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ABSTRACT—The *macfarlanei* subspecies of the Western Screech-owl (*Megascops kennicottii*) resides in the dry southern interior of British Columbia and is federally endangered in Canada. We captured and radio-tagged 11 adult screech-owls (6M, 5F) between July 2005 and January 2008 to collect ecological information needed to direct effective conservation. We collected point radiolocations from tagged owls to estimate seasonal and year-round home ranges with the 95% isopleth of the utilization distribution calculated using fixed kernel methods. Screech-owl home ranges averaged 64.5 ha ($s = 10.6$, $n = 5$), with no substantial difference in size between males and females. Owls used considerably smaller areas during the breeding season ($\bar{x} = 20.4$ ha, $s = 15.3$, $n = 7$) than the non-breeding season ($\bar{x} = 88.6$ ha, $s = 44.5$, $n = 6$). During the breeding season, males and females of a single pair overlapped extensively, whereas outside the breeding season very little overlap occurred within pairs. We did not detect overlap between neighbouring pairs. Home ranges of Western Screech-owls were highly associated with riparian forests; most screech-owls had ≥10 ha of riparian forested habitats within their home ranges. These results have implications for habitat conservation for this endangered species.

Key words: British Columbia, home range, *Megascops kennicottii macfarlanei*, overlap, spatial organization, Western Screech-owl

The *macfarlanei* subspecies of the Western Screech-owl (*Megascops kennicottii*) is a small brownish-grey owl that resides in the dry southern interior of British Columbia from Lillooet to Cranbrook (Beaucher and Dulisse 2004). The subspecies is listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002) and is resident in Washington, western Montana, Oregon, and Idaho.

Patterns of space-use by Western screech-owls are largely unknown and much of our understanding has been gleaned from natural history observations of vocalizing owls that respond to call-playback. It is from these observations that researchers believe that screech-owls defend a territory from conspecifics throughout the year (Cannings and Angell 2001), and can occur in densities of up to 14 pairs along 6.4 km of river (Feusier 1989). However, data from vocalizing owls or incidental observations of the species do not provide unbiased indications of space use or movements.

Western Screech-owls have long been known to be closely associated with riparian forests (Cannings and Angell 2001) with researchers assuming that home ranges are centred on these habitats (Hayward and Garton 1988). Indeed, the species has been used as an indicator of the health of riparian ecosystems (Chaundy-Smart 2002). However, because of the lack of unbiased space-use data, the requirements of screech-owls for riparian forests are unknown and previous work has been unable to determine if these habitats are required for resident owls to occur within the landscape.

The difficulty of identifying occupied habitats hampers conservation efforts for this species. Our objective was to quantify the home range size of radio-tagged owls within our study area and characterize the ecosystem composition of their home ranges. These data will allow estimation of potential densities and distribution of the species throughout its range in British Columbia to facilitate prioritization of areas for habitat conservation. Examining the habitat composition of home ranges will also provide land managers with information on other habitats (outside of riparian forests) that owls may need to include within their home ranges.

