Observing wildlife in the crowns of old-growth trees using motion-sensitive cameras

Joshua M. Malt and David B. Lank

Centre for Wildlife Ecology, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6

Introduction

Forest canopies, defined as the sum of all tree crowns in a forest stand, are habitats of global importance to biodiversity (Ozanne et al. 2003). In the canopies of temperate old-growth rainforests of British Columbia, lichens and mosses form thick vegetative mats on tree limbs (Franklin and Spies 1991, Sillett and Neitlich 1996). The Carmanah Valley of Vancouver Island supports a unique community of soil microarthropods (Winchester and Ring 1996, Winchester 2006). Forest canopies also support a diverse assemblage of vertebrate species. Mammalian use of this habitat ranges from species that only occasionally use forest canopies, to species such as the Northern Flying Squirrel (*Glaucomys sabrinus*), which are almost exclusively arboreal (Carey 1996). Forest canopies are also ideally suited for the mobile nature of passerines and other birds, as this structurally complex habitat provides many foraging opportunities and potential nest sites (Sharpe 1996).

Despite the diverse and intriguing nature of forest canopies, these habitats still remain understudied. This is mainly due to the difficulty of accessing the canopy, which can reach heights of 90 m in temperate old-growth forests (Franklin and Spies 1991). In British Columbia, considerable effort has been taken to describe the invertebrate community of the forest canopy (Winchester 2006), but few researchers have formally documented use of this habitat by vertebrate species. In this study, we use motion-sensitive cameras to document vertebrate species visiting artificial nests in old-growth forest canopies. These photographs provide a unique perspective of wildlife activity in a habitat which is difficult to observe from the forest floor.

"Despite the diverse and intriguing nature of forest canopies, these habitats still remain understudied."

Study Area

This study was conducted in the Nimpkish Valley on Northern Vancouver Island (50° 12' N 126° 37' W; Figure 1), from June to July, 2005. Elevation ranges from sea level to 1500 m, mean summer (April-August) temperatures are 13.4°C, and cumulative precipitation is 300 mm. Forests at lower elevations are within the Coastal Western Hemlock Zone (CWH), and forests above 900 m are within the Mountain Hemlock Zone (MH) (Klinka et al. 1991). Common tree species in CWH are western hemlock (*Tsuga heterophylla)*, western redcedar (*Thuja plicata)* amabilis fir (*Abies amabilis),* Douglas-fir (*Pseudotsuga menziesii*), *and* sitka spruce (*Picea sitchensis)*. MH contains the additional species mountain hemlock (*Tsuga mertensiana)* and yellow cedar (*Chamaecyparis nootkatensis),* but lacks Douglas-fir and sitka spruce.

Methods

This study was part of an investigation of variation in nest predation risk on simulated Marbled Murrelet nests (Malt 2007, Malt and Lank *in press*). As seabirds, Marbled Murrelets are improbable denizens of the forest canopy. By shifting to arboreal nesting, this species freed itself from reliance on islands or cliff ledges utilized by other alcids, and allowed it to spread its breeding distribution from central California to western Alaska (Nelson 1997). Artificial eggs and nestlings (skinned *Coturnix* quail stuffed with cotton balls) were placed in the canopies of 136 old-growth trees (≥ 250 years old) at 34 sites (Figures 1 and 2). Average height of trees (± s.d.) was 36.0 ± 8.12 m, and artificial nests were 25.8 ± 7.3 m from the ground.

