DECLINING NUMBERS OF WESTERN SCREECH-OWL IN THE LOWER MAINLAND OF BRITISH COLUMBIA

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Abstract—During 1998-2002, I visited 22 locations in the Lower Mainland where Western Screech-Owls (*Megascops kennicottii*) were known to occur. I visited each location five or more times and used playback tapes to attract screech-owls. There were positive responses from five locations during the first portion of the study, but by the end of the study, I concluded that screech-owls had disappeared from all 22 locations. Christmas Bird Count data from 1988 to 2004 indicate that on Vancouver Island, screech-owl numbers declined at an average annual rate of 17% while those in the Lower Mainland declined at an average annual rate of 32%. Screech-owls declined earlier for those Christmas Bird Counts which showed an earlier increase in Barred Owls (*Strix varia*) and for those which showed the greatest final number of Barred Owls (i.e. post-invasion). By combining my data with those of Robertson *et al.* (2000), I found that screech-owls were detected more often in fragments of forest that were smaller than approximately 20 ha. I therefore concluded that screech-owls were rapidly disappearing from the Lower Mainland and that the likely causes were predation by Barred Owls, in conjunction with increased competition for cavities and habitat loss.

Key Words: Western Screech-Owl, *Megascops kennicottii*, Barred Owl, *Strix varia*, predation, population decline, habitat, competition.

The Western Screech-Owl (*Megascops kennicottii*) was once one of the most common birds in southwestern British Columbia, inhabiting virtually every forested area, from old-growth to urban woodlots. For example, Setterington (1998) found it to be the most abundant owl species in the Nimpkish Valley. However, screech-owls seem to have recently disappeared from many locations.

Many birders have commented on the precipitous decline of Western Screech-Owls in southwestern British Columbia. On Vancouver Island, screech-owl numbers apparently declined or disappeared during the 1990s from parts of Newcastle Island and the Nanaimo, Duncan and Victoria areas (Chaundry-Smart 2002). At the University of Victoria campus there are no longer any pairs present although up to 13 pairs bred there during the 1970s (Levesque 2000). In the Lower Mainland, screech-owls declined at Pacific Spirit Park, where at least four pairs occurred during the 1980s (pers. comm., R. Cannings, Penticton, B.C.). They also disappeared completely from Campbell Valley Park (Chaundry-Smart 2002). G. Clulow (Burnaby, B.C., pers. comm.) surveyed 14 locations in central Burnaby (Deer and Burnaby Lakes and Byrne Creek corridor) for screech-owls during 2004 without finding any. He estimated that the region supported about 10 pairs prior to the mid 1990s. His last record was 23 March 1998, at Deer Lake, although most individuals had disappeared at least two years previously. Robertson *et al*. (2000) surveyed 26 locations in the Lower Mainland during 1995-98 and found screech-owls at 46% of these locations. Wildlife Data Centre records also show a decline in urban areas (Preston and Campbell 2004). However, Preston and Campbell (2004) claim that screech-owl range has expanded elsewhere on the coast because the number of 1:50 000 grids with screech-owl records at the Wildlife Data Centre has increased since 1943, although they do not correct for increased observer coverage. Despite evidence for a decline in screech-owl populations, Chaundry-Smart (2002) considered populations of the coastal subspecies *M. k. kennicottii* to be large and stable enough to remain unlisted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which currently lists it as a species of "Special Concern". The Interior form *M. k. macfarlanei* is listed as Endangered because of its small and declining population size (Chaundry-Smart 2002).

Three reasons for screech-owl declines have been advanced and are discussed immediately below.

(1) Predation by larger owls (Cannings and Angell 2001; Chaundry-Smart 2002). Robertson *et al.* (2000) noted that at most sites where they detected screech-owls they did not find large owls. They suggested that screech-owls occurred more often at locations that were smaller than 10 ha because large owls used those locations less frequently. Their sample size was too small to test this hypothesis quantitatively. Barred Owls (*Strix varia*) are recent arrivals on the coast, and since the screech-owl decline coincided roughly with the Barred Owl expansion, Barred Owls are frequently assumed to be the cause of screech-owl declines (Chaundry-Smart 2002). The first Barred Owl coastal record (Surrey) was 1966, the first Christmas Bird Count record was 1983-84 (at Pender Island, Vancouver, Sooke and Victoria). The first breeding record (Langley) was 1986 (Ryder 1986; Campbell *et al*. 1990), and Barred Owls are currently widespread breeders in Greater Vancouver (Elliott and Gardner 1997). Furthermore, in eastern North America, Eastern Screech-Owls (*M. asio*) primarily occupy different habitats than Barred Owls, perhaps as the result of predation by the larger owls (Gehlbach 1995). Preston and Campbell (2004) noted that Barred Owls and Western Screech-Owls coexist within many of the 1:50 000 grids used by the Wildlife Data Centre, and conclude that there

was no evidence for Barred Owls excluding Western Screech-Owls from regions. However, this interaction likely occurs on a much smaller scale; although both species may occur within the same grid, their home ranges may not overlap and they may not occur within the same area of forest or park.