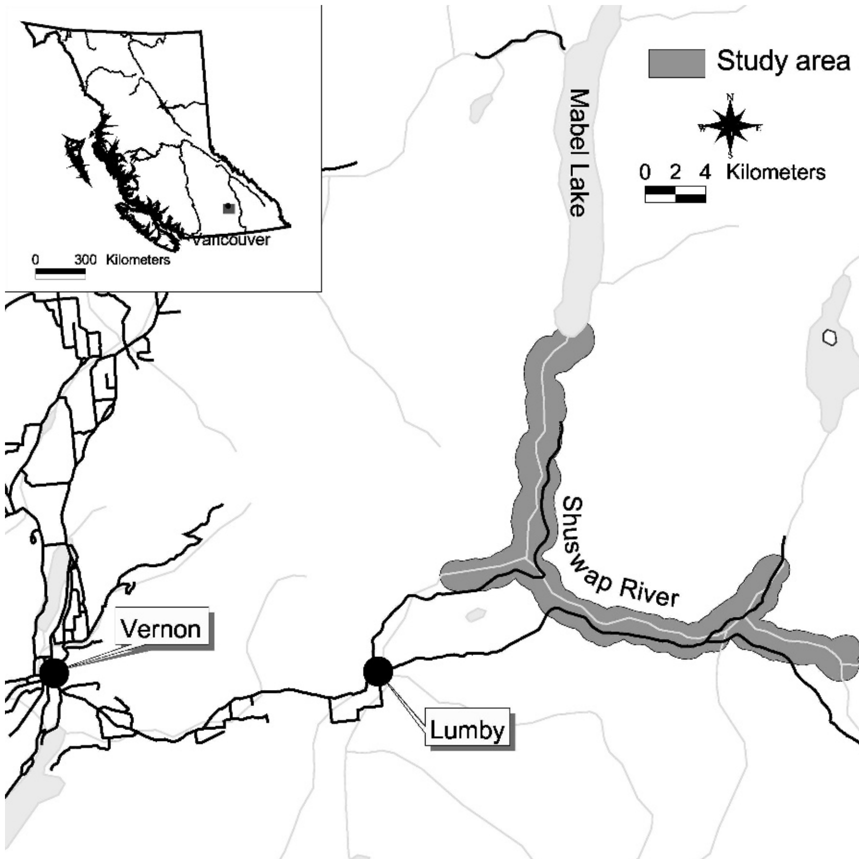

FIGURE 1. Location of research study area along the Shuswap River, near Lumby, British Columbia.

METHODS

Study Area

The study area covered approximately 83 km^2 of cottonwood riparian forests, agricultural lands, and upland coniferous forest along the Shuswap River, approximately 10 km east of Lumby, British Columbia (UTM Zone 11, 360000E, 5568300N, NAD83; Fig. 1). Elevation at river level ranged between 410 and 480 m. The area was within the Northern Okanagan Highlands ecosection (Demarchi 1995) and included the moist-warm subzone of the Interior Douglas-fir biogeoclimatic zone (IDFmw1 variant; British Columbia Ministry of Forests 2004).

Forest ecosystems within the study area were typically dominated by Douglas-fir (*Pseudotsuga menziesii*), with components of Ponderosa Pine (*Pinus ponderosa*), Trembling Aspen (*Populus tremuloides*), Paper Birch (*Betula papyrifera*), Western Redcedar (*Thuja plicata*), and hybrid spruce (*Picea glauca* × *engelmannii*). Black Cottonwoods (*Populus balsamifera* ssp. *trichocarpa*) occurred as prominent components of riparian and floodplain ecosystems within the study area. Common Snowberry (*Symphoricarpos albus*), tall Oregon-Grape (*Mahonia aquifolium*), Birch-leaved Spirea (*Spiraea betulifolia*), Saskatoon (*Amelanchier alnifolia*), Red-osier Dogwood (*Cornus stolonifera*), Thimbleberry (*Rubus parviflorus*), Black Gooseberry (*Ribes lacustre*) and Douglas Maple (*Acer glabrum*) were common shrubs.

Much of the study area has undergone considerable disturbance resulting from human development. The creation of a power project during the late 1920s that included the installation of 2 dams in the Shuswap watershed contributed significantly to habitat changes along the Shuswap River. Specific to this project, unnatural flow fluctuations on portions of the river likely affect both terrestrial and aquatic organisms. Approximately 60% of the riparian forests between Sugar Lake Reservoir and Mabel Lake have been cleared for agriculture, in addition to some selective cottonwood harvesting in the late 1970s. However, some extensive tracts of late-successional cottonwood riparian forests remain along the Shuswap River.

Capture and Radiotagging

We captured and radio-tagged Western Screech-owls at sites where owls had been detected during previous call-playback surveys (Resources Inventory Committee 2001). We attracted owls for capture using audio recordings of the territorial call of the Western Screech-owl broadcast from a megaphone located below a mounted decoy (Smith and others 1983). We used one or two 38-mm mesh mist nets to capture owls that flew in to attack the decoy.