Trees were climbed by professional tree-climbers using a three-step process (Figure 3). First, we shot a weighted arrow, attached to a reel of fishing line, over a sturdy tree limb with a longbow or crossbow.
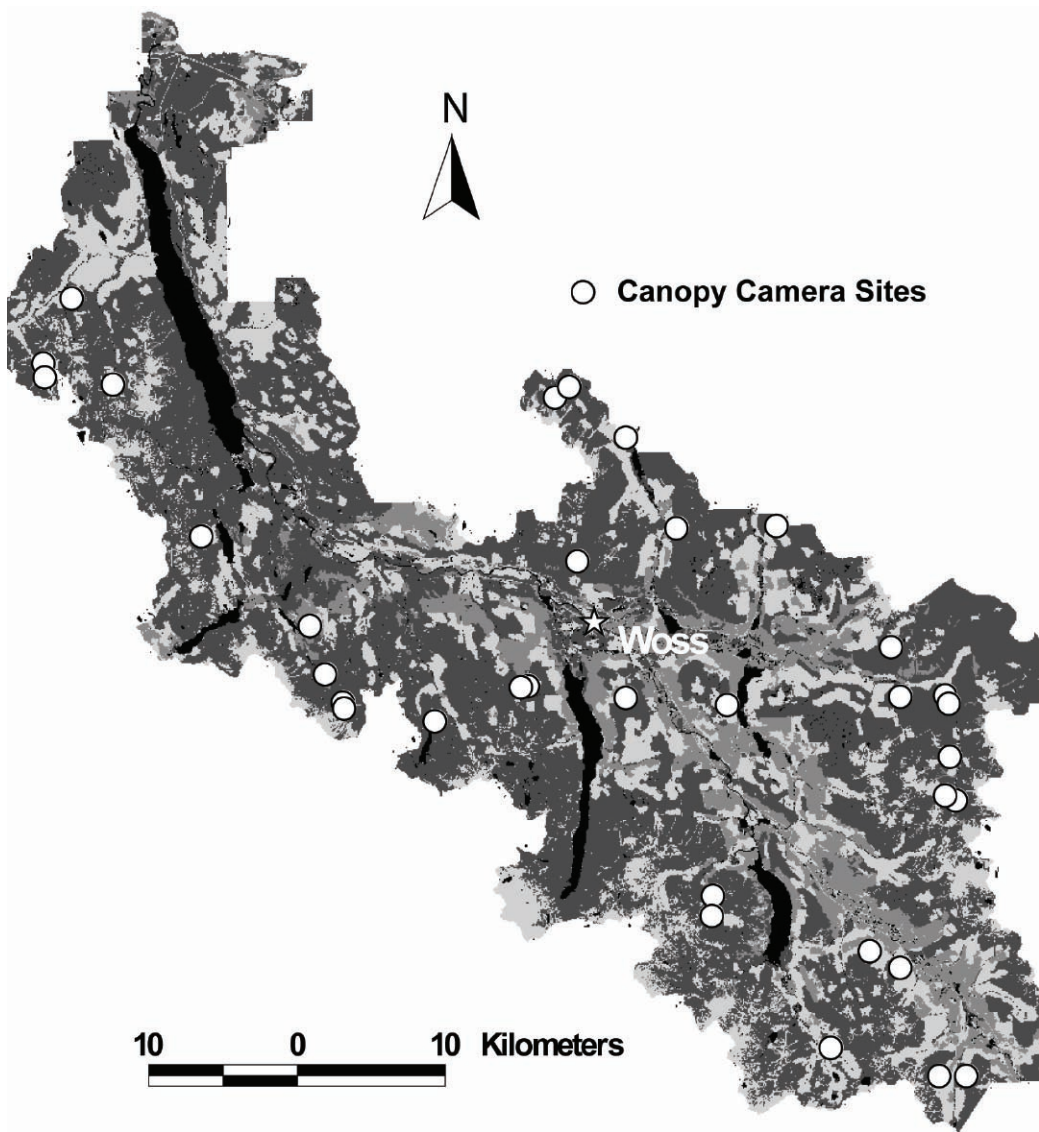
Figure 1. Locations of 34 canopy camera sites in our study area, the Nimpkish Valley, on Vancouver Island, British Columbia.

Second, we attached a 5 mm cord to the line and pulled it over the tree by "reeling in" the fishing line. Lastly, we brought the climbing rope over the tree by pulling the cord back. The rope was then secured to a nearby tree, and the other end of the rope was climbed directly, using mechanical "Jumar" ascenders.

Nest cameras were constructed from digital cameras and infrared sensors, and housed in waterproof Pelican® cases. These were similar to

Figure 2. Artificial Marbled Murrelet eggs (a) and nestlings (b) in the canopies of old-growth trees. Nests were approximately 1.5 m below each camera.