(2) Competition for cavities with other introduced species. Screech-owls disappeared from Alaksen National Wildlife Area in Delta during the 1970s when numbers of European Starling (*Sturnus vulgaris*) increased dramatically (pers. comm., W. Weber, Delta, B.C.). Five out of eight screech-owl boxes erected at Burnaby Lake Park, Burnaby, were subsequently inhabited by Eastern Grey Squirrels (pers. comm., G. Clulow, Burnaby, B.C.). Furthermore, the screech-owl decline coincided with the expansion of grey squirrels in the Lower Mainland and southern Vancouver Island during the 1990s (Gonzales 1999).

(3) Habitat loss. Er (2003) and Er *et al.* (2005) inventoried birds in Vancouver city parks. Their results suggested that Western Screech-Owls could not persist indefinitely within Vancouver city limits because Vancouver parks are too small and disconnected for this species. Eastern Screech-Owls (*M. asio*) are largely tolerant of habitat alteration, with suburban habitats often containing higher densities than rural habitats (Gehlbach 1995). Western Screech-Owls appear to be less tolerant of habitat alteration. They are much less common in urban and suburban habitats than rural habitats in Baja California (Rodriguez-Estrella and Careaga 2003), and the highest detection rates on Vancouver Island were in old-growth forests (Setterington 1998). However, Western Screech-Owls can apparently survive in urban habitats in British Columbia (Cannings and Angell 2001) and have done so in wooded areas of Vancouver. Nonetheless, the loss of mixed riparian woodlots, favoured habitats in the Lower Fraser Valley (Campbell *et al*. 1990; Cannings and Angell 2001), likely contributed to their decline. When faced with urban development, screech-owls seem willing to relocate to other wooded areas; when the breeding grounds at the Fraserview Golf Course in Vancouver were destroyed to make a pond, the owls moved to another part of the golf course (pers. comm., R. Toochin, Vancouver).

The purpose of this paper is to provide further evidence for declines of Western Screech-Owls in Greater Vancouver and to discuss possible causes of these declines. To this end, I surveyed 22 locations in Greater Vancouver which had previous records of Western Screech-Owls, either from the Vancouver Natural History Society's database, or through conversations with other birders. I used play-back tapes to determine whether Western Screech-Owls were present at each location. I also compiled Christmas Bird Counts and anecdotal sightings, to provide a broader context for this study. Finally, I examined the size of forest fragments as a possible factor affecting screech-owl presence. Whereas Barred Owls would likely limit screech-owls to smaller fragments of forest, competing cavity nesters generally prefer edge habitat, and thus should have greater impact in small fragments. Based on island biogeography, I expected that loss of habitat would lead to screech-owls persisting longest in large fragments. In Vancouver's highly fragmented landscape, screech-owls have very limited ability to use the surrounding matrix and remaining fragments can be treated as islands (Er *et al*. 2005).

METHODS

In 1998–2002, I visited 22 locations in Greater Vancouver during the peak calling period of February to May (Campbell *et al*. 1990; Cannings and Angell 2001). At each location, I played a compilation of National Geographic and Peterson Western Screech-Owl sounds for at least one hour, in two minute intervals separated by eight minute breaks. I visited all sites on at least five occasions during calm, clear weather, and surveyed all areas with suitable habitat (waterbodies and open fields were excluded).

In order to minimize bias associated with differences in observer coverage, I visited all parts of each park on at least five occasions. For larger parks, this meant more than five visits to a given park, with each survey covering different portions of the park. Five visits is the standard used by other researchers to establish the presence or absence of Western Screech-Owls, because if screech-owls are present they will respond within five visits, during calm, clear weather, more than 95% of the time (Hardy and Morrison 2000; Rodriguez-Estrell and Careaga 2003). My results support this benchmark as I never encountered a screech-owl on a subsequent visit that I had not encountered within the first five visits. Later visits determined the time when a screech-owl had disappeared from a given location. Nevertheless, I may have missed some pairs, as screech-owls are notoriously inconsistent at responding (Cannings 1997; Mico and Van Enter 2000), and for a larger park (e.g. Burnaby Lake, Pacific Spirit) where the entire park was not covered on single visits, it is possible that screech-owls relocated between visits.