Captured owls were weighed to determine sex (Pyle 1997; Cannings and Angell 2001) and marked with a US Fish and Wildlife Service leg band. We affixed Holohil model PD-2 transmitters (3.8 g) to adult owls in good condition based upon total body mass (at least 150 g). We affixed Holohil model R1-2C transmitters (6.0 g) to adult females that had a body mass of at least 215 g. These ratios of transmitter:body mass are below 2.5%, which corresponds to a reduction in surplus power (Caccamise and Hedin 1985) of $<2\%$. We attached radiotransmitters using the criss-cross backpack harness described by Smith and Gilbert (1981) for use on screech-owls. Following handling, owls were placed in a small dark box for 10 to 15 min so that they could acclimate to the new weight before attempting flight (Smith and others 1983). All capture and handling protocols were approved by the provincial Animal Care Committee (recognized by the Canada Council on Animal Care) and met or exceeded capture and handling guidelines outlined in the protocols for Wildlife Capture and Handling (Resources Inventory Committee 1998a).

Screech-owls with radiotransmitters were monitored year-round, usually one or more times per week, using standard ground telemetry procedures (Resources Inventory Committee 1998b) for the entire period that their transmitters were functional. When possible, we homed in on the signals to visually locate the owls and identify roost or nest sites. When it was not possible to home in on owls, we collected ≥ 3 directional bearings from ground stations using a 3-element, collapsible Yagi antenna. We estimated locations and 95% error polygons (Nams and Boutin 1991) from ground telemetry using Locate III software (Nams 2005). We then assessed the precision of each location using the 95% error polygons for ground locations. Most (78%) radiolocations were of daytime roost sites; night-time radiolocations were rarely outside of the bounds of the roost site radiolocations. Because of the extremely mobile nature of screech-owls, we considered locations to be temporally independent for home range analyses if they were separated by >2 h.

Home Range Estimation

We used only those radiolocations for which the 95% error polygon was ≤ 4.35 ha for home range analysis. This criterion was selected because it was equivalent to approximately 5% of the average minimum area used by tagged screech-owls, which we considered to be an acceptable level of precision.

We estimated the size and location of home ranges for each resident screech-owl for which we gathered ≥ 30 radiolocations. We estimated home ranges using the 95% isopleth of the utilization distribution (UD) generated from the fixed kernel method with the smoothing parameter selected by least-squares cross-validation (Worton 1989; Seaman and others 1999). For screech-owls with repeated observations at 1 location (such as nest sites or roost trees), we estimated the UD using the fixed kernel method for a dataset without repeated observations. Using the value of the smoothing parameter generated from this technique, we re-ran the fixed kernel on the complete dataset. We used the Animal Movement extension to ArcView (Hooge and Eichenlaub 1999) for home range calculations.

We calculated aggregate (that is, year-round) and seasonal home ranges for each screech-owl. We pooled locations across years for each screech-owl for the calculation of their aggregate home range, using data from individuals for which we collected radiolocations for ≥10 mon. We estimated home range size for the breeding (that is, egg-laying to fledging; approximately 1 April to 15 June; specific to each owl) and non-breeding seasons.

We examined spatial overlap of the home ranges among screech-owls using a coefficient of overlap (Walls and Kenward 2001). This measure allowed us to assess the overlap between 2 home ranges with a single dyad measurement:

$$\text{Coefficient of overlap} = 2 * \left(\text{overlap}_1 * \text{area}_1\right)/(\text{area}_1 + \text{area}_2),$$

where the home range area_x of screech-owl_x has a coefficient of overlap_x.