commercially available trail monitors, but with the sensor focused 1-2 m from the camera. Cameras were mounted on tree trunks approximately 1.5 m above all 136 artificial nests (Figure 4), and left in the field for approximately two weeks. The sum of exposure times for all cameras at all sites resulted in a total of 44,448 hours of camera observations in the field. Cameras took approximately four seconds to power up and initialize following motion detection, and so missed vertebrates that visited the nests for short periods. Therefore, our pictures were biased towards vertebrates that spend more time investigating or manipulating nest contents. This likely resulted in an overrepresentation of pictures of mammals (squirrels and mice) relative to birds. We looked for temporal, spatial, and behavioural differences in canopy usage by species groups: birds, mice, and squirrels. We divided the 24-hour day into six discrete categories: early-morning (0-359 h), morning (400-800 h), late morning (800-1159 h), afternoon (1200-1559 h), evening (1600-1959), and night (2000-2359 h), and tested whether the time of day pictures were
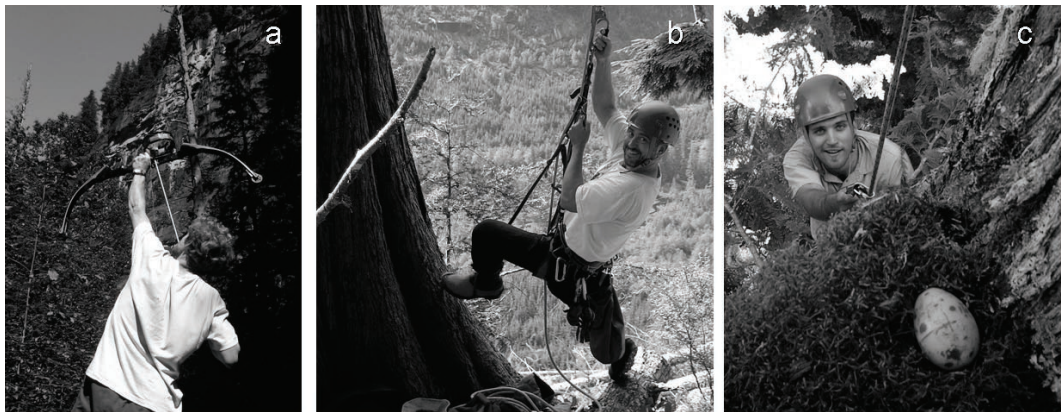

Figure 3. Demonstration of the tree climbing technique we used to access the canopy. Our technique included a) shooting a fishing line over the tree, b) establishing and ascending a climbing rope, and c) accessing the canopy.

Figure 4. Example of the motion-sensitive cameras established above each of the artificial nests.

taken varied by visitor species group (all times are given in Pacific Daylight Time). We examined differences as a function of nest height. We tested if the number of observations on each tree species differed relative to the total tree availability, for each visitor species group. We assigned behaviours of individuals in pictures to the following categories: pecking/chewing on nest contents, removing nest contents, stationary (perched or standing), moving, or unknown, and tested for different distributions among groups. Tests for statistical differences were done with contingency Chi-Square tests.

Our cameras captured images of songbirds (Figure 5), corvids (Figure 6), mammals (Figure 7), and a raptor (Figure 8). Species included mice (*Peromyscus* spp.), Red Squirrels (*Tamiasciurus hudsonicus*), Chestnut-backed Chickadees (*Poecile rufescens*), a Common Raven (*Corvus corax*), a Dark-eyed Junco (*Junco hyemalis*), a Golden-crowned Kinglet (*Regulus satrapa*), Gray Jays (*Perisoreus canadensis*), a Hermit Thrush (*Catharus guttatus*), a Sharp-shinned Hawk (*Accipiter striatus*), Steller's Jays (*Cyanocitta stelleri*), and Varied Thrushes (*Ixoreus naevius*) (Table 1). Two Gray Jays and two Steller's Jays were juveniles (Figure 9). The height of the nests where pictures were taken was similar among visitor species groups (Table 2).

The time of day pictures were taken varied by species group ($\chi^2_{10} = 47.82$, $P < 0.0001$). The majority of bird pictures were taken during the daytime, with a peak in the morning (600-800 h) (Figure 10). The exceptions were two pictures of Gray Jays, who were photographed at nests at 79 and 29 minutes before official sunrise (both pictures had sufficient pre-dawn light for identification). In contrast to birds, mice were only photographed during the night time (2200-400 h). The time of squirrel photographs were more variable, with the peak in the early morning (400-800 h), followed by observations later in the day, and even at night (2200-2400 h).

Birds were present at tree species disproportionate to their availability ($\chi^2_4 = 13.34$, $P = 0.01$), with amabilis fir avoided, and Douglas-fir preferred (Figure 11). *Peromyscus* used amabilis