I compiled the number of Western Screech-Owls counted in Christmas Bird Counts on the Lower Mainland (Chilliwack, Ladner, Pender Harbour, Pitt Meadows, Squamish, Sunshine Coast, Vancouver and White Rock) and Vancouver Island (Campbell River, Comox, Deep Bay, Duncan, Nanaimo, Port Alberni, Pender Island, Sooke and Victoria). Only those counts done consistently from 1988 to 2004 were included. Of the 289 potential counts at these locations during the period, 17 had not been completed (six percent). In these cases, I used a five-year moving average for that site around the missing count year. I also compiled records submitted to the Vancouver Natural History Society between 1995 and 2000.

To test the hypothesis that Western Screech-Owls persist in small forest fragments, I pooled data provided by Robertson *et al*. (2000) with data from this study, as neither dataset provided high statistical power on its own.

Robertson *et al*. (2000) felt that their roost searches led to high detectability in the relatively small regions they surveyed and were "equally useful" as playback surveys for detecting screech-owls. Data outside Greater Vancouver (Howe Sound, Squamish and Sunshine Coast) were excluded from tabulation. The northern and southern sections of Pacific Spirit Park were pooled with Spanish Banks, and Delta Nature Reserve was pooled with Cougar and Blake Canyons, as these locations are interconnected and the pooled data provide a better estimate of fragment size. Fragment size (hectares of forest at each location) was estimated from city or park maps.

For analysis, I classified the two sites where screech-owls were present in 2000 as "present" since this is more directly comparable with the time period of Robertson *et al*. (2000). However, the same analyses was also done with all data classified as "absent", because by 2002 screech-owls were absent from all sites. If that change resulted in a change in statistical significance, the change is pointed out in the description of results. To estimate screech-owl density, I divided the reported number of screech-owls by the fragment size.

Fragments of forest were divided into four size categories, based on information from other researchers on the home ranges of Barred Owls (*Strix varia*). In Saskatchewan, breeding home ranges of Barred Owls averaged 150 ha and the smallest breeding home range was 38 ha (Mazur *et al*. 1998). In Minnesota (Nicholls and Fuller 1987) and Washington (Hamer *et al*. 1989) average breeding home range sizes were approximately 200 ha with minimum sizes of 60 ha. During the non-breeding season, home ranges were larger (Hamer *et al*. 1989; Mazur *et al*. 1998). I used four size categories: <10 ha (based on the suggestion of Robertson *et al*. 2000), 10-37 ha (fragments smaller than smallest recorded home range size), 38-200 ha (fragments smaller than average home range size) and greater than 200 ha (fragments greater than average home range size).

I used χ^2 tests (MS Excel 98) to determine whether Western Screech-Owls were more likely to be present, or in greater density, in each fragment class than would be expected from random distribution. To determine whether Western Screech-Owl densities were significantly higher in fragments smaller than 38 ha I used two-tailed t-tests (MS Excel 98) after testing for normality. A Wilcoxon Ranked Sum (JMP 4.0) test was used to determine whether Western Screech-Owls were present significantly more often in fragments smaller than 38 ha. Since "absent" and "present" are discrete possibilities, a sigmoidal function is the appropriate statistic to model screech-owl presence, relative to fragment size. Non-linear least squares regression (MS Excel 98, Newton's method) was used to determine the best-fit sigmoidal function, and Akaike's Information Criterion (AIC) was used to determine whether this best fit improved upon the null model. Although technically not applicable to an ordinal dataset with many zeroes, logistic and linear regressions were also used to provide a simpler description of the results.

In order to examine the relative timing of the Western Screech-Owl decline and Barred Owl invasion, a logistic regression (JMP 4.0) was fitted to the number recorded in each Christmas Bird Count circle for each of the species for the years 1988 to 2004. The value of 0.01 was used in place of zero, to avoid taking the natural logarithm of zero. For each count circle, I determined whether there was a decline (negative logistic regression) or no decline (positive or flat logistic regression) in screech-owl counts. For those count circles with a negative logistic regression, the regression equation was used to determine the year when screech-owl numbers fell to 50% of their original levels, as an index of the time period when the steepest declines occurred. For the purpose of analyses, I assigned "50 yrs" as a conservative estimate of the time screech-owls would persist on count circles showing no declines. Increasing this estimate upwards would only have strengthened the conclusions. All but two count circles showed a positive logistic regression for Barred Owl counts, and I therefore used two variables, the carrying capacity and time for Barred Owls to reach 50 % of their carrying capacity, to characterize the population expansion. The two count circles which lacked a positive logistic regression were not used in the analyses of time to reach 50% of their carrying capacity. For analyses involving carrying capacity, the average number of Barred Owls reported on those count circles was used as an index of carrying capacity. The "carrying capacity" is a statistical tool, measuring the relative abundance of Barred Owls on the count circle, and does not refer to the actual carrying capacity. After testing for normality, a two-tailed t-test was used to determine whether count circles that showed a declining trend for screech-owls were more likely to also have earlier Barred Owl expansions or higher Barred Owl carrying capacities than those not showing a declining trend. In addition, a linear regression was used to test whether those count circles where screech-owls declined earliest also were those count circles where Barred Owls increased earliest.