We used several sources of geographic data to evaluate spatial relationships among owls and their habitat. We overlaid the aggregate 95% UD home ranges on 1:20,000 terrestrial ecosystem maps of the study area (Grods and Uunila 2008, conforming to Resources Inventory Committee 1998c standards) to determine the habitat composition of the home ranges of resident screech-owls. Following provincial standards (Resources Inventory Committee 1998c), polygons in the mapped area were delineated as homogeneous stands based on their ecosystem unit (that is, site series; Lloyd and others 1990) and structural stage (Resources Inventory Committee 1998c). We grouped ecosystem units into 7 broad categories: open forests dominated by Ponderosa Pine and Douglas-fir (IDFmw1/02, IDFmw1/03, and IDFmw1/04 site series; Lloyd and others 1990); zonal forests dominated by Douglas-fir (IDFmw1/01 sites series; Lloyd and others 1990); riparian forests dominated by Black Cottonwood, Western Redcedar, and hybrid spruce (IDFmw1/05 site series; Lloyd and others 1990); wetlands; river or open water; exposed soil; and agricultural (cultivated fields and pastures). We measured distances to the edge of the Shuswap River using Terrain Resource Inventory Management data (Ministry of Sustainable Resource Management 2005). We also quantified where owls situated nest sites within the home range by calculating a UD based on all non-nesting radiolocations and identifying the isopleth of the UD in which the nest occurred. The value of the UD score represented the probability of an owl using that portion of its home range; nests with low UD scores were closer to the core of the non-nesting home range, whereas those with UD scores closer to 95% were situated near the periphery.

RESULTS

We collected 704 radiolocations of 11 radio-tagged screech-owls between 12 July 2006 and 18 January 2008, of which 659 were suitably precise for inclusion in home range analysis. Owls were monitored between 5 and 675 d, depending on survivorship and transmitter performance. We radio-located tagged owls between 5 and 132 times ($\bar{x}$ = 57 radiolocations, s = 38, n = 11), although data from some owls were not used in the analysis because insufficient radiolocations (that is, <30) were collected to calculate their respective aggregate or seasonal home ranges. We estimated aggregate home ranges for 5 owls (3 M, 2 F); 95% fixed-kernel estimates averaged 64.5 ha (s = 10.6, n = 5), based on an average of 89 radiolocations per owl (s = 31, n = 5). Aggregate home ranges of males were very similar in size to those of females ($\bar{x}_{\text{Male}}$ = 62.5 ha, s = 6.8, n = 3; $\bar{x}_{\text{Female}}$ = 67.6 ha, s = 18.0, n = 2). Owls used considerably smaller areas during the breeding season ($\bar{x}$ = 20.4 ha, s = 15.3, n = 7; based on an average of 39 radiolocations per owl, s = 10) than the non-breeding season ($\bar{x}$ = 88.6 ha, s = 44.5, n = 6; based on an average of 46 radiolocations per owl, s = 17).

Overlap of home ranges varied among and within individuals. Overlap only occurred within male-female breeding pairs and among home ranges of different owls through replacement of individuals. We did not detect overlap of home ranges of neighbouring pairs. Overlap within pairs during the breeding season averaged 71% (s = 8, n = 3); however, overlap reduced to 43% (s = 10, n = 2) during the non-breeding season. Individual screech-owls also segregated their use of space throughout the year; overlap between the breeding and non-breeding home ranges of individual owls averaged only 35% (s = 22, n = 4).

The home ranges of the tagged owls comprised many different ecosystem units and structural stages. Using 1:20,000 scale terrestrial ecosystem data, 5 screech-owls included between 22 and 52 stands within their home ranges ($\bar{x}$ = 33 stands, s = 11). Although the