Figure 5. Passerine species photographed at artificial nests in the forest canopy, including a) Golden-crowned Kinglet, b) Chestnut-backed Chickadee, and c) Varied Thrush.
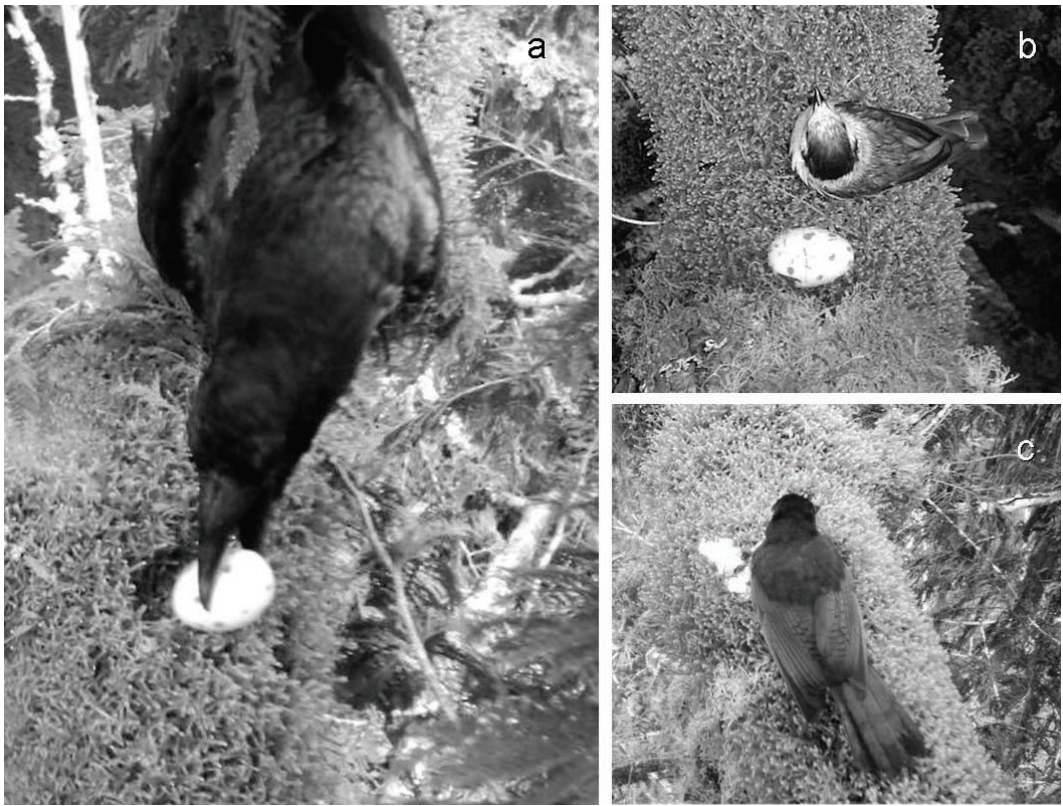
Figure 6. Corvids photographed at artificial nests in the forest canopy, including a) Common Raven, b) Gray Jay and c) Steller's Jay.
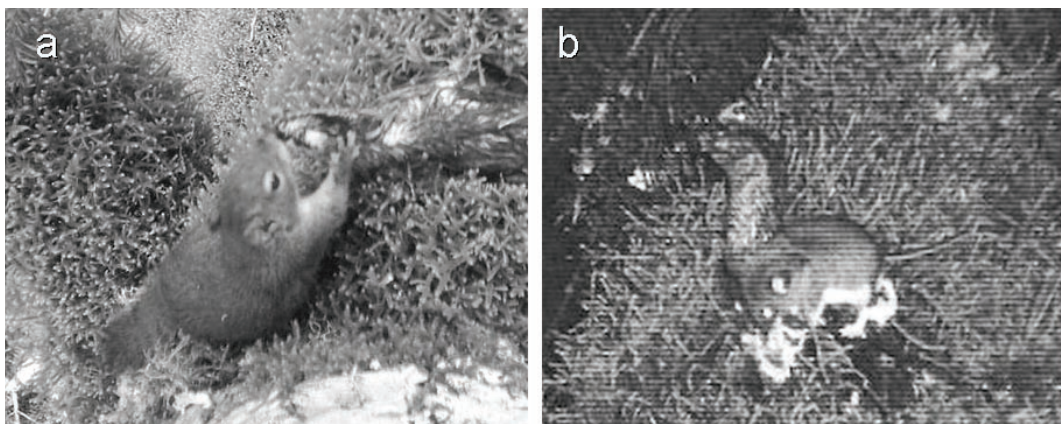

Figure 7. Mammalian species photographed at artificial nestlings in the forest canopy, including a) Red Squirrel, and b) mouse (*Peromyscus* spp.).

Wildlife Afield

Figure 8. A Sharp-shinned Hawk photographed on an artificial nestling in the forest canopy.

Table 1. Frequencies of species documented by motion-sensitive nest cameras at artificial nest sites in the Nimpkish Valley, Vancouver Island, B.C.

Species	Species Group	Number of Nests visited	Proportion of Total
Peromyscus spp.	Mice	15	0.25
Red Squirrel	Red Squirrels	13	0.20
Chestnut-backed Chickadee	Birds	12	0.20
Common Raven	Birds	1	0.02
Dark-eyed Junco	Birds	1	0.02
Golden-Crowned Kinglet	Birds	1	0.02
Gray Jay	Birds	9	0.15
Hermit Thrush	Birds	1	0.02
Sharp-shinned Hawk	Birds	1	0.02
Steller's Jay	Birds	4	0.07
Varied Thrush	Birds	3	0.05
Total		**61**	**1.00**

Table 2. Average height of simulated nests and trees (± s.d.) for each species group captured on camera. Ranges are in brackets, and n = number of trees.