RESULTS:

Western Screech-Owl Surveys. There were 14 positive responses during 215 visits to 22 different locations (Table 1). All positive responses were during the early years (1997-2000), and extensive re-visits to areas with positive responses elicited no responses during later years (2001-2002).

Table 1. Response to playback of tape at 22 locations in the Greater Vancouver area. The tape played a compilation of Western Screech-Owl calls. It was played for two minutes, followed by an eight minute break, for at least one hour at each location during peak calling period, February to May, between 1998 and 2002. Each location was visited in at least three of the five years and at least five times in total. Sizes are the estimated amount of forested habitat at each location.

Location (Number of visits, hours in parentheses)	Size (ha)	Results
Alaksen National Wildlife Area (6, 22)	150	No response.
Blake Canyon, North Delta (11, 11)	5	No response.
Bear Creek Park, Surrey (5, 13)	45	No response.
Burnaby Lake Park, Burnaby (6, 31)	147	No response.
Burns Bog, Delta Nature Reserve (8, 22)	60	Responded on 5 Feb. 1998 near the Blake Canyon entrance.
Campbell Valley Park, Langley (13, 52)	550	No response.
Central Park, Burnaby (5, 21)	70	No response.
Crescent Park, Surrey (5, 8)	24	No response.
Cougar Canyon, North Delta (34, 34)	20	No response.
Deer Lake Park, Burnaby (6, 25)	90	No response.
Fraserview Golf Course, Vancouver (12, 15)	8	Regularly seen at roost in 1997-2000. Responded twice in the spring of 2001.
Green Timbers Park, Surrey (5, 29)	224	No response.
High Point Development, 0 Ave, Langley (20, 21)	4	Heard calling twice during February 2000.
Musqueam Park, Vancouver (8, 35)	150	Responded from top of Musqueam ravine on 10 April 1998.
Pacific Spirit Park, southern section, Vancouver (13, 82)	405	Responded from Camosun Street entrance on 10 April 1998. One pair known to have nested near Clinton Trail in 1998 and another detected along Imperial Trail in 1999 (pers. comm., J. Smith, Zoology, Univ. B.C.)
Pacific Spirit Park, northern section, Vancouver (22, 106)	405	No response.
Lily Point area, Point Roberts (5, 34)	130	No response.
Redwood Park, Surrey (5, 9)	32	No response.
Spanish Banks, Vancouver (10, 14)	30	No response.
Stanley Park, Vancouver (6, 31)	405	No response.
Sunnyside Acres, Surrey (5, 26)	130	No response.
Tsatsu Shores, Tsawwassen (5, 21)	64	No response.

I concluded that by 2002, screech-owls had disappeared from all 22 locations where they were formerly present. For example, during February - April 2001, I visited Pacific Spirit Park on 17 different nights. This was once the best location to hear or view screech-owls in Vancouver and the species nested as recently as March 1998 (pers. comm. J. Smith, Zoology, Univ. of B.C.). I walked every trail in the park at least twice during that period, playing screech-owl tapes regularly. I played tapes in the vicinity of the 1998 nest on 10 different nights in 2001 without any response. I also conducted intensive surveys of Cougar Canyon (17 nights) during 1997 and Campbell Valley Park (11 nights) in 2002. No owls were detected at either location, although screech-owls were easily heard and attracted to tapes at these locations prior to the mid-1990s.

Christmas Bird Counts and other evidence. Numbers of screech-owls on Christmas Bird Counts declined sharply on both Vancouver Island and the Lower Mainland (Figure 1). A linear regression on the combined total for both Vancouver Island and the Lower Mainland (1988-2004) showed a significant negative relationship with date ($t = -3.8$, $df = 16$, $P = 0.002$). On Vancouver Island, numbers declined at an average annual rate of 17% ($t = -3.2$, $df = 16$, $P = 0.006$). In the Lower Mainland, numbers declined by 32% ($t = -3.7$, $df = 16$, $P = 0.002$). These declines occurred despite increased observer effort.

More evidence can be found in anecdotal bird records submitted to the Vancouver Natural History Society (Campbell *et al*. 1972, 1974; Elliott and Gardner 1997). There were 22 reports in 1971, 16 in 1972, 9 in 1995 and 12 (2.4 per year) in 1996-2000. This excludes reports from the Fraserview Golf Course, where there were many reports of the same pair. This decrease was not because of decreased effort. Over this period, the total number of records submitted per year for all bird species increased from 22 000 to 70 000. While in 1971-72 most records were within Vancouver city limits (Campbell *et al*. 1972, 1974), in 1995 no records were within the city limits (Elliott and Gardner 1997).