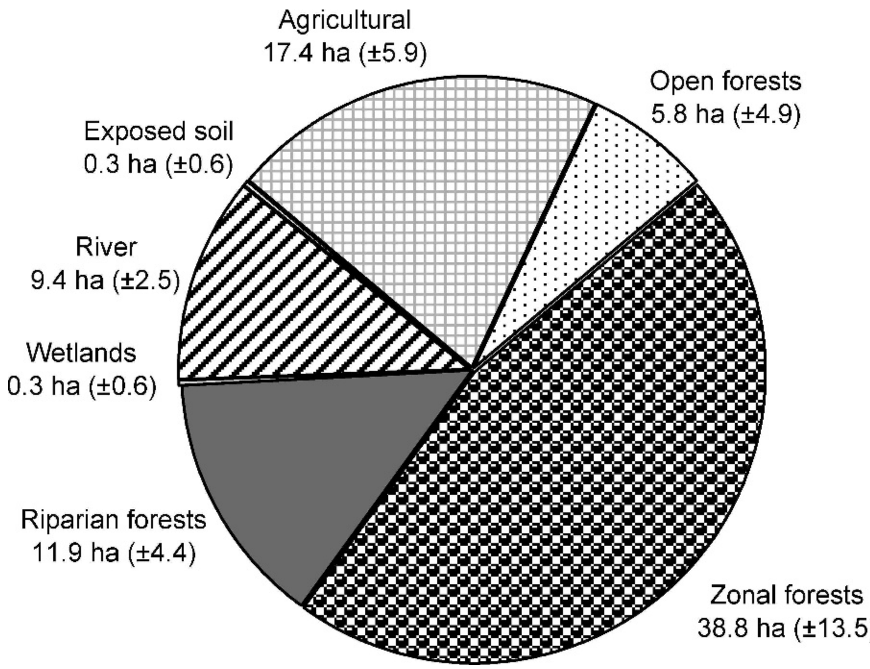

FIGURE 2. Mean area (± s) of ecosystem units occurring within aggregate home ranges of Western Screech-owls tagged along the Shuswap River, British Columbia, 2005–2008. n = 5 owls.

composition varied among individuals, home ranges, on average, included 11.9 ha of riparian forest (s = 4.4, n = 5; Fig. 2), which represented 19% of the home range on average (s = 8%). Mature and old forest structural stages comprised, on average, 13% of an aggregate home range (s = 9%, n = 5), equivalent to 10.4 ha (s = 6.2 ha, n = 5; Fig. 3). All home ranges overlapped at least 867 m of riverfront ($\bar{x}$ = 1198 m, s = 250, n = 5) of the Shuswap River.

Nests were not situated in either the geographic center or core area of the home range. The mean score for the utilization distribution of the home range at the nests was 54% (s = 24, n = 9 owls), indicating that nests occurred outside of the 50% isopleth, where 50% of the activity of the owl occurred. This suggests that the home ranges were not centered on the nest.

DISCUSSION

Our results showed that Western Screech-owls in our study had large home ranges relative to those previously estimated for the species (2.5 to 10 ha; Cannings 2004) that, although each included considerable stretches of river, incorporated a wide variety of ecosystem units and structural stages. The use of their home ranges varied considerably throughout the year, with much apparent spatial segregation between portions of the home range used during the breeding period relative to the remainder of the year. These observations may have considerable implications for effective estimation of density and refinement of survey protocols. Without such refinement, population size based on previous home range estimates may greatly overestimate the actual density.

Prior to our research, much of the understanding of screech-owl ecology was based on surveys or inventories conducted during the nesting season, when owls are most responsive to call-playback (Cannings and Angell 2001). However, our data showed that space-use by Western Screech-owls during this period was at its most constrained. Our data also indicated that the area used by screech-owls during the remainder of the year was almost 4 times larger than that used during the breeding season and included considerably different habitats. Thus, previous approximations of the size of screech-owl home ranges (such as Cannings 2004) were likely underestimates.