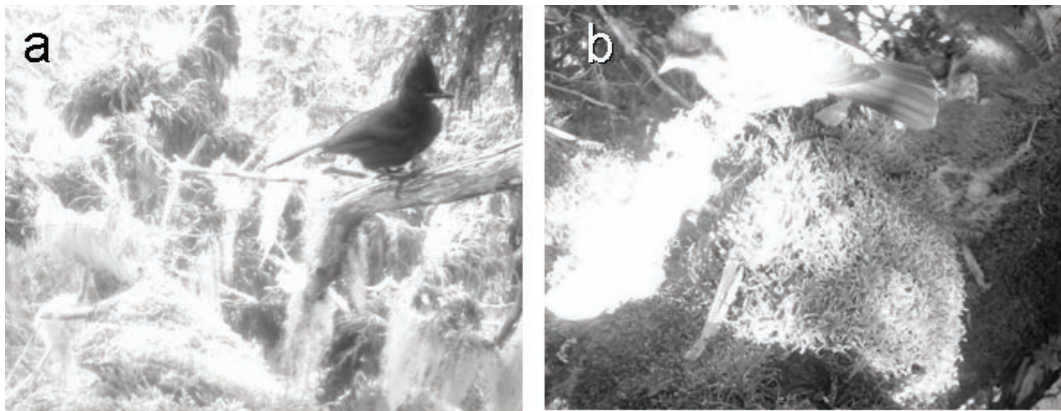| Species Group	n	Nest height (m)	Tree height (m)
Birds	33	29.93 ± 7.51 (17-42)	42.50 ± 7.08 (32-54)
Red Squirrels	13	30.56 ± 5.98 (25-42)	38.00 ± 5.29 (31-47)
Mice	15	27.53 ± 5.80 (18-40)	37.67 ± 5.98 (29-48)

Figure 9. Photographs of juvenile corvids at artificial nests in the forest canopy, including Steller's Jay (a), and Gray Jay (b).
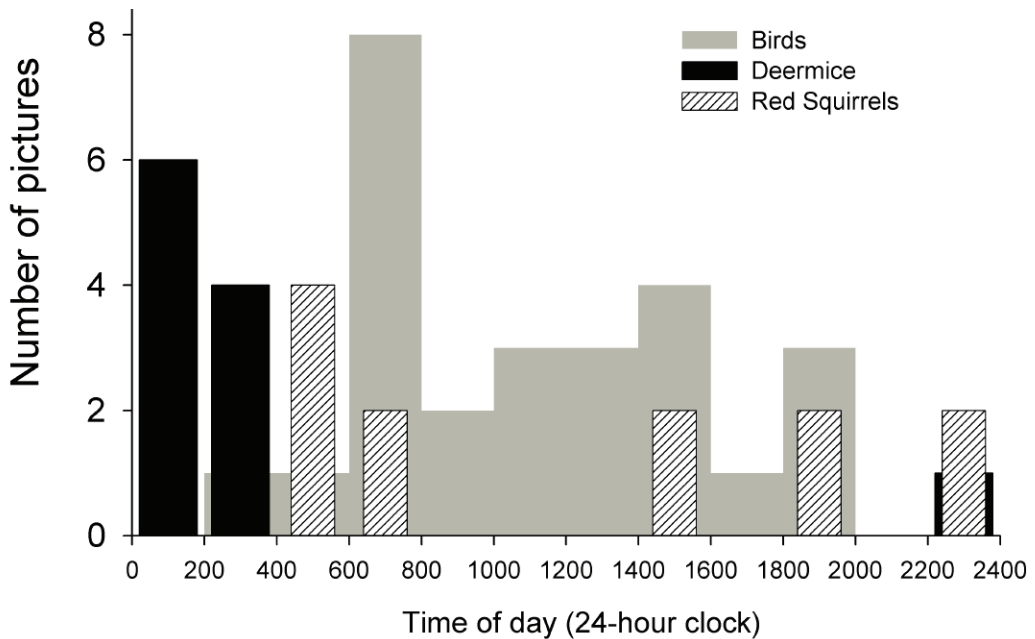