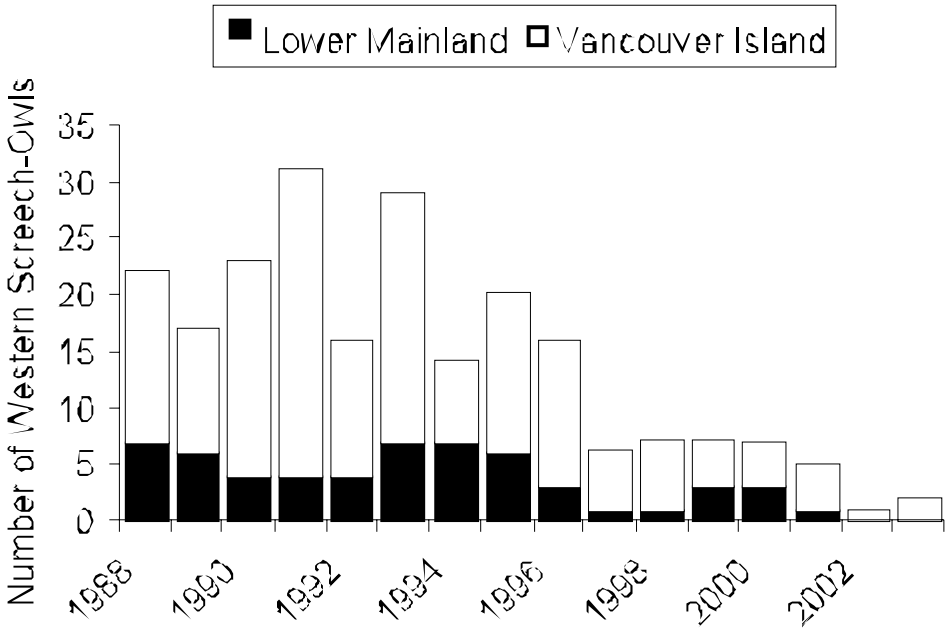

Figure 1. Numbers of Western Screech-Owls reported on Christmas Bird Counts. Analysis and tabulation described in the text.

The effect of fragment size. In this study, screech-owls persisted until at least 2000 at two of the smallest locations, which were the only two locations where I never recorded Barred Owl. One of these locations was High Point, where I have never seen or heard Barred Owls, despite having my residence there for five years (Great Horned Owls (*Bubo virginianus)* nest nearby). The second location was Fraserview Golf Course. Jaramillo (1997) also did not record Barred Owl on detailed, weekly surveys adjacent to Fraserview during 1995-96 (Great Horned Owls are present).

Pooling my data with those of Robertson *et al*. (2000), the proportion of sites with screech-owls in each size class was: 0.0 in forests >200 ha, 0.18 in forests 38-200 ha, 0.25 in forests 10-37 ha, and in forests <10 ha, the proportion was 0.83 (with Fraserview and High Point "present") or 0.50 (with Fraserview and High Point "absent"). A χ^2 test indicated that screech-owls selected fragments <10 ha more than expected and >200 ha less than expected ($\chi^2 = 8.8$, df = 3, P = 0.03). However, when Fraserview and High Point were considered "absent", the relationship was no longer significant ($\chi^2 = 3.1$, df = 3, P = 0.37). The average density of screech-owls in fragments less than 38 ha was significantly higher than the average density of screech-owls in fragments greater than 38 ha (t = 2.5, df = 17, P = 0.02). Furthermore, screech-owls were more likely to be present in fragments <38 ha than in fragments >38 ha (Z = 2.1, P = 0.03). The sigmoidal function which gave the best fit (ΔAIC for nul = 6.45) was:

$$P(O) = \frac{1}{(1 + 1.4F^{1.4})}$$

where *F* is the logarithm (base 10) of fragment size and *P(O)* is the probability that a screech-owl will be absent (Figure 2). Notably, the inflection point is 20 $\pm$ 8 ha, which is just below the minimum reported home range of 38 ha for Barred Owl. Both logistic ($r^2 = 0.14$, P = 0.04 ΔAIC for nul = 4.5) and linear ($r^2 = 0.09$, P = 0.09, ΔAIC for nul = 5.1) regressions also supported the hypothesis that Western Screech-Owl presence was negatively correlated with fragment size. As six different statistical tests support this conclusion, it appears to be statistically robust.

