in suburban areas and 55% in rural areas (Gehlbach 1994), and 61%–67% annual survival for all adults in northern Idaho (Van Camp and Henny 1975). Our results are quite similar to the observations of these banded populations, with a range of 28%–50% turnover based on call structure alone.

One of the key assumptions in this research was that calls remained stable between years. Research has shown that non-passerines have stable vocalization structure between

years, with less variation within than between individuals (Cavanagh and Ritchison 1987; Galeotti et al. 1993; Appleby and Redpath 1996; Hill and Lill 1998; Peake et al. 1998; Delpont et al. 2002), but see Puglisi and Adamo (2004). Recent results of long-term monitoring of Common Loons (*Gavia immer* (Brunnich, 1764)) (Walcott et al. 2006), however, observed changes in individual call structure for males that switched territories. Despite this, call structure for males that remained on the same territory changed little. The vocalizations of some owls are innate (see review in Delpont et al. 2002), further suggesting that these vocalizations may remain stable over time. A certain level of variation between years is expected, but overall the differences within birds should be far less than between birds. Environmental effects may cause small differences in recordings between seasons, as noted by Delpont et al. (2002). High-quality recordings are therefore essential for between-year comparisons. To ensure consistent measurements, only examples of calls in which all notes are clear and sharp should be used for analysis.

Our results indicated that the DFA technique was highly reliable in identifying individuals within a season and appears sufficiently robust to assist researchers in long-term monitoring of Western Screech-owls. It is unknown how typical it would be for this non-migratory species to switch territories, and if a change in territories would influence an individual’s territorial call. However, even if males do change call structure during territory switch, there is no evidence that they would necessarily converge on the call of the previous resident. Walcott et al. (2006) found that the change in Common Loon calls after territorial shifting actually resulted in higher differences between the calls of new and previous residents, suggesting that the calls may be aiding in distinguishing a new owner. If parallel results occurred among Western Screech-owls, we would expect to

find even greater discriminatory ability to detect that a turnover had occurred. Further research, especially cross-validation with individual banding, but also measuring factors that may contribute to vocal variability between years, is required to reach the full potential of vocal individuality as a long-term monitoring tool. The addition of a qualitative spectrogram assessment, especially for ambiguous classifications, may also provide a useful confirmation of quantitative re-identification between years as applied by Galeotti and Sacchi (2001).

A number of papers have indicated the potential use of vocal individuality for long-term monitoring of avian species, but few have actually applied it with this purpose in mind (Eakle et al. 1989; Galeotti et al. 1993; Galeotti and Sacchi 2001; Peake and McGregor 2001; Rebbeck et al. 2001; Delpont et al. 2002; Gilbert et al. 2002; Terry and McGregor 2002; Holschuh and Otter 2005; Walcott et al. 2006). Of direct application to species conservation is the understanding of turnover rates within a given population, which could provide information on population trends, and reflect habitat quality and availability. Based on the accuracy of vocal tagging in some species, plus the potential to monitor aspects of individual condition and territory quality through song or call (Godfrey 2003), the addition of vocal individuality to current inventory and monitoring methods for Western Screech-owls would be useful for conservation efforts.

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