Figure 10. Frequency of pictures taken by time of day for birds, mice, and Red Squirrels. All bars indicate the two-hour interval they are bounded by (*i.e.,* first bar is from 0-200 h).
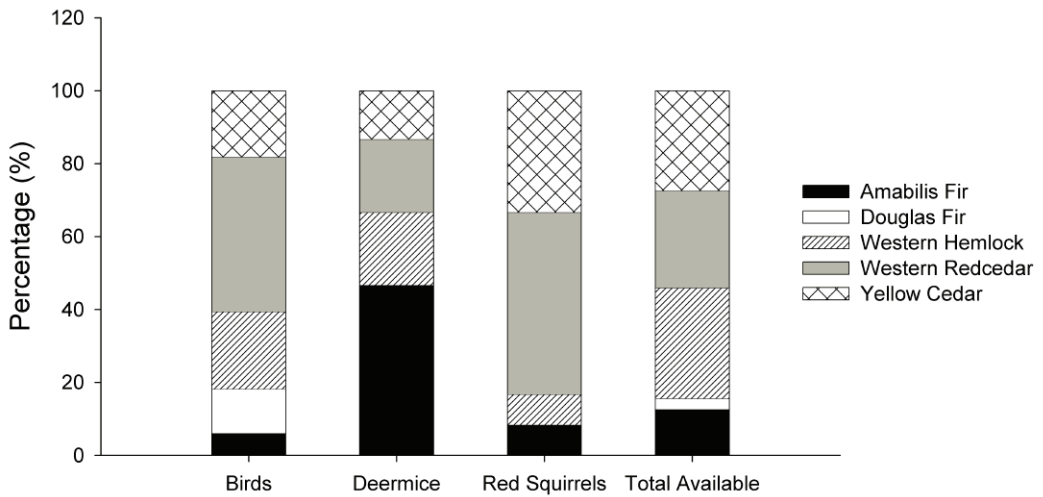
Figure 11. Proportions of pictures that were taken in different species of trees for birds, mice, and Red Squirrels, compared to the availability of tree species.
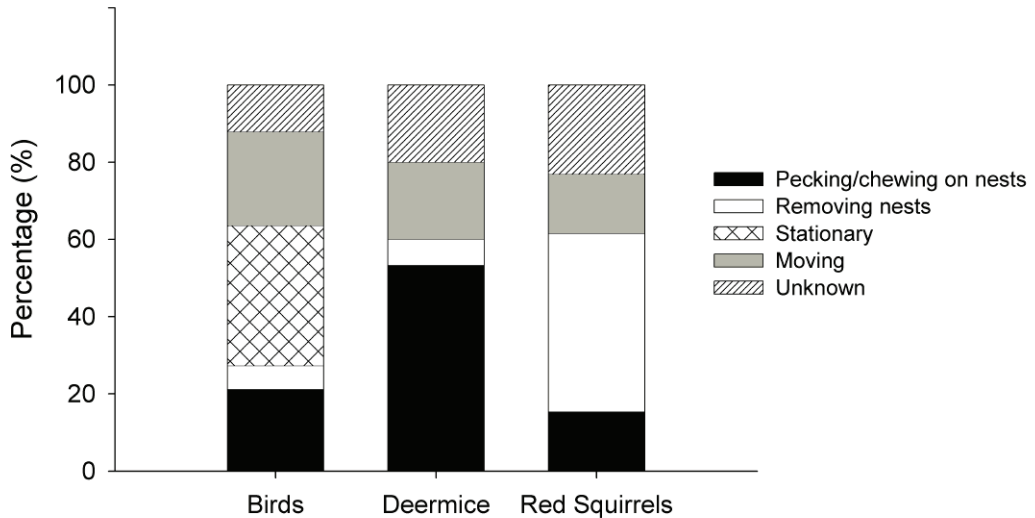

Figure 12. Proportions of pictures where individuals were engaged in various behaviours for birds, mice, and Red Squirrels.

disproportionate to their availability, but were never found in Douglas-firs ($\chi^2_4 = 13.03$, $P < 0.011$). There was no evidence that the use of tree species by Red Squirrels differed from their availability ($\chi^2_4 = 5.83$, $P = 0.212$).

Behaviours at artificial nests varied by visitor species group ($\chi^2_8 = 28.68$, $P < 0.001$). Squirrels and mice chewed or removed nest contents in the majority of their pictures (Figure 12). Mice chewed on nests much more often than they removed them, but nest remains and picture sequences indicated that they almost always removed material from nests that they chewed. Birds were pictured in all behaviours in roughly equal proportions. In contrast to mammals, birds were often stationary (perched), and rarely removed nest contents.