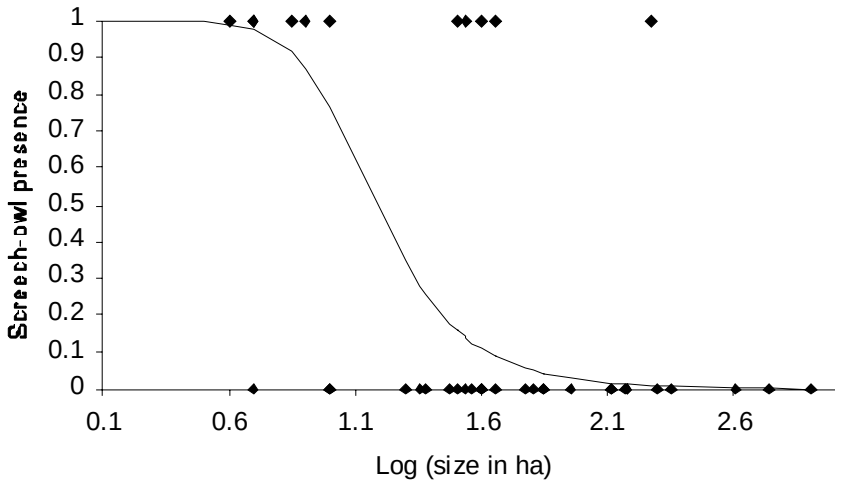

Figure 2. Western Screech-Owl presence at 33 sites in Greater Vancouver relative to the size of forest fragment. Present = 1, Absent = 0. Solid line represents the best fit sigmoidal curve as given in the text. Data are pooled from this study and Robertson *et al*. (2000).

Timing of Barred Owl expansion and screech-owl declines. Barred Owl numbers increased on Christmas Bird Counts over the time period when Western Screech-Owls declined (Figure 3). Those Christmas Counts in which screech-owls declined had higher Barred Owl carrying capacities (t = 1.77, df = 15, P = 0.05). Barred Owls reached 50 % of their final numbers earlier on count circles where screech-owls showed declines (t = 5.2, df = 13, P = 0.0002). Screech-owls declined first on Christmas Bird Count circles where Barred Owls expanded most rapidly (t = 3.2, df = 16, P = 0.01) and where the final number of Barred Owls was highest (t = -2.7, df = 16, P = 0.02).

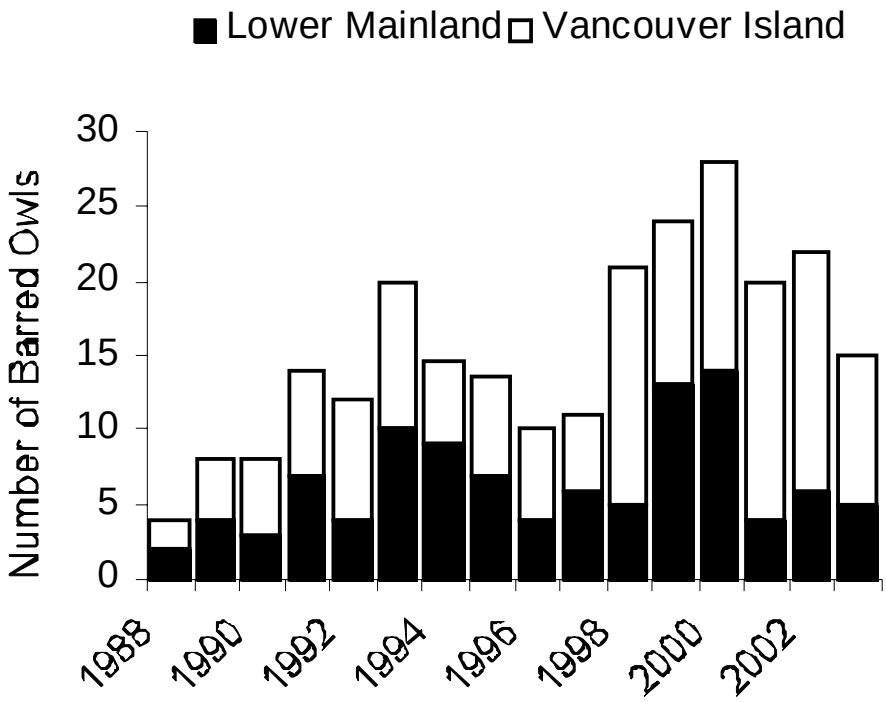

Figure 3. Number of Barred Owls reported on Christmas Bird Counts. Analysis and tabulation described in the text.