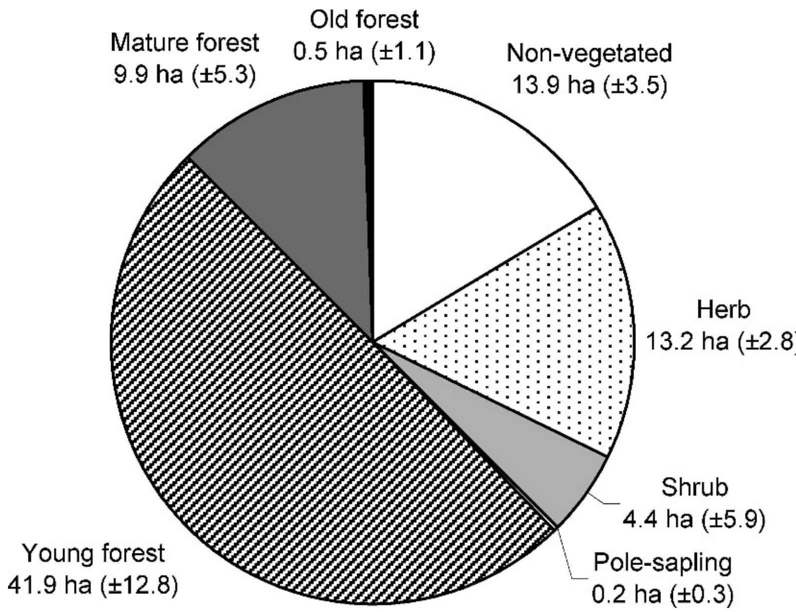

FIGURE 3. Mean area (± *s*) of structural stages occurring within aggregate home ranges of Western Screech-owls tagged along the Shuswap River, British Columbia, 2005–2008. $n = 5$ owls.

There are several possible explanations for the shift in space use from breeding to non-breeding periods. Because owls spent >2 mon at nests, it is likely that prey became depleted in the nest area. Therefore, the shift in space-use that we observed could be related to foraging efficiency. Also, it is possible that prey were not evenly distributed throughout the home range of each owl, and that prey concentrations fluctuated among habitats and seasons. Interspecific competition from other owl species present within the study area may also have occurred within the breeding home range, so a shift to other areas when the owls were not constrained to the nest may reduce this competition.

Resource partitioning may also help explain the reduction in overlap of space-use among breeding pairs during non-breeding periods. We observed that members of a pair used considerably different areas during the non-breeding period, roosting on opposite sides of the territory for much of November though January. This may be another strategy to decrease competition within a pair for limited food resources, in addition to the reduction in dietary overlap among sexes previously observed (Davis and Cannings 2008).

Home ranges were centred on riparian habitats in close proximity to the Shuswap River; however they were not centered on the nest. Riparian habitats occur most widely on fluvial systems where frequent inundation and consistent sub-surface moisture (Lloyd and others 1990) allow for the establishment and development of large deciduous trees such as Black Cottonwoods. Because of their decay characteristics (Jamieson and others 2001), these large deciduous trees are one of the few species that develop cavities of sufficient size to house nests. The formation of suitable nest sites may be a very rare occurrence, and it is likely that a cohort of many large trees is needed for 1 tree to develop the attributes needed for nesting. Our observation that a large proportion of home ranges comprised of cottonwood riparian forest may be linked to the supply of potential nest sites; males seemed to establish their territories around nest opportunities, and these opportunities were likely most common in large old deciduous trees (Jamieson and others 2001) that were most prevalent in these forests.

The inferences that we could draw about the factors that affected where screech-owls occurred within the landscape were limited by the extent of ecosystem mapping that was available. Ecosystem mapping was completed for 46% (38 km^2) of the study area. Because the mapping was completed for areas immediately adjacent to the Shuswap River, it was not a representative sample of ecosystem units within the dry Douglas-fir forests of south-central British Columbia. The mapping likely overestimated the relative abundance of the forested riparian ecosystems because the mapping was completed for areas immediately adjacent to the river, where this ecosystem was most likely to occur. Despite this bias, the screech-owls in our study included substantially more forested riparian ecosystem in their home ranges than was expected from the mapping ($\bar{x}$ = 19% within home ranges compared to 6% within the mapped area). Thus, we suspect that screech-owls may select for home ranges largely on the ability of an area to supply, on average, 12 ha of later-successional cottonwood riparian forest within a 65-ha home range.

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