Discussion

Mammals

Our canopy cameras documented a variety of vertebrate species using the forest canopy. The most frequently observed vertebrates were mice (*Peromyscus* spp.). We could not identify mice individuals to species, but we assume that they were *Peromyscus keeni* ("Northwestern forest mice"), which are considered the most arboreal of mice (Carey and Johnson 1992). Researchers on the Olympic Peninsula in Washington state have also documented *Peromyscus* in the forest canopy of old-growth trees (Luginbuhl et al. 2001). These observations suggest that *Peromyscus* may utilize the canopy more frequently than previously thought. For instance, in a review of 13 mammalian species that use the forest canopy, Carey (1996) considered *Peromyscus keeni* to be the least arboreal. Similarly, it was previously thought that mice only climbed trees to heights of 15 meters (Carey and Johnson 1992). On the contrary, we found that *Peromyscus* are highly active in the forest canopy, particularly during the night, reaching heights of up to 40 meters. We repeatedly observed *Peromyscus* removing cotton from artificial nestlings, often returning multiple times in a single night. It is possible that they were using this cotton as material to line their own nests.

Red Squirrels were also frequently documented by our cameras in the forest canopy. This was expected, as Red Squirrels and their congeners, Douglas Squirrels (*Tamiasciurus douglasii*; not present on Vancouver Island) are well adapted for travel and foraging in an arboreal environment (Carey 1996). The crowns of conifer trees provide an abundance of seed resources for these squirrels. Squirrels were frequently observed removing eggs and nestlings from the nest sites, probably to cache them in other locations.

Small Passerines

Chestnut-backed Chickadee was the most common passerine observed in the canopy. This species reaches their greatest abundance in old-growth forests (Sharpe 1996), which have an abundance of snags and decaying trees for cavity excavation and nesting. Moreover, chickadees forage within the canopy on arthropods and seeds (Ehrlich et al. 1988). Chickadees may have been attracted to our artificial nestlings as a source of feathers and plant down which they could use to line their nests (Ehrlich et al. 1988). The Golden-crowned Kinglet appeared to be using the artificial nestlings for this purpose, as we observed an individual next to a nestling with cotton in its bill (Figure 4a). We observed a peak in bird pictures in the early morning, which is likely related to high activity of songbirds during the dawn chorus.

Corvids

We documented both Gray Jays and Steller's jays at our artificial nests. These jays are generalist predators whose main prey include arthropods, berries, and carrion (Strickland and Ouellet 1993, Vigallon and Marzluff 2005). Jays will also depredate eggs and nestlings when they encounter them incidentally, although they may not search specifically for bird nests (Vigallon and Marzluff 2005). Also, jays frequently use the forest canopy for perch sites, from which they can survey the surrounding area for potential prey (Masselink 2001). Therefore, jays may have discovered our nests while searching for other prey from within the forest canopy. Another interesting observation is that a substantial portion of the jays visiting our nests were juveniles. These juveniles may have discovered the nests while foraging or travelling within their natal

territories.

Our cameras photographed 13 jays at nest sites, but only a single Common Raven. Ravens have home ranges that are considerably larger than those of Gray Jays or Steller's Jays (Marzluff and Neatherlin 2006), and therefore may occur in lower densities. Consequently, while ravens may be important nest predators, the probability of predation by ravens is probably less than that for jays. Similar results were found in Washington, where cameras established at 48 canopy nests took five photographs of jays, but none of ravens (Luginbuhl et al. 2001).

Raptors

Our sole raptor picture was of a Sharp-shinned Hawk, which we observed plucking feathers from an artificial nestling. This accipiter feeds almost exclusively on small birds (Bildstein and Meyer 2000), and during nesting a large proportion of its diet consists of chicks from open-cup passerine nests (Joy et al. 1994). In addition, nesting Sharp-shinned Hawks often forage in the upper canopy (Reynolds and Meslow 1984). Thus, it is possible that this individual encountered the nestling while hunting for prey within its breeding territory.

Tree Selection

Our analysis suggests that birds and mice exhibited preferences for certain tree species. Birds were positively associated with Douglas-fir and western redcedar, but were rarely photographed on amabilis fir. Use of particular tree species and avoidance of others may reflect the availability of prey resources for insectivorous birds. For example, the type and abundance of arthropod prey may vary among different tree species, and access to that prey may vary with respect to differences in tree architecture and foliage cover (Holmes and Schultz 1988, Sharpe 1996). Preferences for tree species may also be related to the presence of cavities for cavity-nesting species such as the Chestnut-backed Chickadee (Mannan et al. 1980).

Mice were photographed disproportionately in amabilis fir trees relative to their availability. Amabalis fir branches have a high density of needles, which may provide cover for protection against predators and act as a buffer against microclimate extremes. Red Squirrels did not appear to exhibit preferences for any particular tree species, likely because the trees we examined had comparable seed availability.

About the Authors

Josh Malt recently received his M.Sc. from Simon Fraser University, where he worked within the Centre for Wildlife Ecology. His thesis work involved investigating the effects of forest fragmentation on habitat suitability for the Marbled Murrelet. Josh's interests in ornithology and conservation biology have been fostered during many field seasons spent in the old-growth forests of southwestern British Columbia.