DISCUSSION

Results suggest that Western Screech-Owls have disappeared from most of Vancouver, Burnaby, Delta, Surrey and Langley. Habituation to playback is an unlikely explanation since very few birders had likely used playback tapes recently at certain locations (e.g. Alaksen, Crescent Park, Tynehead). At other locations, birders have used frequent playback over the last thirty or more years without an observable reduction in response (e.g. Campbell Valley, Pacific Spirit). It is possible, however, that screech-owls vocalize less often than in the past to elude Barred Owls; Great Horned Owls apparently vocalize less frequently during low food years to avoid being cannibalized by other Great Horned Owls (Rohner 2004). Robertson *et al*. (2000) located screech-owls at 46% of the sites they surveyed. However, those locations bordered extensive forest, and surveys were completed in an earlier period (1995-98). Results of the present study suggest that screech-owls have since disappeared from many of the regions they surveyed. The combined results of this study and the study by Robertson *et al*. (2000) demonstrate that Western Screech-Owls are persisting in small forest fragments, particularly fragments less than 20-30 ha.

Causes for the decline. Predation by Barred Owls, competition for nest cavities and habitat loss have all likely contributed to the demise of the screech-owl, although the persistence of screech-owls in small fragments supports the conjecture that Barred Owls were the most significant of these factors during the 1990s.

The grey squirrel hypothesis is not supported by four details. Screech-owls have declined on Salt Spring Island (Neville 2004) and locations on Vancouver Island (Chaundry-Smart 2002) where grey squirrels do not occur. Second, screech-owls disappeared from several locations (e.g. Cougar Canyon, Campbell Valley) before grey squirrels arrived and from other locations where grey squirrels are still absent or rare (e.g. Tsawwassen, interior of Pacific Spirit Park). Third, since grey squirrels are most common in deciduous and urban habitats rather than forest interior (Gonzales 1999), this hypothesis does not explain why screech-owls are most common in small fragments. Fourth, grey squirrels and Eastern Screech-Owls coexist in very similar habitats in eastern North America (Gehlbach 1995). Nevertheless, the grey squirrel expansion has likely had a negative effect on screech-owls and other cavity-nesters, either through competition or nest predation. Other nest predators, such as racoons, and competitors such as starlings may have also played a role, although there is no evidence for sudden changes in these species over the period when screech-owls disappeared.

The habitat loss hypothesis is contradicted by two pieces of information. First, screech-owls disappeared rapidly from many locations (e.g. Pacific Spirit, Campbell Valley) where habitat did not change. Second, because large forest fragments would likely support larger screech-owl populations than smaller forest fragments, screech-owls would be expected to persist longest in large forest fragments. This study shows the opposite pattern. Distance between fragments and sources (e.g. continuous forests) likely also plays a role although Er *et al*. (2005) show that screech-owls have a limited ability to disperse between forest fragments in urban Greater Vancouver, and that these fragments can be approximated as islands. After disappearance from a location, however, the loss of habitat and wildlife corridors in Greater Vancouver would prevent screech-owls from recolonizing fragments. Thus, habitat loss within Greater Vancouver likely explains why screech-owls have disappeared from urban landscapes while persisting in areas where large amounts of continuous forest remain (e.g. Coquitlam, Hope, northern Vancouver Island). Habitat type also plays a role. For example, Robertson *et al*. (2000) recorded 5-6 screech-owls using a 50-ha plantation of 25-30 year-old Douglas-firs in Howe Sound. This site was contiguous with mature stands and likely did not have Barred Owls, which prefer mature, mixed forests (Hamer *et al*. 1989; Mazur *et al*. 1998).

The Barred Owl hypothesis is supported by four lines of evidence. First, screech-owls persisted longest at sites that were free of Barred Owls (e.g. Fraserview, High Point, also see Robertson *et al*. 2000). Second, screech-owls persisted longest in smaller fragments. In particular, the size range where screech-owls persisted longest was just below the smallest recorded home range for Barred Owls, suggesting that the larger owls may be excluding screech-owls from large forest fragments. Third, the period of greatest decline in screech-owls coincides with the period shortly after Barred Owls became widespread breeders in southwestern B.C. (Figures 1, 3). Fourth, screech-owls declined earliest in Christmas Bird Counts with the largest number of Barred Owls and in which Barred Owls increased first. For example, consider Victoria, where screech-owl numbers declined much earlier (50 % of historical levels about 1992) than in Duncan (about 1999). The Victoria Christmas Bird Count regularly gets the most Barred Owls of any count on the coast and Barred Owls reached 50% of their current levels about 1992. Duncan, meanwhile, gets roughly half the number of Barred Owls, and Barred Owls reached 50% of their current levels much later (roughly 2001).