David Lank is a behavioural ecologist associated with the Centre for Wildlife Ecology at Simon Fraser University, and a member of the Canadian Marbled Murrelet Recovery Team. He has a particular interest in mating and migration systems of shorebirds, and has studied a captive bred flock of Ruffs (*Philomachus pugnax*) for over 20 years.

Literature Cited

Bildstein, K.L., and K. Meyer. 2000. Sharp-shinned Hawk (*Accipiter striatus*). *In* The Birds of North America, No. 482 (A. Poole, ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/482

Carey, A.B. 1996. Interactions of northwest forest canopies and arboreal mammals. Northwest Science 70, Special Issue:72-78.

Carey, A.B., and M.L. Johnson. 1992. Small mammals in managed, naturally young, and old-

growth forests. Ecological Applications 5:236-352.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon & Schuster, New York, New York.

Franklin, J.F., and T.A. Spies. 1991. Composition, function, and structure of old-growth Douglas-fir forests. Pages 71-80 *in* L. R. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285. Pacific Northwest Research Station, Portland Oregon.

Holmes, R.T., and J.C. Schultz. 1988. Food availability for forest birds: effects of prey distribution and abundance on bird foraging. Canadian Journal of Zoology 66:720-728.

Joy, S.M., R.T. Reynolds, R.L. Knight, and R.W. Hoffman. 1994. Feeding ecology of Sharp-shinned Hawks nesting in deciduous and coniferous forests in Colorado. Condor 96:455-467.

Klinka, K., J. Pojar, and D.V. Meidinger. 1991. Revision of biogeoclimatic units of coastal British Columbia. Northwest Science 65:32-47.

Luginbuhl, J.M., J.M. Marzluff, J.E. Bradley, M.G. Raphael, and D.E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology 72:556-572.

Malt, J.M. 2007. The influence of habitat fragmentation on Marbled Murrelet (*Brachyramphus marmoratus*) habitat quality in southwestern British Columbia. M.Sc. Thesis. Simon Fraser University, Burnaby, British Columbia, Canada.

Malt, J.M., and D.B. Lank. *In press*. Temporal dynamics of edge effects on nest predation risk for the Marbled Murrelet. Biological Conservation 140: 160-173.

Mannan, R.W., E.C. Meslow, and H.M. Wight. 1980. Use of snags by birds in Douglas-fir forests, Western Oregon. Journal of Wildlife Management 44:787-797.

Marzluff, J.M., and E.A. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. Biological Conservation 130:301-314.

Masselink, N.M. 2001. Responses by Stellar's Jays to forest fragmentation on southwest Vancouver Island and potential impacts on Marbled Murrelets. M.Sc. Thesis. University of Victoria, Victoria, British Columbia, Canada.

Nelson, K. 1997. Marbled murrelet (*Brachyramphus marmoratus*). *in* A. Poole, and F. Gill, editors. Birds of North America, No. 276. Academy of Natural Sciences, Philadelphia, USA.

Ozanne, C.M.P., D. Anhuf, S.L. Boulter, M. Keller, R.L. Kitching, C. Körner, F.C. Meinzer, A. W. Mitchell, T. Nakashizuka, P.L. Silva Dias, N.E. Stork, S.J. Wright, and M. Yoshimura. 2003. Biodiversity meets the atmosphere: a global view of forest canopies. Science 301:183-186.

Reynolds, R.T., and E.C. Meslow. 1984. Partitioning of food and niche characteristics of coexisting accipiter during breeding. Auk 101:761-779.

Sharpe, F. 1996. The biologically significant attributes of forest canopies to small birds. Northwest Science 70, Special Issue:86-93.

Sillett, S.C., and P.N. Neitlich. 1996. Emerging themes in epiphyte research in westside forests with special reference to cyanolichens. Northwest Science 70, Special Issue:54-60.

Strickland, D., and H. Ouellet. 1993. Gray jay (*Perisoreus canadensis*). *in* A. Poole, P. Stettenheim, and F. Gill, editors. Birds of North America, No. 40. Academy of Natural Sciences, Philadelphia.

Vigallon, S.M., and J. Marzluff. 2005. Is nest predation by steller's jays (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? Auk 122:36-49.

Winchester, N. N. 2006. Ancient temperate rain forest research in British Columbia. Canadian Entomologist 138:72-83.

Winchester, N.N., and R.A. Ring. 1996. Northern temperate coastal sitka spruce forests with special emphasis on canopies: studying arthropods in an unexplored frontier. Northwest Science 70, Special Issue:94-103.