Three objections to the Barred Owl hypothesis are frequently raised. First, there is little direct evidence for screech-owl predation by Barred Owls. This is not surprising as screech-owls make up a very small

proportion of their overall diet, and predation rates are notoriously difficult to quantify. Although Barred Owls are rarely observed eating screech-owls, they clearly attack screech-owls fairly regularly, as shown by their response to tape playback. Many birders have commented that to hear a Barred Owl, one should play a Barred Owl tape; to see a Barred Owl, one needs to play a screech-owl tape. During my screech-owl surveys, I attracted Barred Owls on 27 occasions. They always approached without vocalizing. On 11 occasions they attacked me, making contact on four occasions. I have never seen Barred Owls react in this way to their own playback, so it appears to have been predatory rather than aggressive behaviour. Assuming that 13% (27 out of 215 surveys) of vocalizations attract Barred Owls, screech-owls would be attacked on roughly one out of every seven nights during their period of vocalization. Clearly, Barred Owls are at least occasionally successful in capturing screech-owls, as there are several observations of Barred Owls eating screech-owls (Cannings and Angell 2001, photographed in Langley by G. Ryder as reported by G. Clulow, Burnaby B.C., pers. comm.). Finally, there are several examples of generalist predators eliminating rare species that make up a small proportion of their diet (e.g. brown tree snake on Guam, Conry 1988). A second objection is that Barred Owls and Eastern Screech-Owls coexist in the East. However, Barred Owls regularly prey on Eastern Screech-Owls there, and Eastern Screech-Owls occupy largely different habitat than Barred Owls, possibly because of interactions between these two species (Gehlbach 1995). A third objection is the apparent delay between the period when Barred Owls peaked and when screech-owls declined. However, early colonizing Barred Owls in the 1980s and early 1990s may have experienced an abundance of food and therefore had little impact on screech-owls. By the mid to late 1990s, Barred Owl populations were likely near carrying capacity and might have required larger and more diverse food sources, thereby having a greater impact on screech-owls.

While the present study suggests that Barred Owl predation was the most significant factor causing the observed declines, it is entirely possible that another, as yet unmentioned factor, such as disease, or a series of poor winters, may have reduced screech-owl populations to such an extent that they were unable to recover in a fragmented landscape. Alternatively, there may have been a reduction in food supply. Insects, especially moths, and frogs make up a large proportion of screech-owl diet (Cannings and Angell 2001) although Ryder (1973) found that small birds were more important at Campbell Valley Park during the breeding season. Little is known about changes in insect or frog populations in the Lower Mainland. Although the proximate cause of the decline may be Barred Owls, ultimately, the decline is largely due to habitat loss. Fragmented landscapes provide Barred Owls with easy access to screech-owl habitat while simultaneously reducing the ability of disconnected screech-owl populations to recover. Screech-owls appear to be surviving in areas of continuous forest throughout southwestern British Columbia, possibly because populations that have been eliminated from one location can be replenished from other nearby populations.

Future of Western Screech-Owls in Greater Vancouver. Western Screech-Owls will no doubt persist in southwestern British Columbia wherever there is habitat suitable for screech-owls and unsuitable for Barred Owls. Screech-owls are still quite common on northern Vancouver Island (Setterington 1998; Mico and Van Enter 2000; Preston and Campbell 2004), Howe Sound (Robertson *et al*. 2000) and in the Chilliwack/Hope region. Although screech-owls may be currently persisting in small fragments, large areas of habitat less suitable for Barred Owls than screech-owls (e.g. young conifer plantations, non-riparian old-growth forests) may be essential for the species' long-term survival. There are several recent records of screech-owls from urban areas in Coquitlam (e.g. Timbs 1998; Clulow 2004) and North Langley (e.g. Robertson *et al*. 2000; KHE, pers. obs., 2006, Jan. 01), and perhaps these regions are sufficiently connected with "source" populations in the nearby mountains that they will be able to persist indefinitely. There are also records from Burns Bog until at least January 2006 (my surveys of Burns Bog were restricted to the Delta Nature Reserve, where Barred Owls regularly occur). Most of Burns Bog is stunted conifer bog, suitable for screech-owls and unsuitable for Barred Owls. Whether or not Western Screech-Owls can persist at Burns Bog likely depends on the current population size, as immigration is unlikely. I encourage anyone with access to Burns Bog to survey it for Western Screech-Owls. Screech-owl boxes in Burns Bog and elsewhere may also help them persist, if grey squirrels can be excluded.

Anyone willing to share observations of screech-owls is encouraged to contact the author at haliaeetus@gmail.com.

ACKNOWLEDGEMENTS

I would like to thank I. Robertson and G. Clulow for discussions about screech-owls. A special thanks to J. Smith for his extensive comments, which significantly improved the quality of this manuscript. Comments from R. Cannings, G. Clulow, M. Preston and J.B. Sprague also greatly improved this manuscript.

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Western Screech-Owl.
Drawing by B. Heybroek. 2006.